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Economic and technical optimization of solar district heating concepts based on local renewable energies and seasonal thermal energy storage for rural villages in Germany

Summary

Solar district heating networks with seasonal thermal energy storage support a rapid decarbonization of existing residential areas. This contribution will evaluate solar district heating concepts for providing climate-neutral supply of heat and domestic hot water in rural residential areas using transient system simulations. These concepts focus on combining local renewable energies such as solar radiation and a seasonal thermal energy store.

Keywords: solar district heating, seasonal thermal energy storage, system simulation, innovative operating strategies, TRNSYS, system simulation

Field of application for the findings: Sustainable and Efficient Districts

Addressed audience: Researchers, engineers, and practitioners in the fields of sustainable district heating concepts, seasonal thermal energy storage and system simulations, decision makers of municipalities

1. Introduction

Most residential buildings in small German towns have decentralized, fossil-fuel-powered heating systems. According to Volk et al. (2025), setting up a solar district heating network results in a substantially faster decarbonization than individual renovations combined with heating system conversions. Over time, this translates into considerable absolute savings in CO_2-emissions. Furthermore, the study found that both methods of decarbonization result in approximately similar specific costs.

However, with regard to rural areas, there currently exists only one solar district heating network with high solar fraction in Germany. It is located in Bracht, a small village with around 900 inhabitants, 20 km northeast of Marburg. Therefore, a current research project is investigating how a combination of local renewable energies, such as solar radiation and a seasonal thermal energy store, can provide a climate-neutral supply of heat and domestic hot water in rural residential areas. This is done using the example of Müsen in North Rhine-Westphalia with around 2,200 inhabitants and a heat demand of approximately 7,000 MWh/a.

2. Methodology

First, several solar district heating concepts with a seasonal thermal energy store were defined focusing on local renewable energies and deliberately excluding biomass. The goal is to quantify the ecological and economic impacts of different solar fractions and climate-neutral heat supply technologies, such as solar and wind energy applications, heat pumps as well as mine water geothermal energy.

Subsequently, numerous transient system simulations are performed with the software TRNSYS to determine the dimensions of key components, such as the capacity of the seasonal heat store and the area of the solar collector field. Heating and domestic hot water load profiles were derived from synPRO by Fraunhofer ISE (2024). These profiles were weighted according to the local building structure and scaled to match the expected annual heat demand of the district heating network. To meet the hygiene criteria for domestic hot water supply, the supply temperature follows a heating curve with at least 70 °C.

To further improve economic efficiency, several innovative operating strategies will be investigated, such as using regional surplus wind power and providing balancing energy for the transmission grid in power-to-heat

applications. Existing simulation models of the defined district heating concepts will be extended by high-resolution modeling of these power sources. After evaluating the characteristic data of the simulated concepts and operating strategies regarding economic and ecological aspects, a preferred concept will be identified and further optimized through a systematic parameter study.

The proposed contribution will present the different investigated solar district heating concepts and innovative operating strategies. Furthermore, the results of the transient system simulations as well as of the economic assessment will be discussed in detail.

3. References

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