High-temperature heat pumps in local heating networks: With the right system configuration to economic efficiency

Themenbereich 3: Integrierte Netze der Zukunft

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Motivation and central question

With the decision to draft an amendment to the Federal Climate Protection Act of May 12, 2021, the Federal Government of Germany tightened a central goal of climate protection policy, with which the greenhouse gas reduction in 2030 is to be increased from minus 55 to minus 65% compared to 1990 [1]. In the building sector, the current target is a greenhouse gas reduction of 66 to 67% by 2030 compared to 1990 [2]. On the other hand, however, there is a renovation rate of one percent that has stagnated for years [3], which means that the desired goal of an almost climate-neutral building stock by 2050 cannot be achieved through thermal energy savings alone. And although the population has not yet been sensitized to the greatest possible extent, the pipeline-based thermal energy supply in the form of local and district heating networks must move further into focus in the course of the decarbonisation of heat supply. Because here in particular there is the possibility to reach a large number of buildings at once and to supply them efficiently and climate-neutrally with renewable energies without first having to assume that the buildings will have to be renovated.

In addition to the direct use of renewable energies, such as solar thermal energy, the focus is on the electrification of the heat supply. Heat pump technology is an important link with which environmental and low-temperature waste heat can be harnessed and integrated into heating networks efficiently and intelligently, using green electricity from solar, wind and hydropower for the sustainable generation of thermal energy. This will play a key role in the future of pipeline-based thermal energy supply.

From this tension arises the central question of this study for an economical system configuration of a high temperature heat pump including a heat storage in connection with a PV system, with which a wide range of supply scenarios can be covered, so that in the future not only inner-city areas, but also rural structured regions can be supplied with heat sustainably and as climate-neutral as possible.

Methodical approach

The hypothesis of this study is that by optimizing the system configuration in terms of power consumption of the high-temperature heat pump, peak performance of the PV system and the size of the thermal energy storage, monetary savings can be increased compared to fossil-fueled thermal energy generators.

The basis for the hypothesis listed here is the acquisition of measurement data from a cascade air-water heat pump with 65 kW_{therm}, which can generate flow temperatures of up to approx. 78 °C. The demonstrator heat pump was developed as part of the InnoNEX research project [4], built in 2020 and currently supported and operated by Stadtwerke Neuburg an der Donau. Using statistical modeling of the real data, the operation of the heat pump can be mapped, the amounts of energy generated can be characterized in relation to the ambient temperature over the course of the year, and heat supply scenarios can be derived.

With the help of a mathematical optimization, an overall energy system can be simulated, which is optimally coordinated in terms of system size and configuration and offers the most economical operation through a high proportion of self-generated electricity from the PV system. The aim is to examine what influence the size of the PV system and its orientation have on the one hand and what flexibility potential is available through the use of a sufficiently dimensioned heat storage system with regard to load management in the power grid, so that the contribution to sector coupling can also flow into the monetary assessment.

The heat generation costs of the overall system are calculated as a reference value and compared with currently common fossil fuel combustion technologies that can be used in the field of pipeline-based heat supply in a local heating network.

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Results and Conclusions

The result of this study is a thermal energy supply system optimized for technical and economic framework conditions, consisting of a high-temperature heat pump, a PV system and a thermal storage system, which will meet the future challenges of pipeline-based thermal energy supply.
Figure 1 shows the electrical power consumption of the aforementioned high-temperature heat pump with 65 kW_{therm} over the course of the day. In addition, the generation capacities of two PV systems with south orientation (50 kWp) and east-west orientation (25 kWp each) are shown. The share of self-generated electricity used by the second-mentioned PV system is higher despite the lower peak power. The first advantages with regard to load management can be seen.

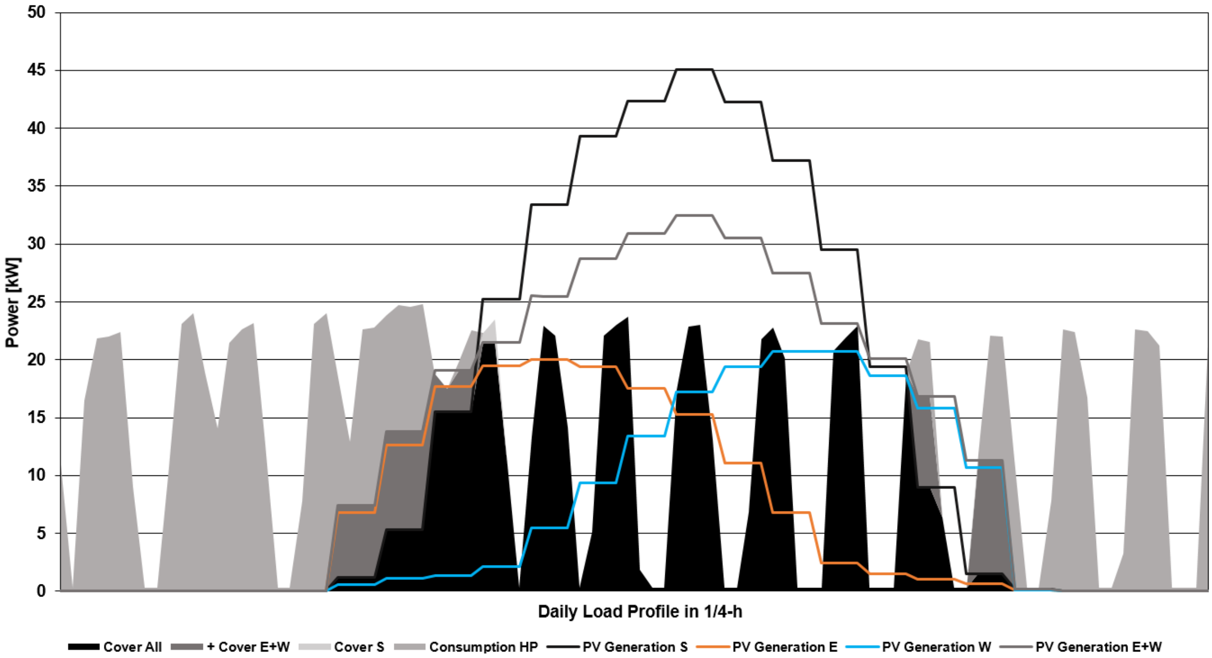

Figure 1: Comparison of a PV system with a south and east-west orientation for the power supply of a high-temperature heat pump

In the transition period of the heat transition, i.e. especially in the period in which the building stock is still being renovated and there are still old buildings in the heating network areas, it will be necessary to operate the network temperatures at a flow temperature level of 65 – 70 °C due to the preparation of domestic hot water. However, in order to avoid having to burn fossil fuels in the transition periods and summer months, and on the other hand to be able to integrate renewable energies in the form of environmental or low-temperature waste heat into heating networks, the high-temperature heat pumps mentioned above are particularly suitable for this application.

Literatur

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