

Current developments and examples of sustainable energy technologies



Heat pumps in the energy system of the future

Pioneering technologies and developments
from Austria

Heat-pump technology has all the potential to become a vital building block in the energy system of the future. Pioneering developments in this field are not only concerned with conserving resources in heating and cooling buildings; deploying large scale heat pumps in industry and commerce, the heat pump in intelligent energy systems, and ways of tying the technology into communal infrastructure are important research topics of great current interest.



*Air/water heat pump,
photo: Viessmann Werke*

Heat-pump technology for an efficient, resource-conserving energy supply system

Today heat pumps are in common use as an environment-friendly way of heating and cooling buildings. In an energy system of the future, with priority given to making more use of renewables and boosting system efficiency, this versatile technology could well play an increasingly vital part. Using ambient heat is an important advantage of heat pumps; heat stored in outdoor air, the groundwater or the ground is raised from a lower temperature to a higher one by means of an efficient technology, making it available for space heating and supplying hot water. In the case of cooling the flow of refrigerant is reversed (active cooling). With ground-source or groundwater-source heat pumps low ground temperatures can also be exploited directly (passive cooling). Heat pump technology has considerable potential when it comes to heating and cooling efficiently via thermal grids and to making efficient use of energy in industry and commerce.

Austria's technology road map for heat pumps

In 2016, commissioned by the Ministry for Transport, Innovation and Technology (bmvit) and the Austrian Heat Pump Association, AIT Austrian Institute of Technology and e-think drew up an Austrian road map for heat pump technology. This spotlights heat pumps' economic potential up to 2030, and includes an R&D agenda which identifies the crucial steps to be taken and details the appropriate framework for the introduction on the market. As between the four main areas of application, "Heat pumps for residential and non-residential buildings", "Smart electric grids and heat pumps", "Heat pumps in thermal grids" and "Heat pumps for industrial processes", the need for research and innovation as regards heat pump technology in Austria varies.

In the area of new buildings, residential and non-residential, the heat pump has steadily gained acceptance as a heating technology over many years. The area of renovating buildings is seen as a

major market of the future with real potential. Here there are research issues of system integration and control to be tackled, particularly in the field of hybrid systems. With applications to deliver temperatures above 100°C there is a need for additional research to develop technology for heat pump units that can be integrated into industrial processes so as to minimize heat wastage.

Market situation and trends in Austria

In 2015 roughly 78,700 process-water heat pumps, 158,100 heat pumps for space heating, 4,700 air-conditioning heat pumps and several hundred industrial heat pumps were in operation in Austria. Domestic sales of heat pumps for space heating are currently going up fast; in 2015 17,451 such pumps were sold in Austria, an increase of 9.8 % on 2014.

Most heat pumps for space heating are installed in new detached and semi-detached residences, where pumps in the lowest rating category are employed (up to 10 kW); in 2015 this sector grew by 21.4 %. However, heat pumps are also in use in blocks of flats and in service-sector buildings.

In the mid term the largest potential for heat pumps in space heating will be in renovating existing buildings. In this field heat pumps can also be used to dry buildings out. As regards sources of heat, there is currently a strong trend to air/water systems (for economic and structural reasons), but more use has also been made of direct-vaporization systems in recent years. ■

NexGen Next-generation gas heat pumps

A large proportion of the residential buildings in Austria (around 43 %, according to Statistik Austria for 2015) are heated with fossil fuels, more or less equally divided between natural gas and fuel oil. Using conventional, fossil fuels more efficiently and increasing the share of renewable sources of energy are key elements in developing a sustainable energy supply system. One innovative and highly effective technology is the direct-fired absorption heat pump or gas-absorption heat pump. Apart from the energy stored in the fuel, this technology can make use of ambient heat (e.g. from the ground) for heating purposes. With this approach an efficiency 50 to 100 % higher than with condensing-boiler technology (the most up-to-date boiler technology available today) can be achieved.

Pioneering technology development

In collaboration with the Institute of Thermal Engineering at Graz University of Technology and the Tyrolean company E-Sorp GmbH, AIT Austrian Institute of Technology GmbH has carried out a research project aiming at developing a compact, power modulating gas absorption heat pump (up to 18 kW) based on the so-called GAX (Generator/Absorber Heat Exchange) process, which makes full use of the energy content of the fuel to desorb the refrigerant in the generator. The key component here is the GAX generator/absorber; the value of the entire system depends on its performance.

The gas absorption heat pump has to work efficiently both in winter, with temperatures below zero outdoors, and in spring and autumn, with outdoor temperatures typically in the range of 5 to 10 °C. This was the reason for equipping the system with capacity modulation. To start with, various GAX cycle configurations were simulated at Graz University of Technology; the most promising generator concepts were implemented and their characteristics investigated experimentally at AIT. E-Sorp implemented a prototype of a whole GAX absorption heat pump, including a control arrangement, and this was tested at Graz University of Technology with respect to energy efficiency and the stability of the control algorithm.



Photo: E-Sorp

„In terms of sustainability and resource conservation in the heating and renovation market, the NexGen project is a real milestone. In the course of intensive R&D activities with a highly motivated team we have succeeded in overcoming technical obstacles. Collaboration with key global players in this sector will ensure appropriate market penetration.“

Andreas Bangheri
CEO Heliotherm Wärmepumpentechnik Ges.m.b.H



Photo: Heliotherm

Results of the project

Measurements as per the standard in force (EN 12309) showed that, for applications with a low inlet temperature (35°C) or high inlet temperature (55°C) for the heating system, the maximum seasonal efficiency of gas consumption was 167 % or 152 %, respectively. Hence, in the special case of renovated buildings the gas-fired absorption heat pump developed can save more than 30 % of the gas which a condensing boiler would consume; in the case of new buildings or systems which can cope with a low inlet temperature, gas consumption is actually down by more than 40 %. Depending on the extent of modulation, electricity consumption comes to only 3 to 10 % of the thermal energy to be supplied.

The results of the project show that at low ratings (5 to 18 kW) a fully modulating gas-fired absorption heat pump can make a useful contribution to reducing primary energy consumption. This type of heat pump is of special interest for renovated buildings, where infrastructure such as a gas supply line, heating pipes and radiators are already on hand; here this technology has a real future as an alternative to outdated gas boilers. ■

HyPump Highly-efficient hybrid heat pumps for industry

Various industrial processes involve large amounts of waste heat, which has to be disposed of at extra expense in many cases. But this waste heat is a valuable resource, given that it is generally at a temperature of around 30 to 60°C – significantly higher than that of ambient air or the ground. These days large scale heat pumps for industrial processes are usually adapted to the particular circumstances and produced in short runs; the refrigerants commercially available impose a temperature limit of at most 80°C on the heat sink side, e. g. top water. Quite a number of industrial processes require heat at higher temperatures, though, up to 110°C.

By means of high-temperature heat pumps industrial processes could be made much more energy-efficient. In the HyPump project the Institute of Thermal Engineering at Graz University of Technology has developed an highly-efficient hybrid heat pump to recover waste heat in industry, with AIT Austrian Institute of Technology and Frigopol Kälteanlagen GmbH as project partners.



Photo: Frigopol Kälteanlagen GmbH

Benefits of the new development

With the innovation of a combined absorption/compression heat pump using a special working pair it is possible to achieve high supply temperatures (above 100°C) without increasing the facility's operating pressure. The „HyPump“-concept is scaled for low to medium ratings and follows these objectives:

- > high efficiency even at high temperatures, so carbon-dioxide emissions can be reduced significantly
- > wide range of application, since the process can be adapted to the heat sink temperature desired

„The project ‘Highly-efficient hybrid heat pumps to recover waste heat in industry‘ has yielded several practical insights that may be of importance for future products. For our company working together with research organizations and universities is vital, so as to stay permanently innovative. This close collaboration gives us access to new developments and many kinds of know-how, while making it possible to implement theoretical knowledge in practice quickly. And all the partners in the project benefit in consequence!“



Photo: Frigopol Kälteanlagen GmbH

Johann Herunter
CEO Frigopol Kälteanlagen GmbH

- > medium capacity range (approx. 50 kW) for decentralized deployment
- > cost-effective even with modest ratings, thanks to the use of standard components
- > use of an environment-friendly working substance (a blend of ammonia/lithium nitrate)

Project results

In the course of the project a prototype hybrid heat pump was installed at Graz University of Technology, to make it possible to assess the design as regards capacity and efficiency under different operating conditions. Individual components were evaluated in detail and potential for improvements was identified. The results show that with extended control options the system of a hybrid heat pump is of interest for a wide range of applications, particularly at higher temperatures.

As part of the project a cost analysis was carried out and the relative cost of the individual system components examined in detail. The compressors, the solution pump, the plate heat exchanger and erection and servicing account for 70 % of total cost. With the extended control options more instrumentation is needed, too. Cost reduction potential is given by making changes in the design and standardization.

The findings can be used to compare performance and cost structure with those of alternative heat delivery systems in the case of future practical applications; they serve as a basis for preliminary investigations in connection with additional research projects or pilot facilities. ■



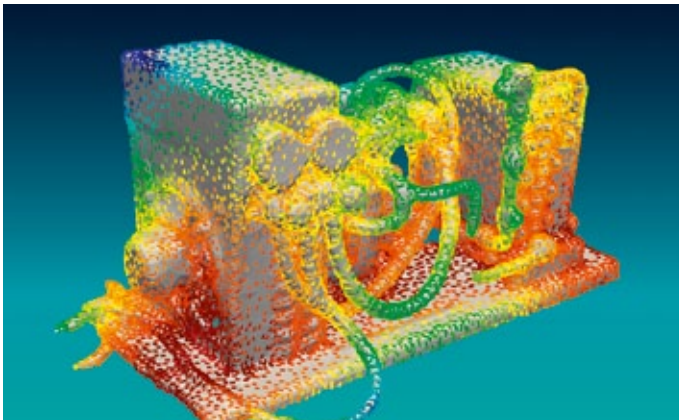
SilentAirHP

Reducing acoustic emissions of air-source heat pumps

Throughout Europe air-source heat pumps are among the heat pump systems most widely sold for heating and also cooling residential buildings. Their advantages include modest space requirements, relatively low investment cost and straightforward installation. However, in operation air-source heat pumps can emit objectionable noise. This could make it difficult to employ them extensively, particularly in built-up areas. Given the high air flow rate needed, beside the emissions of the compressor, the blower and the vaporizer could also have an effect on the sound level. In spring and autumn noise emission levels can rise because the vaporizer ices up, in which case higher local flow speeds result in more and sometimes tonal emissions being observed.



In the past qualitative assessment was applied to measures concerned with design and control methods, as well as component-specific and active steps to minimize noise emission levels. At AIT Austrian Institute of Technology advanced numerical and experimental methods of quantitative assessment for noise abatement measures in air-source heat pumps have now been employed; this is intended to help Austrian manufacturers in developing/adapting their products in the mid term.



The researchers are developing new methods of acoustic measurements with which to distinguish and localize sources of noise by frequency. They perform simulations of the complete system, taking the level of noise emitted into account (even when the outdoor module is iced up). To investigate the effects of noise abatement measures experimentally, an industry-oriented modular air-source heat pump is to be set up.



Apart from quantifying selected “passive” measures, approaches such as using anti-ice coatings from the WYSS Institute for Biologically Inspired Engineering at Harvard University to deal with icing up and thawing, and noise cancelling as an “active” measure are evaluated. In collaboration with the Acoustic Research Institute at the Austrian Academy of Sciences, selected noise abatement measures are also being analyzed psychoacoustically. The project’s findings will be incorporated in a catalogue in which established and innovative noise abatement measures are assessed quantitatively. ▣

from top down: 1) Data collection/analysis system in front of a heat pump in the climate chamber, 2) Preparations for a space-resolved acoustic measurement of the GreenHP with 64 microphones, 3) Result of a beam-forming analysis mapped to the surface of a test heat pump. The colours show the intensity of the noise source at roughly 1 kHz, 4) Acoustic camera in ring shape (64 channels) with a thermal camera located in its centre, ready for use in the climate chamber; Photos: 1 and 4 AIT/Ludwig Schedl, 2 AIT/Lukas Ilgner

Energy from sewage water Heat pumps in integrated communal energy systems

Wastewater from households, commerce and industry contains a good deal of energy. So far, though, very little use has been made of sewage water as a source of energy in Austria. The thermal energy contained in sewage can be recovered in heat exchangers and raised to the temperature level required for heating or cooling by means of heat pumps. Wastewater temperatures are at or above 10°C all year round, so they are very suitable for heat-pump applications. In general sewage water accumulates in substantial quantities where energy is needed, i.e. where there are enough customers for heat and cold. The engineering and economic prerequisites for using energy from sewage water, and the possibility of incorporating this in communal energy supply systems, have been investigated in several of the Austrian Energy Agency's research projects, in collaboration with Ochsner Wärmepumpen GmbH. On the basis of the results obtained a facility was implemented for STADTwerke Amstetten while the project was still in progress.

Recovering heat from sewage water

The aim of the project "Energy from sewage water" was to explore the technical possibilities of recovering energy from sewage water



with a heat pump, assess the potential and the legal framework, and thus create a basis for spreading this way of obtaining energy in Austria. The investigations revealed that there are worthwhile possibilities of utilizing heat from sewage plant wastewater, e.g. to dry sludge and to heat sewage plant buildings and other buildings close to sewage treatment plants and main sewers. From numerous examples in other countries it is clear that when heat from sewage water is put to work downstream from the sewage plant even buildings several kilometres away can be supplied cost-effectively.

Whether recovering heat from sewage water is feasible technically and cost-wise at a given location always needs to be investigated in detail. In the course of research work strategies and planning tools were developed for communal spatial planning for energy purposes, e.g. to decide whether nearby buildings can be linked up via pipelines, or to estimate how the demand for heat and cold will develop in new settlements. The issue of whether/how the

The STADTwerke Amstetten project

A showcase project for heating and cooling with energy from sewage water has been implemented in Amstetten in Lower Austria. In 2012 heating the STADTwerke Amstetten premises with natural gas and the power station with electricity stopped; since then a heat exchanger 42 metres long has recovered heat from the main sewer belonging to the sewage disposal association. A heat pump with a rating of 228 kW uses this energy to heat and cool the premises. The existing gas-fired boilers have been retained as a backup system and to cope with exceptional peak demand (the heat pump system covers 99.9%). Heat is distributed via storage tanks and a low-temperature local heating grid; the various buildings supplied are equipped with underfloor heating.

In its first year of operation the facility saved 20,500 Euro; the investment should pay off in around 12 years. With the new system carbon-dioxide emissions are down by just under three-quarters (a reduction of 55 tonnes per year). In the process of planning facilities to utilize sewage water the impact on sewage plant efficiency must be taken into account. In this particular case there are no ill effects on sewage plant operation, as the sewage water at the plant is cooled down a mere 0.15°C and its temperature in

the sewer is high: 22°C on average (in winter). In the meantime the energy from sewage system has been adapted so that the warm water from the sewer heat exchanger (at 27°C) can also be used for heating directly, i.e. without a heat pump. Research activities will continue in the project "Energy from sewage water". The focus is on the utilization of existing energy resources from the sewage plant for surrounding heat consumers.

www.abwasserenergie.at

Energy-from-sewage system at STADTwerke Amstetten:

- Total heat requirement roughly 230 kW
- Maximum inflow temperature for local heating grid 45 °C
- Annual Carbon dioxide reduction 54.40 t (72.43 %)

OCHSNER SWS210ER2 heat pump

- Heating rating 228 kW
- Temperature of energy source (water) 15/10°C
- COP (coefficient of performance) 5.4

ThermLiner sewer heat exchanger

- Overall length around 42 m
- Wastewater temperature around 22°C



demand for heat and cold close to sewage plants can be increased in cases where new facilities with a constant demand for low temperatures all year round (such as greenhouses, gymnasia or indoor swimming-pools) are involved was also analysed.

Technology for utilizing sewage water

To obtain heat or cold, sewage water can be utilized upstream or downstream from the sewage plant, or inside the actual building. Energy is recovered either from the sewer (raw sewage) or downstream from the sewage plant (treated sewage). Wastewater from large buildings can be utilized directly via a settling basin. The key components in an energy-from-sewage facility are the heat pump and the wastewater heat exchanger. How efficient and how cost-effective the system is depends on how these elements are matched to each other. In a specific application a suitable wastewater heat exchanger, a heat pump with a specially tuned

„Wastewater systems are an ideal source of heat for systems involving heat pumps. In towns 5 % of the total heat consumed could be provided with energy recovered from communal sewage. This is a tried and tested technology which should be given appropriate weight in comprehensive energy planning.“

*Karl Ochsner
CEO Ochsner Energie Technik GmbH*



Photo: Ochsner Energie Technik GmbH

refrigeration circuit for maximum performance and a heating/cooling system matched to the heat pump's characteristics need to be selected. It is also important to define the right temperature level as early as at the planning stage, since this has a major effect on overall efficiency. Research activities continue within the project „Energy from sewage water“, with focus on the utilization of energy resources of the sewage plant for surrounding heat consumers. ■

The Bat – the thermal battery in a smart grid in combination with heat pumps

For renewables to be used efficiently on a large scale in buildings, we need cross-technology approaches and intelligent, optimized complete systems. Working together with research partners, experts at the Austrian firm Heliotherm Wärmepumpentechnik Ges.m.b.H. are currently investigating how to combine heat pumps with photovoltaics (PV) integrated in buildings and/or solar heating systems, and to link them up to a smart grid in an intelligent, predictive way.

Here possible ways in which heat pumps and PV can interact to level loads, and the best arrangement for feeding power into/drawing it from the grid, are being assessed and suitable strategies developed. These are based on a sophisticated algorithm for the interaction between the thermal storage masses in the building, the domestic water storage tank and a user-tuned energy management system involving predictive control. Various reference buildings, facilities and control systems are comprehensively modelled in simulation tools (such as TRNSYS, Matlab),

together with their interactions. A physical model of a heat pump with advanced thermodynamic cycles (desuperheater switching, steam injection) plus predictive control algorithm is being developed. The control units are set up and fine-tuned to take user behaviour, comfort criteria, energy consumption in the building, grid requirements and weather forecasts into account.

On the basis of these simulations various approaches to using heat pumps as storage and its direct linking to the PV equipment are to be improved, so as to level loads and minimize cost for the reference buildings. A direct link between PV and heat pump, and the control strategies developed, will be tested on a prototype. ■



Heat pump, Photo: Heliotherm

International collaboration on research into heat pump technologies

In the **International Energy Agency's heat pump programme (IEA-HPP)** information about heat pumps, refrigeration engineering and air-conditioning is generated and disseminated, so that the environmental and energy-relevant potential of these technologies can be exploited more extensively in the member states. Austria's RTI activities in the field of heat pump technology are tied into this international collaboration. Austrian key organizations participate in various technology initiatives; the main emphasis is on new technologies such as the gas-fired absorption heat pump, on applications for large scale heat pumps in industry and commerce, and on assessing the technical and

economic prerequisites for employing electric heat pumps to level loads in smart grids. Austrian experts are acting as leaders for the following annexes (amongst others):

- IEA-HPP Annex 35: Application of industrial heat pumps (leader: Institute of Thermal Engineering, Graz University of Technology)
- IEA-HPP Annex 42: Heat pumps in smart grids (leader: AIT)
- IEA-HPP Annex 43: Fuel driven sorption heat pumps (leaders: AIT and Institute of Thermal Engineering, Graz University of Technology)



Photo: AIT

„Within the framework of the IEA heat pump programme new insights, systems and methods for heat pump technologies from national research projects are being brought together. This leads to major gains in knowledge – and thus to further interesting topics for research. Within the IEA platforms AIT Austrian Institute of Technology is at hand here with significant findings especially in the areas ‘Heat pumps and smart grids’, ‘Industrial heat pumps’ and ‘Heat pumps in district heating grids’, as well as various applications for buildings.“

Thomas Fleckl, AIT Austrian Institute of Technology GmbH

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Austria's technology road map for heat pumps

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