Projektinfo **06**/2018

Detailed information on energy research

Which heat sources are optimal for heat pumps?

Geothermal energy is combined with solar thermal energy and a new tool supports analysis in energy and economic terms

BINE
Information Service

The number of buildings heated by heat pumps continues to rise. In recent years, air-water heat pumps have been the dominant force in this regard. More energy efficient alternatives exist, however, to outside air as a heat source. Examples include geothermal energy, ground water, exhaust air and solar thermal energy. The variety of potential heat sources and of heat exchangers tapping these presents an incredible challenge for planners. Validated concepts, objective decision-making guidance and analyses are consequently called for. This endeavour is supported by two research groups.

Geothermal heat collectors require a relatively large surface area, which is why they are something of a rarity. A research group of the Institute for Solar Energy Research in Emmerthal consequently hopes to slash the necessary geothermal heat collector surface area through the regeneration of ground soil with solar thermal energy. In an effort to analyse the concept with greater precision, the researchers, together with the German heat pump association (Bundesverband Wärmepumpe) and tewag GmbH, have developed a simulation model for geothermal heat collectors and validated it experimentally using data from a prototype system. Parameter studies reveal how best to design such hybrid systems without causing thermal depletion of the ground soil during operation.
In a further project, researchers at the Institute for Building Services and Energy Design in Braunschweig hope to support planning efforts for heat pump systems by providing clear and objective decision-making guidance for the early planning phase. This involves the development of a simple, Excel-based tool. The tool facilitates the selection of suitable heat sources and heat exchangers and the rapid assessment of these based on current market data and empirical system parameters. Comparisons in energy and economic terms are possible for

This research project is funded by the

Federal Ministry for Economic Affairs and Energy (BMWi)

Simulation model and planning aids

The "geothermal heat collectors" numerical calculation model is available free of charge from the Institute for Solar Energy Research (ISFH) as TRNSYS Type 710. Contact: Susanne Schiewe, s.schiewe@isfh.de.
An information sheet with practicable simplified designing rules will be published in the third quarter of 2018 (cf. Fig. 3).

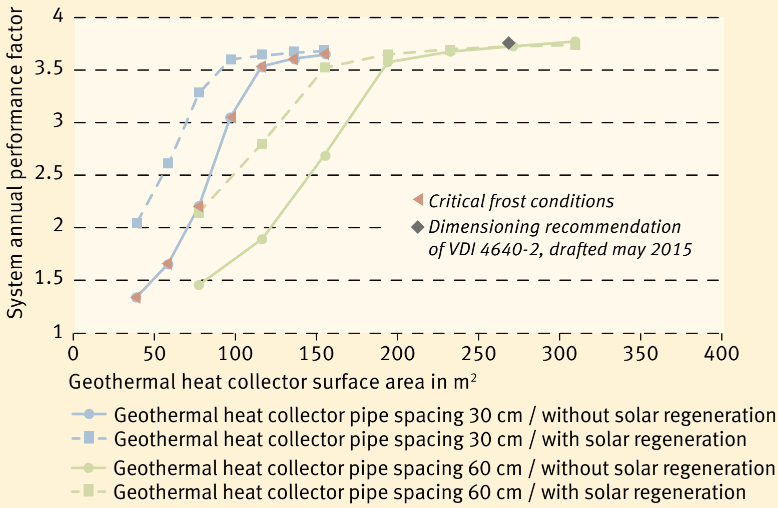

Fig. 1 *System annual performance factors (APF_{sys}) dependent on size of geothermal heat collector, solar regeneration and layout spacings in geothermal heat collector*

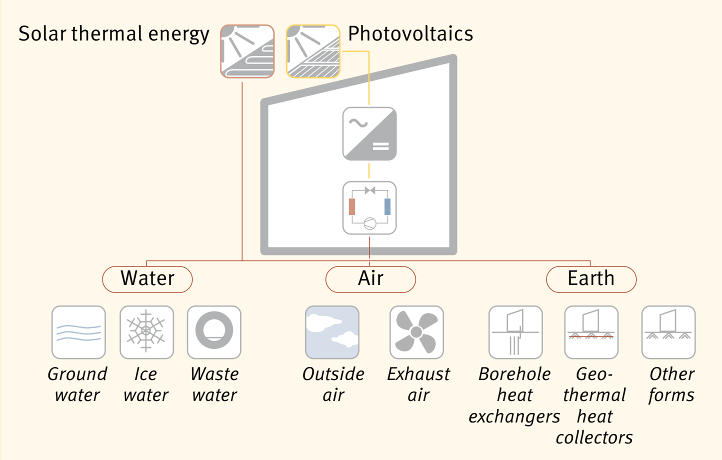

Fig. 2 *Many heat sources and heat exchangers exist. Each project involves identifying the optimal configuration.*

various building and usage types. The calculations are validated using measurement data of genuine systems and simulation.
Ground soil exhibits considerably less temperature fluctuation than ambient air from as little as one meter depth, according to season. The higher average temperature in the warmer months makes it appealing as a heat source for heat pump systems. The slight downward trend observed in the proportion of newly installed plants accounted for by ground source heat pump systems is therefore quite remarkable. Compared to borehole heat exchangers drilled into the earth, horizontally laid geothermal heat collectors often entail reduced outlay in terms of structural works and licensing regulations. They are also largely unaffected by the geological situation of the underground.

Solar collectors supplementing geothermal heat collectors

The required surface area for laying collectors at one to one-and-a-half meter depth often presents a problem. Thermal energy produced using simple, unglazed solar collectors can, in the approach followed by researchers at the Institute for Solar Energy Research (ISFH), help facilitate effective operation using far fewer geothermal heat collectors, without producing critical frost conditions in the ground soil.
This is because in such cases, further electrical heating must be directly implemented, with considerably reduced efficiency.

Simulation tests efficiency and sustainability

To facilitate the accurate assessment and configuration of geothermal heat collectors, a numerical simulation model was developed. It allows for the precise discretisation of a two-dimensional cut through the ground soil, factors in edge influences, freezing processes in the ground soil and the thermal capacity in the ground collector fluid. Embedded in the TRNSYS simulation program and optimised for rapid, dynamic system simulations, it can be used to investigate the influence of individual parameters on overall system properties.

Experiments validate model and concept

The simulation model was experimentally verified on an independently established test facility. The 150 square meter geothermal heat collector consists of four variable interconnectable array sections. With heat pump and heating rod connected in series, thermal energy can be supplied and dissipated at varying output levels. In addition to inlet and outlet temperatures at the geothermal heat collector and heat pump, ground soil temperatures are also measured at various depths and horizontal distances.

Experiments revealed: Measurements and the simulation correspond well. This cleared the way for comprehensive parameter studies intended to ascertain the key dimensioning parameters. In simulations involving differently configured geothermal heat collectors and solar collectors and various regulation strategies, the surface area reduction potentials for geothermal heat collectors were determined.

Parameter studies deliver planning recommendations

The simulation studies reveal that simple, unglazed solar collectors integrated into the heat pump system reduce the surface area requirement – depending on configuration – by more than 50 per cent compared to the current dimensioning recommendation of VDI 4640-2 (drafted May 2015). The reduced layout spacing of geothermal heat collector piping is fundamental in this regard. This boosts efficiency and allows for reduced surface areas. Without regeneration, the risk, however, of critical frost conditions increases, which would be critical for the efficiency and operation of the heat pump.
With reduced pipe spacing, supplied solar thermal energy changes system properties considerably (Fig. 1 and 3). This is because solar thermal energy regenerates the ground soil, which makes thermal depletion less likely. Critical frost conditions and further electrical heating are avoided. Shorter layout spacings and consequently much smaller geothermal heat collector surface areas are thus implementable with the same level of efficiency.

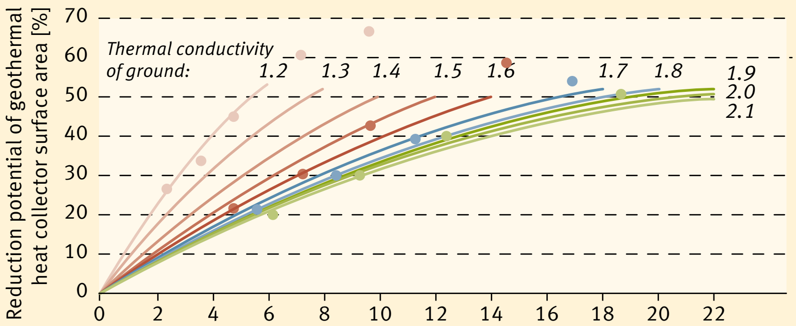

Fig. 3 *The surface area of the geothermal heat collector can be reduced in size as the solar collector surface area increases – dependent on the thermal conductivity of the ground (in W/mK).*

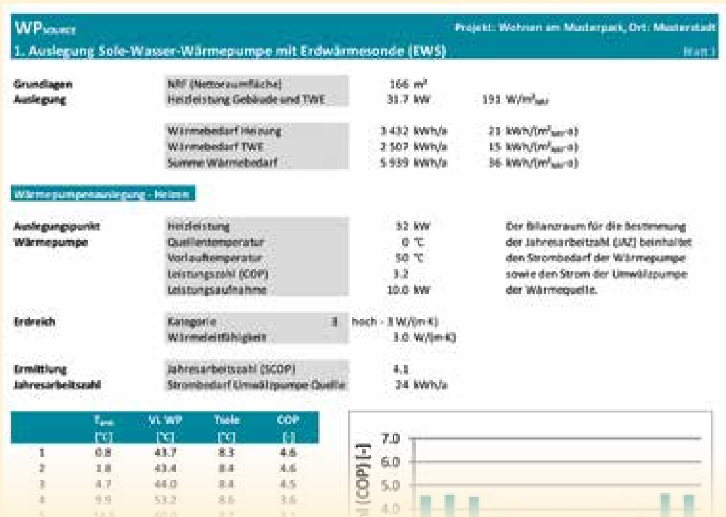

Fig. 4 *WP$_{SOURCE}$ software (only in German available) can be used to evaluate heat exchangers for specific buildings and commercially available heat pumps.*

Geothermal heat collectors are thus also implementable with slightly restrictive surface area availability.

In the case of geothermal heat collectors dimensioned according to VDI guidelines, no appreciable efficiency benefits are derived with additional solar thermal energy. This is down to the power requirements for the solar system's fluid pumps.

Greater clarity on heat sources and heat exchangers

The choice of heat source and heat exchanger impacts on economic efficiency and the surface area requirement, and furthermore on the energy efficiency of heat pump systems. This is no simple task, as the variety of heat exchangers exploiting heat sources has expanded in recent years. Alongside well-known air-water heat pumps, borehole heat exchangers and groundwater wells, many further heat sources and heat exchangers exist, such as geothermal heat collectors, energy piles, geothermal baskets, ice storage systems, air absorbers and heat exchangers for waste water and flowing water. Typically available documentation provides information on individual system concepts and their heat exchangers, yet no direct comparison of different systems and system variants. And it's not rare to see products used with very little credible information available on their cost/benefit gate the various framework conditions, surface area requirements, investment and operating costs and the construction and installation outlay.

Pre-Check-Tool WP$_{SOURCE}$

The Excel-based tool WP$_{SOURCE}$ will contain all design-relevant details. It will be particularly suitable for the early planning phase. The software will appear in the third quarter of 2018 and will be available free of charge (only in German available). Contact: Franziska Bockelmann, bockelmann@igs.tu-bs.de.

Market research and operational analyses

The idea of an information and planning tool for the early planning phase has its origins at the Institute for Building Services and Energy Design. A simple, Excel-based program is intended to facilitate a differentiated analysis in energy and economic terms for specific buildings and their heat and cooling demands. For heat pump concepts, suitable heat sources and heat exchangers can be identified and evaluated.

Key design-relevant data on potential heat sources and market-available heat pumps and heat transfer systems was initially recorded in literature and market research. The Braunschweig researchers furthermore metrologically analysed the operational properties of 14 buildings with different heat pump systems. Using parameter studies and sensitivity analyses, individual thermodynamic effects and scenarios were more closely looked at for specific systems. This approach facilitated the documentation of the performance capability, energy efficiency and operating properties of various low temperature heat sources and associated heat exchangers and validation of the calculation method for the planning tool in development based on real-life system data and using simulation.

Decision aid for early planning phases

An easy-to-use planning aid will be available from the third quarter of 2018 in the form of WP$_{SOURCE}$. It will provide an overview of various heat sources, the constraints associated with these and specific characteristic values and capacities, the resulting energy efficiency of systems and their investment and operating costs. Specialist designers and architects will be able to use the planning aid to preselect heat pump system components according to requirements and in line with project-specific constraints, to identify suitable low temperature heat sources for heat pumps and to roughly dimension heat exchangers. Application areas include basic evaluation and the planning and creation of building energy concepts (Fig. 4).

The initial version of WP$_{SOURCE}$ will include the building types individual homes and apartment buildings as well as office buildings. For residential buildings, heat pump systems will be depictable for building heating and domestic hot water heating. For office buildings, the tool assesses only building heating.

Prospects for WP$_{SOURCE}$

Owing to its modular structure, the tool can be efficiently upgraded and adapted. As part of a follow-up project, researchers also intend to look at the self-consumption of electricity in photovoltaic systems and solar thermal energy for regeneration or as a primary heat source. Expanding the scope to housing estates is also conceivable.

New heat pump ideas

A clear trend towards buildings with significantly reduced heating demand is identifiable. Low temperature levels for heat transfer in heating systems are therefore perfectly feasible. And given the ever increasing proportion of regenerative electricity supplied by the public power grid, heat pumps are becoming an appealing option for heat supply in the buildings sector. All the more important it is therefore that such systems are designed and operated at the highest achievable level of energy efficiency. Alongside the approaches detailed in this Projektinfo brochure, further concepts are also currently being looked at as part of the ENERGIEWENDEBAUEN research initiative.

In addition to simple, unglazed solar collectors for instance, discussion is also increasingly centring around hybrid collectors, known as “PVT collectors”, which simultaneously generate solar power and solar thermal energy. These were similarly the subject of investigation at the Institute for Solar Energy Research (ISFH) in the project presented (03ET1275A-C). Uncovered PVT collectors are suitable for combination with brine-water heat pumps. Solar power drives the fluid pumps for the solar circuit and assists the heat pump drive. Thermal energy produced is dissipated, which contributes to efficiency enhancing cooling of the PV module and is usable as a secondary heat source for a brine-water heat pump.

Researchers are making headway in this regard in the TwinPower research project. The aim of the project is to derive an integrated overall energy supply concept for residential buildings with hybrid collectors as a “bisolar” heat source for heat pumps. Using newly developed PVT modules, the aim is to supply household electricity, domestic hot water and space heating with a high solar fraction (0325867A-C).

A newly developed test method appeals for dependable system planning. The method allows for determining realistic annual performance factors for heat pumps and micro CHP plants. This further allows for better forecasting and energy-optimised planning with respect to system operation. In contrast to previous static methods in accordance with VDI 4650, the researchers at the three universities TU Dresden, RWTH Aachen University and Stuttgart University also want the new method to take dynamic operating conditions into account, such as start-up and shutdown processes as well as thermal storage losses. These have a noticeable impact on the system’s energy efficiency (03ET1211A-C).

Imprint

Project organisation
Federal Ministry for Economic Affairs and Energy (BMWi)
11019 Berlin
Germany

Project Management Jülich
Forschungszentrum Jülich GmbH
Tobias Kollmann
10969 Berlin
Germany

Project number
03ET1275A, B, C (Terra-Solar-Quelle) and 03ET1273A (future:heatpump)

ISSN
0937-8367

Publisher
FIZ Karlsruhe · Leibniz Institute for Information Infrastructure GmbH
Hermann-von-Helmholtz-Platz 1
76344 Eggenstein-Leopoldshafen
Germany

Author
Johannes Lang

Project participants

- **Terra-Solar-Quelle project:**
  Research and project management: Institute for Solar Energy Research | www.isfh.de
  Practical system application and system design: tewag Technologie – Erdwärmeanlagen – Umweltschutz GmbH | www.tewag.de
  Market analysis and technology transfer: Bundesverband Wärmepumpe e.V. | www.waermepumpe.de
- **future:heatpump project: Market analysis, simulation, tool development:** TU Braunschweig, Institute for Building Services and Energy Design (IGS), www.tu-braunschweig.de/igs

Links (in German)

- www.enargus.de (the EnArgus information system provides information on research funding, including in regard to this project)
- www.projektinfos.energiewendebauen.de

More from BINE Information Service

- Double heats better. BINE-Projektinfo brochure 4/2018
- Electrically driven heat pumps. BINE-Themeninfo brochure I/2013
- This Projektinfo brochure is available as an online document at www.bine.info under Publications/Projektinfos.

BINE Information Service reports on energy research projects in its brochure series and newsletter. You can subscribe to these free of charge at www.bine.info/abo.

Contact · Info

Questions regarding this Projektinfo brochure? We will be pleased to help you:

+49 228 92379-44
kontakt@bine.info

BINE Information Service
Energy research for application
A service from FIZ Karlsruhe

Kaiserstraße 185–197
53113 Bonn, Germany
www.bine.info

Supported by:
Federal Ministry for Economic Affairs and Energy
on the basis of a decision by the German Bundestag