1st place: **Vacuum-Ice Slurry-Technology**
Category: Innovations in refrigeration and air conditioning

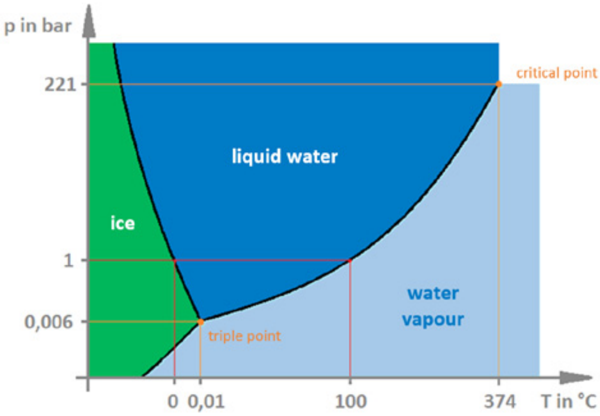
ILK Dresden

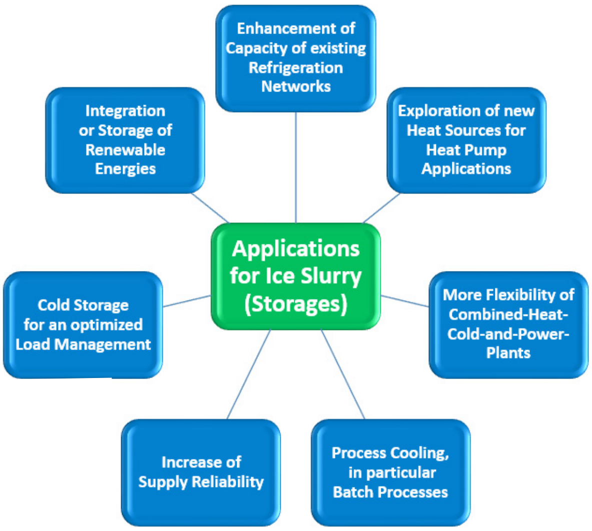
Ice Slurry

For Refrigeration and Heat Supply

Generating cold and heat, storing energy – all we need is water

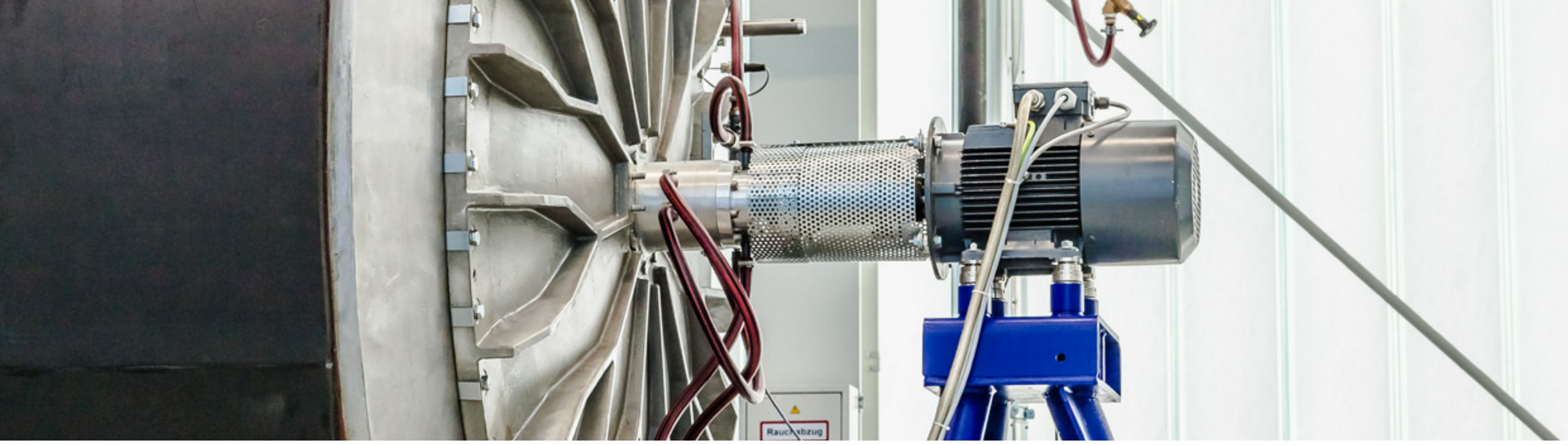
In the future, the increasing expansion of renewable energy will challenge us to use the generated power when it is made available. But how should the energy that is not immediately needed at the time of generation, be stored? Concerning the supply of refrigeration, our ice slurry technology represents a safe, environmentally friendly and very efficient solution to the storage of energy. Our ice slurry technology also sets standards in terms of efficiency of cold generation for all traditional applications of industrial refrigeration processes and air conditioning of buildings. On top of that, the ice slurry technology can be used for heat generation because it enables the exploitation of surface water as a heat source for heat pumps.





What makes this technology so unique if the concept is so easy?

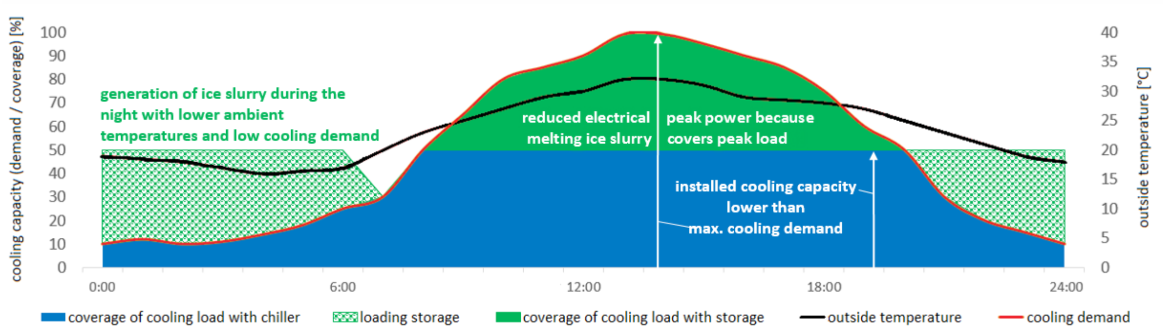
Our method is based on the natural phenomenon that at the triple point of water, the aggregate states solid, liquid and gaseous occur at the same time. Through the evaporation of single water molecules at the water surface, energy is detracted from the surrounding liquid. Because evaporation occurs in a vacuum at the triple point at about -0.5 °C, other water molecules freeze and form ice particles. For the technical use of this phenomenon, the water vapor needs to be sucked from the ice generator to ensure continuous operation. The low density of the water vapor at a pressure of 6 mbar presents a special challenge for the compression process. By now, the ILK Dresden has a decade-long experience in the development of special turbo compressors in these operating conditions and was able to prove their reliable operation in numerous plants for all kinds of applications. Besides the direct utilization of water as a refrigerant in R718-centrifugal-chillers with an output of up to 1 MW, such compressors are also employed in mechanical vapor-compression systems for the desalination of seawater.



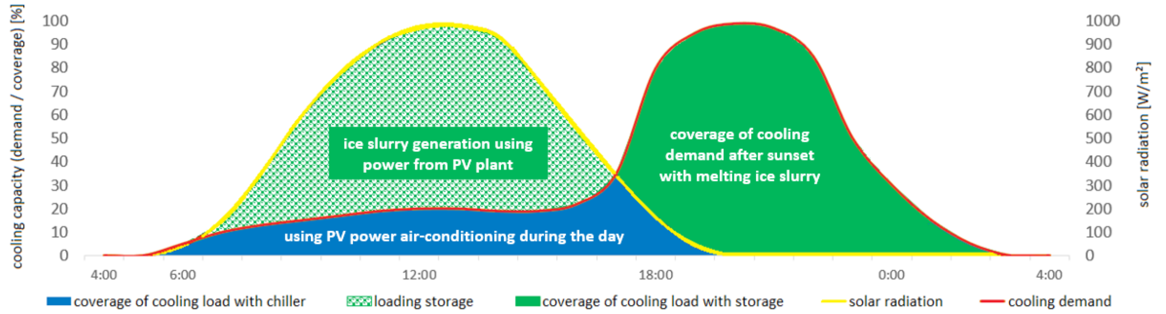
Storing cold – benefits and possibilities

Cold storages serve the coverage of peaks in cooling demand that are typical in many applications for the air conditioning of buildings or process cooling. The use of thermal storages can lower the power peak load and the generation of refrigeration can be moved to times during which power is less expensive or renewable energy is available. The conversion of “excess” (renewable) electrical energy to useable cold is also called “Power-to-Cold”.

Storages for ice slurry are less expensive than conventional ice storages as the module itself does not require a heat exchanger. Therefore, even large storage capacities using a “Power-to-Cold” operation are imaginable and could be materialized. Cold storages make a significant contribution to the energy revolution by integrating reusable energies in the area of cooling and air conditioning.



Coverage of peak load with ice slurry
Example: coverage of cooling demand of an office building or production site



Decoupling of cold generation and cooling demand increasing the self-consumption of PV power
Example: theater with performance in the evening

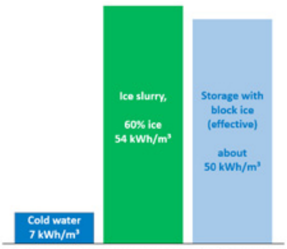
	Ice generation capacity	Storage capacity	Discharging capacity	Storage volume
Minimum (per module)	100 kW	500 ... 10.000 kWh	100 ... 2.000 kW	for 500 kWh: 8 m³ for 10 MWh: 160 m³ (60 % content of ice; incl. 0 to 6 °C)
Maximum (per module)	500 kW			

Feasible performance range with one compressor (higher capacities with parallel operation of several compressors)

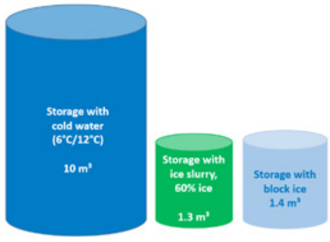
Ice slurry to store cold – technologies in comparison

Cold storages are special kinds of thermal storages, where energy is withdrawn from the storage medium during charging and energy in the form of heat is supplied during discharging. In general, there is a distinction between sensitive storage, in which the medium only changes its energy content based on changes in temperature, and latent storage, in which the medium changes its aggregate state.
The achievable energy storage density in sensitive storage is rather low. In **cold water storage modules** with a temperature difference of 6 °C to 12 °C only about 7 kWh can be stored in one cubic meter.
Through the freezing operation, close to 90 kWh of latent energy can be stored in pure ice per cubic meter. In **conventional ice storages**, water is frozen into a block. A chemical refrigerant is vaporized at temperatures of approx. -10 °C or lower for the production of ice (charging process). As soon as ice builds up on the pipe surface, it has an insulating effect between the surrounding water and the refrigerant, causing the heat transfer and overall efficiency to decrease significantly. This means that the quantity of ice produced per unit of time decreases and the ratio between utilized electrical energy and supplied cooling energy deteriorates.

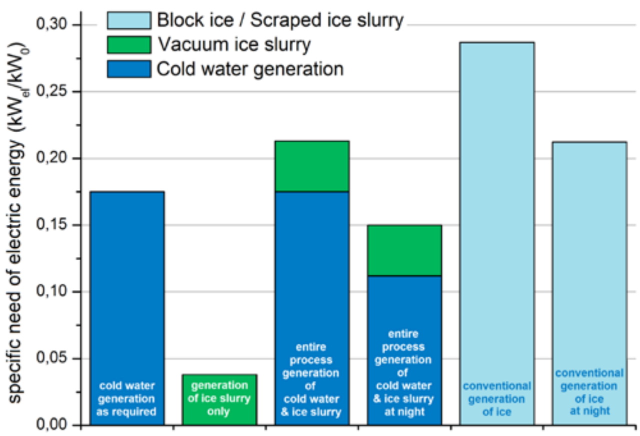
If the consumer side needs refrigeration from the frozen ice storage module, the pipe coil is perfused with brine, causing the ice to melt (discharging process). The output decreases due to the growing water gap between pipe and ice surface during discharge. To counteract the drop in performance, large-scale heat exchangers – some with additional surface enlargements – are deployed. Due to the voluminous heat exchangers required in the storage module, only approx. 45-55 kWh of energy can be stored per cubic meter of storage.



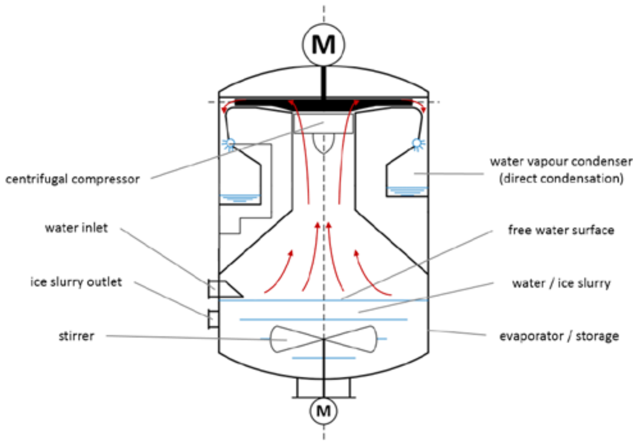
Comparison of volumetric energy storage density



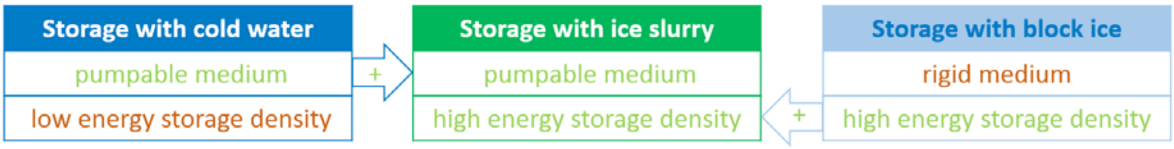
Comparison of storage volume for the same capacity



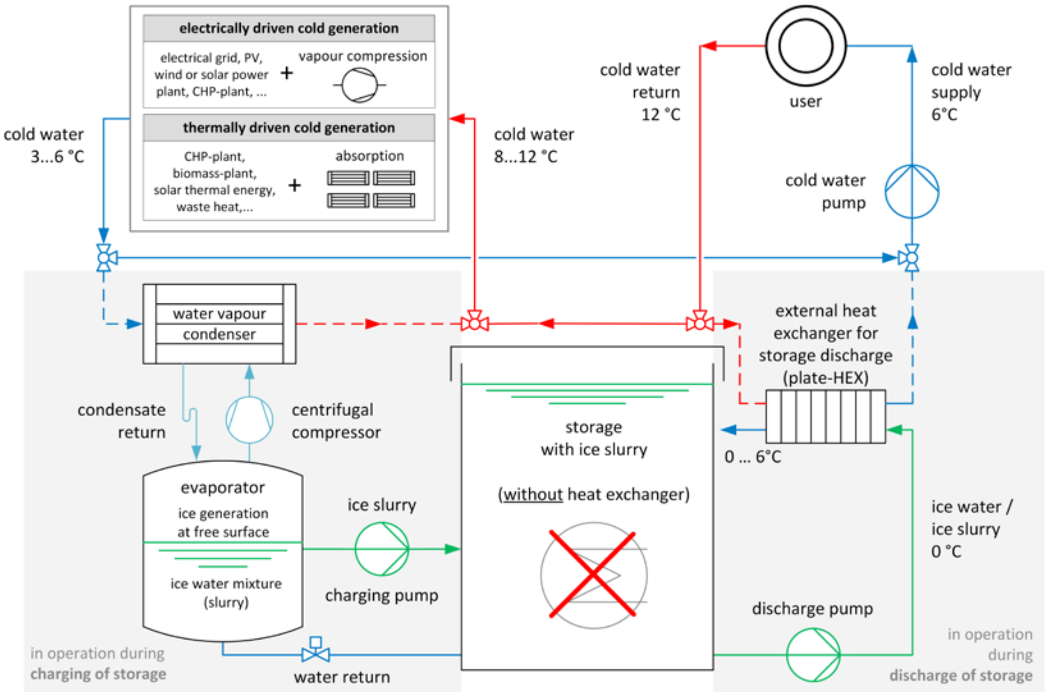
Comparison of the specific need of electric energy



Schematical structure of the ice slurry generator



Ice slurry storages combine the advantages of cold water and ice block



Integration of an ice slurry storage within a chilled water network

The benefits of the above mentioned methods can be combined with so called ice slurry, a suspension of small ice particles in water. The mixture can still be pumped at an ice content of about 50%. With other methods and under great energy expenditure, ice particles are produced in water ice generators through the evaporation of chemical refrigerants, and are mechanically crushed and mixed with water. In our **ice slurry storage**, the enclosed water is a refrigerant and storage medium at once. Inside the ice generator, ice particles are produced through the evaporation of water on the surface during the charging process. This direct evaporation requires neither a chemical refrigerant nor any additional heat exchangers for the ice production. The resulting blend can be stored directly inside the ice generator/ evaporator or pumped into a separate storage module. To discharge the ice storage, the ice slurry is pumped through an external heat exchanger in which either a coolant or a product (i.e. milk) is being cooled off. Both output and temperature remain constant during discharging. Because of the lack of integrated heat exchangers, the volumetric capacity of an ice slurry storage is nearly identical to the energy storage density of ice slurry of 54 kWh/m^3 at 60% ice content.

Ice slurry as a coolant

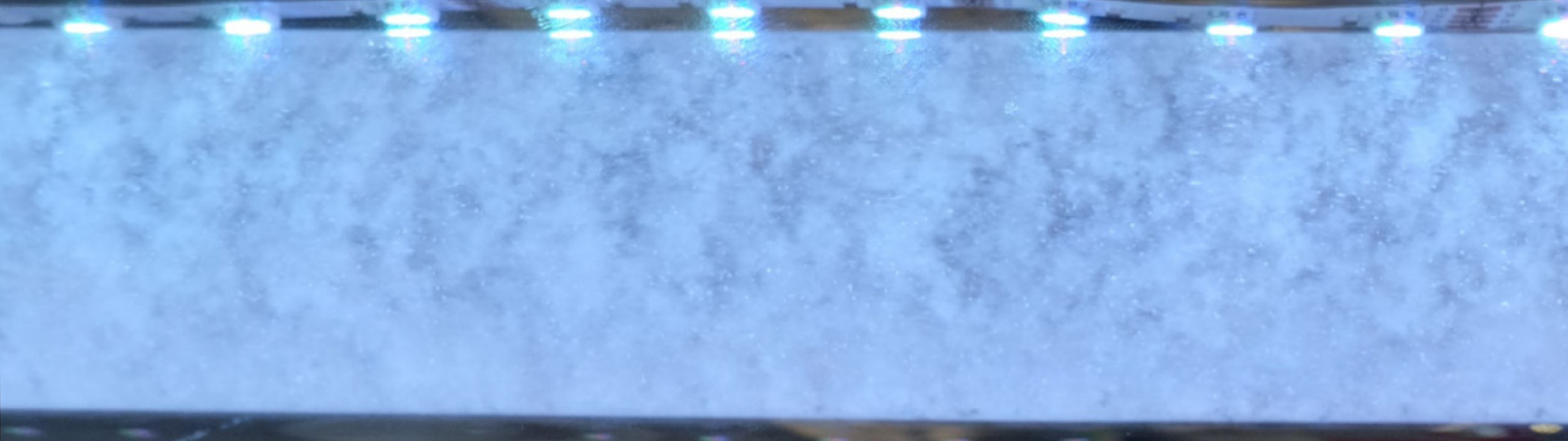
Many industrial applications, i.e. in the food industry, require refrigeration below 6 °C, oftentimes with heavily varying loads. The pumpable ice slurry or the ice water from storage can be directly used as a coolant to cool these processes efficiently and with a high output. That's how air/water or air/glycol heat exchangers that are being used for the dehumidification of air in ripening rooms for cheese or sausage, can alternatively be perfused with ice slurry. The steady temperature of the coolant (melting of the ice) can increase the transmitted power as well as the overall efficiency. This way, hoarfrost on the airside and the consequently necessary defrost cycles can be effectively avoided. The combined application of ice slurry for cold storage and as a coolant is particularly beneficial for industrial batch processes requiring a cooling demand around 0°C. In cases like these, refrigeration supply can be covered using a flexible ice slurry system.

Fields of application are:
- Industrial batch processes
- Breweries
- Dairy plants, cheese factories
- Bakeries
- Meat and sausage processing

Ammonium filling quantity too big? – alternative: ice slurry

Ammonium (R717) is a natural, efficient and above all in industrial refrigeration plants a popularly used refrigerant of safety class B (toxic). However, the use of ammonium in pump-cycle systems, i.e. in refrigerated warehouses, where liquid ammonium is conveyed up to the air-cooled evaporators in cold storage, oftentimes leads to large ammonium filling quantities. Depending on the filling quantity, cost-intensive safety regulations are to be met.

Specifically regarding applications in normal coolness (positive range) the use of ice slurry is an attractive alternative compared to ammonium. Just like with the evaporation of ammonium, ice slurry guarantees a steady temperature on the cold, heat absorbing side of the air-cooled heat exchanger (air cooler). The use of ammonium as a refrigerant can be limited to the refrigeration of the engine room. The cooling distribution occurs through ice slurry.



Cogeneration of heat, cold and power (Tri-generation)

Besides the classic cogeneration of heat and power, predominantly used during winter, it is possible to make use of the heat from (decentralized) power generation for driving absorption chillers during summertime. The operation of tri-generation systems is increasingly influenced by the feed of renewable energies into power grids. The result is that the availability of driving heat for the absorption chiller cannot be guaranteed during times when a demand for refrigeration exists and the absorption chiller should be operated. The storage of cold with high efficiency and energy density by means of ice slurry offers the possibility to make the operation of tri-generation systems substantially more flexible. This means being able to generate cold when the driving heat is available to cover cooling demands at a later time.

Applications with pronounced load peaks can forego the installation of additional refrigeration systems through the use of a cold storage or increase the sustainable energy part in the supply of refrigeration.

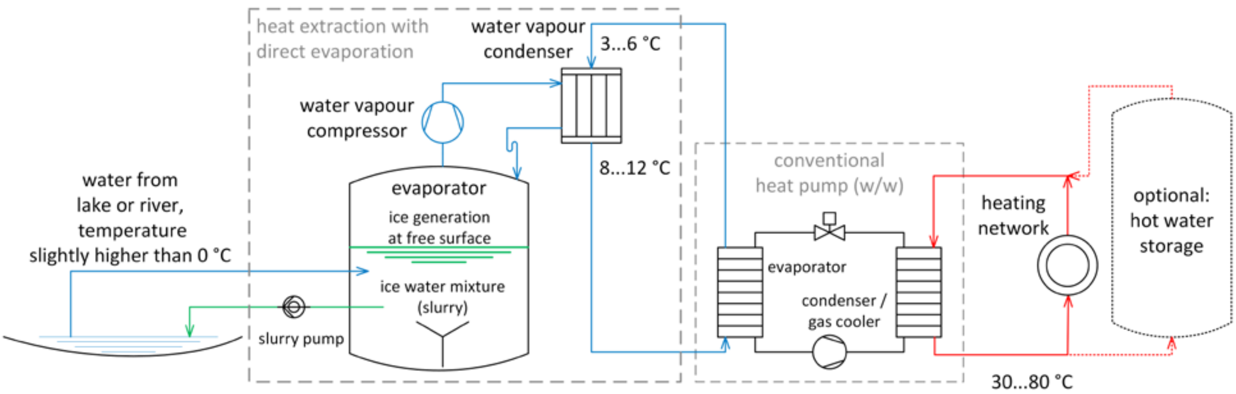
Through the combination of a water - lithium bromide absorption chiller and an ice slurry generator, a variety of process refrigeration applications in the temperature range around 0 °C can be supplied, i.e. food processing and storage. This innovative combination ensures the accessibility of a wider range of applications that used to run on the combination of ammonium-water-AKM. In this case, the consumer can take advantage of a constant supply of ice water or ice slurry from the storage module.

Heating with ice

Heat pump systems are crucial components for the share increase of renewable energies and are gaining popularity. Due to low investment costs, predominately air-based heat pumps are currently used. Further disadvantages besides noise emissions are their low efficiency and operational performance during low air temperatures, meaning specifically times when heating demand is highest.

Due to the risk of frost, surface waters in our latitudes have not been widely used as source of heat for heat pumps.

With the ice slurry system as a first step in a cascade of heat pumps, easily accessible, natural or man-made water reservoirs exhibiting water temperatures above freezing, can be utilized as heat sources. Due to the constant and compared to air-based heat pumps higher heat source temperature, a significant advantage in efficiency is achieved. The exploration expenditures over heat pumps, that use the ground as source of heat, are considerably smaller.



Cascade of heat pumps for using surface waters as heat source

Taking steps towards a sustainable future together

You are interested
in a specific application?

We are ready to create a concept for you, support you during the planning stages and implement innovative refrigeration collaboratively.

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