



IIHF

IIHF GUIDE TO SUSTAINABLE ICE ARENAS 2026

About this guide

This second edition of the IIHF Guide to Sustainable Arenas builds on the first edition, with selected content revised and updated by the IIHF Facilities Committee in collaboration with the Swedish company EKA. A central achievement of this work is the development and adoption of a definition of sustainability in ice hockey, providing a shared foundation for the guide and its recommendations.

The guide explains how ice arenas can provide high-quality conditions for ice hockey while remaining viable for their communities and reducing their environmental impact over time. It covers the building, its technical systems, and the people who operate them, with particular attention to energy and water use, refrigerants, heat recovery, and long-term investment decisions.

The guide begins by presenting the definition of sustainability in ice hockey and explaining its implications for ice arenas. It then uses functions and resources as a practical framework for examining how an arena can meet these goals.

Technical recommendations are supported by research, measured experience, and case studies. The aim is to help arena owners and operators assess improvements, compare solutions over their life cycle, and communicate sustainability results clearly.

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1. Background

1.1 Objective

The scope and objective of this document are to provide a general and not too deep technical overview of the specifics of ice arenas and their technical systems. Special attention is directed to the technical functions that affects resources in one way or another, since the overall aim is to give the readers ideas as to how to successfully make their own arena more sustainable.

1.2 About the authors

EKA specializes in refrigeration, energy analysis, energy efficiency and building physics, with a particular focus on ice arenas. Its core expertise is refrigeration engineering using natural refrigerants and heat recovery solutions. EKA designed Europe's first ice arena with a full CO₂ refrigeration system, where recovered heat met the arena's heating needs. The company advises public and private clients worldwide on sustainable arena design.

EKA has built a body of technical knowledge through research and practical work in ice arenas. Its designs draw on field measurements, accumulated experience and energy calculations made with publicly available softwares. Methods and findings has also been shared through research publications and academic conferences. Today EKA supports clients throughout the development of ice arena systems, from evaluating options to designing and implementing suitable and sustainable solutions.

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2. Introduction to sustainable ice arenas

2.1 What is a sustainable ice arena?

A sustainable ice arena is a facility designed and operated to deliver high-quality ice hockey conditions while ensuring long-term economic and social viability and minimizing environmental impact.

It integrates energy-efficient and low-emission technologies, including natural refrigerants, heat recovery, and renewable energy sources, using well-trained and skilled personnel.

Sustainable arenas also prioritize efficient water management, waste reduction, and durable construction practices. The IIHF emphasizes that true sustainability combines technical performance with community value, safety, and responsible resource use throughout the rink's lifecycle.

For an ice arena, sustainability has two connected elements, shown in Figure 2: the functions the facility must deliver, and the resources used to deliver them. Those functions include reliable ice and safe, comfortable conditions for players and spectators. Energy, water, materials, equipment, staff time and funding are needed to maintain them. Managing these resources efficiently helps the arena remain affordable to operate while reducing its environmental impact over its life cycle.



Figure 1. *A sustainable ice arena consists of long-term solutions that lead to optimum function in a way that manages resources efficiently.*

The building and its technical systems need to work as a whole. The building envelope, refrigeration, heating, ventilation, dehumidification and controls all affect energy use and arena conditions. The benefit of a particular measure depends on how it is designed, integrated and operated within the facility.

Technology alone does not ensure lasting results. Staff and management need the skills to operate and maintain the systems, monitor performance and adjust practices when conditions change. Owners, sports organisations, clubs and other users also influence the arena's priorities, use and financing. Their decisions help determine whether an improvement remains practical and affordable over time.

Functions	Resources
1  Ice arena specific functions • Ice quality • Lighting conditions • Heat load management — minimize unnecessary loads on ice sheet • Moisture load management — minimize unnecessary loads in arena room	1  Technical properties • Building materials • Refrigeration system — Refrigerant and other fluid types • Heating sources • Dehumidifier type
2  Visitor comfort • Temperature levels • Indoor air quality • Air and heat distribution	2  Energy type & its use for • Cooling • Heating • Dehumidification • Ventilation • Lighting • Misc.
3  Structural integrity & health • Load bearing capabilities • Moisture handling — Dehumidification control; Zonal Air management • Moisture safe building envelope design	3  Water usage
4  Visitor safety • During hockey / ice skating activities in general • In case of: ◦ Fire ◦ Refrigerant leaks	 These are of course just a selection of many functional requirements a good ice arena needs to comply with.

Figure 2. Sustainability elements in an ice arena.

Some terms used in sustainability discussions can be misleading unless their meaning and scope are clear. This is particularly important for ice arenas, where for instance refrigeration and dehumidification create substantial, recurring energy demands.

Net zero is often used without a defined baseline or a clear account of which emissions are included. An arena should first measure its emissions and reduce them through efficiency, heat recovery and other direct measures before making a net-zero claim.

Renewable energy should not automatically be described as zero-carbon energy. The result depends on the energy supplied to the arena and on emissions from other sources, including heating, transport and refrigerant impact. **Solar energy** can support loads from many systems, but its overall contribution to refrigeration and other systems must be assessed against the arena's demand throughout the year.

CO₂ neutral can be especially confusing when an arena uses CO₂ as a refrigerant. CO₂ refrigerant can offer a lower climate impact than conventional refrigerants, but its use does not make the whole arena carbon neutral. Emissions associated with electricity, heating and materials still need to be considered.

Offsetting compensates for emissions through projects outside the arena; it does not eliminate emissions from the arena's own operation. The priority should be direct reductions, efficient resource use and measurable improvement, with any remaining emissions reported transparently.

In this guide, sustainable ice arena technology means long-term solutions that maintain the arena's function while using resources efficiently. Progress should be demonstrated through measured results over the facility's life cycle.

2.2 Passive and Active management of ice arena conditions

An ice arena is a building with particular conditions: Within the same arena room there is an ice sheet that needs to stay frozen, while there generally also are heating and air quality demands for visitor comfort. Furthermore, these conditions often result in a special challenge, where the air humidity in the arena room may become too high and needs to be controlled to avoid problems, such as damage to structures. Last but not least, the space should also be well illuminated for comfort and safety reasons. **A well-functioning ice arena must be able to handle the complex heat loads and moisture loads that come along with the abovementioned type of environment.**

This leads to two areas of focus:

1. The Building Structures To **passively** manage the heat and moisture loads within the ice arena.
2. The Energy Systems To **actively** manage the heat and moisture loads within the ice arena.

Sustainable building structures, such as the building envelope, will be treated in this guide. However, Improving the energy efficiency of the ice arena is one of the most important ways to make the facility more sustainable, and for the benefit of the ice rink owner it will often also increase the economic performance of the facility.



Figure 3. *A well-functioning ice arena must be able to handle the complex heat loads and moisture loads that come along with this specific environment. In this picture they are not well managed, causing foggy conditions.*

2.3 The Big Five energy systems

To operate an ice arena there are generally five basic energy systems required:

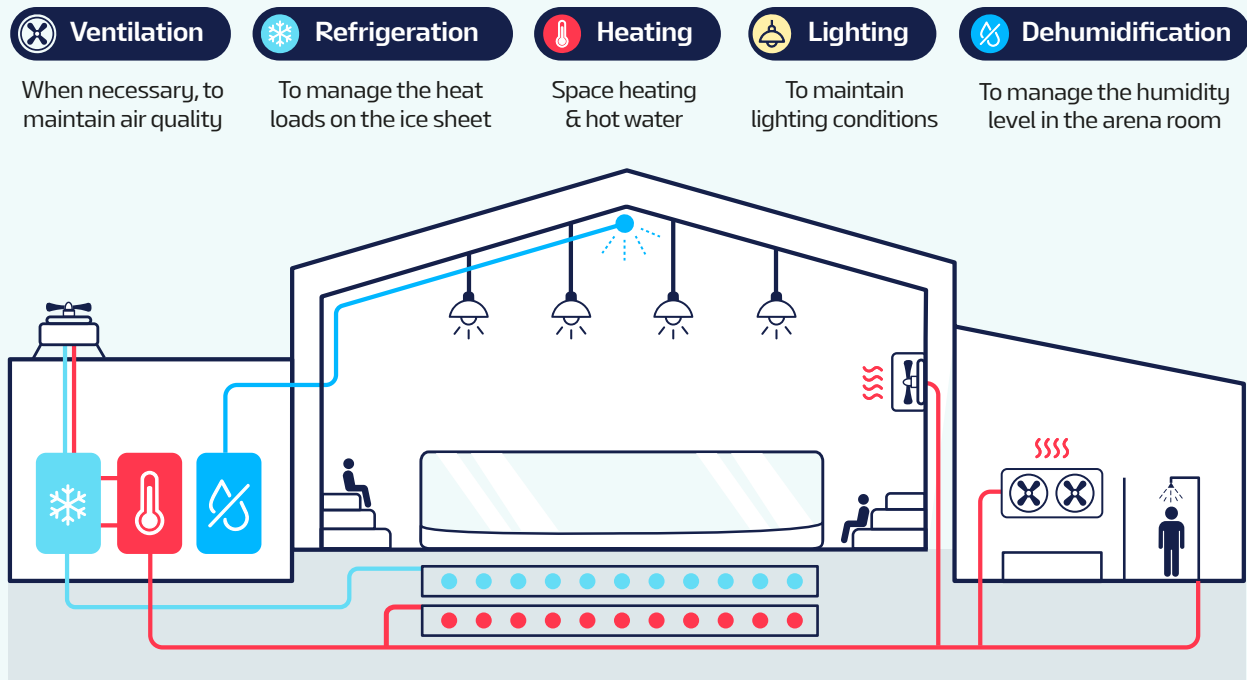


Figure 4. Indoor ice rink energy systems – The big five.

These systems are here referred to as the “big five” because they typically account for more than 90% of the energy used in the ice rink. In the figure below these energy systems are schematically indicated in the ice rink facility.

The figure also shows the big five energy systems interacting with each other. E.g., the warmer the indoor air is kept for user and spectator comfort, the greater the heat transfer to the ice, which increases the cooling demand of the refrigeration system. Lighting and dehumidification also affect the indoor climate and the heat load on the ice. Therefore, the energy systems should not be treated separately but designed and operated as one integrated system.

The big five energy systems are present in essentially every ice rink, regardless of size. These systems always interact, and significant energy savings can be achieved when they are connected and controlled in a sensible way.

To further illustrate the significance of the five main energy systems, Figure 5 is shown. Results from investigations suggest that in conventional ice arenas, the refrigeration system contributes to the largest portion with around 43% and heating demands come next with around 26%. The other functions are estimated with up to a 10% share each.

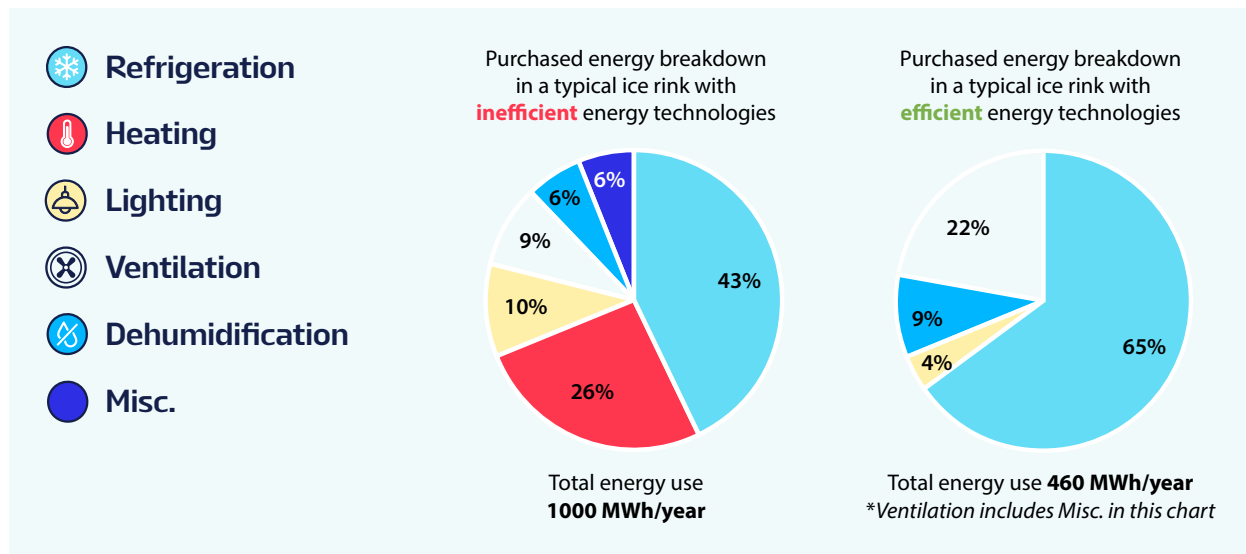


Figure 5. Main energy uses in a typical/conventional ice rink in Sweden with inefficient and efficient energy technologies [Stoppsladd, 2014; ASHRAE, 2017].

In modern ice arenas with efficient system solutions the relations between energy demands are a bit different, as shown to the right in the Figure above, but the conclusion remains nevertheless the same: **the big five energy systems that are emphasized here are of crucial importance and should be the focus when it comes to improving energy efficiency in ice rinks.**

The biggest energy savings potential is often to cover the heating demands with recovered heat from the refrigeration system, with the possibility of eliminating the purchased heating energy demand as indicated in Figure 5, and this will be further discussed later on in the guide.

2.4 Energy cost savings in ice arenas

Savings potential is understandably of high interest to an ice rink owner since it also can lead to increased economic performance of the facility. Below, aspects of energy and cost savings potential are discussed to give an ice arena owner the proper decision-making tools to make the facility more sustainable.

2.4.1 Energy cost structure

Although electricity and heating tariffs vary considerably between countries and regions, energy bills generally consist of both fixed and variable charges. For electricity, the variable cost is primarily based on purchased electrical energy [kWh], while fixed charges may include contracted power [kW], transmission and distribution [T&D] charges and applicable taxes. In some regions electricity prices may also vary throughout the day according to market conditions.

Similarly, district heating or other heat supply systems commonly include a fixed capacity charge together with a variable charge based on purchased thermal energy.

Understanding how these cost components are structured is important when evaluating energy efficiency measures. Most measures are designed to reduce purchased energy [kWh], while reductions in peak power demand [kW] may occur as an additional benefit depending on the facility, operating profile and applicable tariff structure.

2.4.2 Energy optimisation strategies

Energy optimisation is typically carried out in two stages. The first stage consists of operational improvements [quick fixes] requiring little or no investment, while the second stage focuses on major system upgrades that improve the long-term energy performance of the facility.

Both approaches are important and should be regarded as complementary rather than competing strategies.

Table 1. *Energy savings in an ice rink – Comparison of measure groups.*

	Quick fixes	Long-term solutions
Definition	Measures that are aimed at single system adjustments. Require low effort and low/no investment.	Measures that require a comprehensive and often cross-system approach. Require higher effort and investment.
Pros	• Low/no investment. • Short implementation time. • Immediate savings effect.	• Minimized operational costs in the long-term. Optimum functions: e.g. comfortable and healthy indoor environment. • All-encompassing energy system solution. Best possible economic performance long-term.
Cons	• Potentially sacrificed comfort, with unsatisfied visitors as result. • Potential risk of function: e.g. mold growth in structures, condensation and other moisture problems. • Major function and resource inefficiencies may still remain, e.g. non-sustainable refrigerants.	• Requires larger investments. • Longer design and implementation time.

Quick fixes can often be implemented quickly, as they may simply include adjustments to operating settings, schedules or existing control strategies. These measures can be valuable and should normally be investigated first, since they may improve performance with minimal cost. However, quick fixes rarely solve the major technical inefficiencies of an ice arena. They may also risk reducing comfort or function if applied without proper understanding.

Long-term solutions require more planning and investment, but they can address the facility as a whole and usually provide the greatest savings, better function and stronger long-term economy as will be shown below.

Figure 6 compares the energy performance of a large number of Nordic ice rinks, from which data have been gathered. **The shown values in Figure 6 reflect the average amount of purchased energy during a day of ice arena activity.** On the left side of the chart, larger arenas are represented, and this is understandable since they are bigger and more complex facilities with many other additional functions that require purchased energy. They are therefore somewhat more difficult to compare. However, the rest of the ice arenas are by incredible majority of similar size and capacity, making them more comparable in terms of energy performance.

Typical sized ice arenas with conventional technologies purchase more than 3 000 kWh of energy [including electricity and any type of heating energy] per day **during the ice season** on average. With quick fixes an ice rink owner can reach below this limit and improve energy performance with minor savings. **The big savings are however only attainable by applying long-term solutions**, where proven results have shown that existing ice rinks can reach below 1 500 kWh/day, indicating that energy costs get cut by more than 50 %, which in turn make the investments more profitable than continuing with existing solutions.

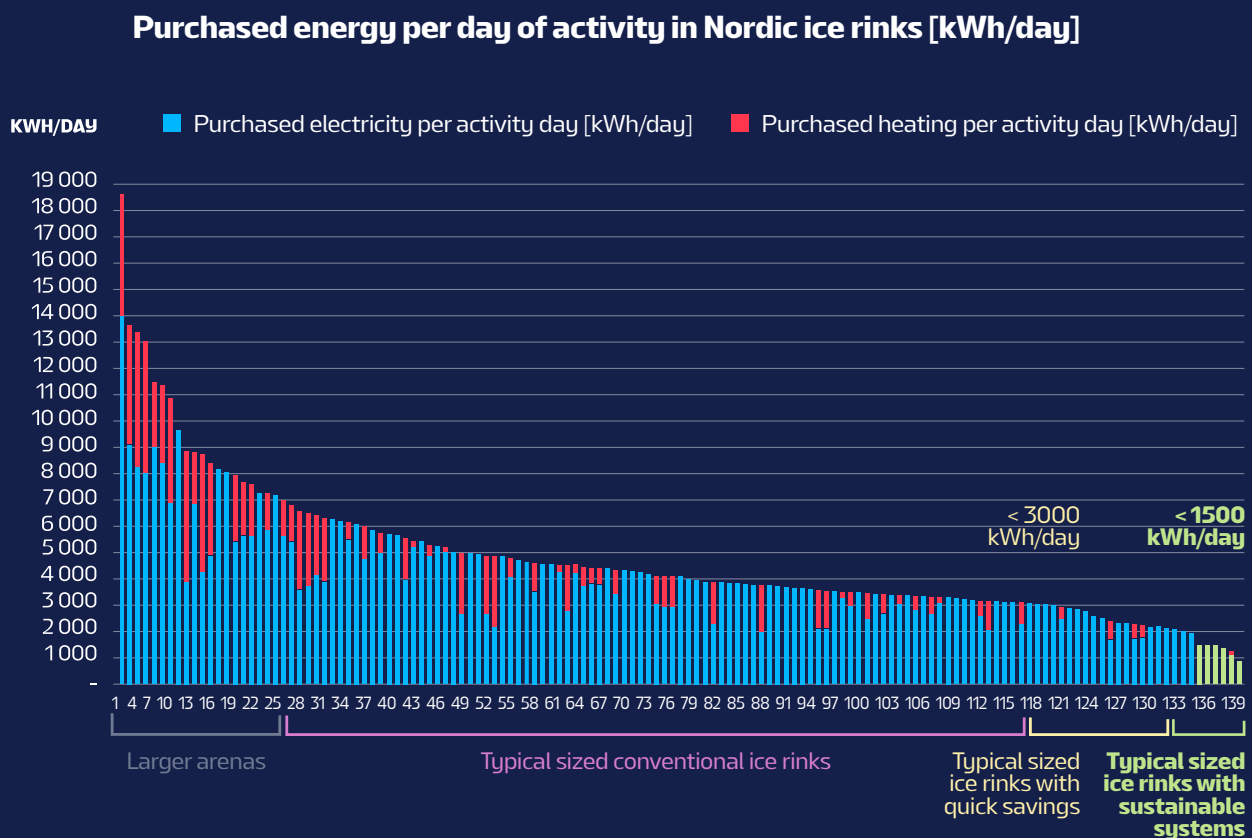


Figure 6. Comparison of energy performance in Nordic ice rinks. The shown values reflect the average amount of purchased energy [electricity and any other potential heat source] during a day of ice arena activity.

2.4.3 Strategic investments

Once operational optimisation has been completed, substantial additional savings often require investments in the building or technical systems. These improvements may involve modern refrigeration systems, heat recovery, ventilation, lighting, control systems or building envelope upgrades.

Although such projects require higher initial investment, they typically provide the largest reduction in purchased energy and operating costs while simultaneously improving reliability, comfort and environmental performance.

Life-cycle cost analysis, or LCC, is therefore a more reliable decision-making tool. LCC compares the total cost of different alternatives over a longer period, often 15-20 years. It includes both investment costs (CAPEX) and operating costs (OPEX), such as energy, service and periodic maintenance.

When alternatives are compared over the full life cycle, as illustrated in Figure 7, the **long-term solutions will generally show a better economic performance than continuing with an existing system.**

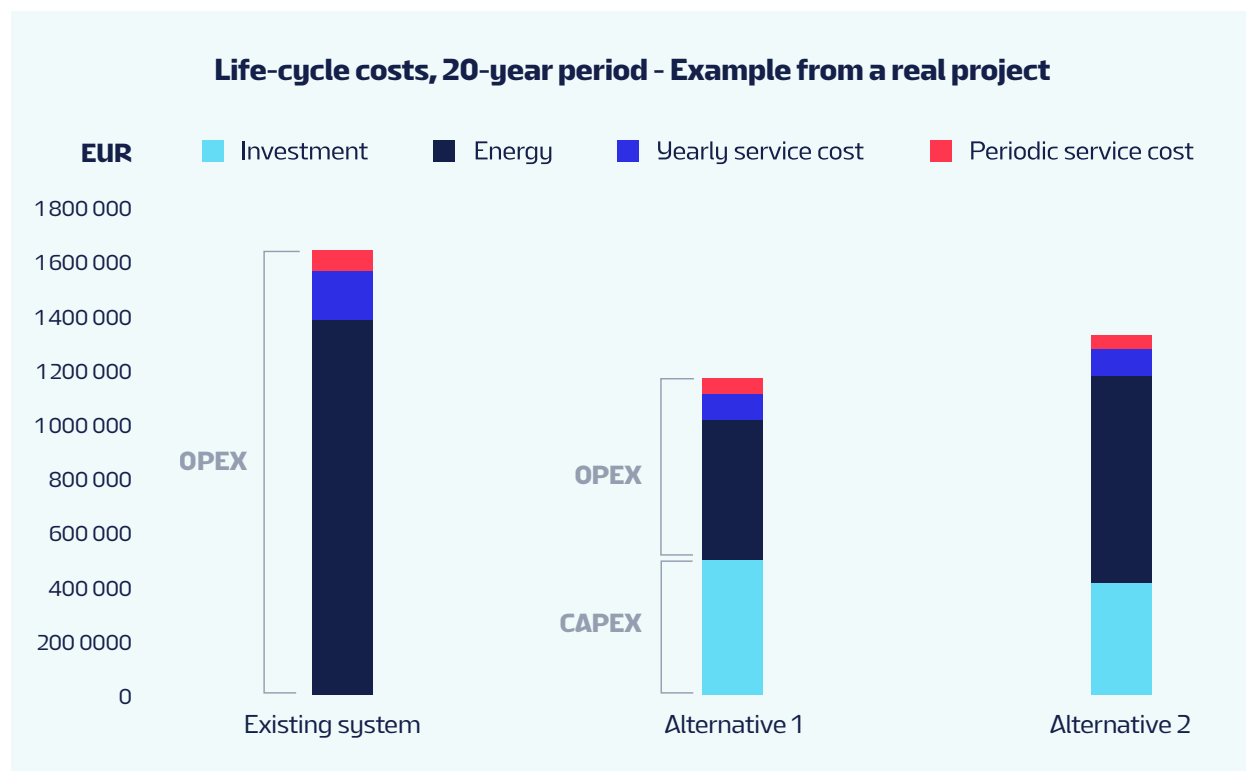


Figure 7. Life-cycle cost results for sustainable energy solutions (alternative 1 & 2) in an ice rink compared to existing system with quick savings only. The results show that investing in long-term solutions will yield the biggest savings for the ice rink owner.

The outcome of a life-cycle cost analysis is highly project-specific and depends on a range of technical and economic assumptions. Important factors include climate conditions, ice season length, electricity and heating tariffs, tariff structures (including energy- and fixed charges), discount rate, assumed economic lifetime of the investment, required arena functions and occupancy, as well as the technical solutions that are feasible for the specific facility. Consequently, the results of one arena cannot be directly transferred to another, and each major investment should be evaluated individually.

2.5 Environmental impact of technical solutions

These days, the economy still often plays the decisive role in the selection of technical solutions. Nevertheless, other factors such as safety and, not the least, environmental impact are gaining more ground.

The importance of minimizing energy and water usage as well as the importance of applying sustainable building materials are themes that are becoming increasingly known to the wide audience, since they are applicable to more or less any kind of building, be it residential, commercial, industrial, etc.

In the world of refrigeration systems and heat pumps, to which ice rinks also belong, **the environmental impact of the refrigerant used in the refrigeration system will also play a significant role whether the facility is sustainable or not.**

Refrigerants have played an important role in the environmental development of refrigeration systems and heat pumps. Historically, several commonly used refrigerants contributed to ozone depletion and global warming, which has made refrigerant choice a central sustainability issue.

The Montreal Protocol, signed in 1987, was introduced to phase out substances that damage the ozone layer. This led to the restriction and eventual ban of several chlorine- and bromine-based synthetic refrigerants.

Later, the focus shifted increasingly toward global warming, as many replacement refrigerants had no ozone depletion potential but still had a high global warming potential.

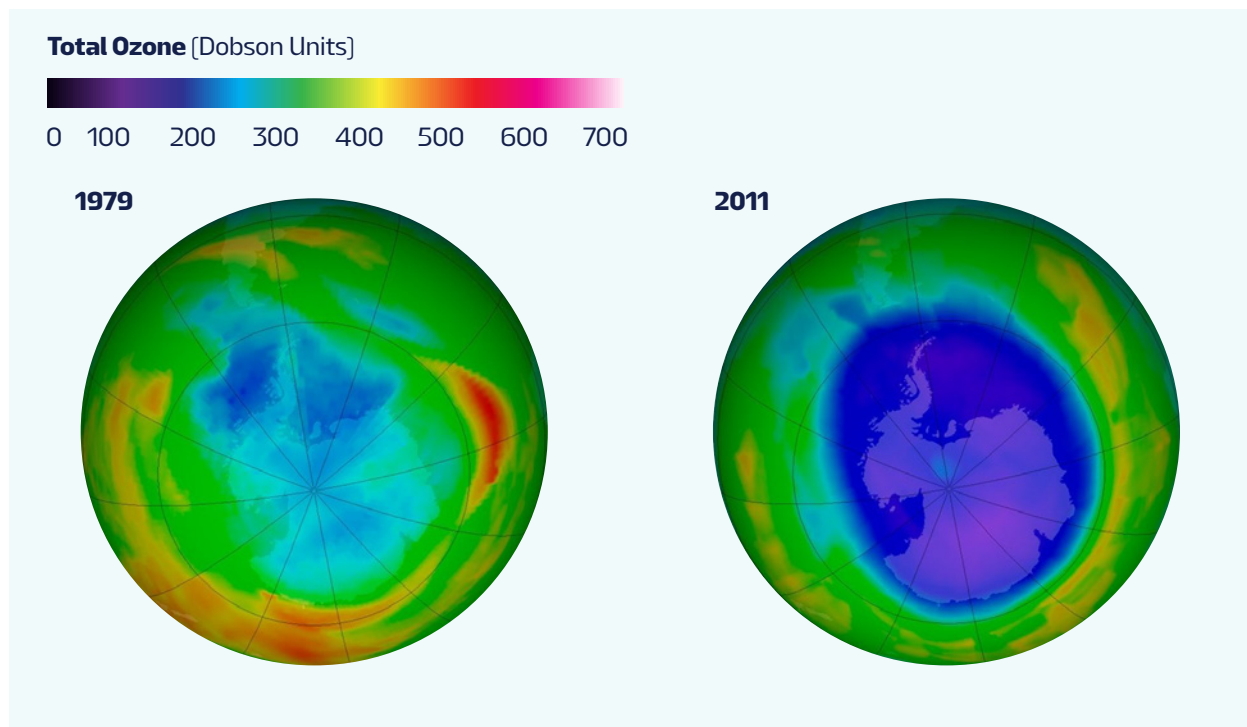


Figure 8. The Antarctic ozone hole on September 16 in the years 1979 and 2011 [NASA Earth Observatory, 2012].

In the EU, the F-gas regulation has become one of the main tools for reducing the climate impact of fluorinated greenhouse gases. By gradually limiting the availability of high-GWP synthetic refrigerants, the regulation has pushed the refrigeration industry toward solutions with lower environmental impact.

A further concern relates to PFAS, often referred to as “forever chemicals”. Some synthetic refrigerants are associated with PFAS or persistent degradation products, creating additional environmental and regulatory uncertainty. This is discussed further in 6.1 Refrigeration system.

Long-term persistence, degradation products and potential future restrictions should therefore also be considered when selecting the refrigerant. This has resulted in natural refrigerants increasingly becoming the standard choice.

Refrigerant properties will be discussed further in this guide when presenting sustainable refrigeration systems.

3. Building and retrofitting ice rinks

– Project delivery and procurement

High performing ice arenas are not created by technology alone. The quality of the planning, procurement and implementation process has a major influence on energy performance, operating costs, reliability and user comfort.

Whether building a new arena or upgrading an existing facility, successful projects typically follow the same principles:

- Define clear objectives.
- Base decisions on measured data and life-cycle performance.
- Evaluate solutions on quality and long-term value, not only first cost.
- Verify results after implementation.

A structured process reduces technical risks, improves procurement outcomes and increases the likelihood of achieving the intended sustainability targets.

3.1 Independent expertise and informed decision-making

Ice arenas are technically complex facilities where refrigeration, heating, ventilation, dehumidification, lighting and building structures interact closely.

Arena owners and municipalities often face challenges when comparing alternative technical solutions. Procurement decisions based solely on initial investment cost may lead to higher operating costs, reduced performance or missed energy-saving opportunities.

Procurement without clear technical specification

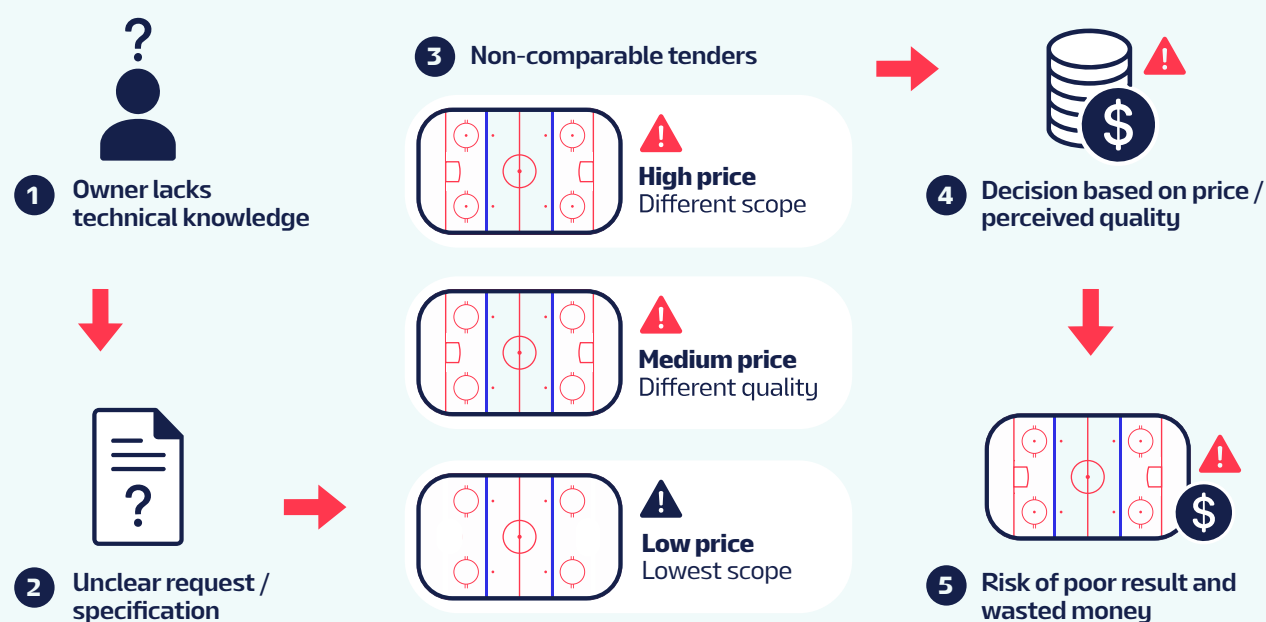


Figure 9. The procurement process contains many pitfalls, which mainly occur due to the lack of knowledge, and may lead to low quality results and/or significant waste of money.

Independent technical expertise can support the project by:

- Establishing performance targets.
- Identifying energy saving opportunities.
- Preparing performance-based procurement documents.
- Assessing existing conditions.
- Evaluating alternative technical concepts.
- Verifying that installed systems achieve the intended results.

The objective is not to specify a particular supplier, but to ensure that competing solutions can be evaluated on a consistent basis and compared fairly.

Procurement supported by impartial technical expertise

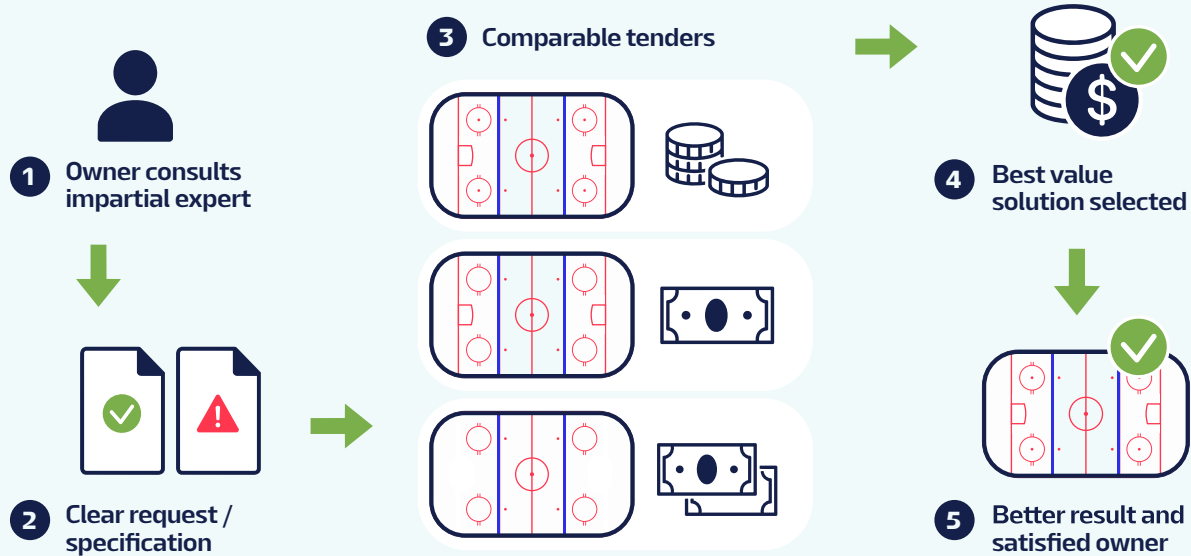


Figure 10. An impartial industry expert can support the ice rink owner in investigating, designing, and specifying the optimum system solution in procurement documents. Tenders will as result be comparable in terms of quality, and the client will get the best possible solution to cover demands for the lowest price.

Projects that combine technical expertise with life-cycle thinking generally achieve better long-term economic and environmental outcomes.

3.2 Retrofits

Most improvements in the ice arena sector will occur through retrofits rather than new construction. A successful retrofit begins with understanding how the existing facility performs. Energy use, refrigeration performance, indoor climate conditions and operational practices should be evaluated before selecting improvement measures. A typical retrofit process includes:

1. Baseline assessment

- Site inspection
- Energy analysis
- System condition assessment

2. Opportunity identification

- Energy-saving measures
- Refrigeration upgrades
- Heat recovery opportunities
- Building envelope improvements
- Control system optimisation

3. Solution development

- Technical design
- Life-cycle cost analysis
- Prioritisation of measures
- Investment planning

4. Procurement and implementation

- Performance-based specifications
- Contractor selection
- Installation and commissioning

5. Verification and optimisation

- Measurement of results
- Operational adjustments
- Continuous monitoring



Retrofits that follow a structured process typically achieve greater and more reliable savings than projects based solely on isolated equipment replacement.

4. Sustainable building envelope

The main function of the building envelope is to separate the indoor climate from the alternating outdoor weather in a controlled manner. Support systems such as heating, ventilation and dehumidification should not have to work more than necessary in order to maintain the desired indoor climate.



Figure 11. Ice arena with wooden material elements in the building envelope.

The building envelope should therefore be designed and built to handle the local outdoor climate conditions in the best way possible.

4.1 Envelope – Roof and wall constructions

It goes without a discussion that the main property of the building envelope is its structural durability. However, the purpose is to separate the indoor environment from the ambient conditions, with the least energy required for the mechanical equipment. This implies that heat and moisture transport should be controlled in a proper manner for the intended application in the prevailing climate conditions.

4.1.1 Insulation

To reduce the capacity required of the heating as well as cooling equipment, insulation is used. It is a thermal barrier in the building envelope structure with the aim to halt the undesirable heat transfer consequences, ensuring that reasonable thermal comfort conditions are achieved at any time of the year.

Materials that can be used for the insulation must have sufficient resistance for the given conditions, which is the governing parameter. Since the availability and price of the material depends on the location, there is a wide range of wall structure combinations. In Nordic ice rinks, for example, two commonly used materials are mineral wool and polyurethane.

4.1.2 Air barrier

Minimization of air leakages is required in order to avoid excessive infiltration or exfiltration rates. In ice rinks, infiltration rate is especially critical for the dehumidification load during the warm part of the season due to the fact that air carries water vapour with it. The heating or cooling demand is also important, since the volume of air that is transferred in or out by air leakage, impacts the heating or cooling demand. In this section attention is paid to moisture rather than heat transfer.

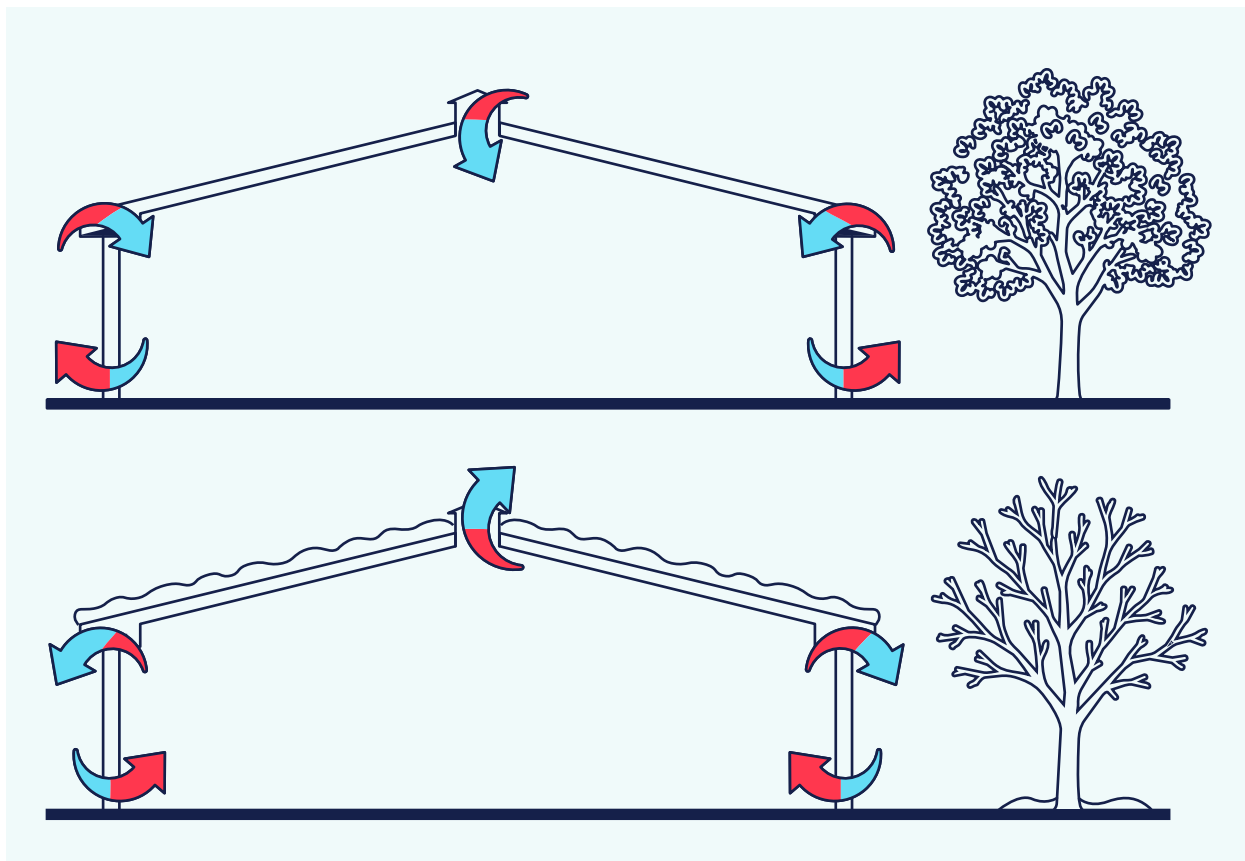


Figure 12. Stack effect in an ice rink depending on a time of a year [Rakennustiето, 2007].

Air leaks through openings or space between joints, or cracks in the building structure, thus a continuous air barrier which seals the whole building envelope is very important. The air barrier material of the wall must seal to the air barrier material of the roof. Usually, in case of improperly sealed envelopes, moisture tends to deposit at a discrete location near the leakage point on the inside of the ice rink arena room.

In Figure 13 an example is shown from an ice rink where evidence of air leakage can be seen. In summertime the total air pressure difference between indoor and outdoor air is negative at the top of the building - above the neutral pressure line, as shown in Figure 12. And provided there are unintentionally created channels for air to flow, infiltration occurs. Condensation eventually happens since the humid outdoor air meets with a material having a temperature that is lower than the dew point of the incoming air.

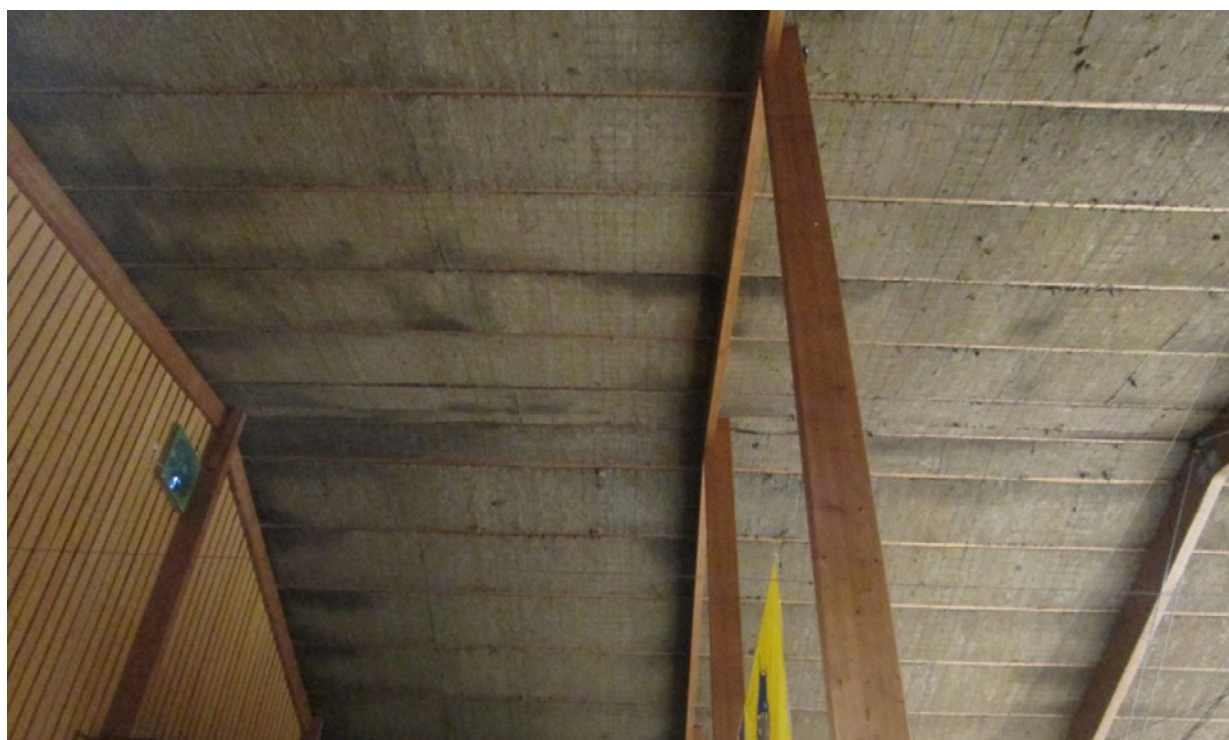


Figure 13. *Air leakage traces near the joint between roof and wall.*

There are materials available with practically zero air leakage, but it is important to account for the complete air barrier system - including joints and all the imperfections, since there are forces applied to the air barrier due to the stack effect, mechanical-system-induced and wind pressures. Therefore, when integrating an air barrier into the wall structure a proper consolidation method must be applied, since if an air pressure difference cannot move air, it will act to displace the materials that prevent the air from flowing.



Figure 14. Vapour permeable Polyethylene self adhering air barrier [Delta Vent, 2019].

In summary, regardless of which materials chosen, the air barrier must be impermeable to air, able to support the peak pressure load, continuously applied from foundation to roof, and durable.

4.1.3 Vapour barrier

Moisture diffusion is a much slower process than air leakage and therefore contributes less to indoor moisture loads in ice rinks. However, condensation caused by moisture diffusion can damage the building structure if moisture accumulates within the envelope.

Materials such as metal sheets, polyethylene foil and plywood have high vapour resistance, while mineral wool and vapour-open air barriers allow moisture transport. In ice rink applications, highly vapour-tight layers may increase the risk of trapped moisture and condensation. Therefore, an airtight but vapour-open construction is generally preferred over traditional vapour barriers.

4.1.4 Example wall constructions

The following examples illustrate typical wall construction principles for ice arenas. They should not be treated as universal standard solutions. The final wall build-up must always be adapted to the local climate, the indoor operating conditions and the selected materials. As a general principle, the higher vapour resistance should be placed on the warmer and more humid side of the wall core, and the solution should be verified for the local climate.

Example 1 – Built-up wall for moderate humid climates

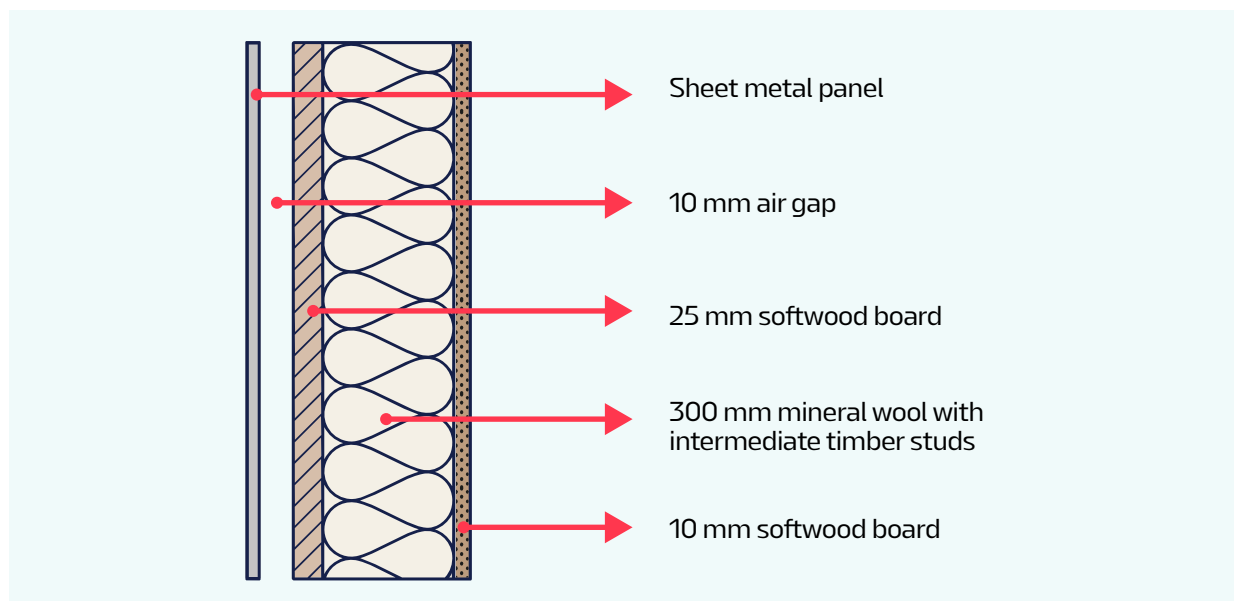


Figure 15. Example of a built-up wall construction for a moderate humid climate. The vapour resistance is higher on the outer side of the insulation. Source: NERIS Del 4.

This wall principle is suitable for climates where the outdoor air is often more humid than the arena room during large parts of the year. The exterior cladding acts as weather protection, with a ventilated air gap behind it. The wall core consists of an outer timber board functioning as wind protection, mineral wool insulation, and an inner timber board. In this type of climate, the vapour resistance is higher on the outside of the insulation than on the inside. This can be achieved by using a thicker timber board on the outer side of the wall core.

Example 2 – Built-up wall for cold / dry climates

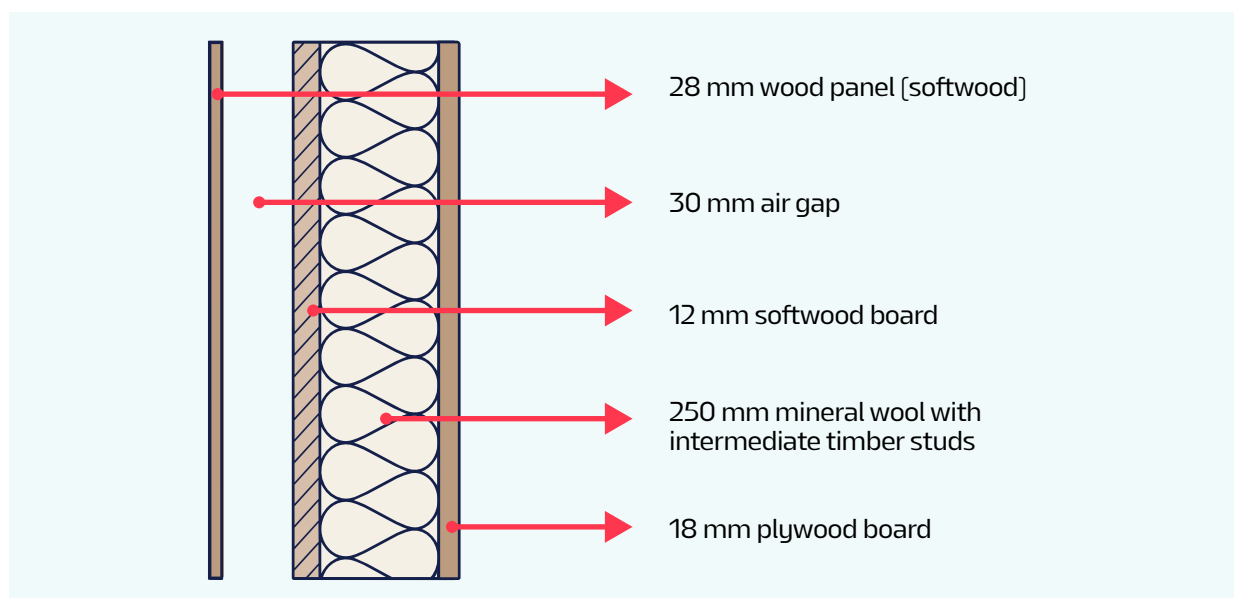


Figure 16. Example of a built-up wall construction for a cold / dry climate. The vapour resistance is higher on the inner side of the insulation. Source: NERIS Del 4.

This wall principle is suitable for colder and drier climates, where the outdoor climate is dry during a large part of the year. The exterior timber cladding acts as weather protection, with a ventilated air gap behind it. The wall core consists of an outer timber board, mineral wool insulation, and an inner plywood board.

In this type of climate, the vapour resistance is higher on the inside of the insulation. This helps limit outward moisture diffusion from the arena room through the wall.

Example 3 – Metal-faced sandwich panel wall

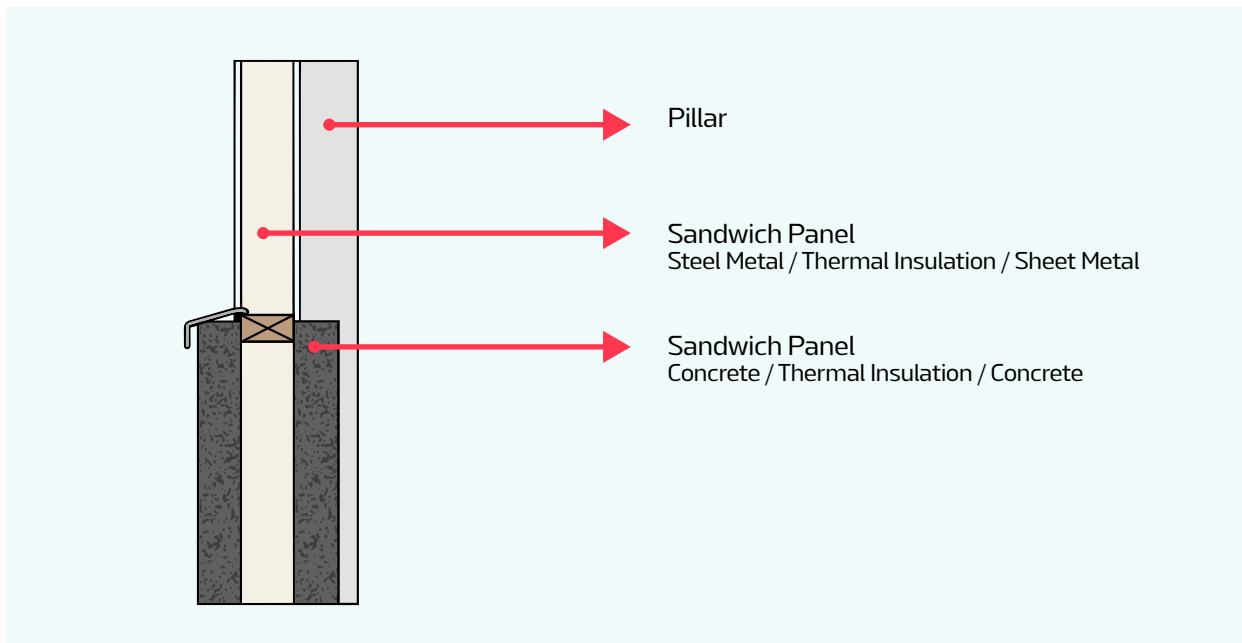


Figure 17. Metal-faced sandwich panel wall [IIHF Official Ice Arena Guide 2024].

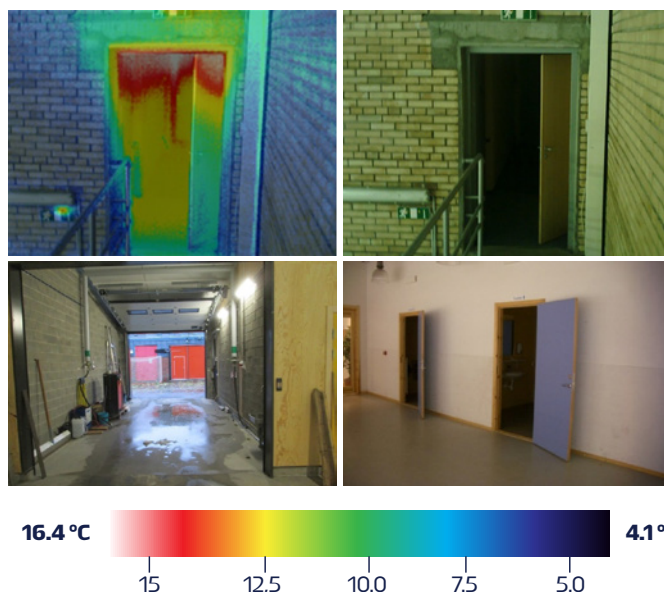
A common ice arena wall solution is a prefabricated sandwich panel with a thermal insulation core and metal sheets on both sides. This type of construction can provide good airtightness, thermal insulation and practical installation. It may also allow later modifications to the envelope at relatively low additional cost.

In this type of vapour-tight panel system, the insulation core should preferably be made of a material with low moisture absorption. If moisture enters the panel through air leakage, openings or poorly sealed joints, it may otherwise become trapped inside the structure. For this reason, insulation materials such as polyurethane or polyisocyanurate are commonly used in cold-room and freezer-room applications, while moisture-absorbing insulation materials should be avoided in sealed sandwich panel systems.

Since the metal facings are vapour-tight, the performance depends strongly on careful sealing of panel joints, penetrations and roof-wall connections. For lower wall sections exposed to mechanical impact or vandalism, more robust concrete panels may be used, with metal sandwich panels higher up the wall.

4.2 Climate zones

Due to the unique indoor climate of an ice arena, the rink space should be separated from outdoor and heated indoor areas using airlocks and well-insulated partitions. This reduces air leakage, moisture ingress, energy use and condensation risk. Particular attention should be given to resurfacers access doors and snow dump areas, where automatic closing systems can significantly reduce uncontrolled air exchange.



In general, it can be recommended to place signs at the doors to the arena room reminding users to ensure that the arena room is kept “closed”. Door type should be selected such that is hermetically sealed and with materials that have a high thermal resistance.

Figure 18.

Open doors either directly towards outdoors, or between comfort and arena zone cause significant energy and moisture influx into the arena room. In addition, basic uninsulated wooden doors are found between climate zones in some ice rinks which is not an optimal solution.



Figure 19. *Doors between the cold space and heated spaces must be with high thermal resistance, hermetically sealed and normally kept close.*



As bringing this essential information regarding closing doors etc. to all ice users have proven to be challenging, an automatic self-closing function is a recommended feature.

5. Sustainable rink floors

The rink floor is a very important component in the ice rink since it is the base for the ice and the largest heat exchanger in the facility. From a construction point of view, it needs to be in level and from a material perspective it must withstand the stress from low temperatures and high weight loads. In Europe most ice rinks have the measure 60x30 m whereas in North America the typical measure is 61x26 m.

5.1 Structure

An ice rink floor typically consists of several layers illustrated in Figure 20, where the top one is the ice sheet with a recommended thickness of 25-30 mm. The floor itself is often made of concrete [designed for freezing temperatures] for best durability, although sand and asphalt may be used as well due to lower investment costs. In the top part of the concrete, the cooling pipes are typically embedded which provides the heat transfer function as the heat load on the ice needs to be transferred to the refrigeration system. The pipes should be placed as close as possible to the ice sheet (max appr. 35-40 mm between top of pipe and concrete surface) to minimize the resistance in heat transfer, since it otherwise implies that the refrigeration system will be forced to work at a lower temperature [and thus become less efficient]. Building codes and construction praxis also sets a limitation as to how thin the concrete layer on top of the pipes and reinforcement mesh can be, therefore it is seldom possible to reduce the thickness above the pipes to less than 40 mm. In total the concrete slab is about 150 mm which also includes reinforcement above and below the pipes depending on the structural load requirements.

Under the concrete slab there is an insulation layer to reduce the heat load from the ground. It is recommended to use the material extruded polystyrene [XPS] or equivalent with closed cells that does not absorb moisture. A product such as EPS is more permeable to air and moisture, and this must not be used since it is not resistant to water vapour. A vapour retarder is recommended to be installed, at least below the concrete layer, to halt moisture transfer from the ground into the concrete. If gaps arise in the insulation layer, moisture may migrate into the concrete.

Below the insulation layer there is very important function – the so-called freeze protection or sub floor heating – which consists of heating pipes. Although there is an insulation layer above, with time, the ground will be cooled to freezing temperatures which may result in frost heaving. If that occurs there is a risk of damaging the rink floor construction including pipe leakages and associated problems.

Controlling the ground temperature is key since too high temperature will increase the heat load on the rink floor. If there is no other facility under the rink floor, the temperature may be just above freezing [2-3°C]. Therefore, temperature sensors must be placed in the ground and preferably in pipes to be interchangeable if they break.

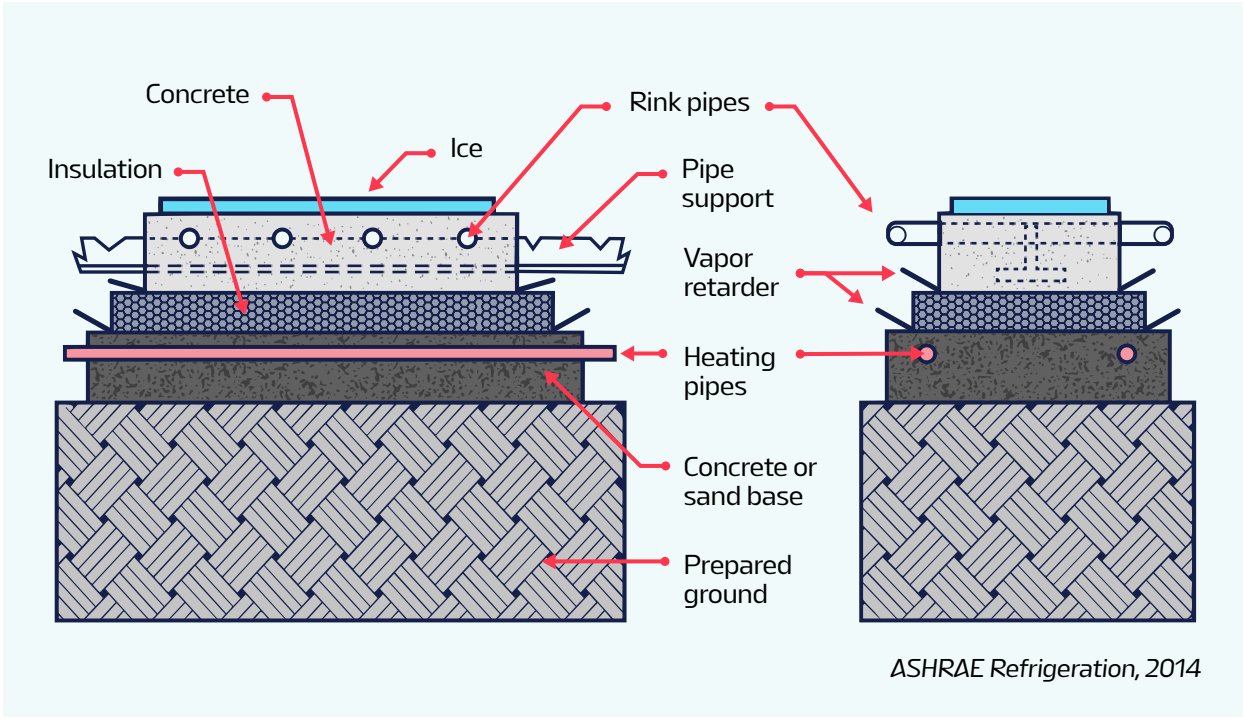


Figure 20. Typical layout of an ice rink floor.

The material used below the rink floor should break the capillary transfer of moisture from the ground towards the rink floor. In case it does, there is a risk that moisture over time may reach the rink floor structure from the ground and cause damage to the structure. Table 2 lists the indicative dimensions for rink floor layers and rink piping.

Table 2. Typical ice rink floor and dimensions.

Parameter	Size
Ice Thickness	25–30 mm
Concrete thickness	150 mm
Insulation thickness	100 mm
Rink pipe headers diameter	150–200 mm
Rink pipe distribution pipes diameter	25–32 mm (PE)
Rink pipe distribution spacing	75–100 mm
Rink floor pipe top – bottom ice distance	35–40 mm

If there is another facility under the ice rink floor such as garage or equivalent, a slightly different approach should be considered. Due to the risk of condensation on the ceiling surface of the floor below, a significantly higher sub floor heating temperature is required. This drives the heat load on the ice rink floor, and a thicker insulation may be considered.

5.2 Rink pipes

There are mainly three types of materials used for the rink piping in the ice rink floor through which the secondary refrigerant flows: plastic, steel and copper. Plastic is the conventional solution used with most aqueous based secondary refrigerants. In refrigeration systems where CO₂ is used as secondary refrigerant, plastic pipes cannot be used due to the high working pressure of CO₂ which during normal operation is typically in the range of 25 to 30 bar. Steel and copper pipes can handle higher working pressures and have higher thermal conductivity than plastic, thus resulting in a more efficient heat transfer and better overall performance.

Material costs vary when comparing copper tubes to steel pipes, but the installation cost of copper tubes is often lower since they can be handled on longer lengths and rolled out on site. Steel pipes on the other hand are often delivered at fixed lengths to be welded.

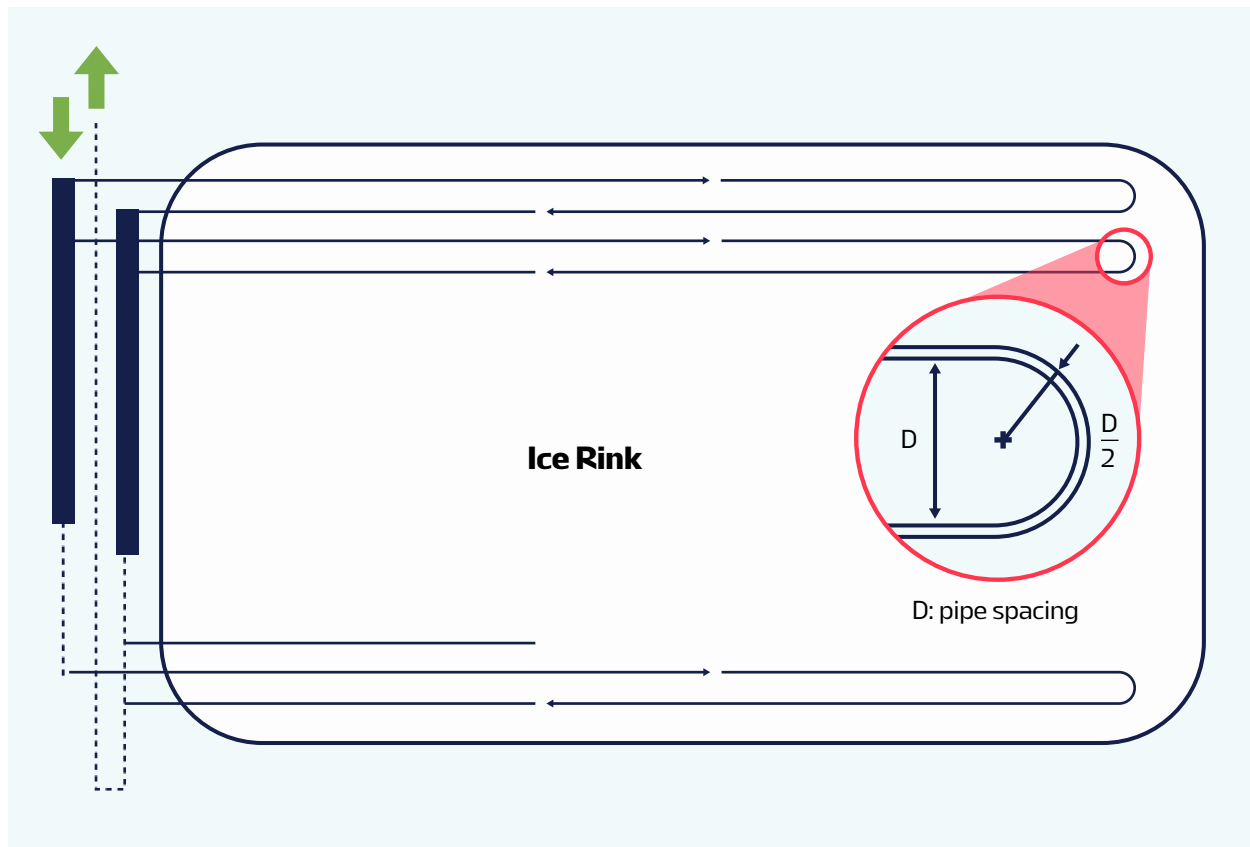


Figure 21. Typical piping layout in Europe with headers on the one short end side.

The piping layout is normally arranged like indicated above where the supply and return headers are placed on the short end side of the ice rink. There is normally a two-pass arrangement where the secondary refrigerant is passed to end of the floor and then returned. To allow for effective capacity control of the distribution pumps it is favourable to arrange a so-called reversed return arrangement on the header side. This is also often referred to as a Tichelmann connection.

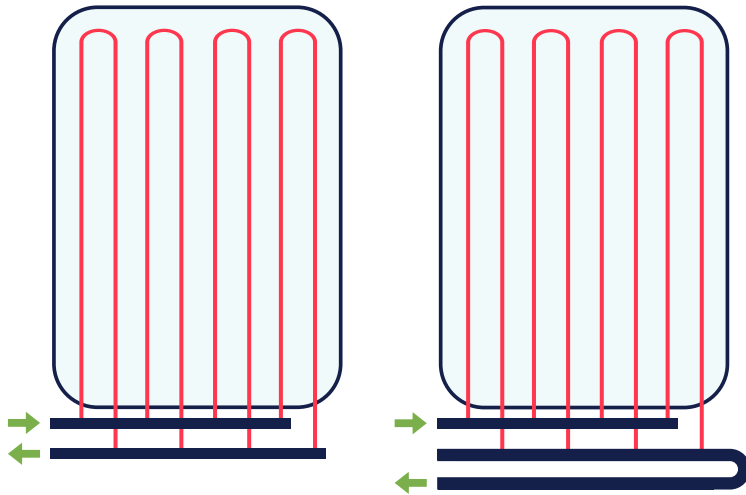


Figure 22. Two different header arrangements: conventional [left] and reversed return [right], where the latter is generally recommended.

The advantage of the reversed return is that since it is “hydraulically balanced” it will provide an even flow distribution regardless of the fluid flow. Some header designs use restrictions to control the distribution, which increases the pressure drop and it cannot be capacity controlled within a larger flow range. Distribution of secondary refrigerant is further discussed in the refrigeration system chapter of this guide.

5.3 Subfloor heating / Freeze protection

Subfloor heating pipes are normally made of plastic, and often of the same quality as the plastic pipes used for the secondary refrigerant distribution with a pipe spacing of approximately 500 mm. As previously described it is important that the subfloor heating fulfils its function at lowest possible temperature level, so that it does not unnecessarily cause extensive heat load on the rink floor itself.

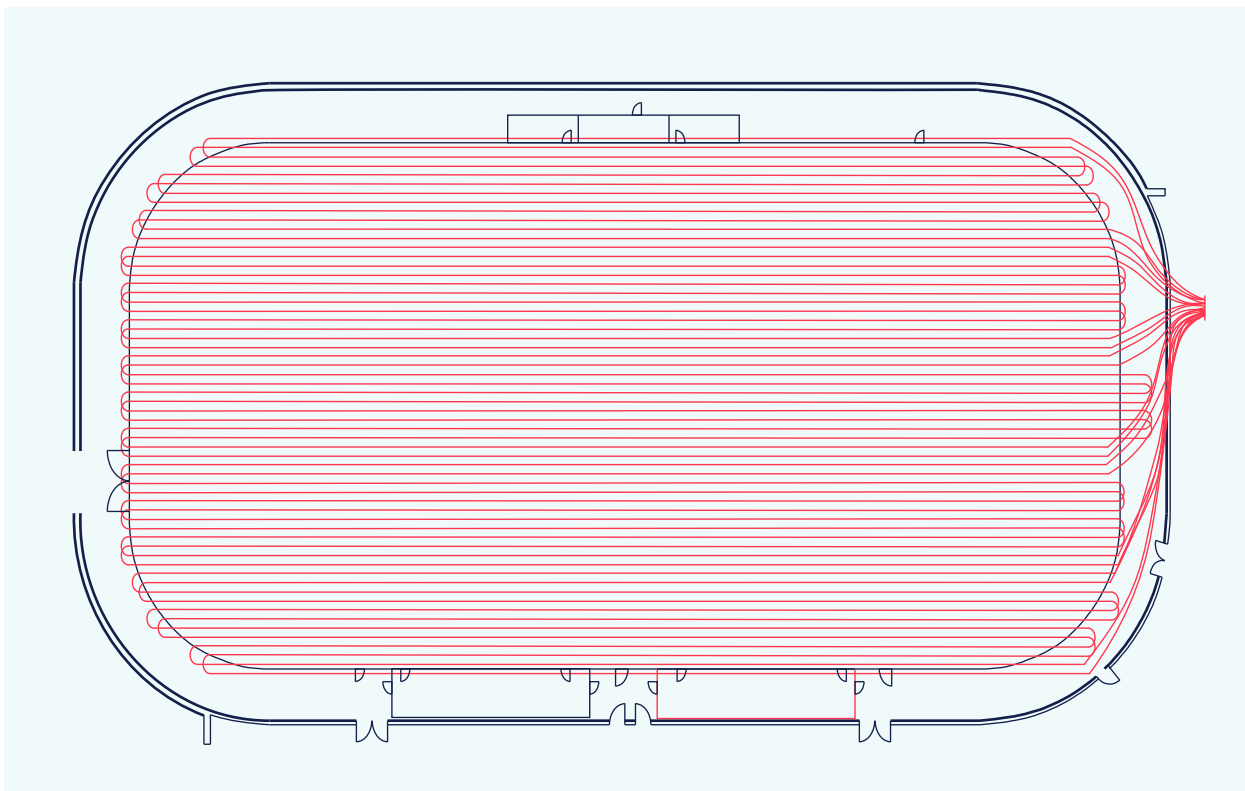


Figure 23. Principle solution on freeze protection distribution below the rink floor.

When a rink floor has a freeze-protection function, the ground temperature should be maintained at 2-3°C. This further indicates that the fluid itself needs to be freeze-protected and a recommended solution here is often an adequate mixture of water with propylene glycol or equivalent with low enough freezing temperature.

5.4 Dasher boards

Dasher boards are generally less of a concern from an energy usage point of view although the tightness and height of the rink have some impact. The dasher board structure may be insulated but this has a neglectable impact on energy and is typically only interesting from a noise dampening perspective. Although, the air temperature inside the boards is a somewhat lower than the surrounding, the difference is small, thus the impact on the heat transfer is minimal.

There is one aspect though, and that is related to the closing of the board system to maintain the somewhat colder air inside the rink. Again, it is more important in warmer arena rooms but the air exchange between the arena room and the ice zone will increase if the dasher board doors are open. This will bring warmer and more moist air to the ice surface during non-activity time, therefore it is strongly recommended to have a closed-door routine in place. A major part of the temperature gradient in the air takes place from the ice surface and up to 1.5-2m which suggests that it may be beneficial if the spectator shielding is intact to this height.



Figure 24. *Dasher boards fulfil important functions, not the least in terms of safety.*

Further, dasher boards are important in terms of function and safety, and an impartial industry expert should be consulted in the design and procurement of services related to dasher boards. Regular maintenance and status checks are also important to ensure that player/visitor safety is upheld.

6. Sustainable energy systems

Whether the specific ice rink facility is going to be profitable to a major extent depend on the awareness of ice rink management that energy usage is a major expenditure. Sustainable energy systems in an ice rink present an opportunity for a significantly more cost-competitive ice rental rates, making ice hockey more affordable.

This chapter provides a general overview about the key energy systems an ice rink depends on. For each system the best practices according to evidence from real installations and research are suggested.

6.1 Refrigeration system

Refrigeration system is the largest energy user in an ice rink and often presents the most significant saving potential. Principally the refrigeration system can be divided into two main subsystems – the primary and the secondary.

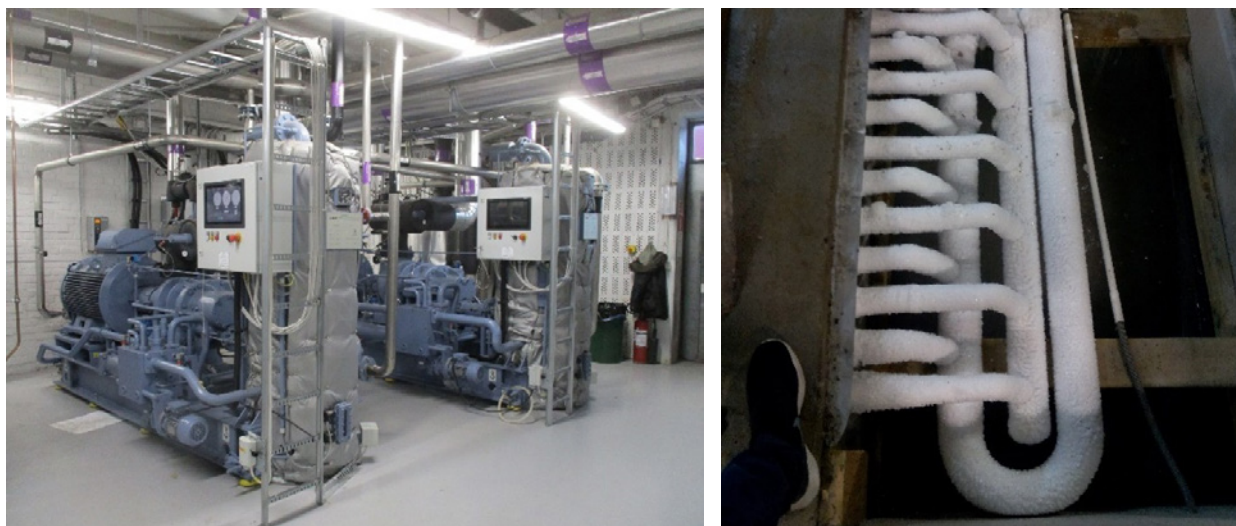


Figure 25. The primary system [on the left] involves a primary refrigerant, it cools a fluid in a secondary system [on the right] that circulates in the rink pipes.

- **Primary system** is the central refrigeration plant with refrigerant, typically placed in a technical room or an outdoor container. A distinct part of a primary system are compressors, heat exchangers among other components.
- **Secondary system** is the cooled fluid circulation system that absorbs heat from the ice slab and transports it to the primary refrigeration system where it is cooled. It is comprised of a long distribution piping that is embedded in the rink floor and with common pipes connected to the primary system.
- **Refrigerant** is the fluid that is used in the primary system.
- **Secondary fluid** is the fluid that is used in the secondary system.

Ice rink refrigeration system can principally be divided in two types – direct and indirect configurations.

An indirect system has a separation between the primary refrigerant that is used in the refrigeration cycle, while the secondary fluid is circulated through the rink piping system and brought to the evaporator.

A direct system has one fluid in the complete system used without separation, i.e., the same refrigerant that evaporates in the rink pipes is also passed through the compressors.

The indirect configuration is more common, partly because ammonia, NH_3 , has historically been widely used as a primary refrigerant. In ammonia systems, an indirect design is normally required because the separate rink pipe loop avoids circulating toxic NH_3 in the rink floor and reduces the total refrigerant charge.

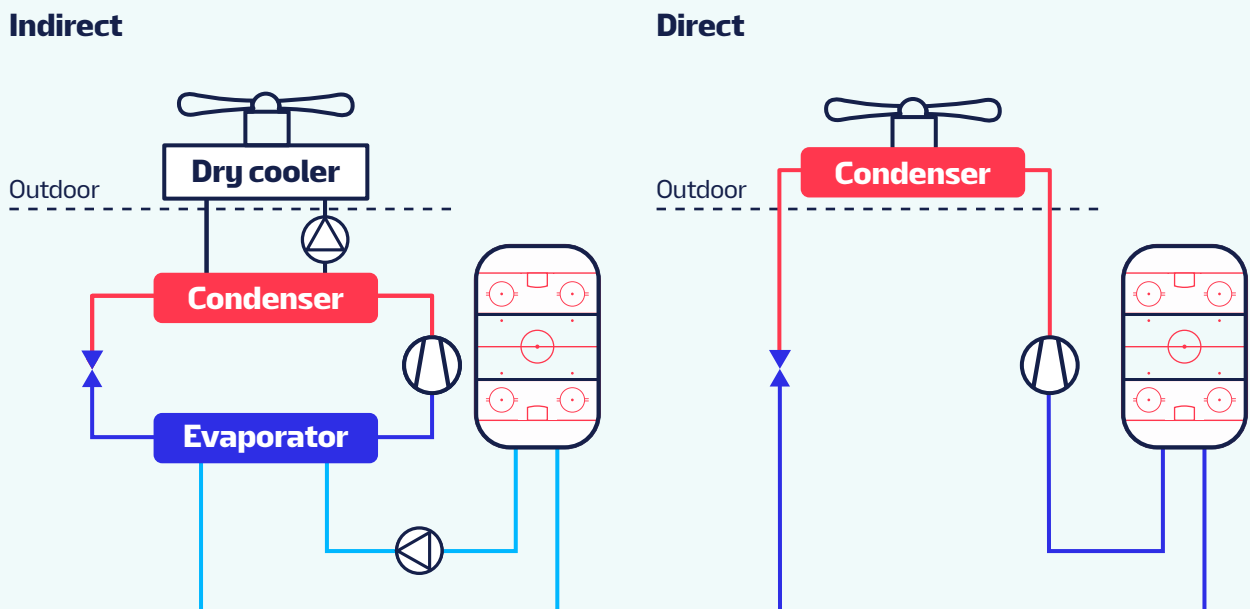


Figure 26. Two main refrigeration system configurations in ice rinks, simplified schematic.

The advantage of a direct configuration is the ability to achieve a more even ice temperature, lower pumping work, and thus higher energy efficiency compared with the indirect design. The key disadvantage is the higher capital cost and limited refrigerant choice.

6.1.1 Primary system

When designing the primary system, several ground principles shall be followed to achieve the best long-term performance.

Selection of refrigerants

Many different fluids [media] can be used as refrigerants; however, for practical reasons the actual usage is limited to a few candidates. Of great importance are the safety [flammability, toxicity, etc.] as well as the environmental impact. The latter has in recent years turned the focus in the direction of natural refrigerants. In Table 3, a couple of refrigerants are listed. As can be seen, natural substances have a significantly lower Global Warming Potential [GWP], thus natural refrigerants do not have long-lasting detrimental effects on the nature when leaked into the atmosphere, which is the case for all synthetic refrigerants.

Table 3. GWP and safety classes of several refrigerants.

Refrigerant	Type	Toxicity	Flammability	GWP
R744 [carbon dioxide]	Natural	Non-toxic	Non-flammable	1
R717 [ammonia]	Natural	Toxic	Low	0
R290 [propane]	Natural	Non-toxic	Hight	3
R404A	Synthetic	Non-toxic	Non-flammable	3922
R134a	Synthetic	Non-toxic	Non-flammable	1430
R513A	Synthetic	Non-toxic	Non-flammable	631
R1234yf	Synthetic	Non-toxic	Low	4

Synthetic refrigerants

HCFC-group - R22

R22 is a synthetic refrigerant belonging to the HCFC group. Due to its ozone-depleting properties, it is subject to phase-out in most parts of the world.

HFC-group - R134a, R410A, R407C, etc.

Together with ammonia, HFCs are among the refrigerants still found in many conventional ice rinks today. HFCs are synthetic refrigerants with no ozone depletion potential, and they are still widely used in some markets. However, due to their high global warming potential, they are not considered a long-term solution and are therefore subject to phase-down or restriction.

HFO-group - R1234yf, R1234ze, R513A, etc.

HFOs, or hydrofluoroolefins, have been introduced as alternatives to reduce the climate impact associated with HFCs. These synthetic refrigerants generally have medium to very low GWP values and do not deplete the ozone layer. However, some HFOs have raised environmental concerns related to degradation products (TFA) and long-term persistence. These aspects are therefore important to consider in addition to GWP.

Regulatory and PFAS considerations

Refrigerant selection should also consider long-term regulatory risk. In the European Union, the revised F-gas Regulation (EU) 2024/573 accelerates the phase-down of HFCs and supports the transition towards low-GWP and natural refrigerant alternatives. This increases the uncertainty related to the future availability and cost of many synthetic refrigerants.

In addition to climate impact, PFAS-related concerns are receiving increased attention. Most synthetic refrigerants are either PFAS themselves or may degrade into persistent PFAS-related substances, such as trifluoroacetic acid, TFA. PFAS as a group have been associated with several potential health concerns, including effects on fertility, development, the immune system and cancer risk. This means that refrigerant selection should not be based only on GWP and ozone depletion potential, but also consider environmental persistence, future regulation, serviceability and life-cycle cost.

Natural refrigerants

R290 [Propane]

Propane is a natural fluid in the hydrocarbon group often referred to as the HC-group. Chemically it has the formula C_3H_8 and is one in a family consisting of many potential refrigerants but used for different applications. One major drawback is the flammability and due to the safety aspects, propane will normally only be used in fully or partly indirect system, confined in a well-ventilated technical room or placed outdoors. Nevertheless, in recent years a significant commercialization of propane refrigeration plants in various applications have been observed making it a widely accepted solution.

R717 [Ammonia]

Ammonia is a commonly used natural refrigerant in ice rinks with the chemical formula NH_3 , and it has been used as refrigerant since “the beginning”. It is environmentally friendly and efficient but also flammable and toxic. The use of ammonia requires well designed safety measures which impacts the cost; therefore, ammonia is normally only used in “larger” refrigeration plants. For safety reasons ammonia is not allowed to be use inside public spaces with people present such as ice rinks. It may still be used as primary refrigerant, inside the technical room, where it will require a secondary fluid which transports “the cold” to the ice sheet.

R744 [Carbon dioxide]

Carbon dioxide is another natural substance with the chemical formula CO_2 . It has a long history as a refrigerant and has in recent years become a common solution in ice rinks due to some favourable properties. In pure refrigeration applications CO_2 may have somewhat lower efficiency in warm-climate operating conditions, compared to other refrigerants, but its non-flammable and non-toxic properties offers interesting technical and safety advantages.

Due to the thermodynamic characteristics CO_2 offers advantages especially in terms of heat recovery. This implies that in applications with combined cooling and heating demands, such as ice rinks, it can often be a very energy and cost-efficient alternative.

Summary:

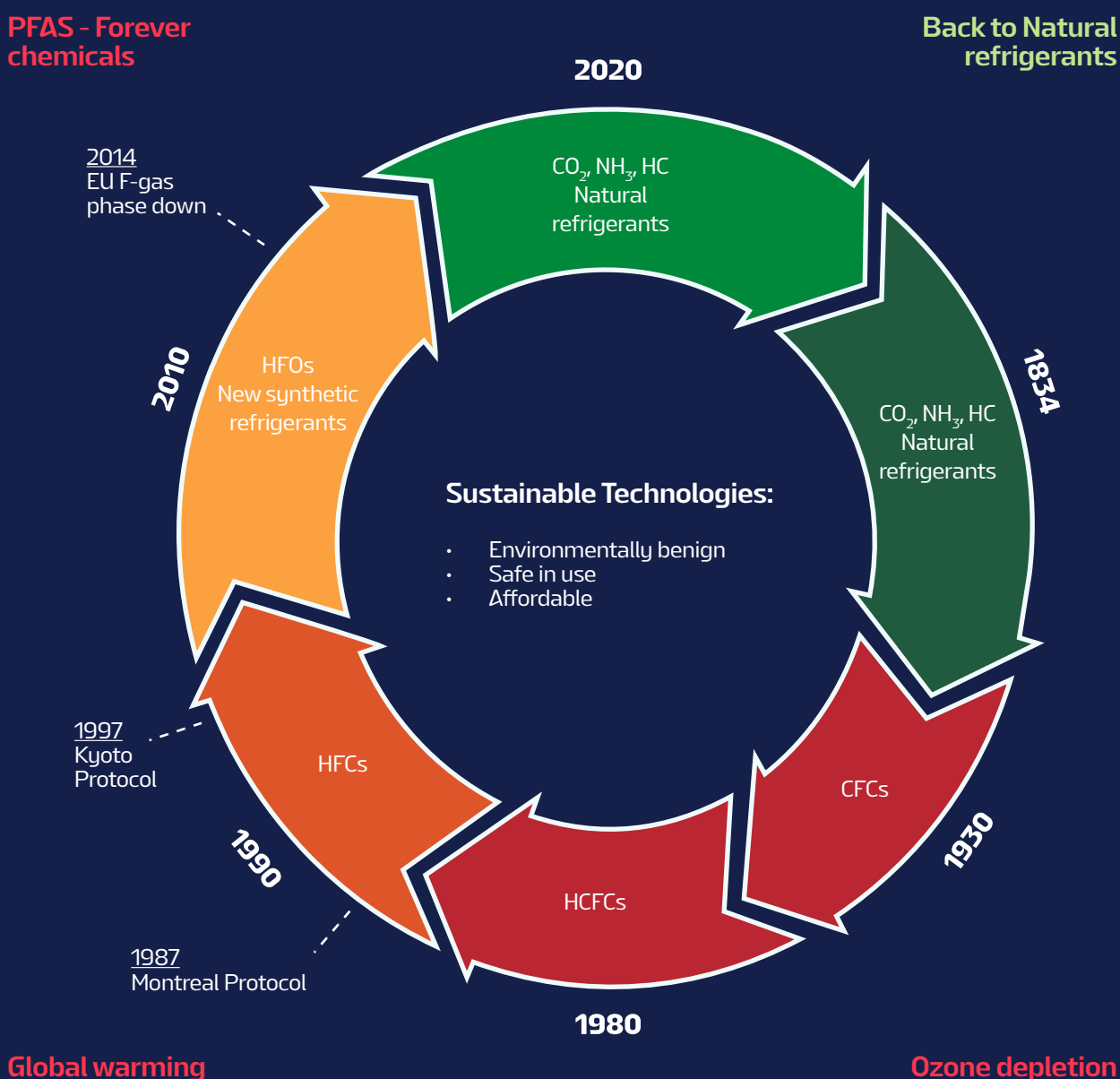


Figure 27. The global tendency is to “return to the roots” and select natural refrigerants [Danfoss].

There are many more refrigerant alternatives out there, but this guide limits the discussion to these above since they are relevant to the topic. As a final comment to the primary refrigerants, it can be said that due to the focus on environmental issues and sustainability, the industry direction is natural refrigerants and/or newly developed synthetic alternatives. The latter is a hot topic today where intensive research and development takes place.

Primary refrigeration system solutions

The primary refrigeration system normally has a technical life of 15–25 years or more, which makes the technology choice important from both an energy and life-cycle cost perspective. For sustainable ice arena projects, CO₂ and ammonia are normally the main alternatives to evaluate. Synthetic refrigerants may still be considered in some markets, especially where local competence with natural refrigerants is limited, but future regulation, environmental impact and long-term serviceability should be carefully assessed.

CO₂ as a primary refrigeration system

After the first ice rink system using carbon dioxide, CO₂, as secondary refrigerant was built in 1999, it took until 2010 before the first ice rink using CO₂ as a primary refrigerant was realized. Today the number of ice rinks in Europe and North America using CO₂ technology is significant.



Figure 28. The first CO₂ primary refrigerant system in ice rink in Europe was installed in 2014 in Gimo, Sweden. Picture source: Google maps.

CO₂ primary systems may be designed either as **direct expansion systems (DX)** or as **indirect systems**. In a direct CO₂ system, CO₂ circulates directly in the rink floor. In an indirect CO₂ system, CO₂ is used in the primary refrigeration plant, while a separate secondary fluid circulates in the rink floor.

Both configurations should be designed with optimized heat recovery. Direct CO₂ systems are generally most suitable for new rinks or projects where the rink floor is replaced, since they require rink piping designed for higher pressure. Indirect CO₂ systems may be more suitable for retrofits where existing plastic rink piping can be reused.

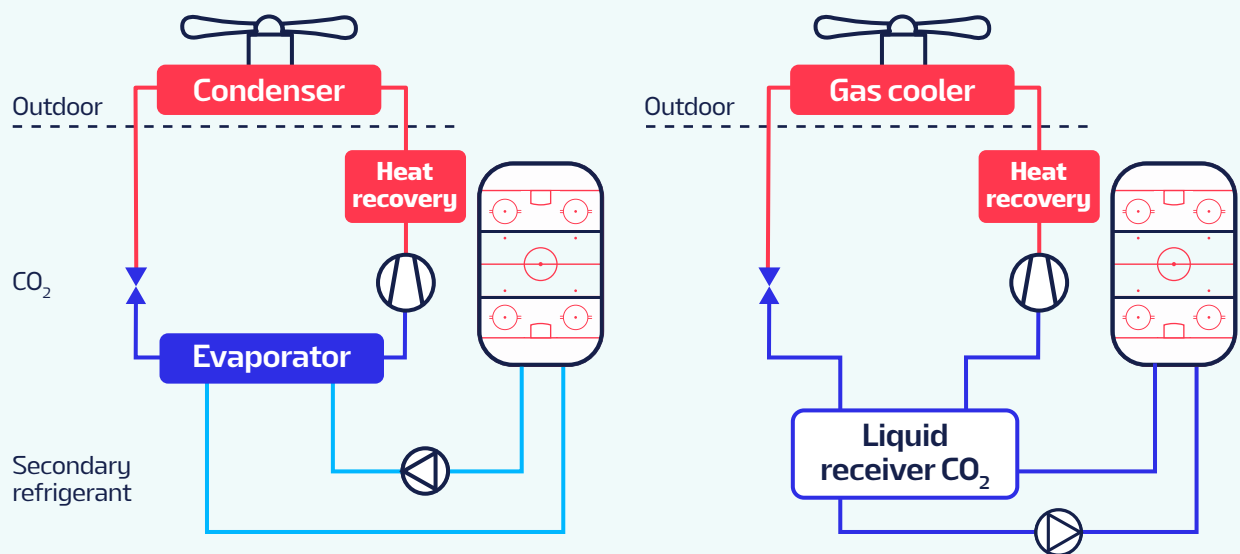


Figure 29. Principle of a CO₂ indirect to the left and CO₂ DX to the right, with heat recovery.

Both systems have their pros and cons when compared to each other, as listed in Table 4.

Table 4. General differences between the possible CO₂ configurations.

	CO ₂ DX	CO ₂ indirect
Pros	• More efficient than CO₂ indirect, less compressor work needed • More accurate ice temperature control	• Safer due to less charge • Lower investment, can often reuse plastic rink piping
Cons	• More CO₂ charge thus theoretically less safe • Requires metal rink piping, higher investment than indirect	• Less efficient due to; heat exchange in the evaporator, more compressor work needed and more pump power • Requires a secondary fluid in the rink floor

In general, direct CO₂ systems are better suited to new construction or projects where the rink floor is replaced, since they require metal piping in the rink floor. Due to the higher investment and lower energy consumption, a longer ice season improves the profitability of this solution. Indirect CO₂ systems can offer a lower investment, since conventional plastic rink piping may often be used. However, the solution is normally somewhat less efficient, which increases operating cost.

The choice of technical solution should therefore be based on facility-related constraints, energy profile, safety, investment cost and life-cycle cost, as these factors will also influence the environmental performance and profitability of the project.

NH₃ as a primary refrigeration system

Ammonia, NH₃, has been widely used as a refrigerant in ice rinks since the first artificial ice rinks were introduced. A traditional fully indirect NH₃ system is a proven solution. In modern form, these systems can offer small refrigerant charges, high efficiency, good capacity regulation and a long service life.

One factor that has increasingly become a decisive reason for changing systems is that ammonia presents a higher safety risk to humans. Even though modern solutions have succeeded in reducing the refrigerant charge considerably, there remain risks that have to be mitigated.

Ammonia is a colorless gas with a strong and irritating smell which may be dangerous at higher concentrations to humans due to its toxicity. However, the advantage is that most people can smell it already at 5-10 ppm which is way below dangerous concentrations.

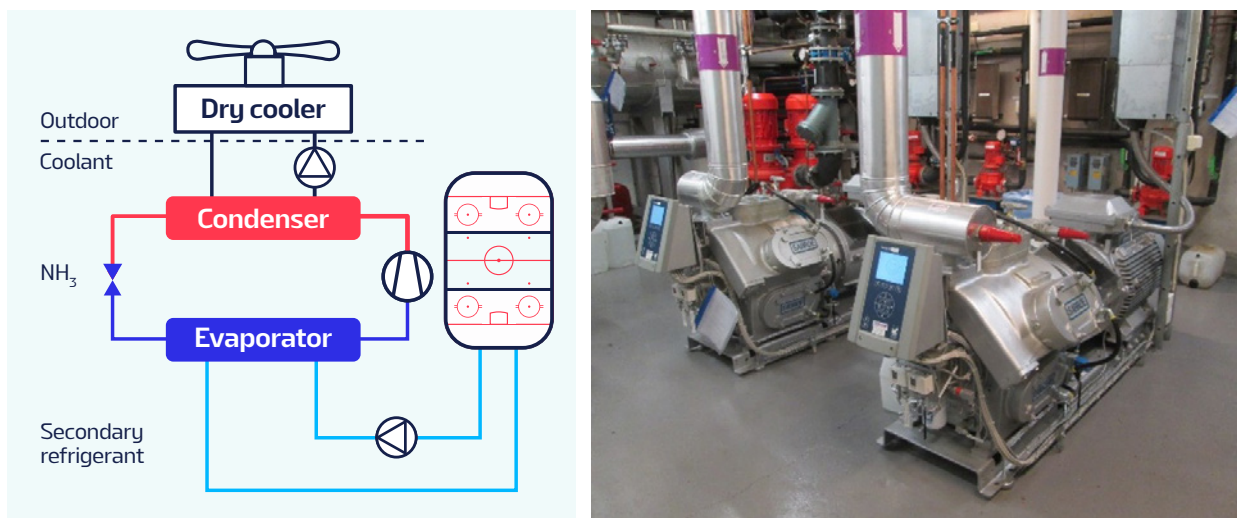


Figure 30. A modern fully indirect NH_3 refrigeration system.

A way to limit the ammonia charge is to use a fully indirect system with secondary fluids on both the cold and the warm side. There is a slight energy penalty compared with direct system solutions due to the auxiliary equipment, such as fans and pumps. Furthermore, the heat exchange on both the cold and warm sides cause some losses in the overall system. As mentioned previously, heat recovery plays a key role in an ice rink's operating economy, and for ammonia the inherent properties are less favourable than for CO_2 , which reduces the heat available at the temperature level needed in an ice rink. In general, ammonia systems may be supplemented with a heat pump or district heating to cover the full heating demand.

6.1.2 Secondary refrigeration system

In an indirect refrigeration system, the secondary refrigerant is the heat transfer fluid that transports heat from the rink floor to the primary refrigeration system via the evaporator. This fluid may also be referred to as a secondary coolant, heat transfer fluid or brine.

Common secondary refrigerants used in ice rinks include **ethylene glycol (EG)**, **calcium chloride (CaCl₂)**, **aqua ammonia (NH₄OH)**, **carbon dioxide (CO₂)** and **potassium formate (KF)**. Less common alternatives include **propylene glycol (PG)**, **ethyl alcohol (EA)** and **potassium acetate (KAc)**.

These fluids may have advantages and disadvantages for use in ice rink refrigeration. Safety considerations include toxicity, which refers to risks from inhalation, ingestion, skin and/or eye exposure, as well as flammability characteristics. Environmental considerations include toxicity and possible damage to local ecosystems.

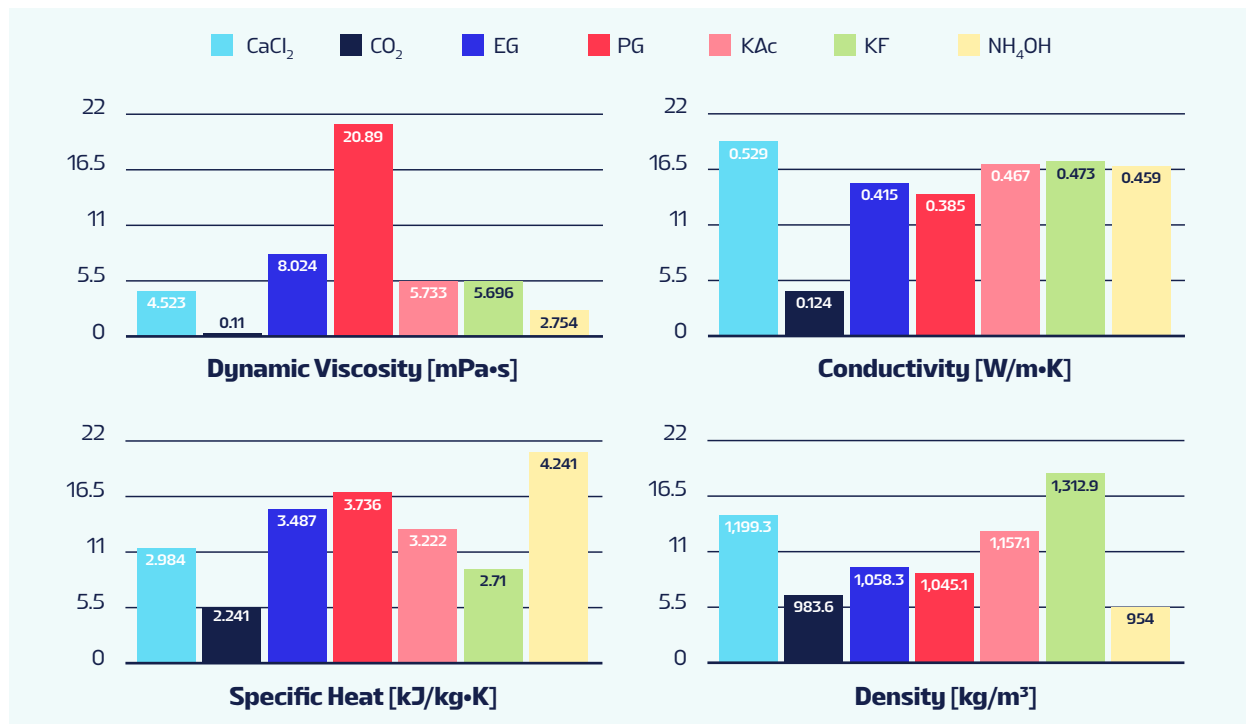


Figure 31. Thermophysical properties of discussed secondary refrigerants at -10°C having freezing points of -20°C [Kilberg, 2020].

The thermophysical properties of the secondary fluid have a large impact on the overall performance of the refrigeration system. From an energy perspective, **low dynamic viscosity, high thermal conductivity, high specific heat and low density are advantageous**, since they help reduce pumping power and improve heat transfer. Most secondary refrigerants used in ice rinks are aqueous solutions, with the concentration adapted to provide a suitable freezing point for the operating conditions of the specific system. As shown in Figure 31, aqua ammonia has favourable thermophysical properties for ice rink applications. CO₂ is more difficult to compare directly with the aqueous fluids, since it is used as a volatile, phase-changing fluid.

Table 5. Summary of the main advantages and disadvantages of the most common secondary fluids in ice rinks.

Secondary fluid	Pros	Cons
Calcium Chloride (Brine)	Non-toxic, non-flammable, low viscosity, plastic material for rink piping allowed, lower investment.	High corrosivity, low specific heat, relatively high pumping power.
Carbon dioxide	Non-toxic, non-flammable, very low viscosity, high heat transfer properties, low pumping power, allows more even ice temperatures.	High pressures, metal material for rink piping required, higher investment.
Propylene glycol	Quasi non-corrosive, low fire hazard, non-toxic, low environmental hazard risk, plastic material for rink piping allowed, lower investment.	High viscosity, high pumping power.
Ethylene glycol	Plastic material for rink piping allowed, lower investment.	Toxic, high environmental hazard risk, high viscosity, high pumping power.
Potassium Acetate and Potassium Formate	Low environmental hazard risk, relatively low corrosiveness, low viscosity, low pumping power, plastic material for rink piping allowed, lower investment.	Toxic.
Aqua ammonia	Low viscosity, high heat transfer properties, low pumping power, plastic material for rink piping allowed, lower investment.	Toxic, however possesses very low danger due to low ammonia concentration.

Among the secondary fluid options presented above, CO₂ and aqua ammonia are, from a technical perspective, interesting and more recent alternatives for ice rink applications and are therefore described further in detail below.

CO₂ as secondary refrigerant

Using carbon dioxide as the secondary refrigerant in the rink floor distribution system can provide several advantages compared with traditional secondary fluids such as calcium chloride and glycol. The most important advantages are that CO₂ uses phase change, evaporation, and has very low viscosity. This can significantly reduce pumping power and contribute to more even ice temperatures.

CO₂ may be used only as the secondary fluid, where it is cooled by another primary refrigeration plant. An even more integrated solution is a direct CO₂ system, where CO₂ serves as both the primary refrigerant and the fluid circulating in the rink floor, see Figure 29.

Pumping energy with CO₂ secondary fluid

Measurements from ice rink applications indicate that auxiliary equipment, such as fans and pumps, can account for approximately **20–25%** of the refrigeration system's energy use. By using CO₂ as the secondary refrigerant, pumping power can be reduced to about **1 kW**, compared with approximately **5–15 kW** for traditional secondary fluids. **In such systems, auxiliary energy use may be reduced to less than 3% of the total refrigeration system energy use.**



Figure 32. *CO₂ receiver in a large ice arena where CO₂ is circulated in the rink piping [NSSO, Beijing].*

The rink floor piping must be adapted to the properties of CO₂, since it operates at much higher pressure than most traditional secondary fluids. Welded steel pipes have historically been used, but copper tubes designed for ice pads are now also common. In existing ice rinks with plastic rink piping in good condition, CO₂ is therefore often not economically favourable as a secondary fluid. In such cases, aqua ammonia may be a more suitable alternative, provided that the existing materials are compatible.

Aqua ammonia as secondary refrigerant

Aqua ammonia is becoming increasingly popular, both in retrofits of existing ice rinks and in new construction. The first ice rink installation using ammonia-water in Sweden was completed in 2007, and by 2018 there were at least 34 installations in indoor ice hockey rinks. Today, this number is considerably higher. Many Nordic ice rinks still use calcium chloride, CaCl₂, but the trend is clearly moving towards CO₂ and aqua ammonia solutions.

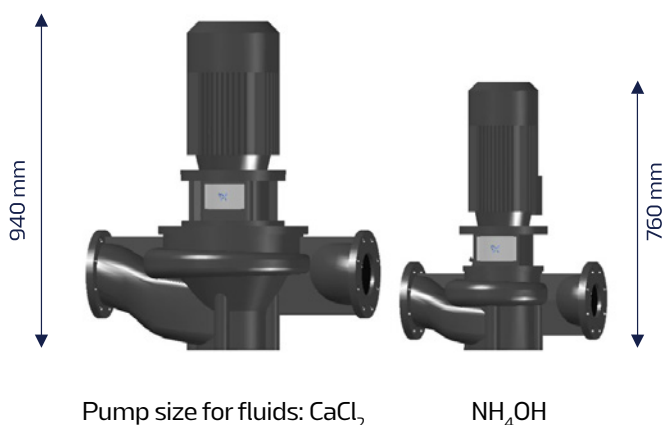


Figure 33. *Required pump size difference between CaCl₂ pump [on the left] and NH₄OH pump [on the right], for the same cooling capacity of 250 kW at -10/-8°C.*

The growing number of aqua ammonia installations is mainly the result of good operating experience. Issues related to calcium chloride have encouraged the market to look for alternatives, and ammonia-water offers several practical advantages, although it also has some disadvantages.

A further reason for the interest in aqua ammonia is the rapid growth of CO₂ primary systems. When CO₂ is used as the primary refrigerant, its high operating pressure can increase the cost of the evaporator, especially when a titanium alloy evaporator is required. If aqua ammonia is used as secondary fluid, a standard stainless-steel evaporator can often be used instead, which may reduce the investment cost considerably.

This saving may offset the cost of retrofitting the secondary fluid system, since the two costs are often of the same order of magnitude. As a result, the retrofit can in some cases be “paid for” by the lower evaporator cost, while the system benefits from lower pumping power throughout the rest of its technical life compared with conventional secondary fluid solutions.

6.1.3 Heat recovery functions

In ice rinks, one of the largest energy-saving opportunities is often found in optimizing heat recovery from the refrigeration system, thereby minimizing the demand for supplementary heat sources. Figure 34 shows an energy balance for an ice rink where 100% of the heating demand is covered by heat recovered from the refrigeration system.

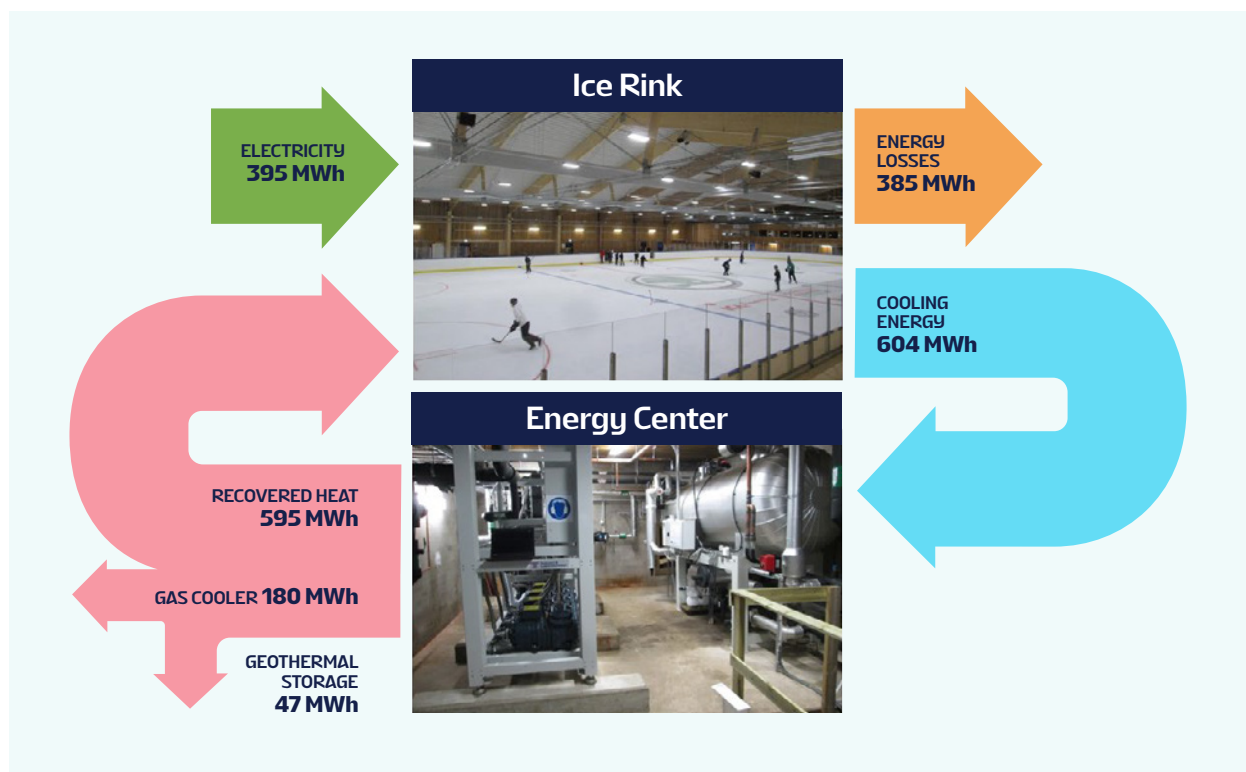


Figure 34. Energy balance in a Nordic training ice rink with 8-month season.

Figure 35 shows an example from a Nordic ice rink, with the cooling demand shown in blue, the heating demand in red, and the available heat from the refrigeration system in green. The figure illustrates that considerable heating savings can be achieved with optimized heat recovery. It also shows that it may be relevant to look beyond the heating demands of the ice rink itself and consider nearby facilities that could potentially use the “free” excess heat.

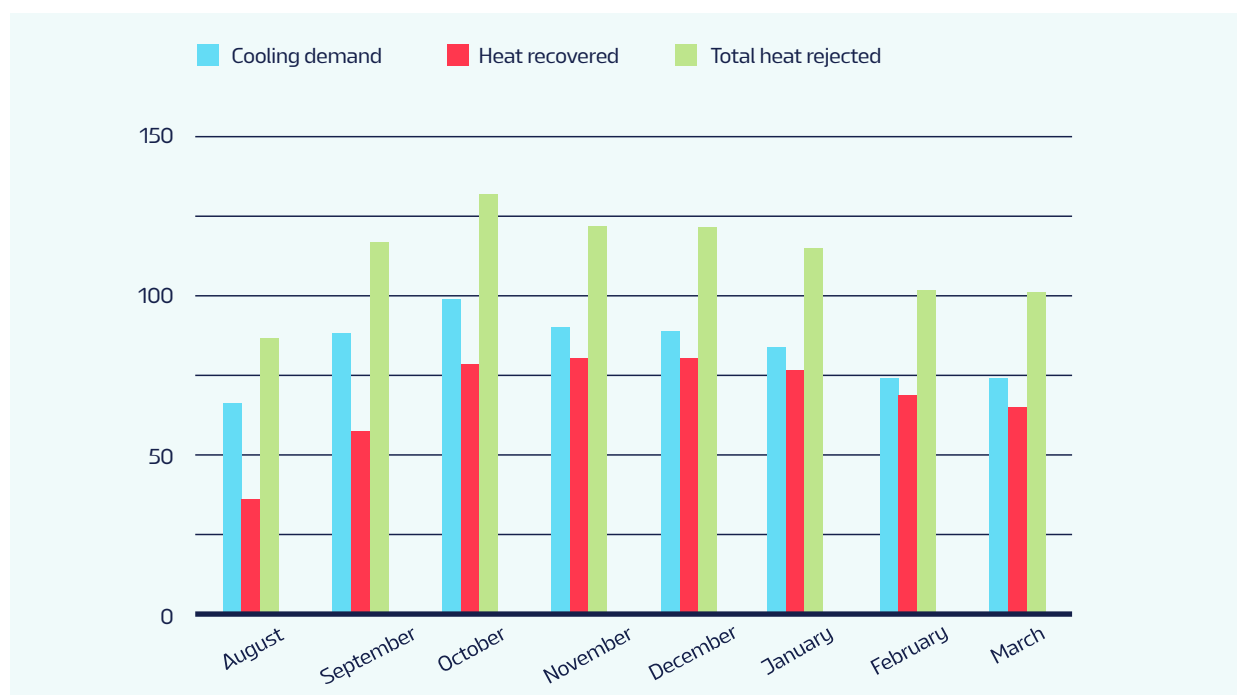


Figure 35. *The refrigeration system usually releases more heat than what a typical ice rink needs. It is therefore interesting to look for heating demands beyond an ice rink.*

The heat recovery system can also be optimized by connecting the refrigeration system to geothermal storage, which provides additional opportunities during both warm and cold weather conditions. During warm periods, the storage may be used to improve the subcooling of the refrigeration process, increasing system efficiency while storing excess heat in the boreholes. The stored heat can later be used during colder periods, when the facility has a higher heating demand.

An optimized heat recovery system can therefore cover the full heating demand of an ice rink, even during colder periods, and may eliminate the need for an external heat source. Reference systems have shown that, in some cases, surplus heat can also be exported to nearby facilities such as swimming pools.

6.2 Heating systems

6.2.1 Heat demand in ice rinks

Ice rinks are heating-intensive facilities with several different heating demands. Space heating is required to provide comfort in public areas such as locker rooms, offices and cafeterias, where temperatures are typically around 20°C. The arena room may be kept at different temperatures depending on the type of arena, activity and comfort requirements, but in most conventional arenas it normally ranges from 5 to 15°C. Hot water for showers and resurfacing water normally needs to be heated to approximately 55–60°C in order to reduce the risk of Legionella growth.



Figure 36. *Ice rinks are heating intensive facilities with many demands.*

To summarize, an ice rink uses considerable amounts of heat for several demands, including:

- Space heating for the arena room and surrounding spaces, such as locker rooms, offices and cafeterias.
- Ventilation air heating.
- Hot tap water for showers, resurfacing water and other domestic hot water uses.
- Subfloor heating/ground freeze protection.
- Melting pit operation.
- Other facility-specific heating demands.

It should be noted that an **ice rink with a tempered arena room**, for example 5–10°C, may use approximately **the same amount of energy for heating as for cooling**.

6.2.2 Heat sources in ice rinks

A variety of heating methods and heat sources are used in ice rinks. However, since an ice rink both requires and produces significant amounts of heat during operation, **recovered heat from the refrigeration system should normally be considered the primary heat source.**

Typical auxiliary or backup heat sources may include:

- Gas or oil boilers.
- District heating.
- Electricity, such as electric boilers or resistance heaters.
- Heat pumps using external heat sources, such as air or geothermal energy.
- Heat pumps using internal heat sources, such as the refrigeration system coolant.
- Wooden pellets.
- Other locally available heat sources.

The choice of heat source depends on several factors, including availability, acceptable investment level, operating cost, security of supply and environmental impact. **Such heat recovery solution from refrigeration is equivalent to any other heat source like gas, oil boiler, etc.**

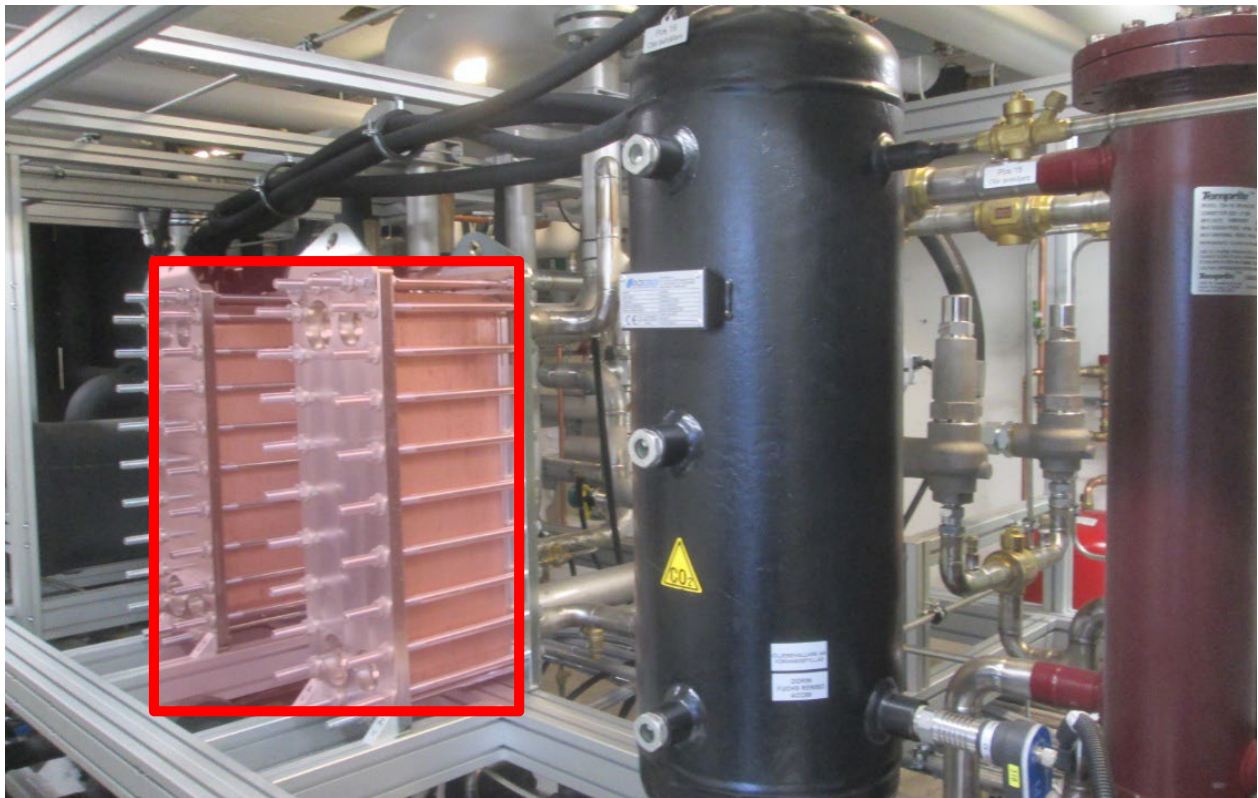


Figure 37. *Heat recovery from modern refrigeration can make the system a two-in-one solution, providing both cooling and heating.*

The refrigeration system of an ice rink produces excess heat during its operation. It is therefore vital to address the waste heat utilization properly by implementing energy recovering measures. Compared to any other heat source it offers the most economical and environmentally friendly performance.

6.2.3 System solutions

Heat recovery from the refrigeration system can be implemented in both new and existing ice rink facilities. To use the recovered heat efficiently, the heating system should be designed according to a few key principles.

A modern heat recovery system is often designed according to the “**waterfall concept**”. This means that recovered heat is supplied to the different heating demands in temperature steps. The demand with the highest temperature requirement is served first, followed by demands with lower temperature requirements. This approach helps **achieve the lowest possible return temperature**, which improves the heat recovery performance, especially when CO₂ is used in the refrigeration system.

The different heating demands can be grouped according to temperature level and connected to accumulator tanks. These tanks store recovered heat over time and help balance the difference between heat production from the refrigeration system and the varying heating demands of the facility.



Figure 38. Groups of accumulator tanks with coils for tap water pre- and post- heating.

Figure 39 shows an example of an ice rink heat recovery system where the temperature profile is adapted to both the heating demands of the facility and the properties of an R744-based refrigeration system. By cooling the primary heating loop to the lowest possible return temperature, the waterfall concept supports an optimized heat recovery system for the ice rink.

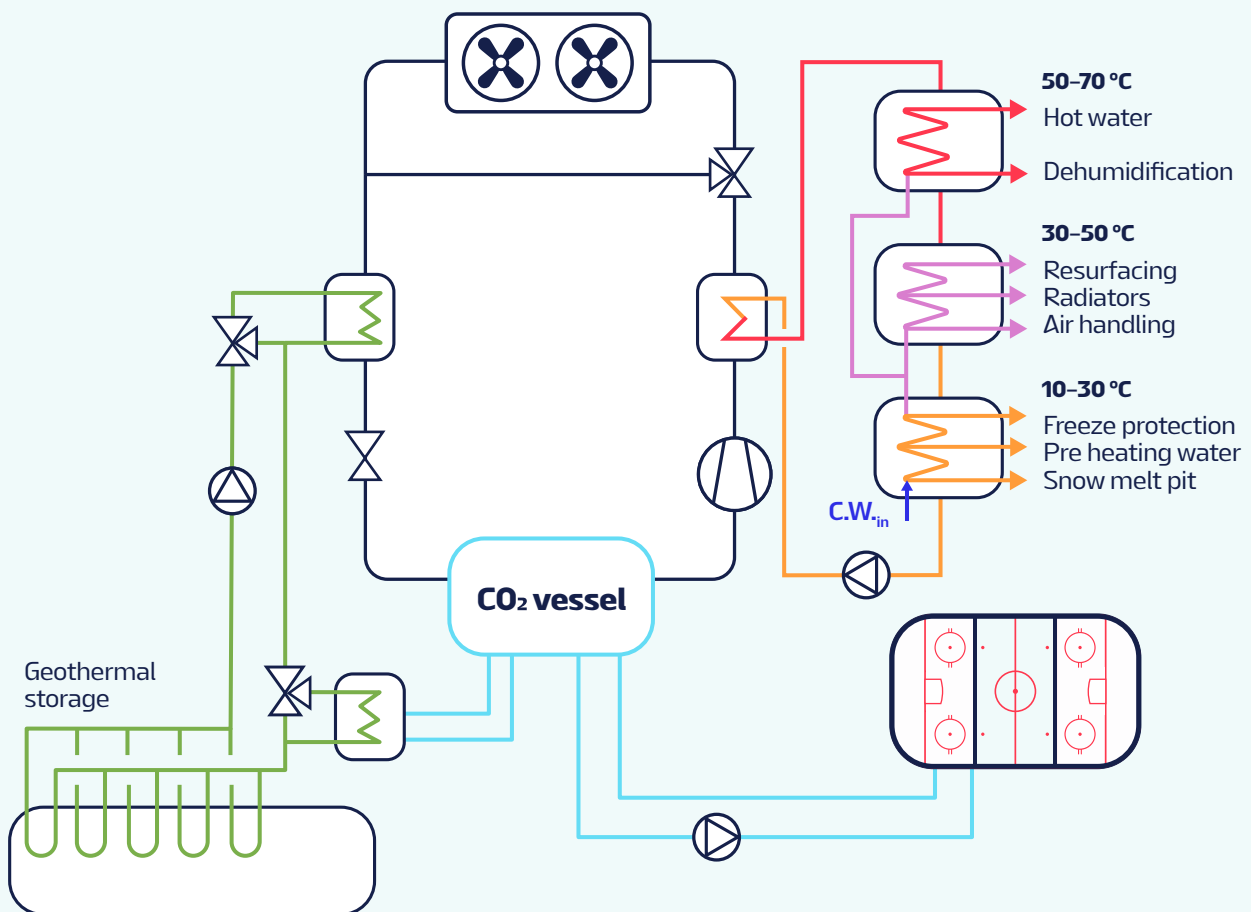


Figure 39. Principle overview of a refrigeration and heat recovery system (Illustration by EKA).

Backup heating is still needed when recovered heat cannot cover the demand, during off-season operation, or during maintenance and system interruptions. In the example shown Figure 39, geothermal storage is used as a “false load”, meaning that it can supply heat to the refrigeration or heat pump system during peak loads or off-season operation. In many facilities, however, backup heat is provided by one of the auxiliary heat sources mentioned above, such as district heating, a boiler or a heat pump.

6.3 Arena room dehumidification

Humidity control is one of the most important functions in ice rinks. To maintain suitable conditions, a dehumidification function is required not only to maintain good ice quality, but also to provide a good indoor climate for people and protect the building structure.

Ice rinks have a large cold surface, and condensation may occur when warm and humid air enters the building through doors, openings or air leakage. Condensation can form on any cold surface with a temperature below the dew point of the surrounding air. In an ice rink, this includes the ice surface, but also potentially the ceiling and parts of the building structure facing the ice, due to radiation heat transfer with the ice. If the arena room climate is too humid, corrosion and mildew growth may occur, leading to an unpleasant and potentially unhealthy indoor climate for occupants.



Figure 40. Moisture problems are known in many ice rinks. Solution to keep the indoor humidity at acceptable level must be used.

6.3.1 Dehumidification technologies

Two types of dehumidification technologies are the most commonly used in ice rinks – **sorption and refrigeration-based**.

Sorption dehumidifiers are the most common type in Nordic ice rinks. They are designed and controlled to maintain a stable dew point in the arena room. In some markets, the reactivation heat for these systems is produced by electric heaters. This is practical, but not always the most energy-efficient solution when recovered heat from the refrigeration system is available, as shown in Figure 35.

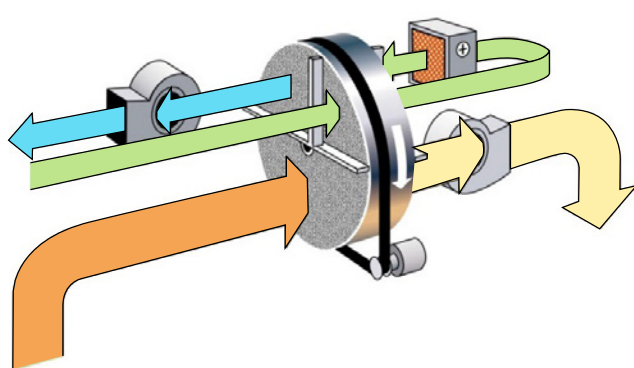


Figure 41. The working principle of a sorption type of dehumidifier [left] and unit [right].

Refrigeration-based dehumidification is based on the condensation principle, where moisture in the air condenses on a cold surface. These systems may use either a separate refrigeration system or the cold secondary refrigerant from the ice rink refrigeration system.

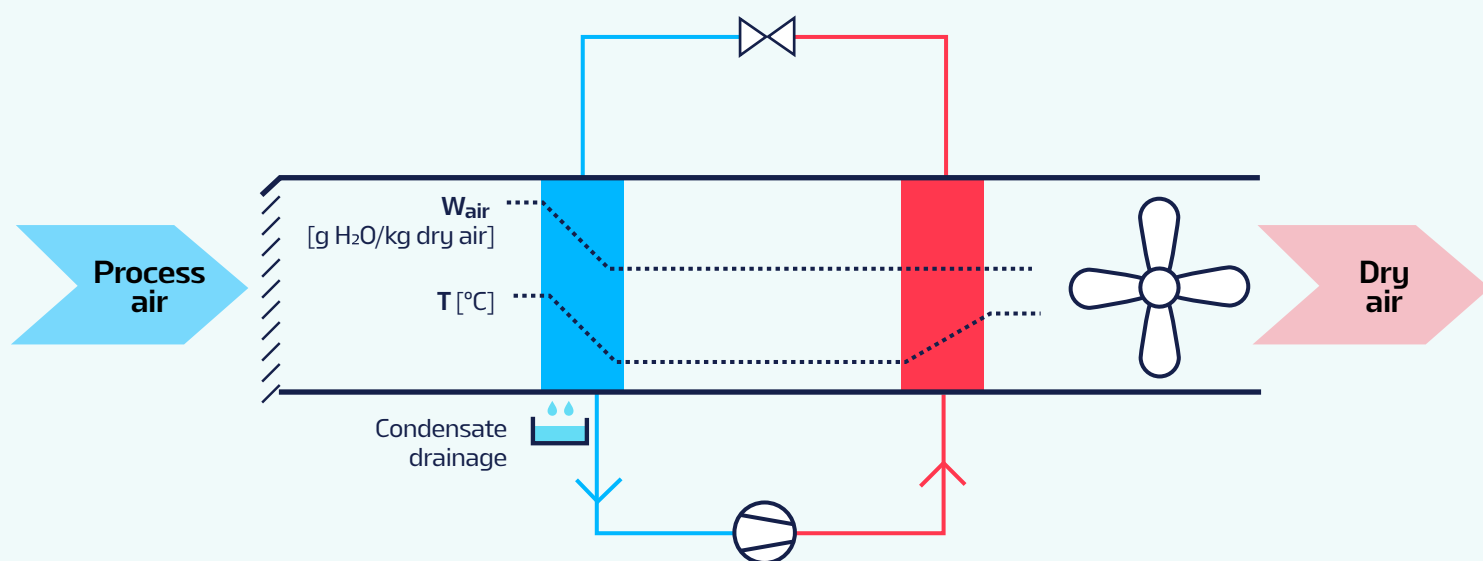


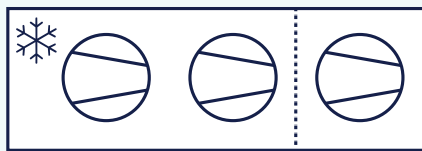
Figure 42. The working principle of a refrigeration type of dehumidifier.

The disadvantage of refrigeration-based dehumidification is that the air can only be dried to a certain limit – typically to a dew point close to 0°C. This is the level that is actually required in the arena room so having this being produced in the dehumidifier is not sufficient. To provide an acceptable climate in the arena room therefore requires very large air flows through the dehumidifier, which will be very costly from a fan power energy point of view.

Another drawback is the inefficient energy usage with this type of technology for dehumidification purpose. In the summer, when there is plenty of heat available from heat recovery, it is cheaper to operate a sorption-type dehumidifier than a refrigeration-based equivalent [NERIS 2018].

Refrigeration based dehumidification

A bigger refrigeration unit



Ice rink cooling

Dehum.

Investment:

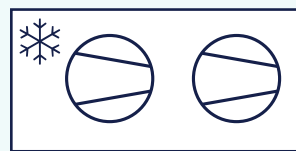


Energy usage:



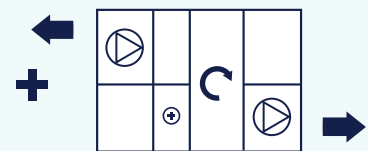
Sorption based dehumidification

A smaller refrigeration unit



Ice rink cooling

Dehum.



Investment:



Energy usage:



Figure 43. Simplified comparison between refrigeration-based and sorption-based dehumidification, showing the potential to reduce electrical energy use by using recovered heat for sorption reactivation.

6.3.2 Sorption dehumidification and heat recovery

Sorption dehumidification has proven to be a suitable technology for ice rinks. It can remove moisture at low dew point levels without the same risk of frost formation and without requiring the same high airflows as refrigeration-based systems.

Most of the energy used by a sorption dehumidifier is required to heat the reactivation air. This is therefore also where the largest energy-saving potential is found. By using recovered heat from the refrigeration system for the reactivation process, the demand for purchased energy can be significantly reduced. The main challenge is to provide recovered heat at a sufficient temperature level.

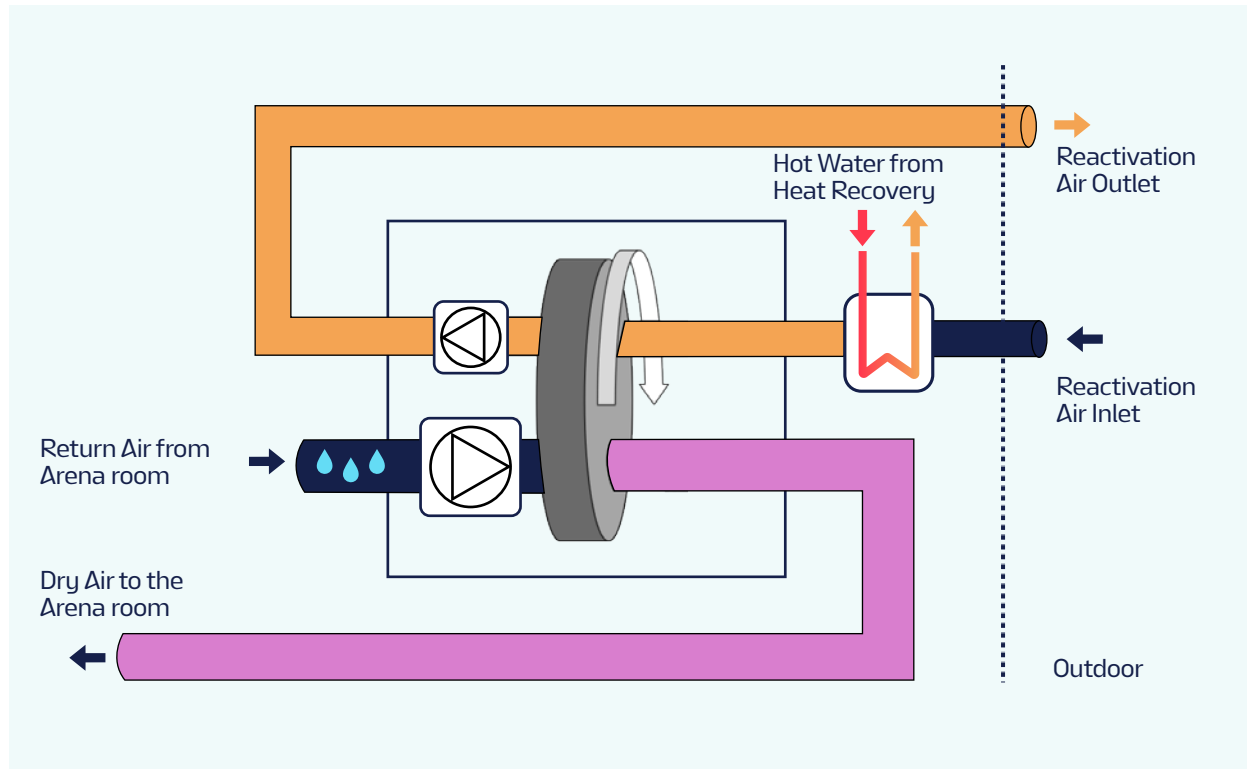


Figure 44. Sorption based dehumidification that utilizes the heat recovery from refrigeration, referred to as Generation 2.

Successful application of refrigeration system heat recovery in the dehumidification process has been documented in both Generation 1 and Generation 2 sorption dehumidifiers. Generation 1 is still relevant for existing ice rinks, where partial use of recovered heat may be possible as a retrofit, depending on the system configuration and available temperature levels.

Generation 1 dehumidifiers are more traditional, where the temperature requirement for the reactivation process is ca 110°C. In this application recovered heat covers the preheating-range that begins with the ambient air temperature and ends at around 55°C, subsequently followed by the electric heater which further raises the temperature from 55°C to 110°C.

Generation 2 dehumidifiers have larger sorption wheels, which lowers the temperature level requirement of the reactivation process down to 55-60°C. This in turn leads to a higher requirement in fan power, but the sacrifice is made in order to be able to cover the reactivation process heat demand with recovered heat only.

6.3.3 Dehumidification control

Correct humidity control is important to achieve good ice quality and a healthy indoor climate in an energy-efficient manner. One project, NERIS 2018, documented more than 30% energy reduction when changing the control strategy from traditional relative humidity control to dew point-based control.

In typical ice rinks, where indoor temperatures range between 5 and 10°C, the dehumidifier should normally be controlled to maintain a dew point between 0°C and approximately 2°C. If the dew point is lower than 0°C, the dehumidifier may operate unnecessarily. If it is higher than 2°C, the risk of condensation-related problems increases (Figure 45).

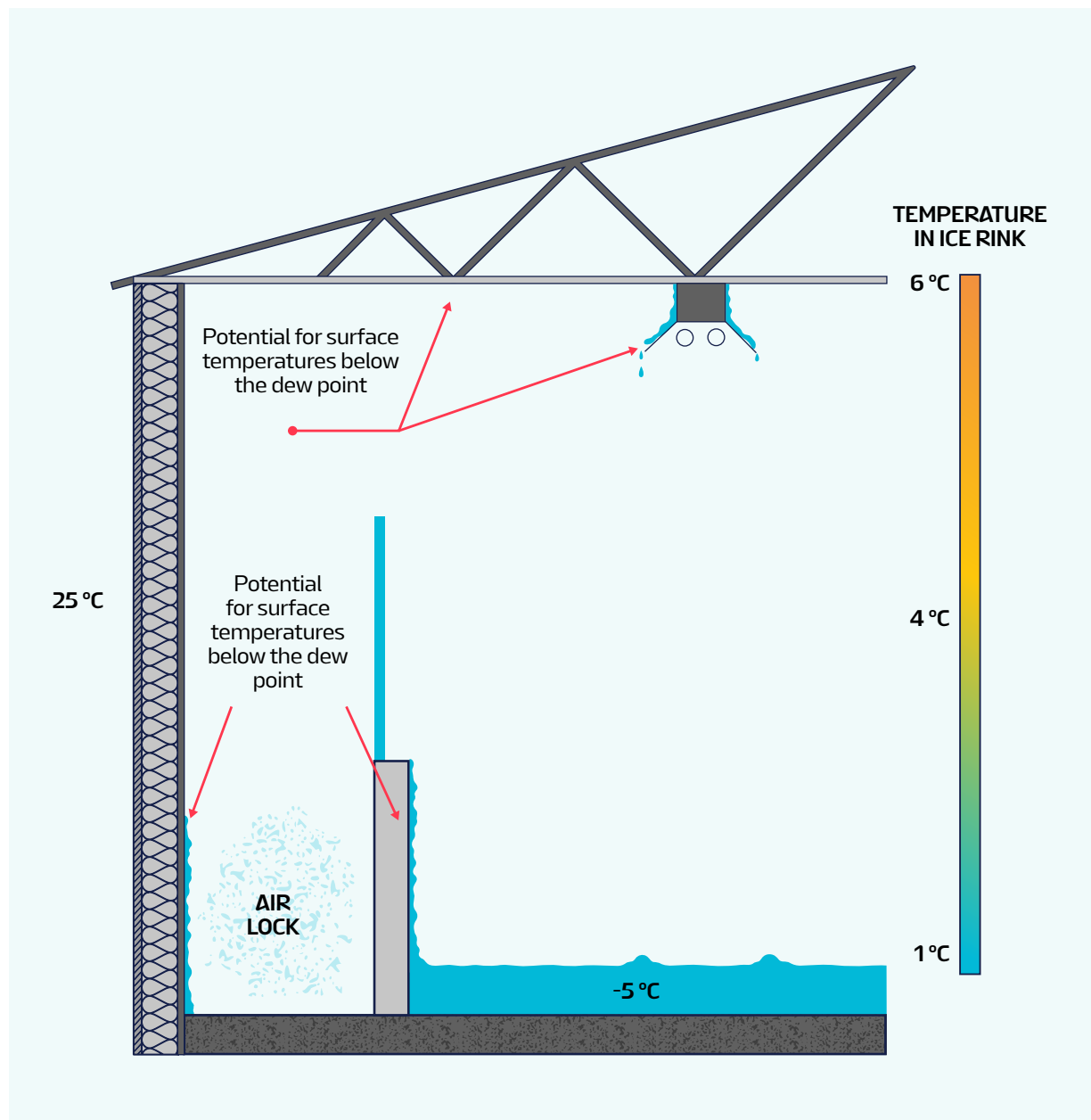


Figure 45. Condensation risk zones and influence of dewpoint.

Figure 46 shows how energy can be saved over time by applying a dew point-based control strategy instead of traditional relative humidity control. Relative humidity control tends to over-dry the arena room, especially during periods when there is no actual dehumidification demand.

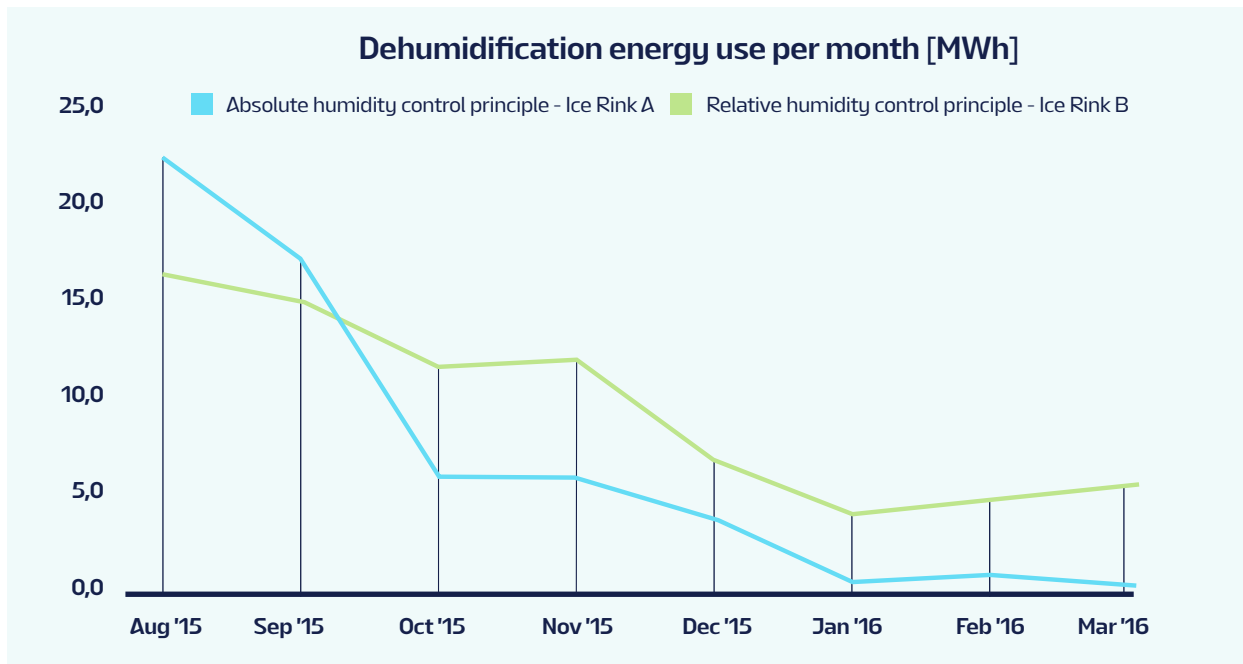


Figure 46. Comparison of energy use between control strategies based on relative humidity and dewpoint/absolute humidity in two ice rinks.

6.3.4 Energy usage

The performance of Generation 1 and Generation 2 sorption dehumidifiers is illustrated in Figure 47. For a Generation 1 dehumidifier, the results show that almost 40% of the total energy use can be saved by using recovered heat that would otherwise be rejected to the ambient air.

For a Generation 2 dehumidifier, recovered heat can cover up to 100% of the reactivation heat demand. Although this solution requires higher fan power, electrical energy is then mainly needed for the fans. A Generation 2 solution can therefore save approximately 85% of the total dehumidifier energy consumption.

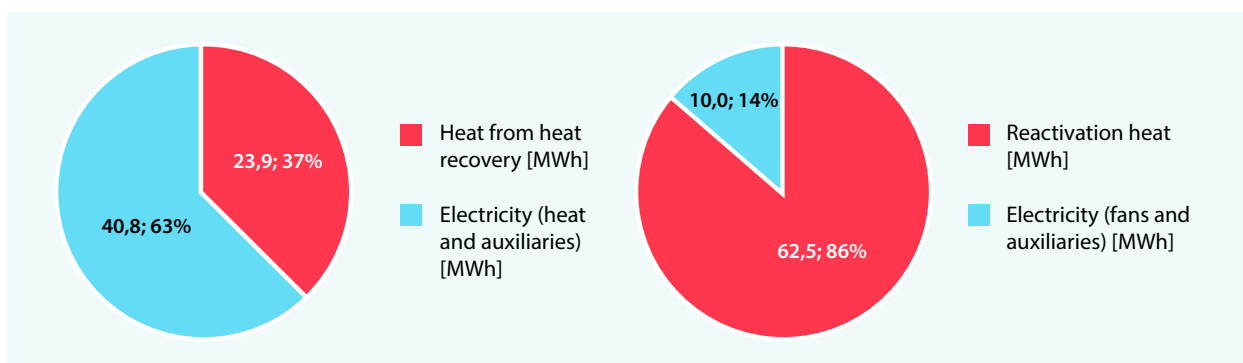


Figure 47. Application of recovered heat from a modern refrigeration system in the reactivation process leads to energy savings of ca. 40% in Generation 1 (on the left) and 85% in Generation 2 (on the right) sorption dehumidifiers.

6.4 Air handling

The main purpose of the ventilation system in the arena room is often to provide space heating and, when needed, also fresh air. The ice arena ventilation is normally divided into different parts: the arena room and surrounding spaces including locker rooms etc. This is due to the special indoor climate of the arena room, which requires its own system solution for successful management. In many ice rinks, the arena room ventilation has been integrated together with the dehumidifier, but the recommendation nowadays is to keep these separate.

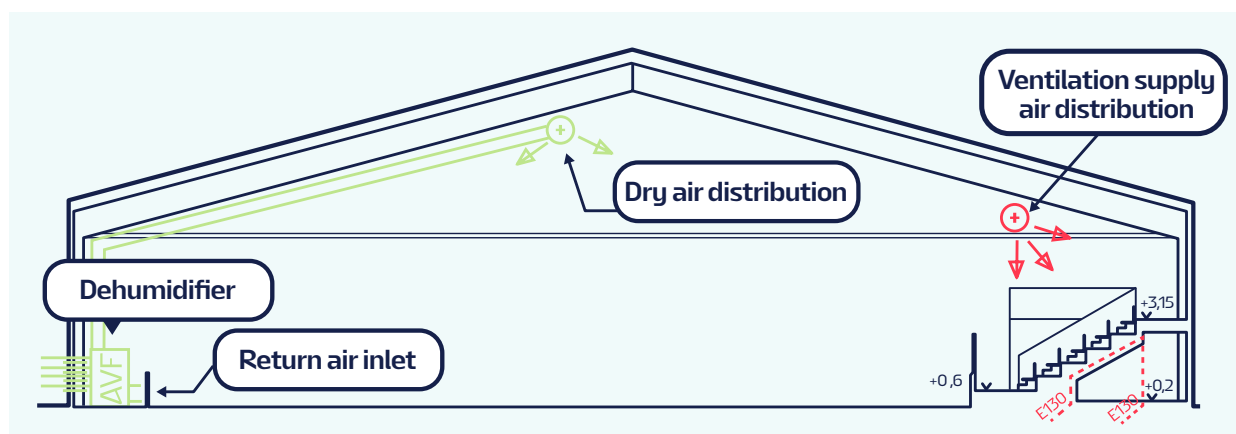


Figure 48. Air supplied to different zones in ice arena: Dehumidified air above the ice, and heated air towards the stands. Fresh air intake only when necessary.

6.4.1 Air distribution in arena room

In order to further maximize the energy efficient climate control of an ice rink, the ventilation and dehumidification distribution systems should be separated in the arena room. Warm ventilation air should be blown towards the spectators where the real heat demand is located, while the dehumidification supply air should be distributed in a duct centered above the ice. This minimizes unnecessary heat loads towards the ice while also maintaining optimal comfort levels where they should be.

In smaller typical sized arena rooms, ventilation/heated air is generally distributed from a single duct above the stands, with its blowing direction away from the ice. In larger arena rooms the duct can be divided into two or more groups so that heat is more optimally spread across the stands to maintain adequate comfort levels regardless of where spectators are seated.

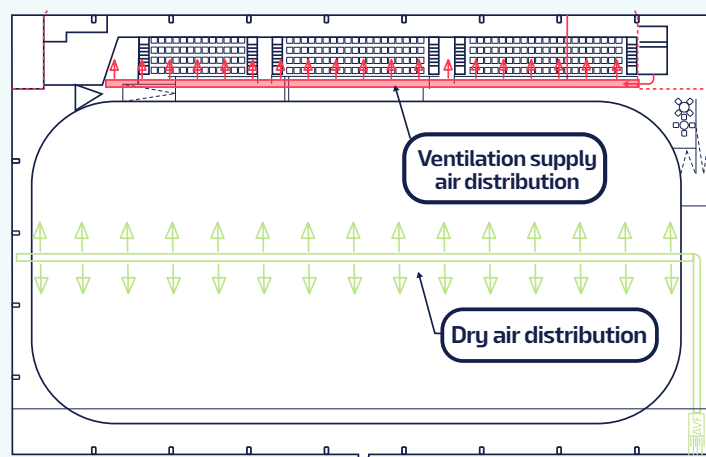


Figure 49. The ventilation and dehumidification distribution systems should be separated.



Figure 50. Textile ducts in an ice rink where dry air is distributed over the ice and “comfort air” to the stands.

6.4.2 Energy efficient principles

Ventilation should generally be based on centralized air handling units, AHUs, serving zones with similar air quality and thermal comfort requirements. A central AHU can provide ventilation to several rooms, which may improve energy efficiency, simplify maintenance and make control adjustments easier compared with several small ventilation units.

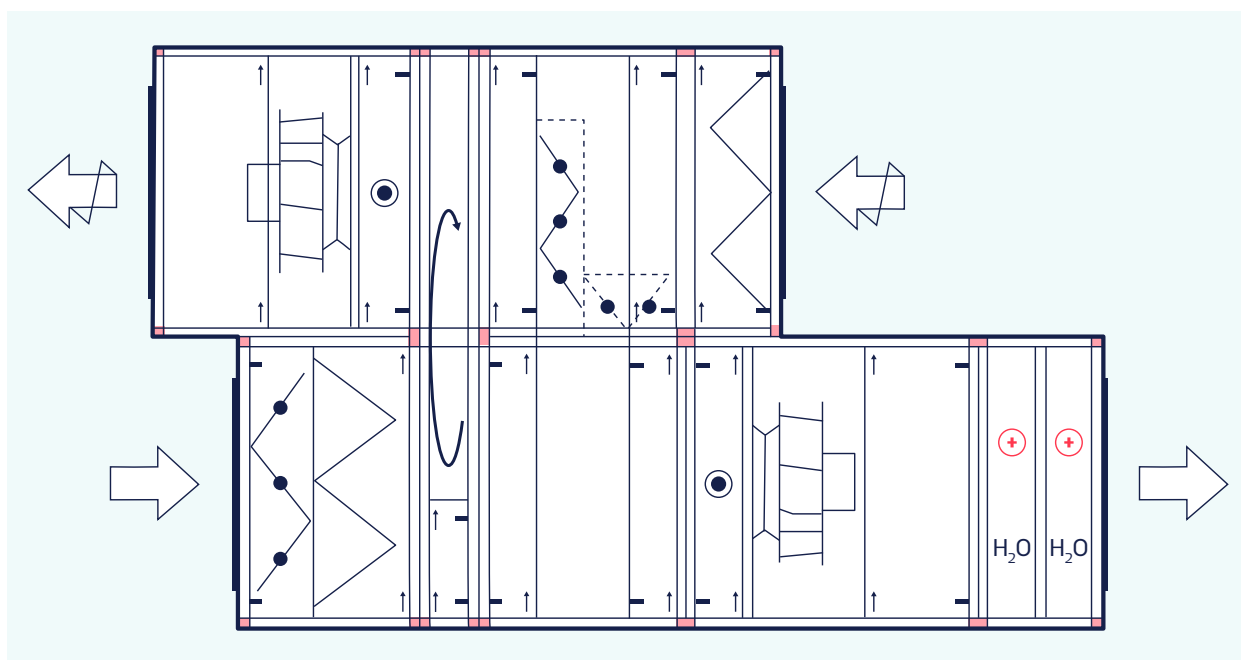


Figure 51. Example of a principle AHU solution for arena room [IV Produkt, 2022].

Energy efficiency for a ventilation system shall be maximized by designing systems with air-to-air heat recovery and efficient fans. In the EU, for example, it is required that AHU is complying with the minimum performance criteria. The latest Ecodesign update was in 2018.

Heat recovery efficiency, which is expressed as the percentage of energy recovered from the extract air flow:

- For rotary heat exchangers, counter-flow heat exchangers or plate heat exchangers > 73%
- For run-around coil heat exchangers > 68%

SFP - Specific Fan Power, is expressed as the electrical input required for the fan to supply the airflow. The lower the SFP, the greater the fan's energy efficiency:

- Internal SFP < 0.8 [considering pressure drop within the AHU]
- Corresponding SFP < 1.9 [considering pressure drop within the AHU + distribution duct pressure 200 Pa]



Figure 52. Example of a central air handling unit in an ice arena, the unit is located in a technical room.

6.4.3 Fresh-air control

The arena room normally has a large air volume, which means that the need for fresh-air ventilation may be limited during many operating periods. At the same time, outdoor air brings both heat and moisture into the arena room, which increases the load on the heating, refrigeration and dehumidification systems. For this reason, unnecessary fresh-air supply should be avoided.

It is therefore recommended that the ventilation/heating function in the arena room is normally operated with recirculated air, and that fresh air is supplied only when needed. This reduces the moisture load and avoids unnecessary heating, refrigeration and dehumidification demand.

In many existing ice rinks, measurements have shown that the combination of a large arena room air volume and background air leakage can be sufficient to maintain acceptable indoor CO₂ concentration during normal operation, even when the ventilation system operates in full recirculation mode, as illustrated in Figure 53. However, air leakage should not be regarded as a controlled ventilation strategy. The preferred solution is to limit uncontrolled leakage through a good building envelope and use demand-controlled fresh-air supply when indoor CO₂ concentration or local requirements indicate a need.

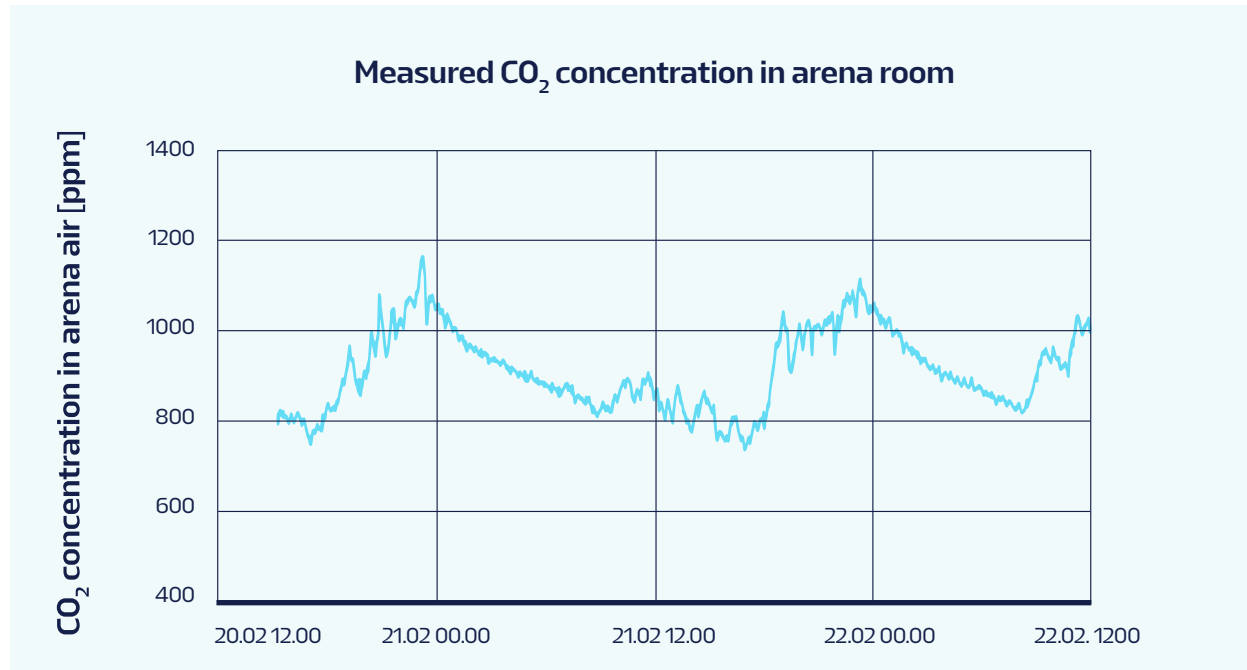


Figure 53. Measured CO₂-levels in a typical Nordic ice rink operating on full air recirculation.

Best practice is to control the fresh-air supply with an indoor CO₂ sensor, so that outdoor air is supplied only when needed. A CO₂ concentration above approximately 1,500 ppm can be used as a starting signal for fresh-air intake, provided that this is compatible with local requirements and the intended use of the facility.

6.5 Arena room lighting

Arena room lighting accounts for around 10 percent of the total energy usage in a typical ice rink. The radiation from the lighting may contribute to the heat load of the ice as well. There are specific requirements for illuminance on the ice surface, it varies between different categories of ice rinks according to local country standards. In order to respect illuminance, there are different alternatives available for the type of technology. The lighting efficiency of the particular technology is important, i.e., what power is needed to provide the necessary illuminance.

Many ice rinks still use different types of light tubes such as T5/T8 HF, although the trend is clearly going in the direction towards LED, which will eventually take over in the ice rinks as the old equipment is being phased out. Other types like halogen and metal halogen still exist but much less frequently.



Figure 54. Example of an ice rink with a light tube installation.

In Figure 55 the lighting efficiency of previously typical lighting solutions is presented over time. Halogen lighting have 4000 lighting hours compared to 9000 hours for metal halogen lighting, which is an increase by 125 percent. It is also clear in the figure that the modern types of T5/T8 are not only more efficient than the other two but also lasts much longer. As said, however, LED is becoming the main alternative in modern solutions.

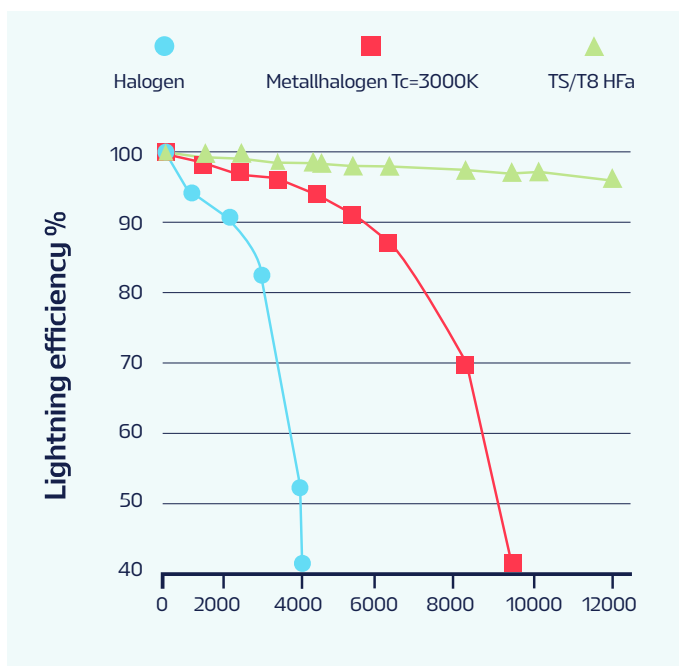


Figure 55. Efficiency of different lighting types during their lifespan.

Nowadays, LED technology is the best solution on the market, both in terms of quality and efficiency. An approximation of energy savings with LED technology compared to previous generation technologies is given in Table 6. As seen between 40 to 75 percent is the possible improvement, and additional benefits of considerably longer LED lifetime has to be taken into account also.

Table 6. Comparison of energy performance in lighting technologies.

Type of Lighting	Typical efficiency	Expected energy savings when replaced by modern LED
Halogen	12-40 lm/W	50-75%
Fluorescent [T5, T8 tubes]	40-80 lm/W	20-40%
Older LED	120+ lm/W	10-15%



Figure 56. An ice rink with a modern LED-lighting system.

In the case of a new LED-lighting system in a typical sized ice rink, a nominal average light intensity of 600 lux and a total installed power of approximately 10 kW is reasonable. The lighting should be controlled according to actual demand, for example with separate modes for matches, training/general use and ice maintenance. In practice, three steps are often used: 0%, 50% and 100%, corresponding approximately to 0, 5 and 10 kW in a typical installation. However, stepless dimming is normally the most favourable solution from an energy and operational perspective.

6.6 Building and energy system management

Ice rink energy and climate controls often appears difficult to manage, as very complex interactions between the various physical processes happen continuously. It may happen that changing a setpoint in, e.g., air handling system, there is a need to adjust a certain setpoint in the refrigeration system.

This leads to a necessity for not only the physical integration but also the control strategy and its implementation. In addition to that a possibility of monitoring the main functions on-site and remotely plays a key role in the failure prevention and long-term energy use reduction.

6.6.1 Monitoring and control

A modern ice arena should apply a monitoring and control system, often a Programmable Logic Controller (PLC) system, which functions as the brain of the facility. In addition to refrigeration, the PLC-system should also control the functions such as heating, domestic hot water, dehumidification, freeze protection, ventilation, and lighting systems, as well as potential geothermal storage or heat export functions. By having an externally accessible control system, it becomes possible to synchronize and/or prioritize the energy systems, when necessary, which also is a prerequisite for the energy optimization process in modern ice rinks.

6.6.2 Visualization

The information that is being measured and calculated by the PLC system shall be visible locally, i.e., in the technical room. The information shall be well structured and user-friendly, so that the technical staff or external experts are able to verify functions, localize problems, etc., as conveniently as possible. That in turn provides the facility management with convenient feedback and allows smoother implementation of control changes.

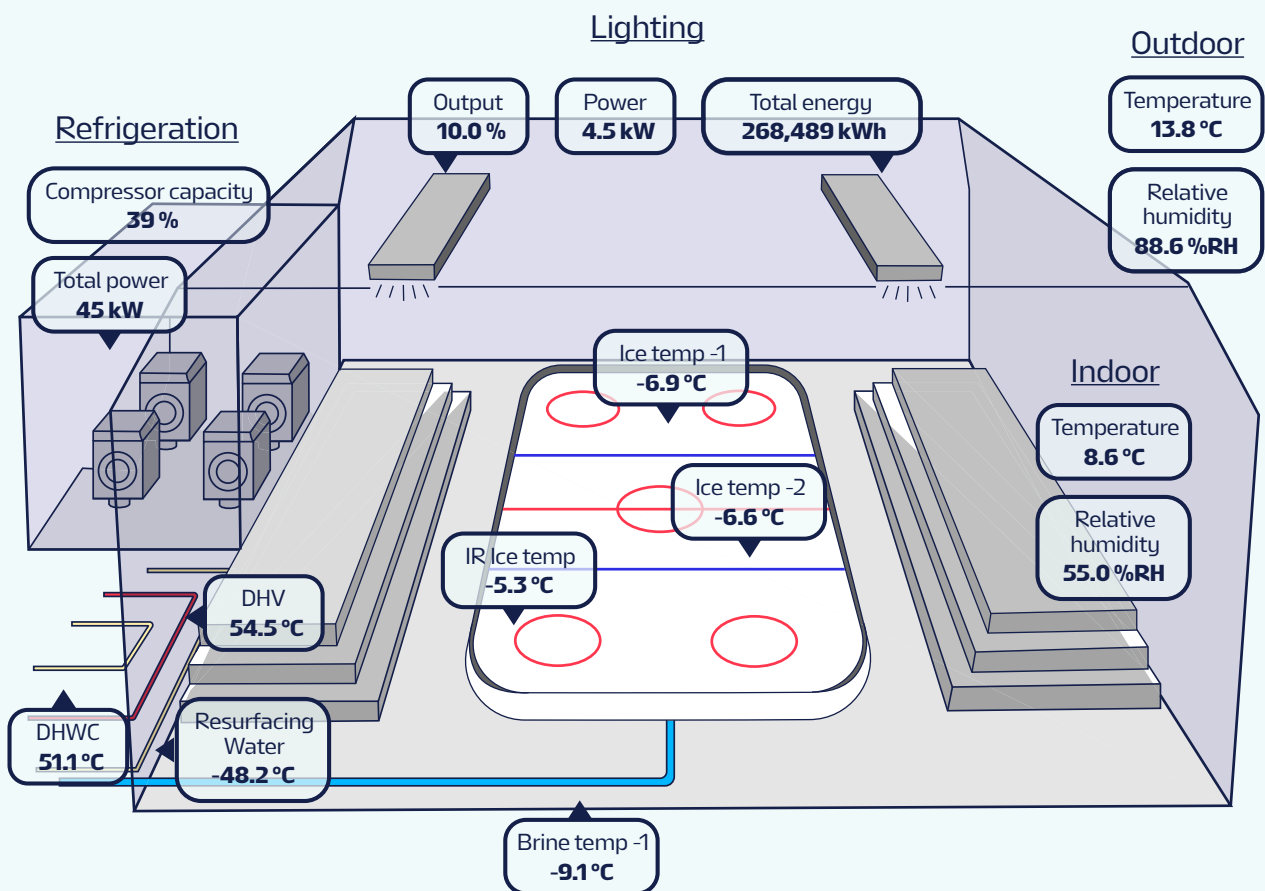


Figure 57. The control system overview in an ice rink showing the lighting control signal, power and energy.

6.6.3 Energy monitoring

Ice rink further benefit from modern control system that measure the energy usage of the big five energy systems individually [refrigeration, heating, ventilation, dehumidification, lighting]. This allows to optimize the performance of each individual system further through analysis and also allows for the follow-up of the results after implemented changes.

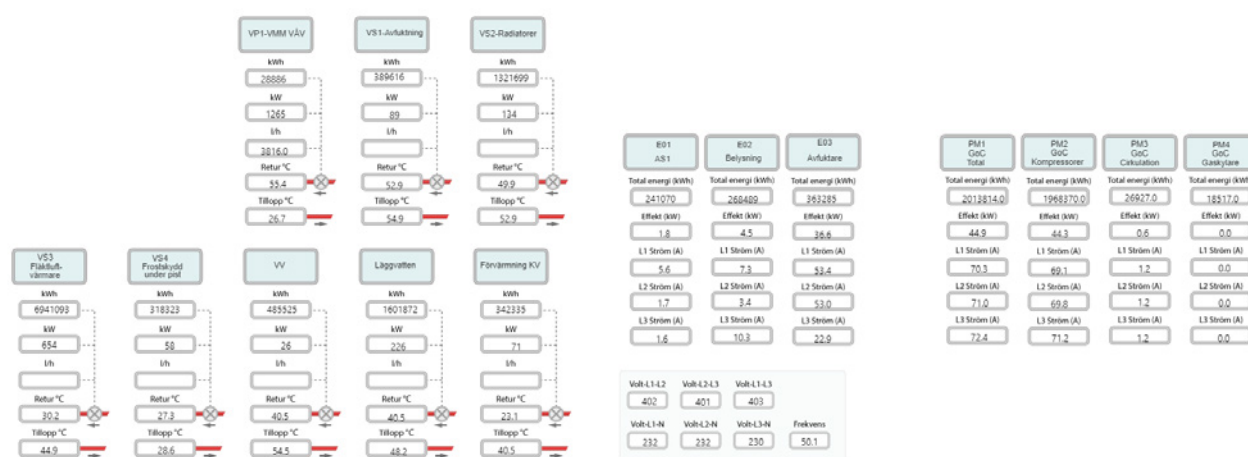


Figure 58. Screenshot from an ice rink online monitoring system that includes 1 main and 6 submeters of both heat and electricity. It allows to analyse and optimize the systems with high accuracy.

A modern control system should also be able to optimize the performance of the energy systems in the ice rinks based on parameters such as energy use, temperature, humidity etc. Furthermore, the control system must log all the data so that it can be analyzed for further optimization or error investigations. Ease of access to the control system is also recommended, e.g. by having it connected to the internet, which allows remote access for operational staff as well as service companies.

7. Water management

Freshwater resources are scarce and becoming an increasingly important issue in many parts of the world. This is particularly relevant in regions where water availability, municipal water supply capacity or wastewater treatment infrastructure are under increasing pressure. According to a UNEP report only 11% of the treated wastewater used globally is reused and the reports states that to fulfil the potential of wastewater it is important to:

- Reduce the volume of wastewater being produced.
- Prevent and reduce contamination.
- Manage wastewater to capture the resources that can be safely reused.

In an ice rink perspective a typical single-sheet ice arena uses 2–3 million litres of water annually, of which approximately 1 million litres are used for ice resurfacing and ice maintenance. The rest of the water is used for showers, cleaning, drinking and other in this context minor users.

Resurfacing water is a large and recoverable water stream in a single-sheet ice arena.

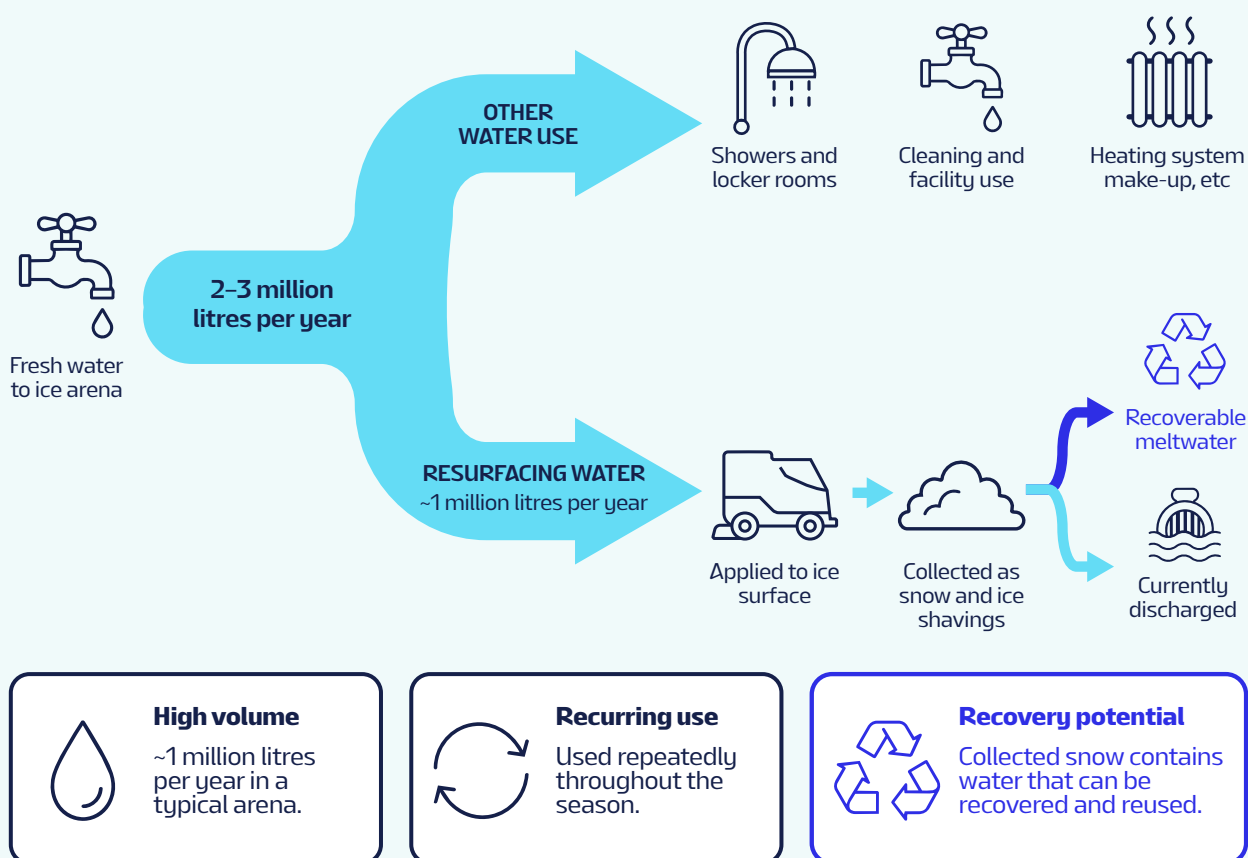


Figure 59. Large share of the water usage in an ice rink may be recycled.

To recycle wastewater to the quality required for use as potable water is quite challenging, however, the process water used for resurfacing is less sensitive. There are still some considerations to respect for process water as well but these are manageable. In this context it is fair to state that recycling process water is a good start.

Today there are technologies and systems available for resurfacer water recovery. Regardless of technical approach chosen, the first step is always to collect and melt the ice shaving coming off the resurfacer. Secondly, the collected water needs to be treated to be feasibly reused in the resurfacer. In this section the potential in recovering the melt water together with the general technical solution is described.

While the ice shaving is technically created by blades scraping the rink, people within the ice rink industry, hockey players, figure skaters, and spectators almost universally refer to it as snow. In this context "snow" is defined by its physical texture and appearance rather than how it was made. Ultimately, rink snow is technically just fine ice shavings which mimics natural snow but has a much higher density, often within the range 400-550 kg/m³.

7.1 Conventional ice shaving handling

During ice resurfacing, the snow collected by the ice resurfacer is often transported to an outdoor snow dump. After melting, this water will enter the storm- or wastewater system and is discharged from the facility.



Figure 60. Issues often present by conventional resurfacing snow dump. On the left – tracks on ice due to resurfacer wheel dirt. On the right – snow accumulation outside the ice rink.

The challenges and disadvantages with conventional resurfacing and snow handling by dumping may be summarised below:

- High consumption of fresh and potable water with corresponding wastewater discharge volumes.
- Large seasonal snow accumulations outside the ice arena building, requiring space and potentially periodic removal in colder climates.

- Driving the ice resurfacer outdoors may introduce dirt and debris to the ice, resulting in poorer visual appearance of the ice surface near the resurfacer access point.
- Frequent door openings leads to considerable air exchange which during warm climate periods brings significant amounts of moisture into the arena room. This humidity must consequently be removed by the dehumidifier and thus increasing the cost of operation.
- There is also a health aspect for the operators related to the frequent change in climate when they are exposed to a rapidly changing environment [in- vs outdoor].
- There is also a risk aspect related to the resurfacer handling and driving through areas where there could be people present. Restricting the resurface operation to the garage only is thus safer.

Considering the list above there are a number of good arguments to look for a solution including collection and melting the snow. It should be emphasised that this does not imply a direct investment in the complete system since you may start with a melting pit and later supplement with water treatment and recovery functions.

7.2 Melting pit

The melting pit primary function is to receive the snow / ice shavings from the ice resurfacer and melt it in a controlled environment. Depending on the specific arena operation and the type of resurfacer, the melting pit will have to process a few hundred kilograms up to close to a ton of snow during a single resurfacing cycle. Therefore the pit acts not only as a disposal point, but also as a temporary thermal storage system that enables controlled melting and water collection. It must be emphasised that the correct thermal design is critical for both the melting function as well as the energy [heat] usage. Therefore the pit acts not only as a disposal point, but also as a temporary thermal storage system that enables controlled melting and water collection. It must be emphasised that the correct thermal design is critical for both the melting function as well as the energy [heat] usage.



Figure 61.

The first step towards recycling of the resurfacing water is to have a properly working melting pit.

Several design aspects are important for a reliable operation of the melting pit. It is an advantage if it is logistically located close to the ice resurfacer garage allowing the snow to be emptied safely and without unnecessary transport. The size of the pit should be based on the expected snow load, resurfacing frequency and available melting capacity.

Heating pipes should be arranged so that they provide a good melting capacity without interfering with the necessary cleaning of the pit. Heating elements may preferably be installed on the walls but may also be placed on bottom of the pit. Side-mounted heating pipes are beneficial because they keep the bottom of the pit accessible for sediment and impurity removal.

The pit should include a safe drainage solution to handle the varying snow load, melting rate pumping capacity in case of a water recovery function. Personnel safety must also be considered which includes covers, grates, barriers or operating procedures to reduce fall risks when the pit is open during dumping or maintenance.

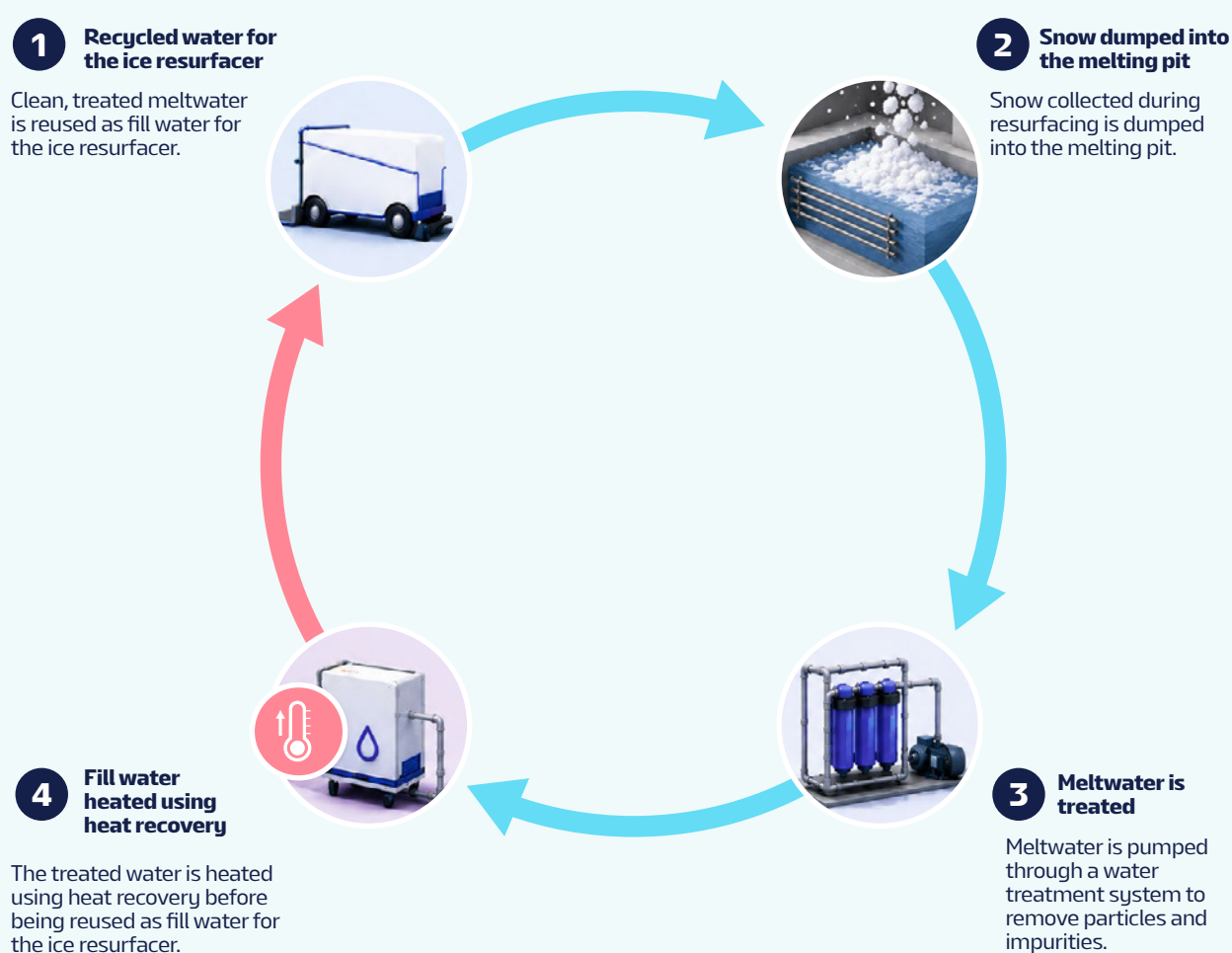
An agitator is advisable to ensure mixing of the slush and separation of solid parts improving the melting process. Another advantage with the agitation is that it improves the convection between the fluid and heating elements, thus increasing the heat transfer. The agitation of the pit will ultimately improve the performance and shorten the melting time. It is not advisable to heat the melting pit to a too high temperature due to the risk of bacterial growth and legionella. Thus, a limitation of 10 to max 15°C of the water should not be exceeded.

If water recovery is planned, the melting pit should not be designed only as a discharge point, but as the starting point of a treatment and reuse process, which is elaborated in the next subchapter.

7.3 Resurfacing water treatment and reuse

In the context of water management, resurfacing water is especially relevant because it is a large, repeated and technically recoverable water stream. With a suitable melting pit, treatment and storage, the meltwater can instead become part of a controlled recycling loop. The primary purpose of such a system is to reduce the need for fresh water.

Melting pit with water recycling



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Figure 62. Melting pit with circulating water. In a closed-loop system, collected snow is melted, treated, heated with recovered heat and reused as resurfacing water.

Meltwater collected from a snow melting pit contains suspended solids and other contaminants originating from the ice surface such as skates, hockey sticks, textile, arena dust and such. As a result, treatment is required before the water can be reused for ice resurfacing. Process water recovery systems typically combine several treatment stages.

They often include sedimentation, coarse mechanical filtration, fine filtration and disinfection before the water is transferred to a storage tank. The finest filter should not exceed 10 µm particle size.

Depending on the available water source and its quality with respect to dissolved particles, Total Dissolved Solids [TDS], a Reverse Osmosis [RO] function may be necessary. RO is a highly efficient water purification process that uses a semi-permeable membrane to remove up to 99% of dissolved salts, impurities, and contaminants from water. From an ice making perspective it may not be desirable to remove all particles but to control it to between 80 and 100 ppm of TDS.

Ultraviolet [UV] treatment is commonly used as a final step where it disinfects biological and some chemical contaminants; it cannot filter out heavy metals, salts, or dissolved solids. The UV treatment only sanitizes the water as it passes through the lamp but provides no residual protection. This implies that bacterial growth can still occur further down the process. It is therefore recommended to heat the water to at least 60°C to avoid bacterial growth and legionella.

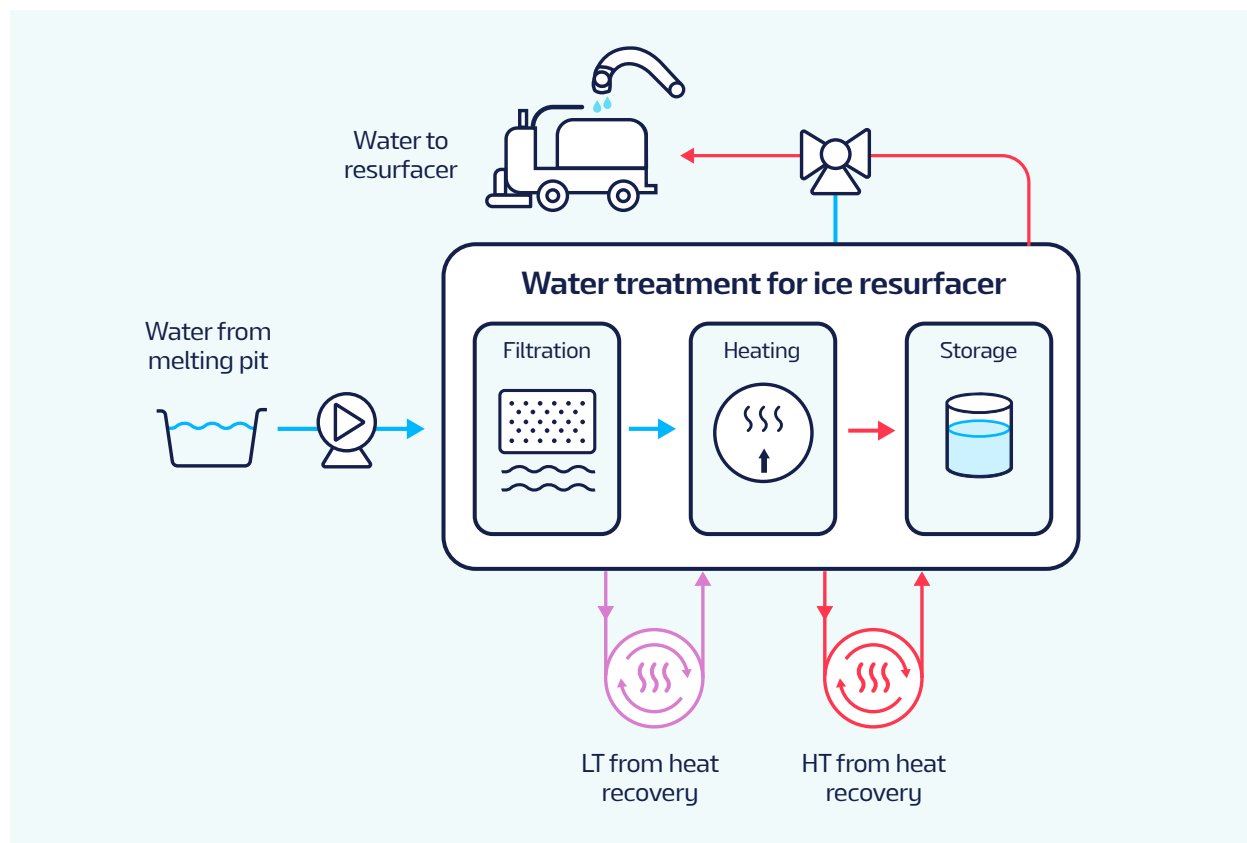


Figure 63. Water treatment function for recycling meltwater from the melting pit as resurfacing water.

After treatment, the water is stored and post heated when necessary to keep it on the safe and desired temperature level. Before supplying it to the ice resurfacer it may be mixed with the not yet post heated process water if a lower supply water temperature is desired.

7.4 Heat requirement

Snow melting and resurfacing water preheating are low-temperature heating applications. This makes them particularly suitable for integration with a refrigeration heat recovery system. Further, the collected energy use for melting and process water reheating is significant and therefore it makes a lot of sense to use recovered heat.

Most heating systems are more efficient if low temperatures may be used, and as a matter of fact, water recycling aligns perfectly in this regard. Melting pit water is typically maintained at relatively low temperatures, often below 10–15°C. This supports efficient heat recovery utilisation while limiting conditions favourable for biological growth. It means heat exchange for melting pit heating may be realized with supply temperature of < 30°C if the volume of the melting pit is sufficient and heating elements are correctly sized.

In the next step, the treated process water should be heated to at least 60°C or higher. Modern low-temperature heating systems based on heat pumps or heat recovery functions may favourably provide the heating in two-stages, where firstly a pre-heating is done, and then followed by final/post heating.

This approach allows relying on the sole supply of recovered heat from the refrigeration system and thus eliminating or reducing the need for supplementary heating sources such as district heating or boilers. To maintain the process water recovery as the green solution it is for the arena, a well-designed heating system solution is key to avoid excessive [external] heat usage. If the energy bill is negatively affected a large portion of the sustainable initiative may be lost.

7.5 Key design recommendations

A summary of key design recommendations is provided in Table 7. These considerations should be evaluated when designing a new melting pit or resurfacing water recycling system for an ice arena.

Table 7. Design considerations for resurfacing water recycling systems.

Parameter	Recommendation
Melting pit volume	Size the pit according to the maximum expected resurfacing frequency, snow production rate, desired melting time and available heating capacity. Consider both peak operating periods and average conditions to calculate the allowed ice accumulation. A rule of thumb is 10–15 m ³ pit water volume per ice sheet.
Clean water storage	Size the water storage tank to provide sufficient resurfacing water for peak operation demand. Consider the resurfacing demand as well as ice maintenance. A rule of thumb is at least 2 m ³ of hot resurfacing water volume per ice sheet.
Heat source	Integrate snow melting and water heating with refrigeration heat recovery if possible. Supplementary heating may be required during peak demand or refrigeration plant downtime.
Heating elements	Heating elements may be installed on the sides or bottom of the pit. Side-mounted arrangements can simplify sediment removal and maintenance by keeping the bottom of the pit accessible for cleaning.
Filtration	Select filtration stages according to the intended water quality. Multi-stage filtration combining coarse and fine particle (max 10 µm) removal is generally recommended. Depending on the available water source an RO function may be used as well. Filtration requirements should be based on the intended water quality and reuse strategy.
Disinfection	Provide a suitable disinfection stage, such as UV treatment, to control biological growth and maintain water quality during storage and reuse. Always post heat the treated and stored water to at least 60°C.
Melting pit maintenance access	Provide safe and convenient access for inspection, sludge removal and maintenance. Consider future cleaning requirements during the design stage. Count on at least one empty and cleaning operation per year.
Room for manoeuvring	Allow sufficient space for resurfacer manoeuvring, snow dumping, equipment maintenance and operator access.
Backup hot water supply	Provide redundancy through a backup hot water line to maintain arena operation during maintenance or temporary outages of the water recovery system.
Access to outdoor snow dump	Where practical, maintain access to a conventional outdoor snow disposal area as a contingency solution during maintenance, emergencies, unusually high snow loads or technical problems.
Monitoring and optimisation	Monitor water quality, temperatures, flows and system performance. Trend analysis can help identify operational issues and optimise energy and water savings.
Safety	Provide a pit cover/lid, grates, barriers or equivalent measures to minimise fall risks and improve operational safety around the melting pit. Inside the pit there should be a fixed mounted ladder or equivalent to allow climbing out in case of a fall in or maintenance.

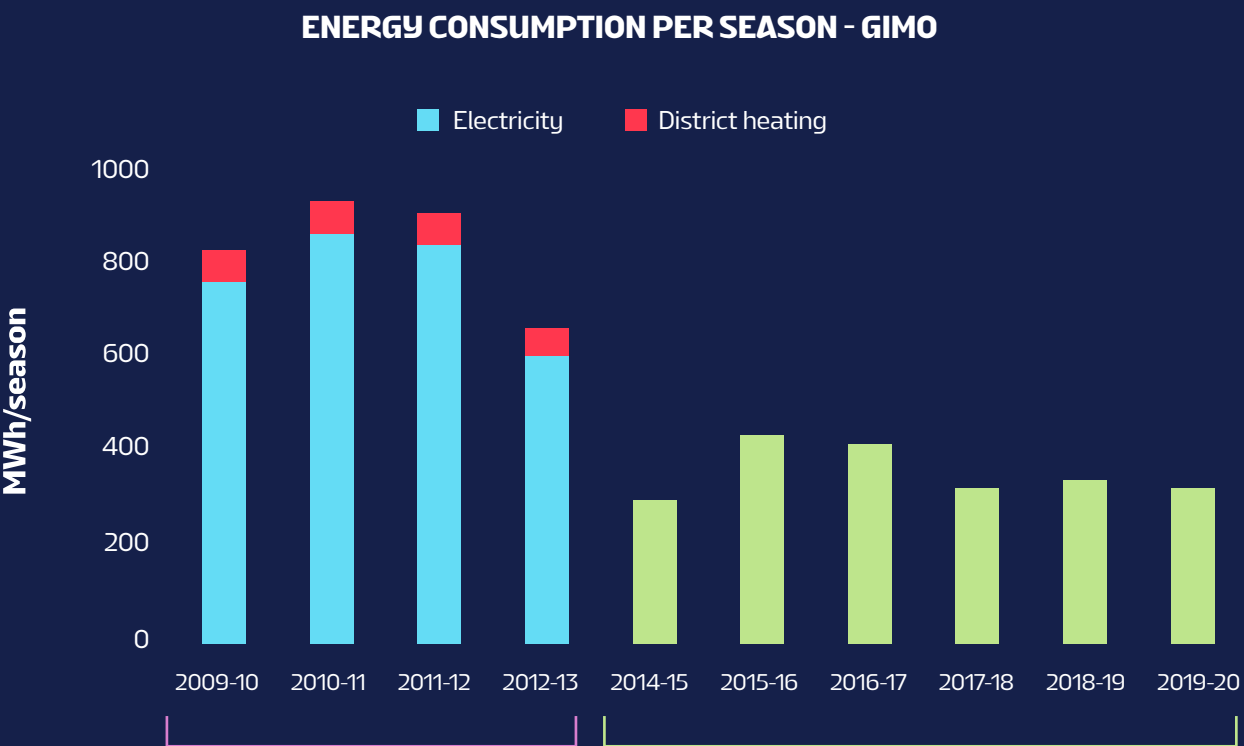
8. Case studies

8.1 Facility case studies

This chapter looks into case studies on a facility-basis, i.e. individual ice arenas where each have been subject to a number of measures and the changes in total performance is are discussed.

8.1.1 Ice rink 1 - Gimo [Sweden]

The municipality of Östhammar in Sweden wanted to lead by example and apply the most environmentally friendly technology in the renovation of Gimo ice rink. In this system the **ice rink refrigeration is combined with a heat pump function and geothermal storage**. The facility used to depend on district and electric heating for its heating purposes, but it is now **self-sufficient on the heat recovered from the refrigeration system**.

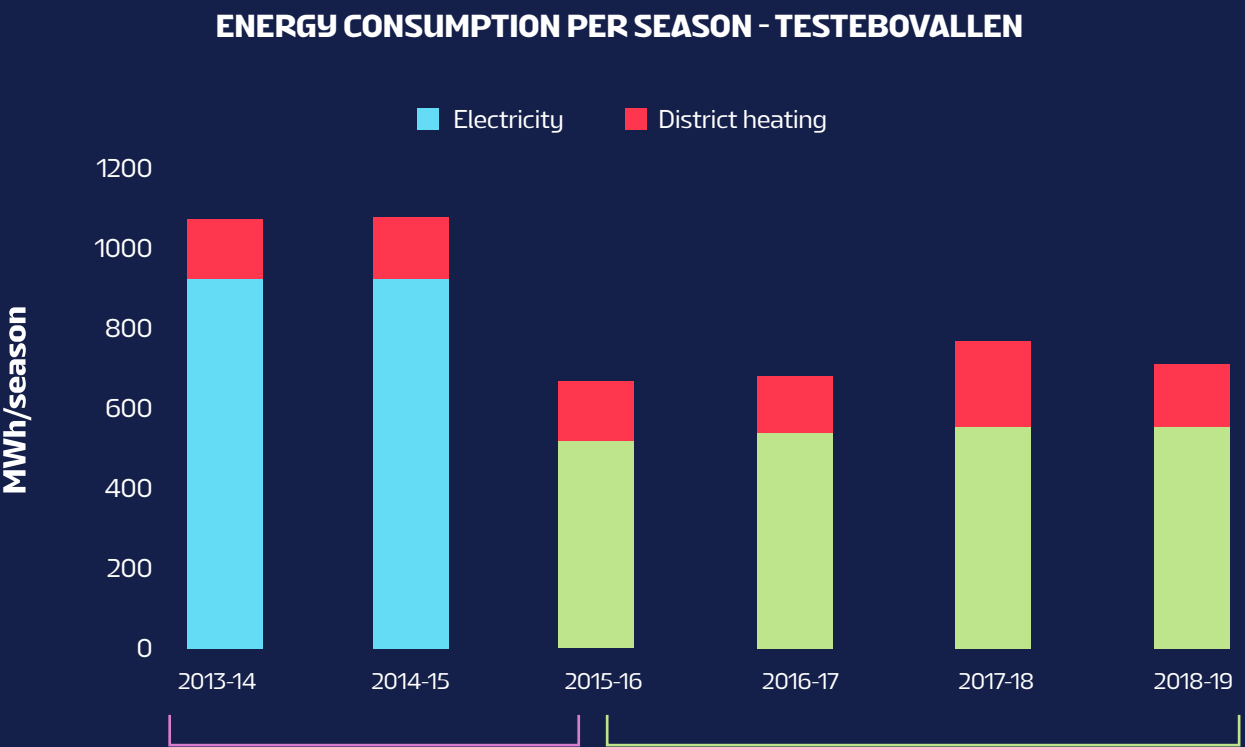


The ice rink became the first of its kind in Europe, where the outstanding results together with its growing reputation have sparked the concept “**the ice rink of the future**”.

	Before	After
Primary Refrigerant:	Ammonia	CO ₂
Secondary Refrigerant:	Calcium Chloride	CO ₂

8.1.2 Ice rink 2 - Testebovallen [Sweden]

This facility consists of two ice sheets [ice hockey and curling in separate buildings] and a sports hall. Before interventions, a **R404A** refrigeration system was used. The heating demand was mainly covered by district heating. In 2015, an **indirect CO₂ refrigeration system** replaced the old one. The existing secondary circuits were reused and retrofitted with aqua ammonia, reducing the pumping power demand.

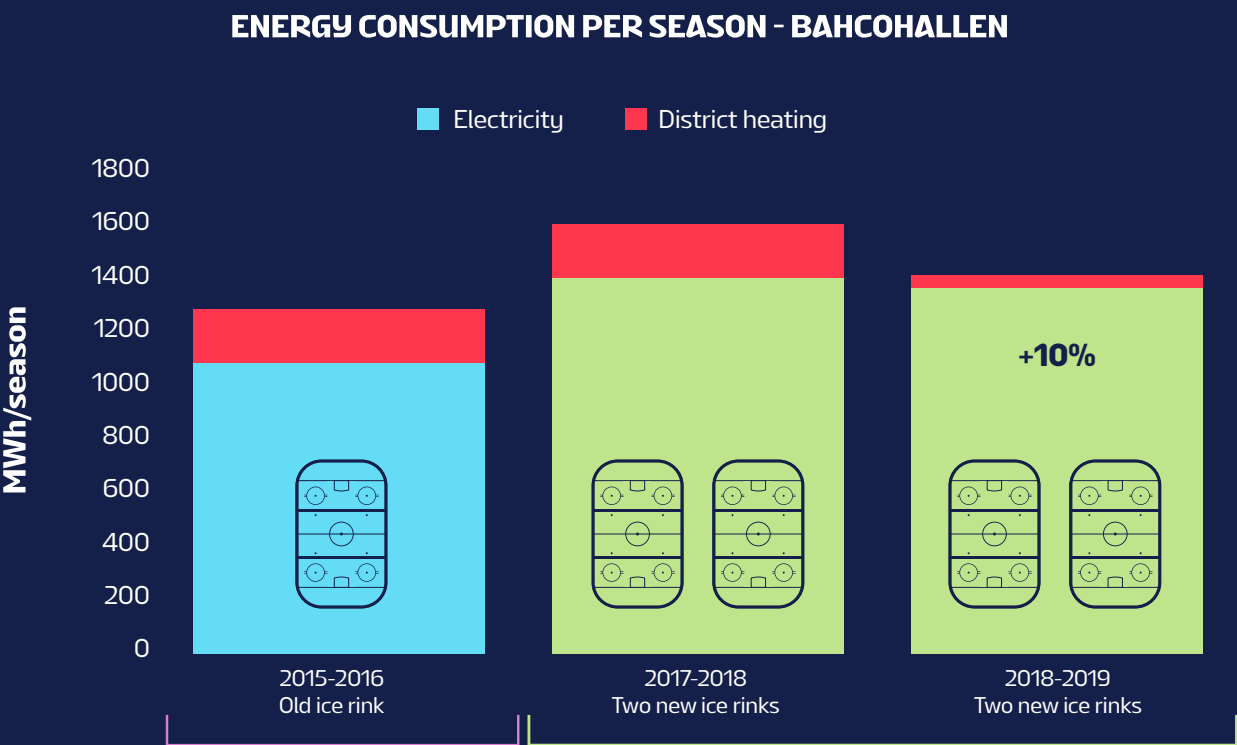


The new system provides a new complete **one-stage heat recovery function with a constant 60°C forward temperature**. A new sorption dehumidifier utilizes part of the recovered heat for reactivation, lowering its energy consumption.

	Before	After
Primary Refrigerant:	R404A	CO ₂
Secondary Refrigerant:	Calcium Chloride	Ammonia-Water

8.1.3 Ice rink 3&4 - Bahcohallen [Sweden]

Bahcohallen was a typical single sheet ice rink, with a heated arena room. An ammonia refrigeration unit was connected to a brine circuit in the rink floor. In 2016 a new CO₂ system was installed to replace ammonia, with direct expansion. An additional indoor ice sheet located in a brand-new building adjacent to the existing ice rink completed the renovation in 2017.

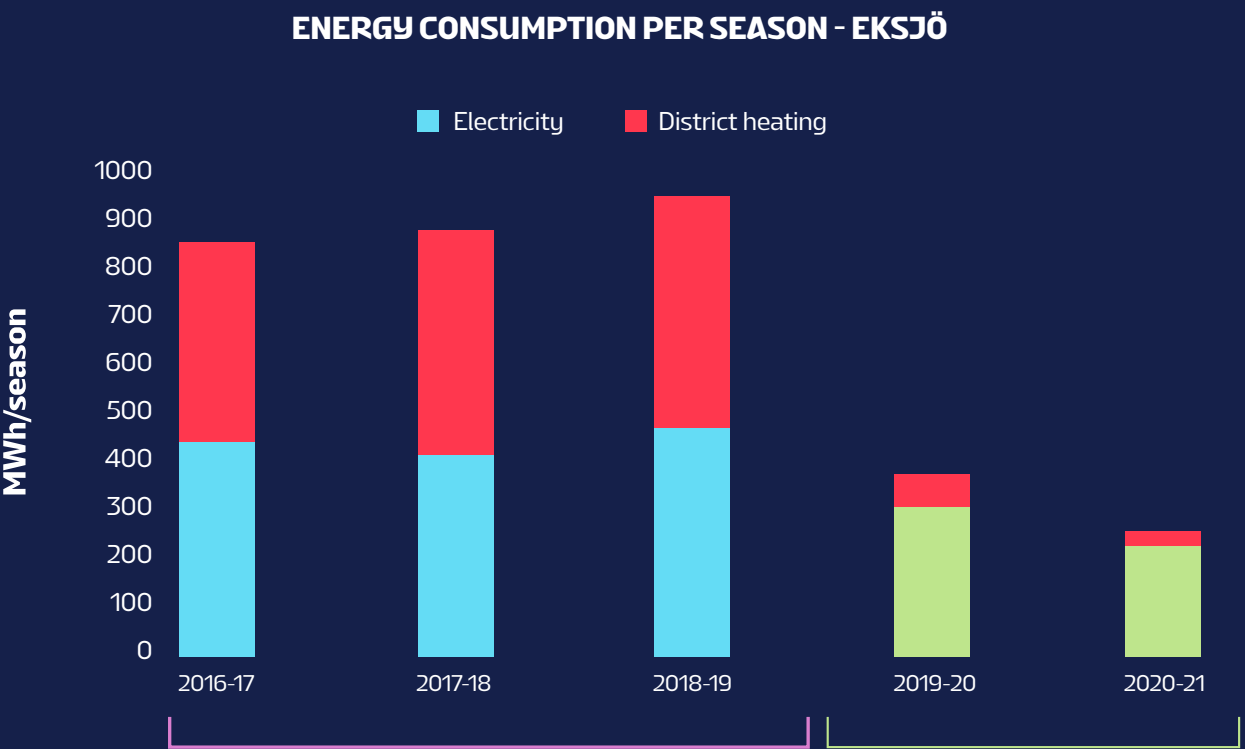


The new ice sheet was connected to the unit at the beginning of the season 2017-2018. The CO₂ system is **now able to run two ice sheets with an energy consumption that is only 10% higher** than what the previous ammonia system needed when running one ice sheet. Almost no district heating is utilized.

	Before	After
Primary Refrigerant:	Ammonia	CO ₂
Secondary Refrigerant:	Brine	CO ₂

8.1.4 Ice rink 5 - Eksjö [Sweden]

This facility consists of one ice sheet. Before interventions, an ammonia refrigeration system was used. The heating demand was mainly covered by district heating. **In 2019, a direct CO₂ refrigeration system replaced the old one.** The old ice sheet has been replaced by a new concrete floor with copper piping.



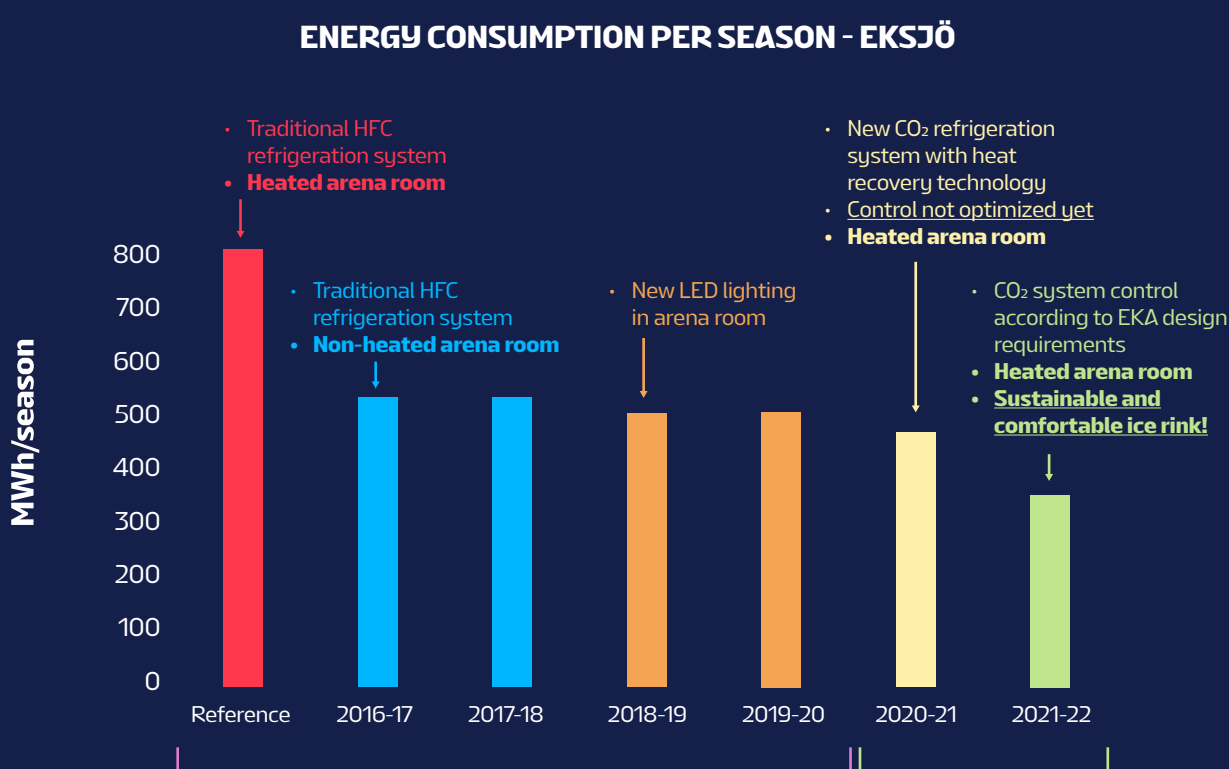
The new system provides a **new complete two-stage heat recovery function with a constant 70°C forward temperature.** A new sorption dehumidifier utilizes part of the recovered heat for reactivation, lowering its energy consumption.

	Before	After
Primary Refrigerant:	Ammonia	CO ₂
Secondary Refrigerant:	Calcium Chloride	CO ₂

8.1.5 Ice rink 6 - Pirkkala (Finland)

This facility consists of one ice sheet. Before interventions, an **R404A** refrigeration system was used. The heating demand was mainly covered by electric heating. In order to minimize costs, the arena room was not heated, which lead to regular complaints from visitors regarding comfort.

In 2020, an **indirect CO₂ refrigeration system** replaced the old solution and was connected to the existing rink floor which uses Freezium as secondary refrigerant.



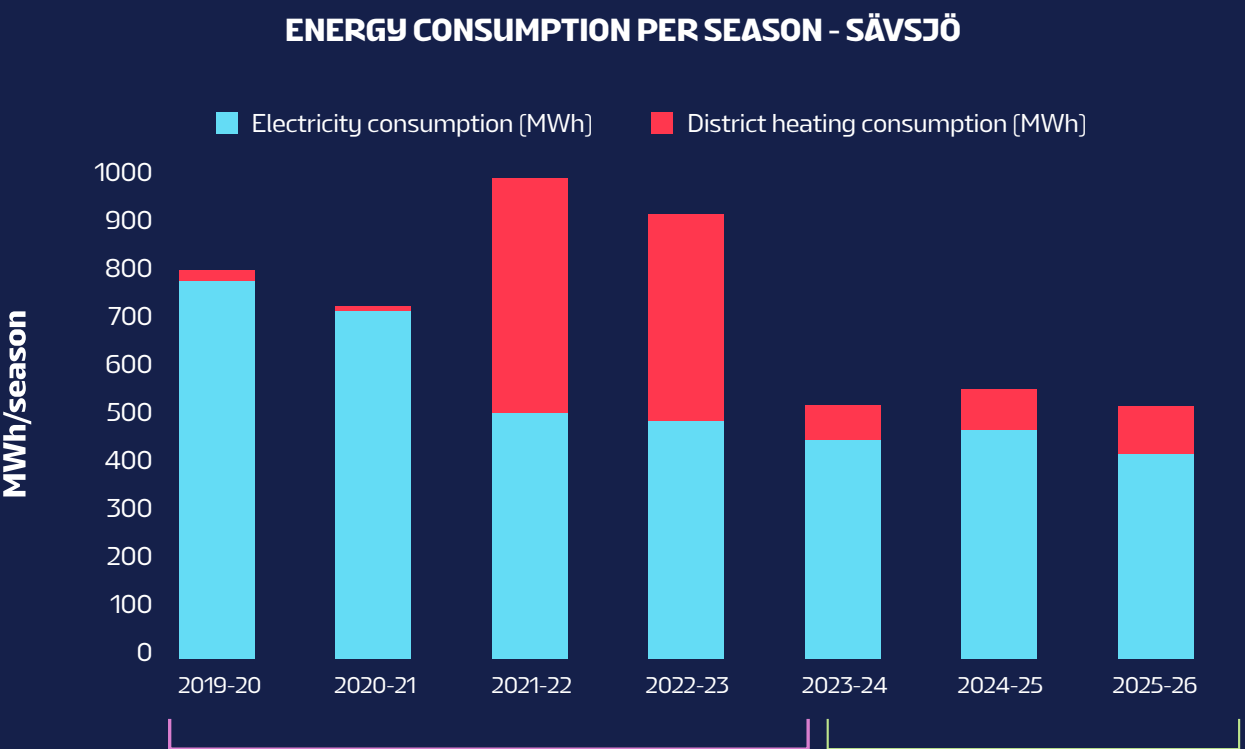
The new system provides a new complete **two-stage heat recovery** function with a **constant 70°C forward temperature**. A new sorption dehumidifier utilizes part of the recovered heat for reactivation, lowering its energy consumption.

Today the ice rink arena room is heated and spectators can be found sitting comfortably in the stands in the sustainable ice rink.

	Before	After
Primary Refrigerant:	R404A	CO ₂
Secondary Refrigerant:	Freezium	Freezium

8.1.6 Ice rink 7 - Sävsjö [Sweden]

This is a single ice sheet rink which before the renovation used a rather old ammonia system with poorly utilized heat recovery. In 2021 the district heating system was expanded but unfortunately poorly controlled which impacted the total energy situation negatively. In 2023, a direct CO2 refrigeration system and new rink floor was installed together with heat recovery driven dehumidification and various other measures.



The new facility comprises a modern control system which allows a convenient follow up of process parameters as well as energy usage. The users report improved arena room climate as well as better ice quality and shorter ice buildup during start of the ice season.

	Before	After
Primary Refrigerant:	Ammonia	CO ₂
Secondary Refrigerant:	CaCl ₂	CO ₂

8.2 Function case studies

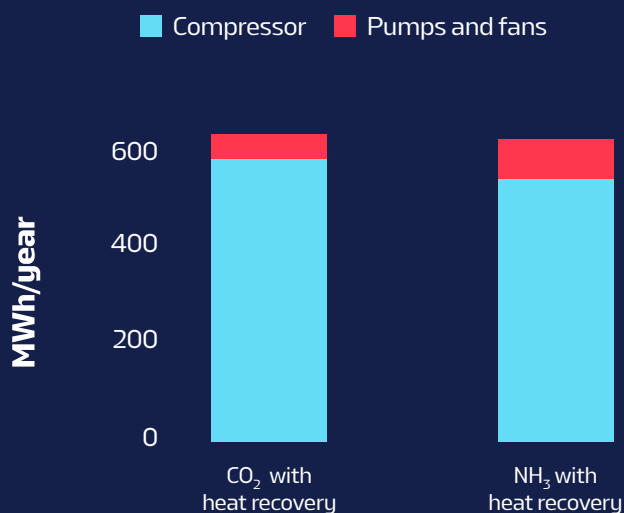
This chapter looks into case studies on a function-basis, i.e. how a change in an individual function has changed its performance.

8.2.1 Refrigerant heat recovery performance – Zinkensdamms IP [Sweden]

In this project, two different solutions for supplying **cold and heat to a Bandy and to an Ice Hockey arena**, located in the center of Stockholm, Sweden, were assessed.

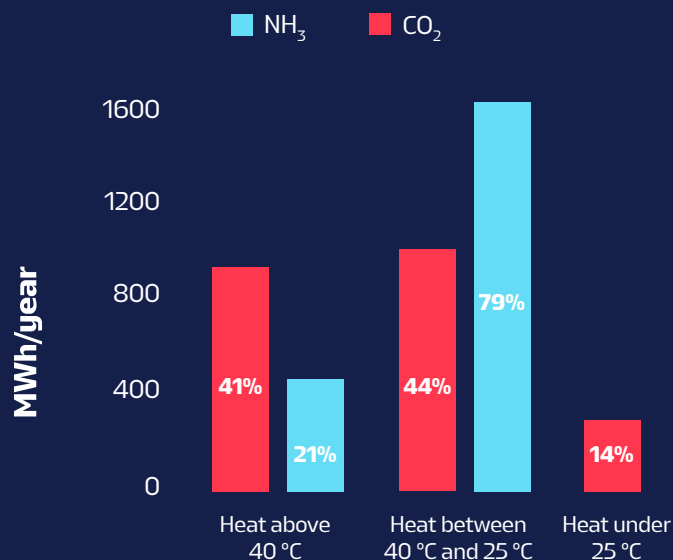
The aim of the study was to identify the best solution in terms of system layout and refrigerant. The calculation shows that difference in terms of power consumption between CO₂ and ammonia is negligible.

POWER CONSUMPTION COOLING & HEATING



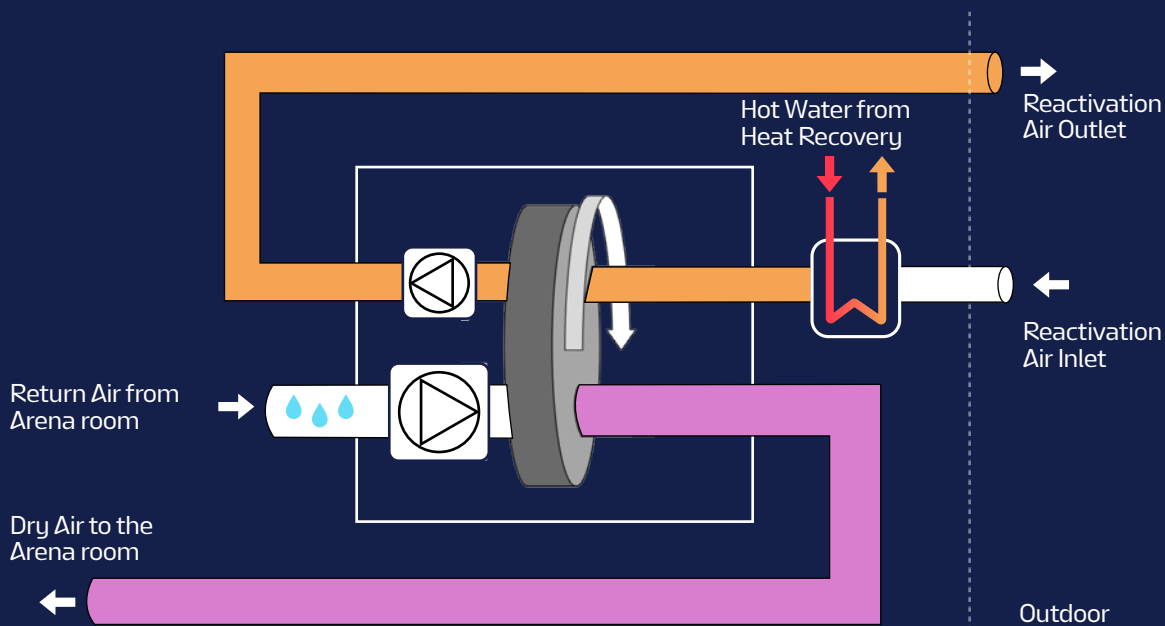
Since, CO₂ has more heat available at high temperature. Considering that 2/3 of the heat in ice rinks is consumed at temperatures higher than 40°C, **CO₂ was chosen as the best solution.**

HEAT AVAILABLE FROM THE REFRIGERATION SYSTEM



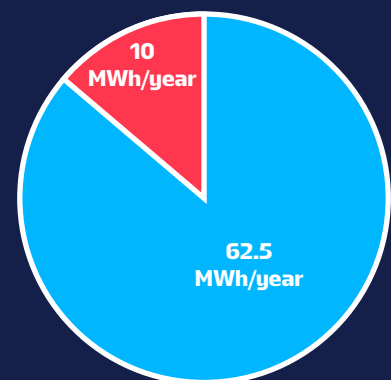
8.2.2 Dehumidification with Full Heat Recovery – Testebovallen [Sweden]

A common best practice in ice rinks is to use **sorption-based dehumidification systems**, to take advantage of the heat recovery from the refrigeration system. The full heat recovery solution is characterized by a relatively low **reactivation temperature [55-60°C]**. Therefore, the **heat recovered from the refrigeration cycle is enough to heat the reactivation air**.



Heat recovered from the refrigeration cycle can be utilized for dehumidifying the air. In the sport facility called Testebo, Sweden, the solution was implemented where ca **85% of the energy cost** for dehumidification can be covered by the heat recovery. The estimated energy saving is equivalent to 5000 - 6500 €/year.

TESTEBO, ENERGY USED FOR DEHUMIDIFICATION



- 85% Recovered Heat [free]
- 15% Electricity

8.2.3 Climate Control of large arenas – Scaniarinken [Sweden]

In **medium and large arenas**, ensuring comfort for the spectators while providing dry and cold air on the ice sheet can be very challenging. The presence of **areas with different comfort levels**, such as restaurants, can complicate the picture further.

One of these examples is Scaniarinken, an ice hockey stadium in Sweden with **capacity of 6200 spectators**. Before interventions there was a temperature difference of 8°C between the top and the bottom of the stands. **Nowadays, this temperature difference is reduced to less than 2°C only.**

The system solution, as indicated in the pictures, is **mainly based in dividing the air distribution in “rings”**, where the innermost is purely used by the dehumidification system and the rest for ventilation / air heating.



9. Quick savings in existing ice arenas – No/Low investment

While the long-term sustainable solutions will require some investments, as discussed in this guide, many ice arenas can already achieve some quick savings by making adjustments to their existing systems with little to no capital cost. This is often a good first step in the process of making the ice arena more sustainable, since it engages staff and decision-makers into making changes happen.

Below a number of typical quick savings tips are listed, these are further treated in the document Quick Ice Arena Energy Savings, which is available separately via IIHF. It should, however, be stressed again that the biggest savings by far are achieved by retrofitting ice arenas according to this guide.

Quick tip #1
Reduce arena room
air temperature

Quick tip #2
Increase ice temperature
during no activity

Quick tip #3
Optimize refrigeration
system operation

Quick tip #4
Optimize condenser
performance

Quick tip #5
Optimize pump
control

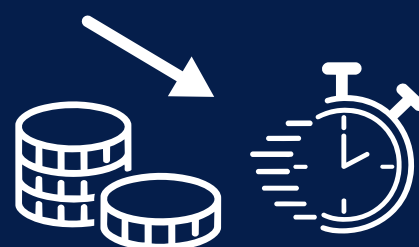
Quick tip #6
Optimize dehumidifier
control

Quick tip #7
Optimize ice
thickness

Quick tip #8
Optimize ice
resurfacer use

Quick tip #9
Optimize/reduce
fresh air intake

Quick tip #10
Separate the
climate zones



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Title page photo by Andreas Bobert.

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More studies available via EKA website www.ekanalys.se