energy innovation austria

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Current developments and examples of sustainable energy technologies

Tomorrow's heating networks

Austrian system solutions for sustainable energy supply in urban areas

More than 70 % of Europe's population live in urban areas. If we are to achieve our climate policy goals and ensure a reliable supply of energy in future, too, we shall need intelligent technologies and new organizational solutions for energy-efficient, climate-compatible ways of living and working in the city. District heating and cooling systems can make a major contribution to conserving resources in urban areas by using alternative sources of heat, such as waste heat or heat from renewable sources of energy, on a larger scale. In Austria new solutions for tomorrow's cities are being worked out and demonstrated in a number of R&D projects.

High-pressure heat storage facility at Simmering power station
Photo: Wien Energie/Ian Ehm

Research & technological development for supplying heat in cities

Vienna, Source: Digitalpress, fotolia.de

Urban technologies are particularly challenging, since they require various technological approaches to be integrated into a highly efficient comprehensive system. In a pioneering urban energy supply system improving energy efficiency, expanding the share of renewable sources of energy and cutting back on greenhouse gas emissions are key aims. Integrated solutions for supplying, distributing and consuming energy are needed for this. Particularly in urban areas, district heating provides an option of using existing infrastructure to distribute waste heat from industry and heat from renewable sources of energy at low cost and with a minimum of emissions. In Austria district heating is mainly based on biogenic fuels and natural gas. More than two-thirds of district heating from natural gas, and roughly half of district heating from biogenic fuels, comes via ultra-efficient CHP (combined heat and power) facilities. More than 90 % of the heat in district heating is used to provide space heating and hot water.

AIT Austrian Institute of Technology GmbH are currently drawing up a technology roadmap for district heating/cooling, in collaboration with the Energy Institute at Johannes Kepler University Linz, the Environment Agency Austria and e7 Energie Markt Analyse GmbH, on behalf of the Climate and Energy Fund. As part of this joint effort, the future potential of district heating and cooling is undergoing analysis, and worthwhile research topics and directions for technological development are being identified. The roadmap focusses on the following main issues (as preliminary results of technological and systemic investigation):

District heating lines, Source: fefufoto, fotolia.de

Nerve centre of a large heating system, Source: Ashkan Nasirkhani, fotolia.de

The Federal Ministry of Transport, Innovation and Technology (bmvit) and the Climate and Energy Fund support the development of strategies, technologies and solutions for the "Smart City" as part of their programs. While the Climate and Energy Fund's program "Smart Cities Demo" focusses on comprehensive demonstration and implementation projects, the Ministry's research and technology program "City of Tomorrow" pushes research into the development of new technologies, technological systems and parts of such, and urban services for pioneering cities.

- **Integrating alternative sources of heat/cold:** geothermal energy potential and tying in heat pumps, pilot projects using solar heat, new recooling technologies
- **Heat storage:** large-scale heat storage facilities, systemic integration, materials, operating technology and control engineering, geological options for storing heat underground
- **Hybrid and micro-grids:** coupling electricity and district heating (power-to-heat), splitting large-scale grids down into smaller units, boosting the installation of micro-grids
- **Multi-temperature systems:** ways of linking high- and low-temperature grids together, supply from return line, systems with several supply points
- **Network operation:** hydraulic improved operation at reduced temperature, new hardware and software for monitoring and control, forecasting models, using the network as a storage facility
- **Building services and automation:** using buildings as storage facilities, monitoring, low-temperature systems, return flow at reduced temperature
- **Customers:** establishing new information and communication technologies, new tariff and price models
- **Improving the way supply lines are laid and networks renovated:** cutting costs, improving scaling and maintenance

For sustainable development it is essential to view district heating and cooling systems in the context of the overall energy system. Technological research is to be backed up increasingly by economic, social, ecological and systemic analyses. In this issue we present some current Austrian R&D projects concerned with pioneering strategies and technologies for supplying heat and cold in cities, and with new ways of storing heat. ◘

ECR Energy City Graz-Reininghaus

Urban strategies for a district self-sufficient in energy

In the ECR flagship project the City of Graz (Stadtbaudirektion), the Province of Styria and researchers from Graz University of Technology (the Institutes of Urbanism, of Thermal Engineering, for Electric Drives and Machines, of Process and Particle Engineering and of Technology and Testing of Building Materials) collaborate on working out strategies for sustainably reinventing, constructing and operating Graz Reininghaus as a district self-sufficient in energy. Expert support also comes from the City's Department of the Environment, Energie Graz and various commercial partners and external consultants.

Energy-surplus cluster Reininghaus South, source: DI Martin Grabner

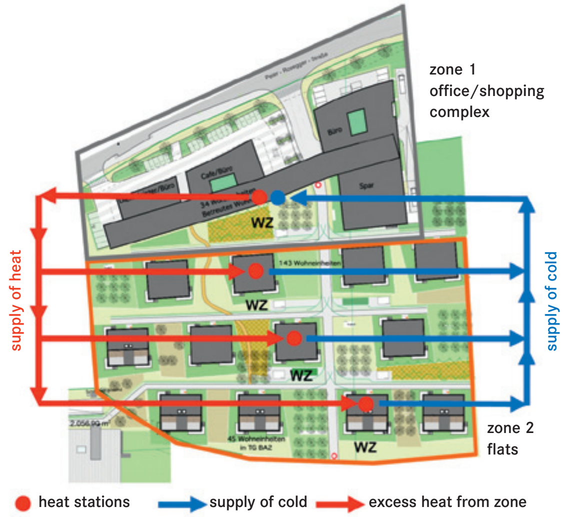
The central aims of the Energy Framework Plan - Energy City Graz-Reininghaus (RPE_ECR) are:

> conception of energy self-sufficiency for the district of Graz-Reininghaus
> initiating and supporting the development process for the sustainable, energy-optimized district
> providing a firm basis for establishing transferable energy targets between the City of Graz and future investors on site
> providing recommendations for future energy-optimized district development schemes in Graz and Styria

Intensive negotiations are currently taking place between the City of Graz, Energie Graz and the investors in the district about the next steps in implementing the energy strategy. A jointly agreed, shared energy supply system for the district should be realized in three stages: optimizing the buildings, tying in available renewable sources of energy, such as solar power, geothermal energy and the deep well in the former brewery, and tying in available sources of waste heat from adjacent industries (STAMAG Stadlauer Malzfabrik and Stahlwerk Marienhütte).

The demonstration project **+ERS - Plusenergieverbund Reininghaus Süd** with 162 flats, plus office and retail premises (project partners: AEE Intec/project lead, Arch. Nussmüller ZT GmbH, TB Hammer and Aktiv Klimahaus GmbH Süd/investor) embodies an innovative solution to supplying heat in cities of the future.

An energy network that links up buildings with differing load profiles and patterns of use raises this settlement to energy-surplus standard. Each row of four blocks is supplied via a heat station (heat pumps with buffer storage tank); these heat stations are



Source of plan: AEE Intec (Project Lead), Arch. Nussmüller ZT GmbH, TU Graz, TB Hammer and Aktiv Klimahaus GmbH Süd (investor)

cross-linked, so as to even out individual peakes in production or consumption, and are connected to the office/shopping complex in front. Synergy effects result: in summer the geothermal boreholes used to heat the accommodation blocks and supply hot water can be assigned to cooling the office/shopping complex. During the heating period excess heat from the office/shopping complex is supplied to the individual blocks of flats.

The demonstration project +ERS underscores the flagship project's aims not only in technical but also in social respects, since the residents turn out to be very satisfied with the solutions implemented. The first residents moved into their new flats in October 2013, the third and last constructed section will be entirely finished in May 2015. ◘

Energy-surplus cluster Reininghaus South, source: DI Martin Grabner

URBANcascade
Energy cascading in urban district heating systems

High system temperatures in district heating networks lead to fairly substantial heat distribution losses, and reduce the potential of renewable sources of energy and of waste heat from industry, as well as the efficiency of conventional production facilities. The temperatures in district heating networks are a function of the direct consumers‘ maximum demand, the production facilities‘ usable temperature level, the extent to which the heat supplied to the consumers drops in temperature, and the amount of heat transported.

In the project URBANcascade researchers from AIT Austrian Institute of Technology are investigating ways of improving urban district heating and cooling systems by cascading heat. Balancing out the temperature levels of waste heat, renewable sources of energy, the grid and the consumers plays a vital part here. The aim is to lower supply and return temperatures by tying in all consumers on the basis of actual demand, analysing alternative ways of configuring the network as between different types of building, and integrating heat pumps into the system.

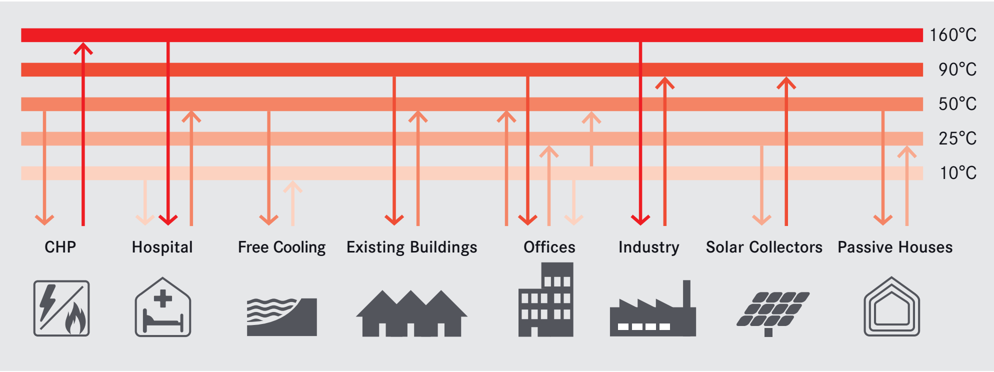
Improvement on three levels

For two test cases (Vienna with a 36 % share of district heating and Klagenfurt with a 30 % share) the potential for improvement is being identified for characteristic types of building, synergy effects in building networks are being examined and the influence of these measures on the temperatures in the entire urban district heating system analysed for various different scenarios. The investigation uses relevant sample buildings to find out how measures inside a building (e.g. renovation, hydraulic balancing, etc.) can lower the temperature required and make the heat transfer medium cool down further.

These sample buildings are then grouped together in clusters, in order to identify synergies across building boundaries by means of cascading high and low-temperature consumers. Finally the effects of these measures on the supply and return temperatures in the entire urban grid, on transport capacity and on on the generating facilities are assessed. Ways of integrating heat pumps on all three levels, and opportunities of installing micro-grids, are also looked into.

The case of Vienna

The Vienna network is divided into a primary grid and several secondary grids; this provides many degrees of freedom in cascading heat. Here the primary grid is supplied with heat from large thermal stations such as CHP plants. The secondary grids draw heat from the primary grid via so-called substations. High-temperature consumers like hospitals or industrial plants are connected to the primary grid, while the secondary grid takes care of the low-temperature consumers, like residential buildings. ◘



District Heating Network Vienna, Source: reinhardkiss, fotolia.de

Source: AIT

Example of cascading various different consumers and generators in the district heating and cooling system

Splitting the network into primary and secondary grids has many advantages. It makes supply more secure, since if problems develop not the entire grid but only parts of the system are affected; and the secondary grid can be designed for a lower temperature and pressure level, so less expensive components can be used.

In the case of Vienna the primary grid is designed for temperatures up to 160 °C and pressures up to PN (Pressure Nominal) 25, so as to be able to transport as much heat as possible. By contrast, the temperature ceiling in the secondary grid is 90 °C, and design pressure is PN 10.

Low Energy Building, Source: Tiberius Gracchus, fotolia.de

District Heating Network - Building connection, Source: Ashkan Nasirkhani, fotolia.de

Photo: AIT

„As it is hard to tell where prices are heading, and differing sectors are competing for fuels more and more, district heating faces a process of fundamental transformation. It will be increasingly necessary to tie in alternative sources of heat, such as solar, geothermal, ambient heat via heat pumps, and waste heat from industry; in many cases these sources are purely local, have a low temperature level and are unregulable time-wise. AIT is developing scientific methods and advanced simulation tools to assist the operators and planners of district heating networks, and manufacturers of relevant components, in coping with these challenges. This includes assessing district heating networks and identifying potential for improvement, analysing the technical potential of alternative sources of heat, developing ways of lowering system temperatures (as in the projects NextGenerationHeat and URBANcascade, for instance), integrating storage tanks and heat pumps hydronically and in terms of control engineering, and working out intelligent operating strategies and control algorithms.“

Ralf-Roman Schmidt,
AIT Austrian Institute of Technology GmbH

NextGenerationHeat
Low-temperature district heating for Austria

High-temperature district heating is often not an economical way of meeting the modest demand for heat in passive and low-energy houses; in relation to the heat consumed in the buildings, the amount of heat wasted in the network is too high, as is the investment cost. Low-temperature district heating networks can provide an alternative way forward here; reduced supply temperatures in the district heating network cut heat losses and the cost of investing in the network, and make it possible to use renewable sources of energy and waste heat from industry.

As part of the project NextGenerationHeat, AIT is developing technical approaches to using sources of heat at temperatures between 35 °C and 65 °C, such as ambient heat with heat pumps, waste heat from industry, or the return flow from conventional district heating networks, to provide space heating and hot water in district heating networks. These approaches will be assessed from an economic and ecological point of view in four representative regions (Güssing, Vienna, Wörgl und Graz).

In the low-temperature networks under review here, roughly 20 to 75 % primary energy can be saved in comparison with boilers running on biomass or gas. CO_2 emissions are roughly 25 to 85 % lower than with fossil sources of energy. In the overall assessment, though, using the return flow from the district network as supply for the low-temperature network is a challenge. Because the return flow cools down, various different effects (varying with grid topology and production technology) occur; these are hard to quantify, particularly in complex grids with several different CHP facilities.

Low-temperature district heating can run into problems if the requirement is to supply hot water with an inflow temperature below 65 °C and to store it. This temperature is the minimum essential to kill legionella bacteria (a health threat to human beings) in hot water. One focus is thus on developing technical procedures for providing hot water at low inflow temperatures hygienically. In particular, using suitable heat pumps to raise the hot water to the requisite temperature level at the substation is the subject of investigation.

Dynamic network simulation can be employed to evaluate hydraulic circuits (generator or grid-side) and substations, and the complex interactions in the overall system can be modelled. The project team works out monitoring strategies and preliminary business cases for variants that make technical and economic sense. ◘

Construction of the high-pressure heat storage facility in progress, source: Wien Energie/Ian Ehm

Heat storage facility, source: Wien Energie/Ian Ehm

More efficient use of energy by means of heat storage in the Vienna district heating network

More than 330,000 households in Vienna and more than 5,600 major consumers are supplied with heat for space heating and hot water via the Vienna district heating network. The City of Vienna's Smart City Strategy is intended to cover 20 % of gross final energy consumption from renewable sources by 2030 and 50 % by 2050. Technologies for harnessing renewable sources of energy, such as deep-lying geothermal energy and solar energy, play an important part here.

17 generator facilities (CHP units, thermal incineration plants, biomass facilities, peak-load boilers, and in future geothermal energy) at 12 locations in Vienna supply the high-temperature district heating network. The bulk of the heat comes from cogeneration in Wien Energie's thermal power stations and an OMV facility; about a third comes from incineration, and a small proportion from peak-load boilers that are in operation only in winter, as the need arises. Because altitudes vary by as much as 150 m in the Vienna district heating network, the water for space heating and hot water must be transported at high pressure, at temperatures between 95 °C and 150 °C.

Storing heat at high pressure

In 2013 the world's first high-pressure, high-temperature storage facility started operation in Vienna Simmering. The new facility has made it possible to uncouple producing and consuming heat from each other. When demand for heat is low, hot inflow water is now pumped from various production facilities, such as a plant that runs on wood chips, the CHP facility in Simmering and some waste-processing plants, into the storage facility and held over for peaks in demand.

The core of the facility consists of two identical storage tanks with a total capacity of 11,000 m^3. The facility uses thermally stratified storage: the tank is always full of water, hot at the top, cold down below. The difference in density keeps the two layers separate. If demand for heat increases, hot water from the tank is pumped directly into the district heating network, while cold water is fed in to compensate for this. Storage capacity is roughly 850 MWh; hot water is supplied to the tanks for about 2,200 hours a year, and drawn off for about 2,200 hours.

Photo: Wien Energie/Ian Ehm

„The high-pressure heat storage facility fits in perfectly with our energy strategy. By 2030 we want to cover 50 % of our production capacity from renewable sources. To achieve this, we focus massively on innovative, sustainable solutions. Not just making more use of renewable sources of energy is an issue – the proper functioning of the entire supply system is far more important.
That is why expanding the use of renewables must go hand in hand with expanding storage capacities and with greater efficiency in consumption and production. With this step we succeed in setting a keystone of the energy transition.“

Susanna Zapreva,
CEO, Wien Energie

High-pressure heat storage facility at Simmering power station, source: Wien Energie/Ian Ehm

As surplus heat is stored, the peak-load boilers are needed less often when demand for heat is high, so less primary energy is consumed; this makes Vienna's district heating system even more energy-efficient and environmentally sound – in the storage facility's first year of operation savings in CO_2 emissions came to roughly 8,800 tonnes.

Improving operation by means of simulation

Scientific support for planning and constructing the facility was provided by the Institute for Energy Systems and Thermodynamics at Vienna University of Technology as part of the research project "Pro WäSpe", in collaboration with Wien Energie.

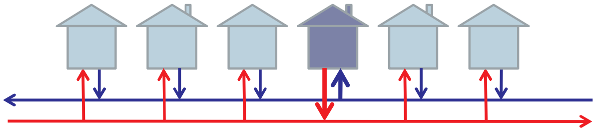
At an early stage the project team developed a process simulation program with which to map the complex storage system and simulate transient operational states. Dynamic simulation computation was used to identify improvements in the overall process, which were then implemented directly. To ensure that the storage system operates reliably, pressure and time windows involving losses are necessary. Within the project these have been minimized, which has improved the steps of storing and discharging heat (in particular).

In the light of simulating and analysing operational states, electricity consumption has been cut and the time taken to store and discharge heat has been shortened. Dynamic computation has not only made the heat storage facility more reliable in operation, but has economized on fossil fuel and reduced CO_2 emissions. ◘

BiNe

Bi-directional tying of buildings with heat supply into heating networks

As part of a project headed by AEE NÖ-Wien, technical and economic aspects of integrating local heat suppliers (solar collector systems, biomass power plants and sources of waste heat) into district heating networks were investigated. The project consortium included the Institute of Chemical Engineering at Vienna University of Technology, the Austrian Biomass Association, BIOENERGY 2020+, the engineering consultants Leo Riebenbauer GmbH and the firms of S.O.L.I.D. GmbH and Pink GmbH.



From consumer to prosumer, source: AEE NÖ-Wien

The technical prerequisites for supplying heat to grids locally were worked out, while system simulations and costing calculations were carried out and possible business cases were discussed. Special attention was paid to scenarios in which consumers turn into prosumers.

Feeding return flow into the supply was identified as a suitable technical approach. Here a heat transfer medium is taken from the return flow and pumped through the prosumer heat exchanger. In this case the pump must overcome the pressure difference between supply and return flow in the district heating network. The system operators prefer this approach, as return flow temperatures stay constant and the prosumer bears the bulk of the cost of pumping. However, the method makes sense only if the pumping energy required by the prosumer is significantly less than the amount of heat transferred. The hydronic situation was investigated for the district heating network in Bruck an der Mur, where it turned out that very little electric power is needed in comparison with the amount of heat fed in. The analysis also revealed that as additional prosumers are tied in the temperature situation in the grid may improve.

The simulation and the comparison between various different scenarios revealed that local infeeding can be of economic benefit to the overall system. In the short term grid extensions will provide the most attractive settings for tying local suppliers in. For supplying heat from local solar collector units, micro-grids are a low-cost, flexible alternative to classical district heating networks. ◘

New materials for compact thermal energy storage

Heat storage is an important technology when it comes to making more use of renewables for supplying energy in future. Long-term heat or cold storage is essential particularly for solar collector systems that achieve high capacity factors. However, water storage tanks need to be very large in such cases, which means that costs are high.

Compact alternatives are available today on a laboratory scale – for instance, PCM (phase change materials) or thermo-chemical storage units. These storage technologies, based on paraffins, zeolites or salts (for example) utilize temperature-dependent conversion reactions to store heat. This makes it possible to match the material‘s properties to the application temperatures in regeneration and use accurately, but also requires more elaborate process engineering.

Within the framework of the International Energy Agency‘s Implementing Agreement **“Solar Heating and Cooling”** Austria is participating in **SHC Task 42 “Advanced Materials for Compact Thermal Energy Storage”**. 16 countries are collaborating in this network, to promote an exchange of new findings in the field of heat storage. The focus of this international collaboration is on investigating and characterizing promising materials, and on experimental testing and simulation with the practical aspects system integration, trial and cost-effectiveness. ◘

Foto: Eric Berger

„Energy storage is a key technology for renewable energy systems. In the case of thermal storage Austrian firms and research organizations are working on new materials and pioneering operating principles that (alongside classical building services) also open up entirely new fields of application. With the aid of these thermal storage technologies it will be possible to cover buildings‘ energy needs completely with solar energy alone, to heat electric vehicles and make industrial processes more efficient in future.“

Gerald Steinmaurer, ASIC Austria Solar Innovation Center

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