Background

Environment-friendly heat supply with heat pumps using natural refrigerants

Large-scale heat pumps use industrial waste heat and waste water to generate new heat and hot water

Industrial processes and refrigeration activities always generate heat. Today, many private households use geothermal energy or ambient air efficiently to generate heat. For industrial needs, waste heat and waste water serve as ideal energy sources due to their higher basic temperatures. Large-scale heat pumps can put the energy of this waste heat to good use for heating or for providing hot water for instance in local heating consortiums, thus making a significant contribution to climate protection.

"Furthermore, the heat pump branch makes increasing use of natural refrigerants such as ammonia, carbon dioxide or even water", explains Monika Witt, Chairwoman of eurammon, the European initiative for natural refrigerants. "These stand out not only by being environment friendly – ammonia and water have no global warming potential at all and that of carbon dioxide is negligible – but also above all through their energy efficiency."

Superlative ammonia heat pump

Energieverbund Schlieren (Schlieren energy consortium) in Zurich with two large ammonia heat pumps at its core, is one of the largest projects of its kind in Europe. It was planned, financed and built by ewz – one of Switzerland's largest energy service providers. SSP Kälteplaner AG was involved in the project as refrigeration specialists and responsible for planning the ammonia equipped heat/refrigeration system.

As first step in 2006, a central energy installation was fitted in Mülligen letter sorting centre followed by the commissioning of the central energy installation in Rietbach in 2009. The ammonia heat pumps in both systems have a heating capacity of around 5.5 megawatt each. By using ammonia as refrigerant, it is possible to achieve the necessary high flow temperatures of around 80°C. When finally completed, the energy consortium will produce annual savings of around 48,700 megawatt hours' worth of fossil fuels, corresponding to a reduction in carbon emissions of 8,100 tonnes p.a.

The ammonia heat pump in Rietbach central energy installation produces its heating and cooling capacity on the one hand using the energy from the treated wastewater of Werdhölzl sewage plant in Zurich, which was previously discharged into the river Limmat. Furthermore, it also uses the waste heat from a nearby computing centre. Over the whole year, the heat pump thus covers 70% of the heat demand. Additional oil- or gas-fired heat generators are available to cover peak demand. The generated heat is transported by a pipeline network to the individual properties where transfer stations then convey it to the building's internal distribution systems.

The cold or heat needed in Rietbach central installation is generated by two refrigerating machines that work independently on the refrigerating side, together with coupled high-pressure heat pump compressors. The two machines are each connected up in series on the cold water side and on the heating side. This is followed by cooling down or heating up in two stages with optimised COP for heating and cooling. The four low-pressure refrigerating machines for generating cold water are equipped with frequency converters for fully variable operation. Eight compressors are installed to operate the heat pumps and can all be switched on and off individually. The two desuperheaters in the low-pressure circuit supply additional heat in cold water operation, which is passed on to the energy consortium via an energy storage device.

In the summer, the treated wastewater is used directly for cooling via an intermediate circuit. If the temperature level of the wastewater is too high for direct cooling, the refrigerating machine is then used. If the waste heat of the refrigerating machine cannot be used in the summer, this is recooled by the river Limmat. If the temperature of the river Limmat exceeds 25℃, a dry cooler is provided for emergency cooling.

The system permanently monitors the energy efficiency of refrigeration/heat production. All major parameters are measured so that any energy losses or changes in the system are swiftly detected and remedied.

Wastewater as renewable source of energy

Since early 2009, environment-friendly heat supply has also been installed in the Swiss town of Rheinfelden for more than 1,000 residential dwellings in Augarten and Weiherfeld together with a nearby commercial estate. On behalf of AEW Energie AG and with support from EnergieSchweiz together with the canton and municipal authorities, Johnson Controls installed a heat pump system that uses treated wastewater from the Abwasserreinigungsanlage Rheinfelden (ARA – Rheinfelden sewage plant) as heat source for the existing local heating consortium. In this way, the refrigeration experts have made a major contribution to linking the ecologically valuable wastewater energy with the energy demand in Rheinfelden.

The heart of the system consists of two heat pumps supplied by Johnson Controls with an output of 1,250 kilowatt each; they were placed at the end of the ARA's secondary sedimentation tank. These are two-stage pumps that operate with ammonia, thus achieving greater efficiency than with synthetic refrigerants – another plus point in the eco-balance. Hot water is supplied to the dwellings by the district heat pipes. To this end, an approx. 500 metres long district heat pipe was installed between the heat pump system in the ARA and Augarten central energy installation, where it was then connected to the existing local heating consortium. Just about 1,500 metres of additional district heat pipes were installed to connect up the new dwellings in Weiherfeld.

Two different operating modes are available depending on the demand for heat output. In the summer, the heat pumps provide the whole network directly with water at a temperature of 67°C as the hot process water supply. ARA’s heat pump system also has a hot water tank with a volume of 50 m³ to cover peak demand for hot water in the morning. When the demand for heat increases in the winter, three existing natural gas boilers are responsible for controlling and reheating the flow to the heat pumps.

Altogether the new heat pump system produces effective heat of around 14,000 megawatt hours per year, thus covering around two thirds of the annual heat energy demand of the residential estates in Augarten and Weiherfeld amounting to around 22,000 megawatt hours. This saves 1.25 million m³ natural gas per year, reducing carbon emissions by 2,650 tonnes. There are already plans to expand the district heating system, so that the nearby KUBA leisure centre can be both heated and cooled using the two existing heat pump systems. Consideration is also being given to using the waste heat generated by the refrigeration plant of the also nearby ice skating rink. This waste heat which is currently discharged into the air could help to cover in particular peak demand during the winter.

World's largest municipal ammonia heating system

The town of Drammen with its 60,000 residents is located around 40 kilometres southwest of Oslo. Here too the town has opted for the natural refrigerant ammonia for heating in future. At the moment, the British company Star Refrigeration with its Norwegian partner Norsk Kulde is working on the installation of one of the world's largest municipal ammonia heat pump systems. The core of the complex system is Neatpump – the heat pump developed by

Star Refrigeration. It operates with the natural refrigerant ammonia and generates heat from the waste heat of large-scale refrigeration systems and air-conditioning plants, and of industrial processes and from wastewater. The heat pump generates water at a temperature of up to 90℃ which is then used to heat large buildings. On completion in January 2011, the system will supply heating capacity with a total of up to 15 megawatt and provide environment-friendly heating for more than 6,000 residents and companies in Drammen. The heat pump is operated by environment-friendly hydroelectric power.

Natural refrigerants on the advance

These examples show that manufacturers are increasingly willing to use natural refrigerants. "Today already, companies are working intensively at implementing sustainable concepts for heat pumps and realising a large number of great role model projects", says Monika Witt. "This is of increasing significance, particularly in the context of the global climate protection targets".

Appendices

Ammonia has been successfully used as a refrigerant in industrial refrigeration plants for over 130 years. It is a colourless gas, liquefies under pressure, and has a pungent odour. 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 and is toxic to skin and mucous membranes. 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 used all over the world as fertiliser. It 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. Furthermore ammonia is lighter than air and therefore rises quickly.

Ozone Depletion and Global Warming Potential of Refrigerants

	Ozone Depletion Potential (ODP)	Global Warming Potential (GWP)
Ammonia (NH_3)	0	0
Carbon dioxide (CO_2)	0	1
Hydrocarbons (Propane C_3H_8, Propene C_3H_6, Iso-Butane C_4H_{10})	0	<3
Water (H_2O)	0	0
Chlorofluoro-hydrocarbons (CFCs)	1	4680–10720
Partially halogenated chlorofluorocarbons (HCFCs)	0.02–0.06	76–12.100
Per-fluorocarbons (PFCs)	0	5820–12010
Partially halogenated fluorinated carbons (HFCs)	0	122–14310

Ozone Depletion Potential (ODP)

The ozone layer is damaged by the catalytic action of chlorine and bromine in compounds, which reduce ozone to oxygen when exposed to UV light at low temperatures. The Ozone Depletion Potential (ODP) of a compound is shown as an R11 equivalent (ODP of R11 = 1).

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).

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 European companies and institutions with a vested interest in natural refrigerants, as well as to individuals e.g. scientists and researchers.

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