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World Map

There are plenty of reasons for the international members to be part of eurammon

eurammon was established in 1996 by European companies, institutions and experts in the field of refrigeration, with the aim of jointly championing the use of natural refrigerants. Several members stated their reasons to join eurammon and explained why they value natural refrigerants.

"eurammon supports the application of natural refrigerants. These will play an important role in future refrigeration solutions."

Albrecht Höpfer
Bitzer Kühlmaschinenbau GmbH

"The year 2025 will show a widespread use of carbon dioxide, ammonia and hydrocarbons."

Dr. Dieter Krauß
Schick Gruppe GmbH & Co. KG

"Natural refrigerants need more support in order to be recognized by more people as the long-term answer to climate change."

Prof. Dr.-Ing. Michael Kauffeld

"The eurammon membership enables me to bring relevant natural refrigerant news to broad international assessment expert groups!"

Dr. Lambert Kuijpers
member of the UNEP
Technology and Economic Assessment Panel

"Natural refrigerants are a key part of our desire to provide cooling and heating solutions that minimise the impact on the environment."

Rob Lamb
Star Refrigeration Ltd.

"For us, the eurammon platform is an excellent vehicle to support the promotion of using natural refrigerants to key users and specifiers. In doing so, we participate in the industry effort to develop sustainable solutions against the impact of the human activity on the climate change."

Patrick Heremans
Baltimore Aircoil International NV

"eurammon enables the international communication of responsible, effective and sustainable use of Refrigeration Systems in which we believe."

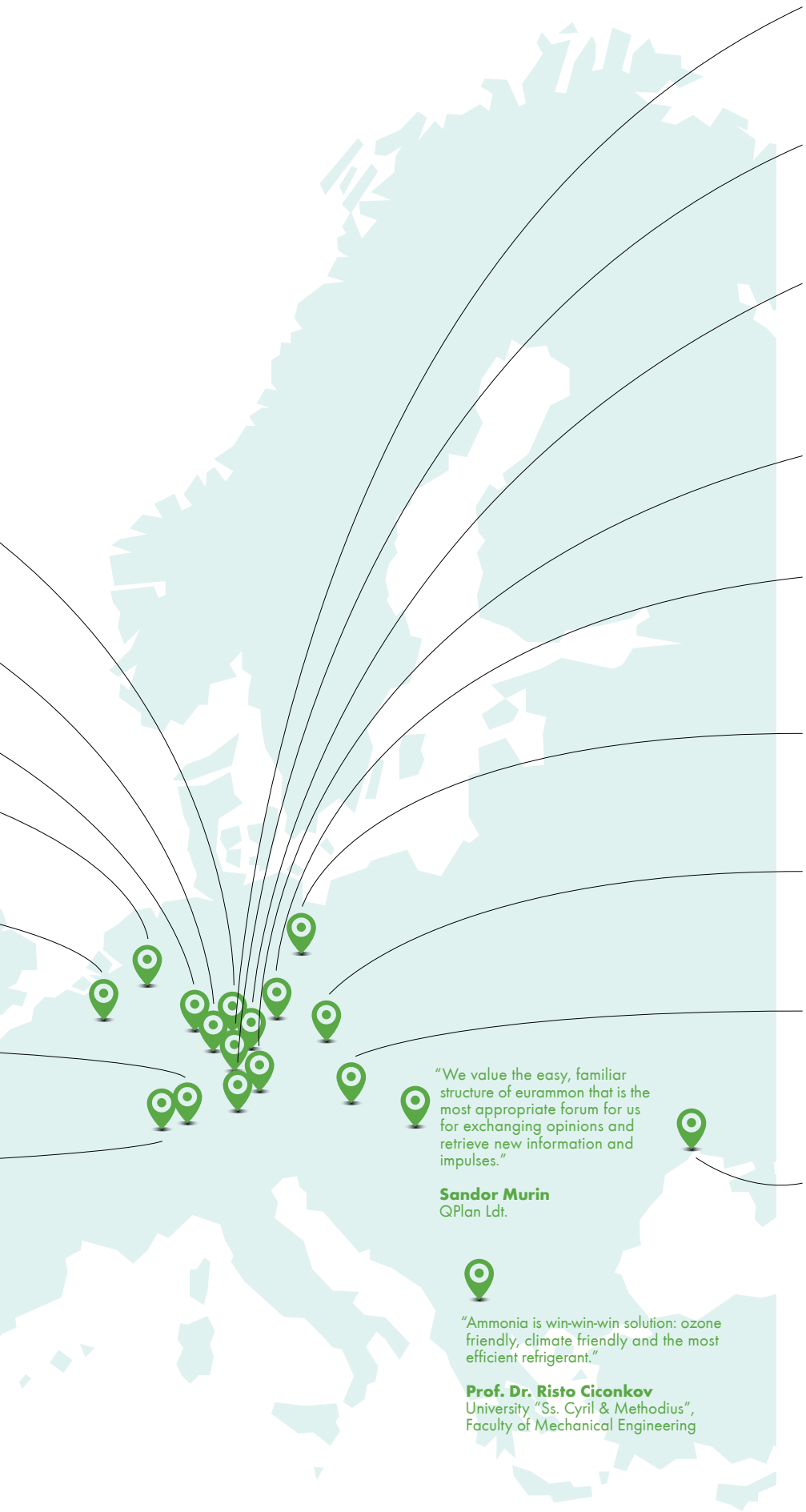
Mark Bulmer
Georg Fischer Piping Systems Ltd.

"An intact environment is the foundation for the next generation and therefore natural refrigerants are an essential part of it."

Beat Schmutz
SSP Kälteplaner AG

"We have known for decades that the future of halocarbons is bleak. eurammon offers a good venue to network with Europe in the field of natural refrigeration."

Dr. Zahid Ayub
Isotherm, Inc.



"Efficient system solutions with components for natural refrigerants assure that the world's resources are treated carefully and that the environment is protected."

Roland Handschuh
Güntner AG & Co. KG

"We are convinced that natural refrigerants will be most important for the future. eurammon shoulders social responsibility in the interest of our eco-industrial policy."

Michael Sauter
GEA Küba GmbH

"As natural refrigerants are economically and ecologically friendly at the same time, they are a real approach to our pursuit of excellence. In the context of eurammon we work on the continuous advancement of solutions with natural refrigerants."

Manuel Fröschle
GEA Bock GmbH

"Natural refrigerants will only come into awareness of society if associations like eurammon stand up for them."

Karl Huber
HKT – Huber-Kälte-Technik GmbH

"Natural refrigerants possess good physical characteristics and are available for reasonable prices. Due to their high energy-efficiency they are the most environmentally-friendly choice."

Willy Löffler
thermofin GmbH

"We promote the use of natural refrigerants, since the refrigeration technology of today should not and must not influence the quality of life tomorrow."

Andreas Meier
GEA Refrigeration Germany GmbH

"Joining eurammon gives us the possibility to exchange information on the field of the use of natural refrigerants."

Dr. Josef Riha
Ostrov Complete s.r.o.

"We care for our environment, and we're convinced, that more and more people do so, which makes investing in natural refrigerants a decision that makes sense, not only from an ethical, but also from an economical point of view."

Johann Herunter
Frigopol Kälteanlagen GmbH

"We are a member of eurammon because, as a state-of-the-art institution, we value the international network in the area of natural refrigerants."

Prof. Volodymyr Zhyvytsya
Odessa State Academy of Refrigeration

"We value the easy, familiar structure of eurammon that is the most appropriate forum for us for exchanging opinions and retrieve new information and impulses."

Sandor Murin
QPlan Ldt.

"Ammonia is win-win-win solution: ozone friendly, climate friendly and the most efficient refrigerant."

Prof. Dr. Risto Ciconkov
University "Ss. Cyril & Methodius", Faculty of Mechanical Engineering

There's a future for natural refrigerants

The question as to how to prevent food from going off is probably as old as humanity itself. Way back in the Stone Age, people knew that food could be kept for longer in the cold, and stored meat and fruit in cool caves protected from heat and the sun. More than 5,000 years ago, the Egyptians used what must be the world's oldest natural refrigerant to cool their food and drinks: ice.

Article by Monika Witt, Chairwoman of eurammon

Development of industrial refrigeration

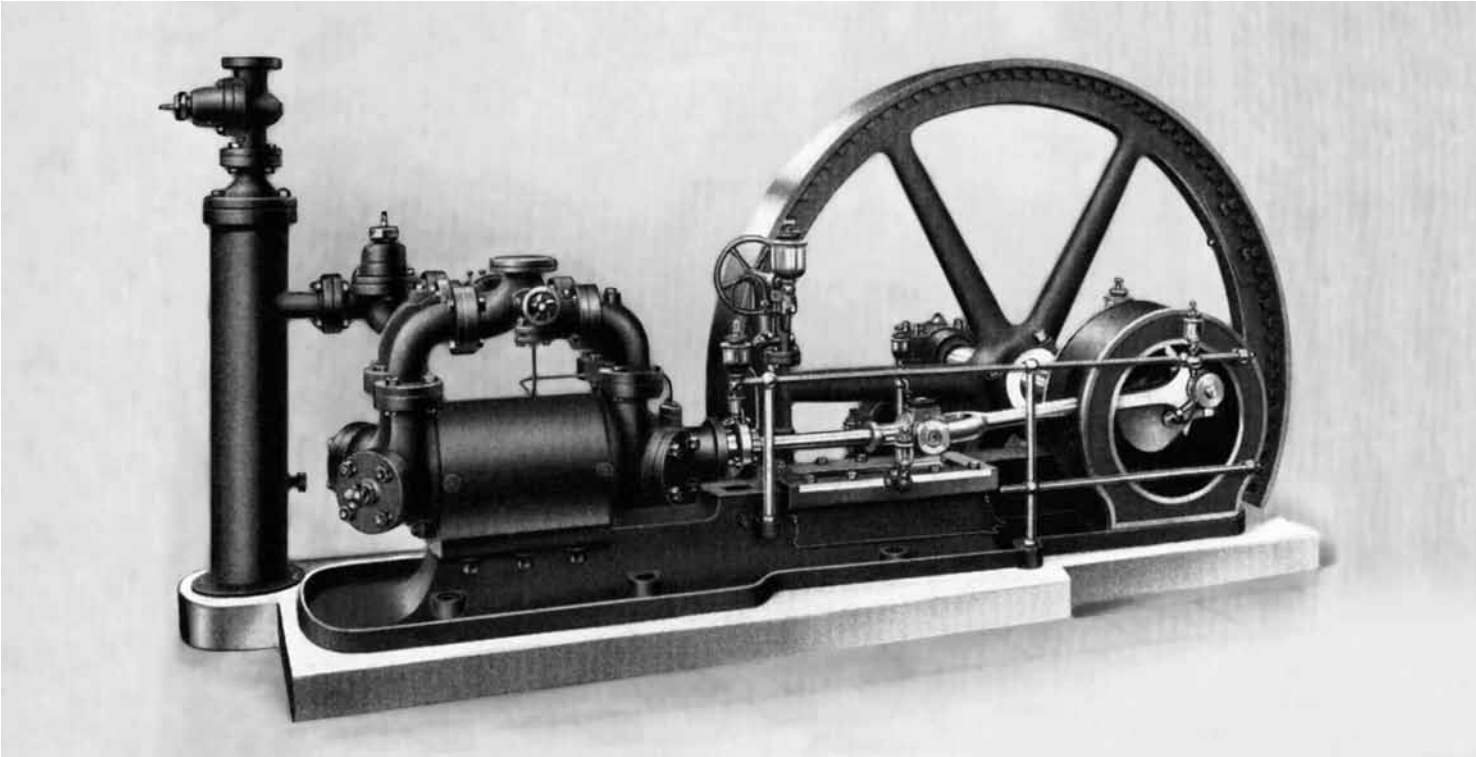
The use of natural ice was common practice through to the second half of the 19th century. Industrial developments made it possible to use machines for refrigeration. The first refrigerating system to operate with the natural refrigerant CO_2 was installed in 1869 by the American Thaddeus S. C. Lowe in Jackson, Missouri. In 1876, Carl von Linde, Professor for Mechanical Engineering at the Polytechnic School in Munich, developed the first compression refrigeration machine with the natural refrigerant ammonia, which became widely accepted on account of its good thermodynamic properties. The first large refrigerated warehouses were built from 1881.

Situation of refrigerants over the years

Natural refrigerants need to be handled carefully. For this reason, the chemical industry started to develop synthetic refrigerants in the early 1930s, using the halogens fluorine and chlorine to completely replace the hydrogen atoms. The chlorofluorocarbons (CFCs) were stable, non-flammable and also neutral in smell and taste, and were therefore propagated as safe, easily handled alternatives. Even if some companies continued to use the natural refrigerant ammonia in particular, due to its good thermodynamic properties and efficiency, from this time onwards, industrial refrigeration systems were filled increasingly with CFCs. However, just 50 years later, chemists issued warnings that the chlorine contained in the anthropogenic CFCs could destroy the ozone layer, as confirmed in 1985 by the discovery of the ozone hole.

Protecting the ozone layer: a global task

This development led to the Montreal Protocol which came into effect in 1989. In the multilateral treaty which is binding under international law, 196 countries undertook to adopt measures to protect the ozone layer. In order to reduce the harmful effect of the refrigerants, partly halogenated chlorofluorocarbons (HCFCs) with lesser ozone depletion potential (OPD) were produced. Since 1996, the use of CFCs has been banned in industrial



top: Horizontal two-stage ammonia compressor around 1900, Linde Group

countries. From 2015, HCFCs may also only be used in existing systems and also only in those cases where there is no interference in the refrigerant circuit or no replenishment.

Global warming and the greenhouse effect are becoming social issues

While newly developed substitute refrigerants called fluorocarbons (FCs) no longer contain chlorine compounds that are harmful to ozone, they still contribute to global warming. The global warming effect could be mitigated by producing partly halogenated refrigerants, so-called HFCs. However, the contribution to global warming (GWP value) is still between 120 and 14,000 times higher than that of the natural refrigerant carbon dioxide. This is why the FCs and HFCs referred to as fluorinated gases are featured together with other greenhouse gases in the international Kyoto Protocol to the United Nations Framework Convention on Climate Change, with mandatory target values stipulated for industrial countries for the first time.

On the European level, the EC Regulation on fluorinated greenhouse gases stipulates specific measures to be taken to reduce refrigerant emissions, including for example regular maintenance and leak checks of the refrigeration and air-conditioning systems. However, a review of the defined objectives in 2011 revealed that the measures currently adopted by the Member States cannot reduce fluorinated greenhouse gas emissions but just keep them constant on the current level – and only if the regulations are implemented consistently by all 27 Member States. But it is precisely the lack of consistent implementation that is criticised by the Review Panel. In turn, this revives the debate about tightening up the Regulation or even banning the refrigerants.

Renaissance of natural refrigerants

Efforts to counteract the progressing greenhouse effect is putting natural refrigerants increasingly back on the agenda again. They have no ozone depletion potential and either no global warming potential (ammonia) or their global warming potential is negligibly low (carbon dioxide: 1, hydrocarbons: 3). Furthermore, systems with natural refrigerants today operate with just the same energy efficiency as systems with synthetic refrigerants.

Natural refrigerants remain the more viable solution

The chemical industry reacted to the increasing legislation and standards aiming to counteract the use of refrigerants with high GWP by developing unsaturated HFCs, called hydrofluoro-olefins (HFOs). They have a shorter lifecycle in the atmosphere which gives them just a low global warming potential. On the other hand, opponents of the new refrigerants argue that their long-term impact on the environment is not clear and that their decomposition in the atmosphere releases harmful by-products such as trifluoroacetic acid. Furthermore, there are additional safety risks in terms of combustibility and flammability. And yet there are adequate supplies of alternatives available, such as natural refrigerants.

We at eurammon are convinced that in future too, natural refrigerants will continue to be the most environmentally friendly option for refrigeration applications. One thing is certain: today, for every refrigeration application, there is also a solution with natural refrigerants which is convincing in both ecological and economical terms. And so, natural refrigerants are a safe investment in the future.

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Supermarkets advocate sustainable refrigeration

The food retailing sector increasingly uses natural refrigerants

For a long time now, consumers not only look at quality and price when making purchases. In the results of a study conducted throughout Germany by IBH Retail Consultants published in December 2010, 60 % of those interviewed indicated that their purchase decisions have also recently started to take account of the extent to which companies implement the meanwhile increasing demands in society at large for a sustainable approach to everyday business practice. Supermarket chains are also increasingly opting for environment-friendly shop concepts with lower emission stores to reduce their carbon footprint.

"Depending on the local conditions, today it is possible to develop an individual solution with natural refrigerants for every supermarket."

The refrigeration systems account for a large share of energy consumption in the food retailing sector. Possibilities for taking a sustainable approach include among others the choice of particular refrigerant. "Depending on the local conditions, today it is possible to develop an individual solution with natural refrigerants for every supermarket", confirms Mark Bulmer, member of the Board at eurammon, the European initiative for natural refrigerants. "Natural refrigerants such as ammonia and CO_2 are used for supermarket refrigeration all over the world. In fact, there are two good reasons in their favour: firstly, they have no or only negligible global warming potential. And secondly, supermarket refrigerating systems with natural refrigerants are energy-efficient in operation."

The type of system suitable for a certain supermarket depends among others on the geographic location and the prevailing climatic conditions on site. Outside temperatures warmer than 26 °C prevent liquefaction of carbon dioxide because the refrigerant temperature on the high-pressure side is above the critical temperature. Such trans-critical CO_2 solutions therefore tend to be used in moderate climate zones such as Canada, Scandinavia or Central Europe", Bulmer explains. "Ammonia-CO_2 cascade systems on the other hand constitute a suitable possibility for environment-friendly, efficient refrigeration in warmer regions. Ammonia is deemed to be the most energy-efficient refrigerant of them all."

Sustainable freezing and chilling with carbon dioxide

In 2010, SSP Kälteplaner AG developed a completely new refrigerating system for the Migros supermarket in the Tivoli shopping centre in Spreitenbach, Switzerland. The modern refrigerating solution covers all the requirements made of supermarket refrigeration while taking optimum consideration of the general local conditions with regard to capital expenditure and energy demand.

The new system consists of two 150 kilowatt combined units for chilling and a 53 kilowatt booster combined unit for freezing. Altogether eight Bitzer reciprocating compressors are used for chilling with another four Bitzer reciprocating compressors in the booster combined unit. Direct evaporation of the environment-friendly natural refrigerant CO_2 is responsible for refrigeration distribution in chilling and freezing. Both systems operate in the sub-critical range whenever possible. Under high outside temperatures or when waste heat is called for, the combined chilling units operate in the

top: Heat recovery achieves additional energy savings at Migros. A heat pump uses the waste heat of the system to provide hot process water and heat for the supermarket and the adjoining restaurant.

right: Transcritical CO_2 refrigeration plant for the chilling process at Migros.

supercritical range with a working pressure of up to 92 bar.

Additional energy savings are achieved by heat recovery. A heat pump uses the waste heat of the system to provide hot process water and heat for the supermarket and for an adjoining restaurant. The remaining residual heat is discharged to the outside via a gas cooler/condenser on the roof.

Changeover to natural refrigerants in South Africa with ammonia and carbon dioxide

At the moment, many supermarket refrigeration systems in South Africa still use refrigerants with a high global warming potential (GWP) and in some cases even a high ozone depletion potential (ODP). The use of natural refrigerants in supermarkets is still relatively unknown in South Africa and has therefore hardly been tested. In view of the constant increase in energy costs of more than 20 % p.a. in some cases, a number of South African supermarkets have decided to change over to natural refrigerants.

In 2009, for instance, KWN Engineering developed, planned and supervised the realization of two new NH_3-CO_2 cascade refrigeration plants in South Africa. Ammonia and a glycol solution are used in the chilling range to keep the dairy and delicatessen cabinets and the refrigerated warehouses at temperatures between 0 and +2 °C. The deepfreeze circuit operates on the basis of direct CO_2 evaporation for the frozen food and ice cream displays. In addition, the waste heat from the ammonia system is recovered to save energy in heating process water for the supermarket.

Various GEA Grasso compressors generate the refrigerating capacity of the ammonia circuits in the various supermarkets, reaching levels between 285 and 860 kilowatt. Furthermore, one supermarket uses part of the compressors to feed a cold water storage tank for air-conditioning of the premises. To this end, a glycol loop freezes water balls in a storage tank. Outside peak times, all compressors work with the same suction capacity so that free capacities from the supermarket's refrigerating circuit can be fed to the air-conditioning system.

"Operators no longer have to revert to fluorinated greenhouse gases for supermarket refrigeration", says Mark Bulmer. "Applications with natural refrigerants offer a good alternative. Thanks to intensive research and development in recent years, natural refrigerants permit energy-efficient operation today in many areas. Depending on the service life, the partly higher investment in the systems can be recuperated by lower overheads, thanks to reduced energy costs and less expenditure on refrigerants."

From producer to consumer: natural refrigerants in the cold chain

The European Union is the world's second largest market for frozen food. The consumption of refrigerated and frozen goods grows here by more than ten percent every year. Managing large quantities of food is no easy task for producers, storage logistic experts and retailers responsible for bringing the goods to their destination – the final consumer. In addition, companies have to ensure that the cold chain remains uninterrupted for the easily perishable goods with only a limited shelf life. Moreover, they are also making every effort to minimise the carbon footprint of their production and storage activities to counteract the progressing greenhouse effect.

Global Warming Potential (GWP)

The greenhouse effect arises from the capacity of materials in the atmosphere to reflect the heat emitted by the Earth back onto the Earth. The direct Global Warming Potential (GWP) of a compound is shown as a CO_2 equivalent (GWP of a CO_2 molecule = 1).

In this context, great significance is attributed to the refrigeration of food with natural refrigerants. "The use of ammonia, carbon dioxide and hydrocarbons can make a major contribution to improving a company's environmental balance", explains Georges Hoetierckx, member of the Board at eurammon, the initiative for natural refrigerants. "Natural refrigerants are environmentally friendly, as they have either no (ammonia) or only a negligible global warming potential. In addition, refrigeration systems working with natural refrigerants are not only energy efficient, with a positive effect on the carbon balance: they also result in lower overheads." The following examples illustrate how companies use natural refrigerants to keep food cold and fresh.

Logistics company reduces operating costs by using natural refrigerants

With more than 60,000 employees in 900 sites spread across 100 countries, the Kühne + Nagel Group is one of the largest

logistics companies in the world. The Group's distribution centre in Wellingsborough/England is responsible among others for the supply chain management of frozen and refrigerated goods for leading British food and drink wholesalers. The refrigeration design team from Star Refrigeration designed a high-efficiency refrigeration system for the Group that runs on ammonia (NH_3) as refrigerant; this system was installed in an existing warehouse building in the record time of just 23 weeks. The finished complete solution takes care of the chilling and deep-freezing sections of the warehouse, which among others has 17 truck loading ramps.

The refrigerating system with an output of 500 kilowatt keeps the deep-freezing section at a temperature of -25°C. The chilling section works at a temperature of +2°C generated by 650 kilowatt. The system consists of a two-stage ammonia plant with a hot gas defrosting system of the evaporators. NH_3 was chosen as environment-friendly natural refrigerant without any global warming and ozone depletion potential. The system comprises a two stage pump circulation ammonia plant with hot gas defrost to the evaporators. The compact and highly efficient system features two low and two high stage compressors, a high stage surge drum and two evaporative condensers. The innovative solution reduced Kühne + Nagel's operating costs by around £50,000 p.a. compared to a conventional pump system.

Fresh fruits all year round thanks to controlled atmosphere

For more than 125 years, Obst Gößl based in Puch/Austria has been trading fruit. The fruit wholesaler takes apples into "controlled atmosphere" storage straight after harvesting. To this end, the oxygen level is reduced in the cold cells of the CA (controlled atmosphere) warehouse. At the same time, the carbon dioxide level is raised and the apples are allowed to "hibernate" at temperatures of one to two degrees Celsius and high humidity levels. This storage technology ensures that apples can be supplied "fresh from the tree" all year round.

In 2009, the company started to plan an expansion of its storage capacities. The intention was to erect three additional CA warehouses each with a surface area of 100 square metres and measuring ten metres in height, to increase their controlled atmosphere storage capacity from 250 tonnes to altogether 300 tonnes. Furthermore, a new additional high rack warehouse was planned, that should offer space for about 6.000 large boxes, each of them providing a filling capacity for 300 ilograms of apples. This also entailed extending the existing refrigeration system. To this end, Johnson Controls installed a refrigeration system that started operations in 2010 with the natural refrigerant ammonia (NH_3). An ethylene-glycol-water mixture is used as secondary refrigerant. To warrant a constant temperature between one and three degrees Celsius maximum in the high bay warehouse, Johnson Controls installed brine circulation air chillers in the area of the warehouse ceiling panels. A double ventilation system consisting of two speed-controlled ventilators fitted under the roof permits free cooling in addition. Moreover, after ozonation, these ventilators are also responsible for purging the rooms and extracting the used air from the warehouse by means of negative pressure. Goods are taken into and removed from the warehouse by means of fully automatic conveyor systems at six openings in the building. At these access points, additional air curtains prevent the cold air from leaving the building, thus boosting the energy efficiency of the system. Two adiabatic glycol recoolers installed on the roof of the building are responsible for heat rejection for the whole system.

To ensure that the three new CA warehouses can be operated independently of each other, Johnson Controls fitted three brine/air coolers in every cold cell, each with its own brine circuit and own brine pump. Altogether eight brine/air coolers were also installed in the aisle zone between the warehouses and in the manipulation section in front of the warehouse. These brine/air coolers keep the temperature at a constant level of between two and four degrees Celsius, thus ensuring adequate chilling of the apples in all parts of the warehouse.

Highly energy-efficient with waste heat utilisation: natural temperature control in cold rooms for baked goods

Glockenbrot Bäckerei GmbH & Co. oHG produces baked goods in the industrial bakery "Backwerk Süd" in Bergkirchen near Dachau/Germany for around 1,100 REWE, Toom and Penny stores. Environmental protection aspects and a well thought-out energy concept were already central issues when the industrial bakery was being planned. This is why the company opted for a refrigeration system with an NH_3/CO_2 cascade system to cover refrigeration and deep-freeze requirements. The combined NH_3 system also chills the secondary refrigerants Temper-20 and iced water. The cold brine is applied to the Güntner air chillers in the pre-chilling rooms; it is chilled in the ammonia system by plate heat exchangers with an output of 700 kilowatt. The evaporators used in the deep-freeze rooms have integrated warm brine defrosting that uses the waste heat of the system, thus increasing its energy efficiency. This solution also saves the costs that would otherwise be

opposite page: A special storage technology ensures that apples can be supplied "fresh from the tree" all year round.

left: The machine room of Obst Gößl in Puch/Austria

40.2 kilogramm per year

The German Frozen Foods Institute (Deutsches Tiefkühlinstitut e.V.) put the average annual per capita consumption of frozen food in Germany at 40.2 kilogram in 2010. Given the current population of 81.5 million, this results in about 3.3 billion kilogram each year.

generatedin defrosting the deep-freeze evaporators and the air chillers in the refrigeration circuit, for example with electric defrosting solutions.

Waste heat not used for this process is dissipated with a Güntner recooler with a heat output of 100 kilowatt. The warm brine for defrosting is generated by the oil cooler. The system has six defrosting coils each with 22 kilowatt. Altogether 16 defrosting points are served. Temper-40 cold brine is used for the corresponding process in the deep-freeze section. The Güntner ammonia condenser has eight ventilators with step control and two with frequency control. The ventilators are regulated with a combination of step and frequency control at the adjusted minimum condensation temperature Tc min = 32 °C.

Supermarkets save energy by opting for refrigeration with natural refrigerants with optimised part load

For 15 years now, the Danish Fakta supermarket chain and their suppliers Superkřl and Advansor have worked constantly at improving the energy efficiency of the refrigeration systems in its stores. Fakta changed over to carbon dioxide as refrigerant already in 2007, and has meanwhile installed 61 transcritical refrigeration systems in the altogether 378 stores. Another 40 of these state-of-the-art systems focused on optimised part load were installed by the end of 2010. The relatively small systems operate with an output of 9 kilowatt in the deep-freeze range and 28 kilowatt in the medium temperature range. Today all systems are supplied as standardised five-unit combined solutions. They all have the same refrigeration appliances, packs and gas coolers; moreover, they all work with the same output. Only the type of installation can vary form one place to the next. All systems work with a booster system with gas bypass. They consist of two compressors, one with AKD inverter for the refrigeration range and two compressors without inverter for the deep-freeze range. They are controlled by the ADAP-KOOL pack controller system by Danfoss. A controller also checks the pressure in the gas cooler to reach the optimum COP in the system. An electric valve regulates the receiver pressure at the same time. A flexible chilling point and overheating regulator permits energy optimization of the whole system. Application-specific presets permit swift adaptation to different refrigeration appliances and rooms. More than one evaporator can be controlled depending on the application. A study of the energy consumption in the first ten installed state-of-the-art systems resulted in energy savings of around 10 percent compared to the HFC plants that were usually found in the stores through to 2007.

Contribution to environmental protection – also in the home

"Time and again, systems with natural refrigerants prove their efficiency as they can be used as an environment-friendly, energy-efficient solution for keeping food cool and fresh", says Georges Hoeterickx from eurammon. Natural refrigerants are also well established solutions for refrigerating food in the home. Today around 300 million refrigerators use isobutane.

Eco-friendly brewing processes use natural refrigerants to produce cold beer for hot days

On hot summer days in particular, many of us appreciate a refreshing beer from our own fridge. However, even during the brewing process itself certain temperatures have to be maintained. For example, the fermentation temperature of top-fermented beer is up to 22 °C, while for bottom-fermented beer it should not exceed 10 °C. For the "amber nectar" to succeed, breweries need refrigeration solutions tailored to their processes and individual requirements. "Nowadays, these systems are not just energy-efficient. If they also use natural refrigerants like ammonia, they are also particularly environmentally friendly," says Georges Hoeterickx, member of the board of eurammon, the European Initiative for Natural Refrigerants. "This is because natural refrigerants have no, or only very low, global warming potential."

It is an accepted fact, that brewers had a mayor influence in regards to the development of refrigeration systems. Already in 1876 an ammonia system enabled a Bavarian brewery to produce beer at any time of the year. Due to the positive properties of natural refrigerants many breweries did not change over to synthetic refrigerants. In the following, some cases from recent years are introduced.

Brewery in England enjoys higher output and reduced energy costs

Since it was established in 1807, the Daniel Thwaites brewery, one of the top ten breweries in England, has been an independent, family-owned and operated company with headquarters in Blackburn. To improve its refrigeration capacity and to save energy costs, the company commissioned the cooling specialists from Star Refrigeration to optimise the existing refrigeration system. Heat exchangers and separator vessels had already been replaced in the course of previous projects. A newly installed GEA Grasso reciprocating compressor, featuring inverter drive and using the eco-friendly natural refrigerant ammonia, increases output from the previous 310 kW to 400 kW, while at the same time reducing operating costs. The improved energy efficiency is largely due to the use of the new inverter-driven reciprocating compressor instead of the original unit that ran constantly at the same speed, and to the installation of a new compressor control system. Energy measurements show that the brewery is saving around £2,000 (approx. 2,500 Euros) a week in electricity costs, and that the investment will pay for itself in less than 18 months.

Eco-friendly beer cooling with heat pump option

The "Herzoglich Bayerische Brauhaus Tegernsee" in the Alps is regarded as one of the oldest remaining breweries in Bavaria and produces around 120,000 hectolitres of beer every year. In 2010, industrial refrigeration specialists Th. Witt supplied an environmentally friendly refrigeration system for chilling the brewing water. Up until the rebuild, the wort chilling (four brews a day) had been done in the traditional way using an ice bank system. Due to the brewery's planned increase in capacity to nine brews, a new refrigeration solution was required. The brief was to design a system that could be operated at almost constant capacity throughout the day. In addition, it was to incorporate the option of subsequently connecting a heat pump to the system so as to supply heat to adjacent buildings like the "Braustüberl" pub and restaurant. During the chilling process, 190 litres of brewing water have to be cooled down from +16 °C to +2 °C within two and a half hours. In the new system, cooling water consumption for the condensers was to be reduced as far as possible. Th. Witt installed a gravity-type NH_3 system with separator and plate evaporator. To assure the supply of cooling at all times, two reciprocating compressors were installed. While one compressor is in operation the second one is in standby.

To completely dispense with cooling water, the engineers designed the system with an air-cooled condenser for condensing the refrigerant. The system cools a secondary refrigerant loop with glycol to a temperature of -2 °C. By means of a secondary plate heat exchanger operating with glycol and fitted with an outlet temperature controller, the brewing water is then cooled to the required temperature of +2 °C and stored temporarily in an insulated basin. The system's cooling capacity is 124 kW and it uses around 100 kg of ammonia as refrigerant.

Modern beer cooling using R723 – the refrigeration solution for the lower output range

The Ottenbräu Brewery from Abendsberg in Bavaria's Hallertau region has been brewing beer since 1609, making it one of the oldest breweries in Germany. In 2011, owner and seventh-generation brewer Robert Neumaier decided to install a completely new state-of-the-art brewing plant. Although various parts of the equipment had been replaced from time to time, the last general overhaul had been carried out by his great-grandfather as far back as 1906.

The brewery commissioned HKT Huber-Kälte-Technik GmbH in Halfing to professionally implement the cooling system and equip brew house and malt store with state-of-the-art refrigeration technology. The new brewery can process two brews

top: For the "amber nectar" to succeed, breweries need refrigeration solutions tailored to their processes and individual requirements.

opposite page: In 2011, the owner of Ottenbräu Brewery from Abendsberg in Bavaria's Hallertau region decided to install a completely new state-of-the-art brewing plant.

107 litres

In Germany, the average per capita consumption of beer in 2010 was around 107 litres.

75,000 hectoliters

A total 75,000 hectolitres of beer were served at the Munich Oktoberfest in 2011.

To avoid noise the Ottenbräu brewery opted for a very quiet stainless steel condenser with a sound pressure level of 36 dB(A) at 10 m, mounted on a special base frame above the compressors' suction side.

per day with a total of 4,000 litres, with the complete brewing cycle taking about eight hours. A plate heat exchanger performs the function of cooling the hot wort from its boiling temperature (95 °C) to a yeast pitching temperature of 7 °C in the fermentation tanks. The primary fermentation, where yeast is added at 7 to 9 °C, lasts eight days. The beer is then matured for eight to ten weeks. About 2,000 hectolitres of beer are brewed annually using this process.

When designing the new brewery, the focus was on energy efficiency and sustainability. In view of the output range of between 3 and 15 kW with direct expansion at -8 °C, the refrigeration solution opted for an ammonia and dimethylether mixture (R723) as refrigerant. Adding DME to the ammonia allows the discharge temperature to be reduced by up to 25 K and achieves oil solubility. As a result, it is possible to build reliable direct expansion refrigeration units with air-cooled condensers, even where ambient temperature is 35 °C. In this specific case, due to the brewery's close proximity to its neighbours, the company opted for a very quiet stainless steel condenser supplied by Güntner with a sound pressure level of 36 dB(A) at 10 m, mounted on a special base frame above the compressors' suction side to avoid noise. The higher suction gas density of R723 results in a 3 per cent higher efficiency than using pure ammonia. This means that even cooling systems with an output of less than 20 kW are suitable for operation with a natural refrigerant. The brewery has achieved energy savings of around 40 per cent as a result of switching from bricked-in fermentation vats to free-standing directly cooled stainless steel fermentation tanks, changing the space cooling of the storage tanks to direct jacket cooling by glycol, replacing ice bank storage systems with single-stage plate heat exchangers with pre-cooled brewing water and using the natural refrigerant R723.

"The examples show that systems using natural refrigerants can now be used energy-efficiently and with minimal environmental impact in breweries of all sizes – even in the lower output range," says eurammon board member Georges Hoeterickx. "It always depends on the overall concept for a system, and the choice of refrigerant is one aspect of this."

About R723

The refrigerant known in refrigeration technology parlance as R723 (R = refrigerant) was developed as a result of several years of research. The designation derives from the mean molecular mass of 23g/mol and the compound's categorisation as a natural refrigerant (700 series). However, it still does not have an official ASHRAE standard classification. R723 is a colourless gas liquefied under pressure and with a pungent odour. It is made up of 60 per cent by mass of ammonia (R717) and 40 per cent by mass of dimethylether (RE170) – a propellant similar to isobutane when used as a refrigerant. Due to its azeotropic boiling point the mixture can be handled like a single-component refrigerant. This means that there is no composition shift during evaporation and condensation. R723 has no ozone depletion potential (ODP = 0) and minimal direct global warming potential (GWP = 8). It offers the energy benefits of ammonia, which means that its contribution to indirect global warming is also comparably low. In respect of its toxic effects, the relevant safety guidelines for ammonia have to be observed. The dimethylether components have no known specific toxic effects.

Further information on R723 is available in eurammon information paper No. 12 on the initiative's website.

Air-conditioning with natural refrigerants

Interview with Thomas Spänich, member of the Board at eurammon, the European initiative for natural refrigerants

Mr. Spänich, according to the German Energy Agency, the operation of ventilation and air-conditioning systems accounts for around 20 percent of all energy consumed by commercial buildings. How do you see the situation?

Thomas Spänich: During the summer months, modern buildings with glass facades heat up in some cases considerably. The use of IT systems and office automation also make buildings heat up, so that in this day and age, air-conditioning of commercial buildings has become almost essential, even in our part of the world. In the context of constantly increasing energy prices, the use of natural refrigerants offers the possibility of energy-efficient, environment-friendly air-conditioning.

In the context of constantly increasing energy prices, the use of natural refrigerants offers the possibility of energy-efficient, environment-friendly air-conditioning.

Which natural refrigerants are suitable for use in commercial buildings?

Thomas Spänich: Basically all natural refrigerants, i.e. ammonia (NH_3), carbon dioxide (CO_2) and hydrocarbons, can be used in building air-conditioning systems. For a long time now, these substances have played a successful role in industrial refrigeration, but have not been used to such a great extent hitherto in air-conditioning systems. However, numerous examples from recent years show that natural refrigerants are ideal for air-conditioning systems. [see info box on next spread page]

Where are natural refrigerants used for air-conditioning today?

Thomas Spänich: The main focus in Central Europe is on the air-conditioning of larger building complexes. These include for example exhibition halls, congress centres or airport terminals, where ammonia-operated water chillers are frequently used. The liquid chilling units are available with smaller refrigerating capacities from about 30 kilowatt. The air is conditioned by a distributor circuit using water or another secondary refrigerant. Large capacities exceeding 2,000 kilowatt can be achieved among others using several chilling units equipped with screw compressors. For example, ammonia chillers have been used since 2004 for the air-conditioning in Terminal 3 of Stuttgart airport.

What is the situation with smaller capacity ranges?

Thomas Spänich: Ammonia and CO_2 are best suited to these applications which are used among others for office air-conditioning. However, at the moment, components for systems with smaller capacity are still being produced in relatively small quantities which makes them about 20 percent more expensive than systems with synthetic refrigerants. On the other hand, the higher costs are offset by good energy efficiency, so that as a rule, the additional costs can be recovered within about two to three years. Hydrocarbons can also be used as refrigerants in company IT and server rooms. Greenpeace's IT and office rooms in Vienna for example are cooled with propane. Statutory filling restrictions apply to hydrocarbons on account of their flammability, so that up to now it has only been possible to use them on a smaller scale. However, it would be better if the restriction were made dependent on the conditions prevailing in each particular case.

CO_2 has not been used for very long in air-conditioning. Can you tell us why?

Thomas Spänich: For a long time it was not possible to use CO_2 in air-conditioning because the components, which have to be rated for the higher pressures in operation with carbon dioxide, were simply not available. Meanwhile, economical solutions are now also available for office buildings with capacities between 50 and 340 kilowatt. Carbon dioxide is used for example to cool the computing centre at the ABM Amro Bank in London. In the long term, carbon dioxide will see increasing use in systems with smaller capacities of up to 500 kilowatt. CO_2 is not flammable and is chemically inactive, giving it the broadest acceptance in the general public of all natural alternatives in unsupervised small and mini systems. But further development work is necessary here, as at present no suppliers manufacture the components in larger quantities, which would generate competitive prices. Research is currently also looking increasingly at the use of CO_2 in heat pumps: the corresponding results could also be significant for future air-conditioning solutions.

Mr. Spänich, eurammon has been advocating the use of natural refrigerants for 15 years now. Which particular advantages do they offer?

Thomas Spänich: On the one hand, natural refrigerants are inexpensive, readily available raw materials. The differences in price to synthetic refrigerants already make themselves felt for example when filling a system for the first time, and also particularly where leakage losses are concerned. Furthermore, natural refrigerants are extremely energy-efficient. Ammonia

as refrigerant has verifiably the best thermodynamic properties and needs only relatively little effort to generate refrigerating capacity. While the efficiency of an air-conditioning system depends more on its overall concept than on the particular refrigerant being used, a number of current projects indicate that systems are particularly efficient and environmentally friendly when operating with natural refrigerants. In addition, natural refrigerants do not contribute to depleting the ozone layer and have no or only negligible influence on the greenhouse effect. They are therefore absolutely unrivalled in terms of the climate.

Airport Stuttgart

What has to happen to make sure that natural refrigerants are used more frequently in air-conditioning systems in future?

Thomas Spänich: While the use of applications with natural refrigerants is on the increase, these systems are still not self-evident. Already the planning and also the implementation, operation and maintenance of air-conditioning systems using natural refrigerants must be accompanied by an intensified exchange of knowledge about the properties and possible uses of natural refrigerants and the handling of their corresponding systems.

Do you see any applications with natural refrigerants as playing a particularly seminal role in future?

Thomas Spänich: Heat pump applications with natural refrigerants are particularly in trend, with heating systems making further use of the waste heat produced by industrial refrigeration systems and computing centres or the purified wastewater from sewage treatment plants. Little energy is consumed by the actual heating-up process on account of the heat that is already available. It is meanwhile possible to reach temperatures of up to 80 °C in this way. This technology has also been discovered by larger energy companies that use large-scale heat pumps to supply whole urban districts with hot water.

Environment-friendly and energy-efficient
Numerous application examples illustrate the long-standing, successful use of natural refrigerants in air-conditioning

1998 KWN Engineering plans the air-conditioning of office and IT rooms for Greenpeace headquarters in Vienna.
The concept features an indirect refrigeration system using the natural refrigerant propane with a liquid chilling unit and a capacity of 30 kilowatt.

1999 Johnson Controls (formerly York) develops an ammonia system for air-conditioning the office rooms at Saab in Linköping, Sweden.
Here the system required for efficient supply of refrigeration for the premises covering 5,000 square metres also needed to be easily upgradable to cope with future expansion. The solution comprised a central plant for remote air-conditioning, consisting of four ammonia liquid chilling units with a refrigerating capacity of two megawatt each. An extensive piping network provides the administration buildings with refrigeration consisting of water at a temperature of 8 to 16 °C (summer) respectively 12 to 16 °C (winter), keeping the temperature in all rooms at a pleasant 20 to 23 °C, regardless of the time of year.

2000 Frigopol installs an air-conditioning system using the natural refrigerant R723 (ammonia/dimethyl ether) in its office building.
The core element of the refrigerating system that operates with a blend of natural refrigerants is a two-circuit liquid chilling unit. The refrigerating capacity is around 60 kilowatt with an evaporation temperature of 0 °C and a condensation temperature of 45 °C. The system comprises two separating hood compressors each with a plate heat exchanger, together with an air-cooled condenser. The structure of the installation corresponds essentially to a conventional HFC refrigeration system.

2000 Berlin's Ostbahnhof train station is equipped by Grasso with a system for the air-conditioning and ventilation of the three-storey building complex.
The necessary air-conditioning and ventilation tasks in the buildings entail cooling the secondary refrigerant down from 16 to 10 °C. The solution consists of three air-cooled ammonia compact liquid chilling units with a total capacity of 1,250 kilowatt.

2004 Stuttgart airport changes over to ammonia.
Grasso installs an ammonia system for the new Terminal 3, comprising two liquid chilling units with an overall capacity of 2,300 kilowatt. The system was designed to work both in ice bank operation and, together with the already installed refrigeration circuits, in a combined hydraulic system, so that maximum efficiency is always warranted even in low-load mode.

2005 Ammonia air-conditioning system installed for 22,000 square metres of working areas at Roche's headquarters in Welwyn Garden City near London.
Star Refrigeration installed two ammonia chiller units with 930 kilowatt capacity each on the roof of the building. In this way, the condensers are chilled by the outside temperature, thus further increasing the efficiency of the system. Three units operating with hydrocarbons are used just for chilling the server rooms, with a refrigerating capacity of 130 kilowatt each.

2006 The London branch of the Dutch ABN Amro Bank chills its computing centre with a two-stage CO_2 refrigerating system by Star Refrigeration.
The chilling system has a capacity of altogether 300 kilowatt. The carbon dioxide is condensed with water at 6 °C via an indirect chilling circuit. The centre is cooled by fans at the back of the server cabinets where the carbon dioxide evaporates at 14 °C, absorbing the heat sucked in by the fans.

2008 Mülligen letter sorting centre, which is the largest building in Switzerland, is provided with refrigeration and heat by an ammonia heat pump from Johnson Controls.
The energy needed for heating and chilling is taken from the wastewater of a nearby sewage plant. The heat pump has a refrigerating capacity of 4.3 and a heating capacity of 5.6 megawatt at 62 °C outlet temperature. Refrigeration is generated in the first stage by three Sabroe piston compressors at an evaporation temperature of 5 °C and a condensation temperature of 30 °C. In heat pump mode, five Sabroe high-pressure piston compressors compress the ammonia and generate a temperature of 65 °C. The high-pressure liquid is supercooled and expanded in two stages via the intermediate pressure vessel.

2010 Johnson Controls develops an integrated refrigeration and air-conditioning concept for the Ozeaneum in Stralsund with a total refrigerating capacity of 900 kilowatt, including around 500 kilowatt for air-conditioning.
A single-stage ammonia refrigeration system was installed with flooded evaporation, consisting of two separated Chill-Pac chilling units with 730 kilowatt each and two hybrid evaporative condensers for chilling cold water. Direct condensation is provided by two Jäggi hybrid chillers installed on the roof with a capacity of 850 kilowatt each. The required total refrigerating capacity of 900 kilowatt is already achieved with the two Chill-Pac units working at 60 %, thus considerably reducing the operating noise level of the system.

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Adding Quality to People's Life

Heat pumps with natural refrigerants – energy-efficient technology with future prospects

The Organisation of Petroleum Exporting Countries (OPEC) expects that around 150 % more energy will be needed by 2032 compared to today[1]. The growing demand also means higher oil prices and therefore higher costs for the users. The issue of heating costs in particular makes companies literally break out in a sweat. They need energy for water heating, for air-conditioning in offices and workrooms or for manufacturing processes.

[1] http://www.opec.org/opec_web/static_files_project/media/downloads/publications/WOO_2011.pdf

Heat pumps constitute one possibility for efficient management of necessary heat energy. Energy can be saved in particular by those applications that are coupled to heat recovery from industrial processes. Waste heat generated in this way can be put to profitable use in the building – a potential that was scarcely used for a long time. "Heat pumps operated with natural refrigerants such as ammonia (NH_3) are also particularly environment-friendly", remarks Thomas Spänich, Member of the Board at eurammon, the European initiative for natural refrigerants. "In contrast to synthetic refrigerants, they have either no or only a negligible global warming potential. Heat pumps with natural refrigerants are already being used for cost- and energy-efficient operation. They can be planned and implemented individually depending on the requirements of the particular building and the customer's specific needs. The market for heat pumps can therefore expect to see further strong growth in the near future."

Heatpump of Fleischtrocknerei Churwalden AG in Switzerland

Energy-efficient district heating for Sarpsborg, Norway

GEA Refrigeration Germany developed a completely new 2 MW heat pump installation for the energy provider Bio Varma Sarpsborg AS in Norway to heat water up to +82°C for the municipal district heating network. The heat pump uses two different waste heat sources to keep energy costs as low as possible. 1.5 MW of power comes from recooling +45°C warm cooling water from a refrigeration system serving the municipal waste incineration plant, with a further 3 MW supplied in the form of +38°C warm water from a biological sewage plant.

Initially the water is heated using the hot oil in the oil separator. But most of the work is performed by the condenser at a condensation temperature of +82°C maximum. The last few degrees then come from a superheater fed by +105°C hot gas on the jacket side.

The special feature of the large-sized ammonia heat pump is the components that are used. For the first time, this kind of system has been equipped with two large oil filters and an oil pump with an 18.5 kW motor capable to pump just about 900 l/min. GEA has also provided a 1,200 kW high-voltage motor and a frequency converter for motor and oil pump. The centrepiece of the system consists in an R-series high-pressure compressor. However, the high-pressure side of the system had to be rated for a pressure level of 52 bar on account of the high condensation temperatures. This resulted in the need for new components, pipes and mouldings to be procured and in some cases even specially designed. The system started operating in September 2010 and has been running perfectly ever since.

Combined cooling and heating in Fleischtrocknerei Churwalden (meat drying plant), Switzerland

Fleischtrocknerei Churwalden AG produces organic quality meat products. Environment-friendly production is part of the corporate philosophy; this also includes ecological efficiency of systems and premises. The refrigeration professionals from SSP Kälteplaner developed a sustainable heating and cooling system, using heat pumps and refrigerating machines that run on the natural refrigerants ammonia and carbon dioxide. The central aspect of heat generation and refrigeration consists in making energetic use of the groundwater stream of the Alpine Rhine plain. Catchments and groundwater pumps take water from the groundwater stream and then return it in thermally changed state. The energy gained in this way – refrigerating or heat energy, as required – is brought to the required temperatures by refrigerating machines and heat pumps for a wide range of uses.

The production and administration buildings need thermal energy at different temperatures

Heat energy of altogether around 950 kW is needed on two different temperature levels: at medium temperatures of about +60°C as process energy among others for climatic chambers, hot process water or container washing machines, and at lower temperatures of up to +40°C as heat energy for heating purposes, for dehumidification, for pre-heating hot process water and for defrosting the cold storage rooms.

A refrigerating plant capacity of 1,200 kW is needed for maintaining temperatures around freezing point for workrooms, and also for temperatures of -8°C in chilled storage rooms and maturing plants, as well as temperatures of -25°C in the deep-freeze storage rooms.

A two-stage ammonia heat pump is used for heating purposes according to the different temperature levels, using groundwater at +12°C and +8°C. Each stage is fitted with two York/Sabroe reciprocating compressors, which are regulated in a stepless manner by frequency changers. Cassette-welded plate heat exchangers by Alfa Laval are used as evaporators and condensers. The ammonia charge in the heat pump amounts to approx. 300 kg. The production systems are rated for temperatures in the medium range of +60°C. The motor waste heat and compression heat from the compressed air and vacuum generation system is fed directly into the system, while the ammonia heat pump generates the necessary remaining energy. The ammonia heat pump also plays a supportive role at the lower temperature level of +40°C and generates the necessary remaining energy. The "warm" groundwater basin acts as heat source.

Environment-friendly production is part of the corporate philosophy of Fleischtrocknerei Churwalden AG. This also includes a sustainable heating and cooling system that runs on natural refrigerants.

Consistent use is made of any generated waste heat. Where possible, it is fed directly into the heat distribution system and distributed again immediately. This is used for cooling motors, including those used for example for generating compressed air or in the central vacuum system. Waste heat on the lower level is dissipated into the "warm" groundwater basin. This includes condensation waste heat from the refrigeration and tool cooling at the packaging machines in the framework of the cooling water circuit.

Two ammonia refrigerating machines are responsible for refrigeration and are cooled with groundwater. After cooling, the water is fed to the "warm" groundwater basin. When the need arises, the heat pump can bring the waste heat from the basin up to a higher temperature. Refrigerating energy of 0 °C and -8 °C is generated in each case by a refrigerating machine using NH_3 as refrigerant and two industrial reciprocating compressors. One of the respective compressors in each case is equipped with a frequency changer. The energy is transported to the refrigeration sites using a water/glycol blend as secondary refrigerant. The recooling energy is taken from the "cold" groundwater basin. Exchanging the water from the heat pump to the refrigerating machine and vice versa achieves maximum efficiency ratios, while keeping the drive motors and refrigerant circuits as small as possible. Buffer storage facilities with a volume of 30,000 l each have been installed for both secondary refrigerant networks in order to optimise operations.

The natural refrigerant carbon dioxide is used in the deep-freeze storage rooms. The refrigerant is evaporated directly with electronic expansion valves in the room chillers, before passing to the reciprocating compressor where it is liquefied to subcritical state in a cascade condenser. The waste heat from the systems is dissipated to the glycol network at a temperature of -8 °C where the heat can be put indirectly to further use.

In summer, needed cooling energy is taken from the "cold" groundwater basin and used directly for room cooling in ventilation systems, cooling ceilings or in server rooms. Apart from the pump conveying energy, no primary energy is used for air-conditioning refrigeration.

Heat pump supplies chocolate factory with hot water free of cost

In 2010, refrigeration professionals Star Refrigeration won an order from Nestlé to develop a heat pump solution for a chocolate factory in the British branch in order to bring about significant reductions in the energy costs for refrigeration and heating applications. It replaced existing R22 packaged chillers and a central coal-operated steam generation unit which supplied all terminal devices and systems using and dissipating hot steam during their work processes. The new concept entailed taking waste heat from the cooling circuit and boosting it to provide process water heating up to the required temperature. Star Refrigeration's "Neatpump" heat pump was to provide water up to a temperature of +60 °C which was to be fed as preliminary heat also to processes needing higher temperatures.

Given the food manufacturer's commitment to keeping its carbon emissions as small as possible, above all, environment-friendly heat pump technology had to be

To generate heat and cold the plant in Churwalden makes energetic use of the groundwater stream of the Alpine Rhine plain.

54,000 litres per day thus saving around £30,000 in gas costs each year

Since starting operations in May 2010, the system uses and heats around 54,000 litres of municipal water per day, thus saving around £30,000 in gas costs each year.

used here. But apart from the fact that heat pumps were still mainly operated with HFCs, for the most part any system using natural refrigerants uses reciprocating compressors or screw compressors, which caused high maintenance costs or worked constantly at their limit.

In cooperation with Vilter Manufacturing Inc. (USA) and Cool Partners (DK), Star Refrigeration developed a high-pressure heat pump solution that works both with ammonia as an environment-friendly, highly energy-efficient refrigerant and also with screw compressors to a temperature of +90°C. The system offers a convenient solution for extracting the waste heat at -5°C from the glycol as the secondary refrigerant from the refrigeration process and raising this to the main heating demand at +60°C. A new gas-fired boiler is used to increase the +60°C water temperature for a number of smaller heating demands on site.

The heat and refrigeration load profiles of the existing systems ascertained in advance showed that the heat pump compressors had to generate about 1.25 MW of high temperatures to satisfy the total demand for hot water. The new solution was therefore chosen with 914 kW refrigeration capacity and 346 kW absorbed power rating from the waste heat. The COP in the framework of combined refrigeration/heating application (COP_{hc}) is a moderate 6.25. The additional energy required to raise the condensing temperature from design summer ambient conditions with air cooled condenser to a temperature suitable for +60°C hot water production was only 108. kW. This results in an incremental COP_{hc} (energy to create +60°C water minus energy to reject cooling load heat at design conditions) of 11.57.

Using the waste heat from the refrigeration applications pays off for Nestlé: Since starting operations in May 2010, the system uses and heats around 54,000 litres of municipal water per day, thus saving around £30,000 in gas costs each year. Since the end of 2010, the site has also been using a further 250 kW in waste heat for its self-contained cooling circuits. The heat provided by the system even doubled by the middle of last year. In this way, the company saves an estimated approx. £143,000 in heating costs while reducing its carbon emissions by 119,100 kg. Moreover, the costs for electrical operation of the plant are reduced by around £120,000 p.a., despite combined refrigeration and heat generation.

Heat pumps with natural refrigerants on the advance

Heating and energy consumption are topics of interest not just to industry: Home owners are also on the look-out for suitable technologies for keeping overheads as low as possible and saving energy. "Hot water heat pumps using CO_2 as refrigerant are particularly interesting", says Thomas Spänich. "They can make full use of the characteristics of the supercritical refrigerant process. Optimum adjustment to the heating up process permits excellent performance ratios with very high water output temperatures of up to +90°C in some cases", the member of the eurammon Board continues. "Japan is a rolemodel: The government subsidises purchases of CO_2 heat pumps so that around two million units had been sold throughout the country already by the end of 2009. This number should reach 10 million by 2020."

Medal-worthy natural refrigerants

2012 is being swept by Olympic fever once again. The whole world is waiting to see which records will be broken in the individual disciplines and which new idols will emerge from the Games. But the focus is currently not just on the sporting aspects. The general public also expects the Games to show "Olympian performance" when it comes to climate protection. The environment should suffer as little as possible.

This requirement is already being heeded in the construction of stadiums and sports halls. There is scope for a sustainable approach particularly in the construction method and supply concepts for the facilities. For refrigeration and air-conditioning, natural refrigerants such as ammonia offer an environmentally compatible solution. "Ammonia is not only highly energy-efficient but also very environmentally friendly to use", explains Monika Witt, Chairwoman of eurammon, the European initiative for natural refrigerants. "In contrast to synthetic refrigerants, ammonia has no global warming potential and therefore makes no contribution to the greenhouse effect."

Ammonia will also be used as refrigerant for the Olympic Games in London. A large-scale Energy Centre is responsible for supplies to all the facilities of the Olympic Park. Necessary refrigeration is generated by combining an electric compression refrigeration system with an absorption unit that uses the waste heat from the Energy Centre.

Regardless of the Olympics, operators of sporting and leisure facilities have long since discovered the advantages of natural refrigerants.

Climbing, tennis and skating all under one roof – combined refrigeration and air-conditioning system in Kitzbühel Sport Park

The 4,500 m² Mercedes-Benz Sport Park in Kitzbühel not only offers scope for daily sport and leisure but is also a venue for

school sporting events, training camps and professional contests, together with other sporting, cultural and corporate events.

The architectural planning concept for a new ice rink to be erected on the Sport Park premises entailed combining the already existing indoor tennis centre with the new skating rink. To this end, the town of Kitzbühel called for tenders including planning the complex. The refrigeration system was to supply the refrigeration capacity for an ice hockey pitch (1,800 m^2), a curling track (600 m^2) and a mobile outdoor ice surface (600 m^2).

In addition, the client wanted a refrigeration system to take care of the entire air-conditioning for the sport complex (skating and curling, skittles, climbing, tennis and restaurant). The curling track and the air-conditioning had to be rated for operation all year round so that the complex could be used as a National Curling Training Centre – the only one of its kind in Austria. Together with an energetically optimised, climate-neutral rating, the requirements included in particular a very low temperature spread across the whole curling track. Curling is a very sensitive sport that is also called "chess on ice" on account of the refined tactics involved, and makes highly specific temperature requirements of the refrigeration system.

Haas Anlagenbau won the tender for the whole refrigeration technology, including cooling the ice rinks. The company planned and built an ammonia refrigeration system with direct evaporation for the ice hockey and curling facility. The system has two GEA Grasso reciprocating compressor units with a refrigeration capacity of 750 kW. Around 30,000 m evaporation piping was installed for the system. Together with the energetic and climate-neutral advantages of ammonia, direct evaporation in particular warrants a low temperature spread across the entire ice surface of the curling track. A secondary glycol circuit which is also integrated in the central ammonia system is responsible for air-conditioning of the sport complex. The mobile outdoor ice surface is also connected to the circuit.

In addition, Haas Anlagenbau installed two different temperature levels to recover heat from the refrigeration process. The waste heat is used for air-conditioning tasks and for melting the snow pits. In addition, the refrigeration professionals equipped the refrigeration plant with a remote monitoring system for on-line support in addition to maintenance on site. As the whole sport complex is located right at the heart of Kitzbühel, the system engineers also worked together with the Austrian authorities and Kitzbühel fire brigade to develop a corresponding safety concept for the ammonia refrigeration plant. The refrigeration plant has now been running for 4 years to the utmost satisfaction of the operator.

Underwater worlds – cooled with environmentally-friendly natural refrigerants

The Ozeaneum in Stralsund was opened mid 2008 by the "Stiftung Deutsches Meeresmuseum". The spectacular new museum with its huge seawater aquariums, the largest of which encompasses 2.6 million litres of water, offers visitors a unique journey through the underwater world of northern seas that is unrivalled in Europe. Altogether the Ozeaneum's aquariums contain six million litres of water. One key aspect in planning the underwater museum on Stralsund's harbour island consisted in environmentally friendly construction and operation of the whole building.

The refrigeration system needed for cooling the water for the aquariums and for air-conditioning the building also had to meet the high ecological demands. Accordingly, SWS-Energie GmbH, a subsidiary of Stralsund municipal utilities and responsible for the project, contracted Johnson Controls Systems & Service GmbH to

6 million litres of water total

The Ozeanum´s aquariums contain total 6 million litres of water. The largest one encompasses 2.6 million litres.

top: The Ozeaneum in Stralsund requires refrigeration capacity of 400 kW for the aquarium systems and 500 kW to air-condition the building.

right: Two Sabroe reciprocating compressors in the machine room of the Ozeaneum in Stralsund.

opposite page: The Curling hall in Kitzbühel: The curling track and the air-conditioning had to be rated for operation all year round so that the complex could be used as a National Curling Training Centre.

draw up the concept and proceed with installation of a sustainable, energy-efficient refrigeration plant. The system was to avoid plumes of steam caused by evaporation as far as possible, while reducing noise to a minimum level.

Altogether, the museum requires refrigeration capacity of 900 kW, with 400 kW for the aquarium systems and 500 kW to air-condition the building. Refrigeration is provided by cold water at a flow temperature of 6 °C and a return temperature of 12 °C. To warrant reliable, sustainable refrigeration supply for the museum, the refrigeration experts at Johnson Controls opted for a single-stage ammonia refrigeration system with flooded evaporation. The system consists of two separate Chill-Pac chillers and two hybrid evaporative condensers to chill the cold water. To warrant high refrigeration capacity even in the event of a disruption, the refrigeration experts rated the two Chill-Pac chillers with an output of 730 kW each and installed them together with the main switchboard in a separate machine room on the ground floor of the energy centre. Direct condensation takes place using the two Jäggi hybrid chillers installed on the roof of the building, each with an output of 850 kW.

The two Sabroe reciprocating compressor units can be operated independently if necessary so that if one compressor fails, a good 80 % of the total needed refrigeration capacity can be provided by the other unit. Each compressor is equipped with a power control to warrant particularly energy-efficient operation of the system. The power stages are triggered and actuated by corresponding power solenoids. In addition, each compressor has a frequency converter for speed control. In this way, the power stages are added constantly and the speed is increased when the system demands more power. When output is reduced, the power stages are switched back accordingly and the compressor speed is reduced. As the total refrigeration capacity of 900 kW is already generated when the two Chill-Pac chillers work at a capacity of 60 %, the refrigeration experts managed to considerably reduce the noise levels. In addition, this power buffer permits dry operation of the hybrid chillers at nominal load up to an outside temperature of 21.5 °C so that no plumes of steam are emitted over the building as a result of evaporation.

Europe's only elevated ice track – with environmentally-friendly refrigeration

On 1 October 2011, the new Lent Park opened its doors in Cologne with ice rink and indoor swimming pool. Europe's only 260 m long elevated ice track is a special attraction which runs around the building as a gallery on the first floor, offering skaters views of the lower 1,800 m² ice rink, the swimming pool and the restaurant.

Energy-efficient refrigeration was the main demand made by KölnBäder GmbH for the new building to be erected on the grounds of the old ice skating and swimming stadium. Accordingly, the Gesellschaft

top: Ice track at Lent Park in Cologne

left: Pool and restaurant at the Lent Park in Cologne

1,800m² ice rink

Only 260m long but a special attraction – Europe`s unique elevated ice track.

für Kältetechnik-Klimatechnik mbH (GfKK mbH) designed both the elevated ice track and the ice rink as a direct evaporation system with the environmentally-friendly natural refrigerant ammonia. A central refrigeration plant was installed with total refrigeration capacity of 819 kW and a refrigerant charge of 7,000 kg NH_3. The system operates with three GEA Grasso reciprocating compressors. The waste heat is put to energy-efficient use for heating process water and melting the snow pits, as well as antifreeze protection. The remaining waste heat is emitted to the outside with an air-cooled condenser that operates with EC ventilators. Refrigeration supply for the elevated ice track is designed to maintain a constant ice quality even under differing framework conditions and heat loads. The plant itself is equipped with a central GfKK control unit with visualisation.

Fair play for the environment – thanks to natural refrigerants

Natural refrigerants are producing Olympian performance in other applications too: the British retailer Marks & Spencer built a new store in the Olympic Village that uses only the natural refrigerants carbon dioxide and propane for refrigeration. And Coca Cola uses only drink chillers that operate without fluorocarbons (FCs) that would boost the greenhouse effect. "Not every natural refrigerant is suitable for a certain application", says Monika Witt, "but today it is possible to find the right solution for energy-efficient, environmentally friendly refrigeration with natural alternatives for all application areas, thanks to the various properties of ammonia, carbon dioxide and hydrocarbons", explains the eurammon Chairwoman. "As refrigerants, they are definitely worthy of a gold medal."

Climate change and its significance for refrigeration technology

Climate change, greenhouse effect and global warming – scarcely any other issue is so omnipresent and so controversially discussed in the 21st century. Those who are convinced in doubting that climate change is man-made refer to various eras in the history of our planet where the earth has heated up or cooled down drastically even without any contribution on our part. In future too, they see climate change as the result of natural causes, including among others a changed ellipsoid orbit of the earth around the sun. Climate researchers counter this by saying that the situation today is exacerbated by a not inconsiderable human contribution to greenhouse gases in the atmosphere, contributing to the fact that the earth will have warmed up by several degrees Celsius by the end of this century. The main cause of this is seen to be industrial and technological development over the last 150 years. However, at the start of this period, climate change and carbon emissions were unknown factors. They have only gradually come into focus of public awareness, with an increasing effect since the 1960s.

Direct and indirect emissions in refrigeration

"Refrigeration and air-conditioning applications fight on two fronts with their contribution to global warming", explains Monika Witt, Chairwoman of eurammon, the European initiative for natural refrigerants. "On the one hand, direct emissions from refrigerants containing fluorine such as FCs and HFCs make a major contribution to the greenhouse effect. Such emissions are caused for example by leaks in refrigeration systems so that the refrigerant escapes into the atmosphere. On the other hand, the operation of refrigeration systems consumes a large amount of energy consumption and as such makes an additional indirect contribution to carbon emissions."

The demand for refrigeration applications is increasing: On a global scale, installed refrigeration capacity has nearly tripled since 2001.

Political approach: Kyoto Protocol and the F-Gas Regulation

Environmental agreements such as the international Kyoto Protocol in general or the European F-Gas Regulation in particular are dedicated to the issue of greenhouse-relevant substances and look for solutions on a political level. But it is proving extremely difficult to bring about an understanding on shared climate protection and reduction levels as well as elaborating generally binding regulations, in view of the numerous individual interests of the many states involved. This is the case particularly with the Kyoto Protocol which expires next year. Already at the Cancún climate summit in 2010, the participating countries were not able to reach agreement on a binding structure for a follow-on protocol or on a shared approach to a new way of calculating emission values.

While the international Kyoto Protocol stipulates binding reduction targets for gases such as carbon dioxide, methane, nitrous oxide, sulphur hexafluoride and fluorinated hydrocarbons, the European F-Gas Regulation refers particularly to the latter group and their use in various installations. "The Regulation is of special significance for the refrigeration and air-conditioning sector because F-gases are used as refrigerants in refrigeration and air-conditioning systems", explains Monika Witt. To reduce emissions, it regulates for example the placing on the market of F-gases, the monitoring and maintenance of installations in order to avoid leaks, and the initial and advanced training of professionally qualified staff.

The European Commission just recently published a Review Report on the effects and adequacy of the F-Gas Regulation over the last four years[2]. It came to the conclusion that the Regulation has had a quite significant effect on F-gas emissions in Europe. By the end of 2010, such emissions were verifiably reduced by 3 million tonnes CO_2 equivalent. But this is not enough in order to reach the EU's long-term targets of reducing emissions by 80-95 % in 2050 compared to 1990. Only about half of all emissions forecast by 2050 could be avoided altogether, and only if all 27 EU Member States were to consistently apply the current specifications from the F-Gas Regulation and the corresponding provisions for mobile air-conditioning units (MAC Directive). This would mean that the emissions would only remain stable on the current level of 110 million tonnes CO_2 equivalent. Crux of the matter: Predictions indicate that there is only very little scope for reducing emissions in the framework of applications covered by the F-Gas Regulation – in the magnitude of around 3 million tonnes by 2010 and around 4 million tonnes by 2050. "It is therefore not possible to reach the target simply by continuing as before", says Monika Witt. "Regulations are only expedient when they are adhered. As long as F-Gas consumption is not closely monitored and more important, so non-compliance is fined, it is very unlikely the consumption can be reduced as planned. Stricter controls and harsher penalties for failure to comply with the requirements are therefore necessary."

[2] German version available at: http://ec.europa.eu/clima/policies/f-gas/docs/report_de.pdf, English version available at: http://ec.europa.eu/clima/policies/f-gas/docs/report_en.pdf.

Natural refrigerants as an environment-friendly alternative

The objective of the F-Gas Regulation should also be to push the development of new technological innovations and alternative technologies. One alternative to F-gases in refrigeration and air-conditioning systems consists of natural refrigerants such as ammonia (NH_3), carbon dioxide (CO_2) and hydrocarbons. "In contrast to the F-gases, these refrigerants offer the advantage of having either no or only a negligible global warming potential", adds Monika Witt. "As a result, their contribution to the greenhouse effect is only marginal, even in the event of leaks or when disposing of the refrigerant." In the framework of its involvement in the expert group reviewing the F-Gas Regulation, eurammon drew attention among others to the high potential for reducing F-gases by using ammonia as a refrigerant for example in stationary air-conditioning systems. The Initiative also emphasised the good thermodynamic properties of NH_3 and hydrocarbons, also for applications in the critical temperature range. There is still widespread opinion that installations operating with natural refrigerants are always less efficient than those using synthetic refrigerants. "This statement must be revised to the effect that solutions with natural refrigerants are at least just as efficient thanks to skilful planning and systematic installation optimisation", states Witt.

"NH_3 for example is deemed to be the refrigerant with the best thermodynamic properties, making it one of the most cost- and energy-efficient refrigerants of all."

The eurammon Chairwoman could also envisage explicit incentives when using systems with natural refrigerants as alternative technology, either in form of subsidies or tax deduction. Another proven possibility could be the penalty for refrigerants with high GWP. In September, the Australian government introduced a bill in Parliament for a CO_2 tax that includes taxation on F-gas imports. In Europe, individual countries have already implemented additional measures to intensify the transition to already existing, more environment-friendly technologies. The Scandinavian countries for example levy an additional F-gas tax. One kilogram of R134a costs € 17.50 in tax in Denmark, € 35.00 in Sweden and even € 39.00 in Norway. "It is important to come to harmonized European standards in order to support the safe use of natural refrigerants. Right now, there exist too many obstacles in certain countries", states Witt.

In addition: putting resources to better use in future

Natural refrigerants are low in costs, available in unlimited quantities and already cover practically all refrigeration applications today. "This must be the basis for optimising and advancing refrigeration technology", advises Witt. "The energy efficiency of installations and components can still be optimised even further by research and development. In the future, it should be possible for installations to produce the energy that they need to operate." But there is still room for improvements to further reduce the energy consumption. "The waste heat produced by installations for example can be used for preparing hot water or for heating. And if an installation does not have to operate at full capacity most of the time, the corresponding output and energy consumption could be regulated with speed-controlled compressors. Moreover, renewable energy sources such as solar energy could be used for power generation and refrigeration to reduce the carbon emissions generated with fossil energy."

eurammon's Technical Committee: pooled European competence to strengthen natural refrigerants

In May 2011, the European initiative for natural refrigerants initiated a new committee for technical issues and new developments in the field of natural refrigerants. This April, Josef Riha (Ostrov Complete) took over the role of Chairman of the Technical Committee from co-initiator Hermann Renz (Bitzer Kühlmaschinenbau).

Josef Riha, Ostrov Complete

Mr. Riha, what exactly is eurammon's Technical Committee?

Josef Riha: We are a team of around 25 experts that looks at technical issues covering all aspects of natural refrigerants that have been brought to eurammon's attention. The issues involved deal with the full range of refrigeration engineering where natural refrigerants are used or could be used. The committee is open to all eurammon members interested in a professional exchange and keen to contribute to the further development of know-how in this field. The idea of the Technical Committee emerged during the eurammon Members' Meeting in May 2011, following a proposal made by Hermann Renz from Bitzer Kühlmaschinenbau. He played a crucial role in setting up the committee, which he also chaired during the consolidation phase.

What is so special about this committee?

Josef Riha: The team of experts consists of representatives of companies from all over Europe, working together to promote

greater deployment of natural refrigerants under the umbrella of eurammon. Pooling professional competence and experience in this field offers an opportunity to make a contribution to the advancement of technical know-how. Companies, the political sector and organisations appreciate the know-how and experience which the initiative brings together. This expertise goes over and beyond the individual know-how of an individual company. eurammon is therefore frequently asked to provide opinions or recommendations on many different topics in the field of refrigeration engineering. The Technical Committee provides support when in-depth technical understanding, practical experience and professional know-how are needed to clarify questions. eurammon members can also submit their own technical questions for clarification by the Committee.

The Technical Committee provides support when in-depth technical understanding, practical experience and professional know-how are needed to clarify questions.

Exactly how does the Technical Committee work?

Josef Riha: There are two regular meetings every year attended by all the experts. Here we discuss various questions and then set up smaller working groups to discuss selected topics in greater detail and elaborate solutions. These groups can also meet at more frequent intervals as the need arises. The results of the working groups are presented at the regular meetings of the Technical Committee and at the eurammon Members' Meeting.

Which tasks is the Technical Committee dealing with at present?

Josef Riha: At the moment, our attention is focused for example on putting together an international overview of the statutory regulations regarding the use of NH_3 as refrigerant. On the one hand, this lets us give our members greater orientation about the special requirements involved in using ammonia. On the other hand, we draw up basic principles that can also provide the foundation for further steps in future when it comes to developing new standards or harmonising legislation throughout the EU. Another item on our agenda includes developing a concept of initial and advanced training measures for eurammon members and their customers. In this way, we hope to give further impetus for planners, system engineers and users to decide in favour of natural refrigerants.

Development and prospects of natural refrigerants – shown at the annual eurammon lecture day in Schaffhausen

Free downloads on eurammon.com

The presentations of the lecture days can be downloaded from the eurammon website after the respective event: www.eurammon.com

The eurammon lecture day in Schaffhausen (Switzerland) is an annual event organized by the initiative since 2010. It aims to show the benefits of natural refrigerants to end-users, planners, engineers and other interested parties to promote knowledge transfer and information in support of a sustainable industry.

The event offers attendants the possibility to get into active exchange of information about natural refrigerants and discuss current topics and developments with experts of the branch.

Presentations predominantly reflect the operators' views and show how to use natural refrigerants in practice. But also political or legal aspects are included in the lectures. Every second year, the event is connected to the award show of the eurammon Refrigeration Award for students and the eurammon Honor Award for companies.

The event is open to participants from across Europe and all over the world.

eurammon Honour Award

The eurammon Honour Award prizes forward-looking exemplary projects that companies develop in the context of sustainable, energy-efficient refrigeration and air-conditioning.

About the eurammon Natural Refrigeration Award

The eurammon Natural Refrigeration Award is a prize being awarded every second years for the best academic thesis paper on the subject of natural refrigerants. The Initiative jointly hosts the €5,000 award together with an associated university and an associated magazine. eurammon wants to support young scientists and motivating them to do further research into refrigeration with natural refrigerants developing sustainable technologies that minimize total emissions arising from refrigeration equipment. All graduates of universities, technical and other colleges, and similar institutes of higher education whose thesis was submitted as a doctoral, master's or bachelor's thesis, or final paper for a similar degree are welcome to apply for the award. An international panel of judges from academia, business and the media picks the winning entries.

International network for natural refrigerants

Since 1996, one of the main objectives of eurammon is to promote innovative refrigeration technology both at a national and international level. From the beginning, eurammon took an international approach, since climate protection is an issue that transcends national borders, and most member companies do business worldwide. The initiative itself networks with international associations and institutions all over the world by means of collaborations and memberships. eurammon's development originally focused on the natural refrigerant ammonia, a historic refrigerant, which experienced a renaissance in the mid-1990s when it became necessary to replace the first generation of CFCs. This focus gives rise to partnerships with the Association Française du Froid's (AFF) Le Club Ammoniac in France and the International Institute of Ammonia Refrigeration (iiar) in the U.S. In the year 2000, eurammon expanded its focus to include all natural refrigerants, such as carbon dioxide and hydrocarbons, since these refrigerants are becoming more important and will contribute to sustainable development – in particular to curbing the man-induced Greenhouse Effect – in many fields of application. This developments were the basis for close collaborations with Spain's Asociación FRIO CALOR AIRE ACONDICIONADO, S.L., The Netherlands' Nederlandse Vereniging van Ondernemingen op het gebied van de Koudetechniek en Luchtbehandeling (NVKL), Australia's Green Cooling Association, the Ukrainian Odessa State Academy of Refrigeration (OSAR), the Southern African Refrigerated Distribution Association (SARDA), the Slovenian Association for Cooling and Air Conditioning (SDHK) and the Swiss Association for Refrigeration Technology (SVK). The partners' activities complement each other in achieving their shared goal: the increased use of natural refrigerants in a broad range of applications in refrigeration and climate control. Their cooperation is based on the individual autonomy of all parties involved. The partners frequently share presentation booths at trade fairs like the Chillventa, organize events (to inform the trade and the general public about their work), and regularly trade expert knowledge in the field of natural refrigerants. These transnational partnerships give eurammon international expertise across all areas of industrial refrigeration. As the initiative provides consulting to its members, the international networks are also beneficial. eurammon supports members with its collective knowledge in all matters related to the planning, permit process, and operation of industrial refrigeration systems.

Publishing credits

Publisher

eurammon
Dr. Karin Jahn
Lyoner Strasse 18
D-60528 Frankfurt

Editorial office

FAKTOR 3 AG
Kattunbleiche 35
D-22041 Hamburg

Print office

Druckerei Gerstenberg
Print run: 3,000

About eurammon

eurammon is a joint European initiative of companies, institutions and individuals who advocate an increased use of natural refrigerants. As a knowledge pool for the use of natural refrigerants in refrigeration engineering, the initiative sees as its mandate the creation of a platform for information sharing and the promotion of public awareness and acceptance of natural refrigerants. The objective is to promote the use of natural refrigerants in the interest of a healthy environment, and thereby encourage a sustainable approach in refrigeration engineering. eurammon provides comprehensive information about all aspects of natural refrigerants to experts, politicians and the public at large. It serves as a qualified contact for anyone interested in the subject. Users and designers of refrigeration projects can turn to eurammon for specific project experience and extensive information, as well as for advice on all matters of planning, licensing and operating refrigeration plants. The initiative was set up in 1996 and is open to companies and institutions with a vested interest in natural refrigerants, as well as to individuals e.g. scientists and researchers. www.eurammon.com

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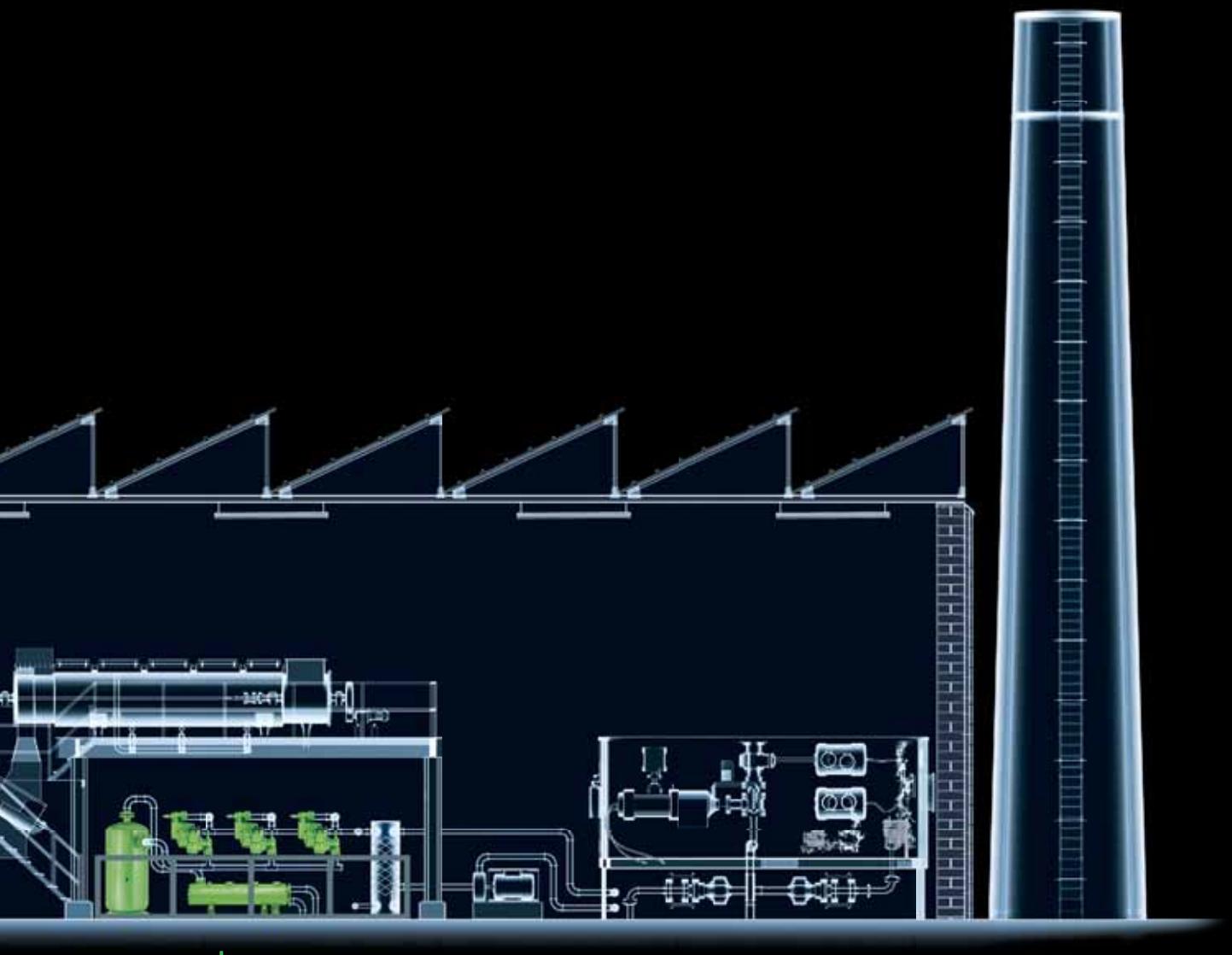

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Product directory

Everything about natural refrigerants on www.eurammon.com

The new eurammon website offers detailed information about natural refrigerants. Read more about the characteristics of natural refrigerants and find case studies, background articles in different languages and information papers about solutions with ammonia, carbon dioxide and hydrocarbons. Be also informed about activities and events of the initiative and its co-operations partners.

Database of products and services offered by eurammon members in the context of natural refrigerants

On the website eurammon offers a product directory data base for refrigeration applications with natural refrigerants. By selecting a category and a product in the drop down menu the user receives a list of eurammon members offering the requested products or services.

About natural refrigerants

Ammonia

Ammonia has been successfully used as a refrigerant in industrial refrigeration plants for over 100 years. It is a colourless gas, liquefies under pressure, and has a pungent odour. In coolant technology, ammonia is known as R 717 (R = Refrigerant) and is synthetically produced for use in refrigeration. Ammonia has no ozone depletion potential (ODP = 0) and no direct global warming potential (GWP = 0). Thanks to its high energy efficiency, its contribution to the indirect global warming potential is also low. Ammonia is flammable. However, its ignition energy is 50 times higher than that of natural gas and ammonia will not burn without a supporting flame. Due to the high affinity of ammonia for atmospheric humidity it is rated as "hardly flammable". Ammonia is toxic, but has a characteristic, sharp smell which gives a warning below concentrations of 3 mg/m^3 ammonia in air possible. This means that ammonia is evident at levels far below those which endanger health (>1,750 mg/m^3). Furthermore ammonia is lighter than air and therefore rises quickly.

Carbon dioxide

Carbon dioxide is known in refrigeration technology as R 744 and has a long history extending back to the mid 19th century. It is a colourless gas that liquefies under pressure, with a slightly acidic odour and taste. Carbon dioxide has no ozone depletion potential (ODP = 0) and negligible direct global warming potential (GWP = 1) when used as a refrigerant in closed cycles. It is non-flammable, chemically inert and heavier than air. Carbon dioxide has a narcotic and asphyxiating effect only in high concentrations. Carbon dioxide occurs naturally in abundance.

Hydrocarbons

Refrigeration plants using hydrocarbons such as propane (R 290, C_3H_8), propene (R 1270, C_3H_6) or isobutane (R 600a, C_4H_{10}) have been in operation all over the world for many years. Hydrocarbons are colourless and nearly odourless gases that liquefy under pressure, and have neither ozone depletion potential (ODP = 0) nor significant direct global warming potential (GWP = 3). Thanks to their outstanding thermodynamic characteristics, hydrocarbons make particularly energy efficient refrigerants. Hydrocarbons are flammable, however, with currently available safety devices, refrigerant losses are near zero. Hydrocarbons are available at low cost all over the world; thanks to their ideal refrigerant characteristics they are commonly used in small plants with low refrigerant charges.

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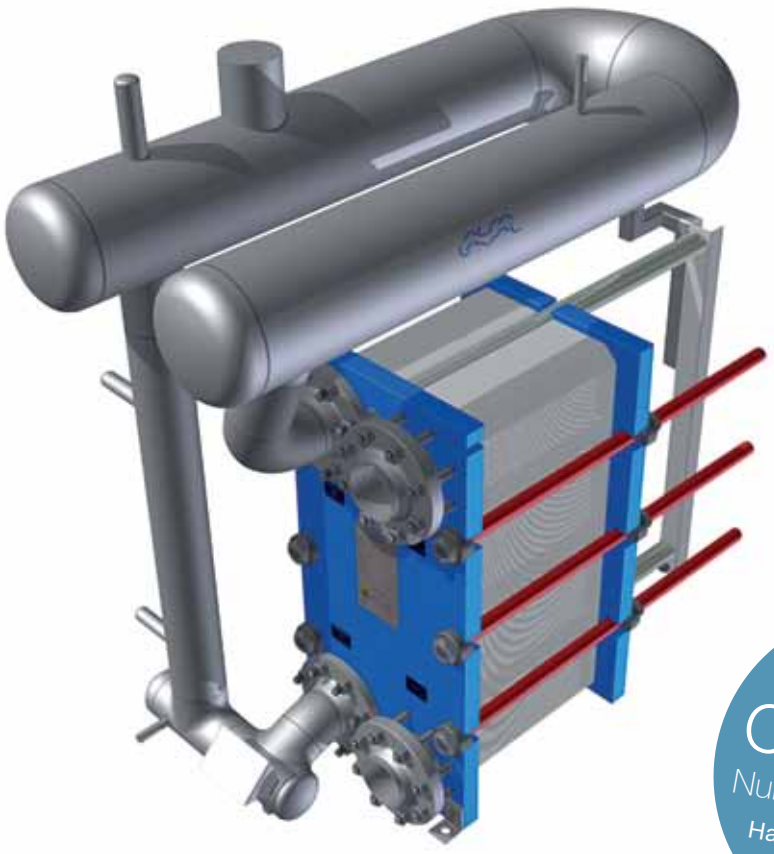

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