POPULAR SCIENCE SUMMARY

The growing global population and the expansion of industry have led to an increased demand for energy, and nearly half of the world's energy consumption is attributed to buildings, a substantial portion of which is for heating and cooling. To address this issue, innovations in district heating have been developed. District heating is a system type that transports energy from the power plants where it's produced to the consumers who need it. Studies suggest that by improving the way we use energy and harnessing energy from natural processes, we could lessen our reliance on power plants. However, there are still financial and efficiency issues with these systems that need to be solved to reach our sustainability and energy efficiency targets.

Previous research discovered that about 20% of heat might be lost during transport due to the difference in temperature between the hot water in the pipes and the cooler surrounding soil. Concepts like low-temperature district heating (LTDH) and fourth-generation district heating (4GDH) have been developed to address this. These concepts aim to minimize heat loss by lowering the water temperature in the heating pipes and raising the final site's temperature. However, these systems' effectiveness varies depending on location and system design, highlighting areas for improvement in terms of economy, efficiency, and environmental impact.

This study delved into these issues by examining a rural LTDH network in Denmark. This network is unique because it doesn't rely on a power plant. Instead, it gathers energy from boreholes—deep holes drilled into the Earth's crust—to tap into underground heat. Initial results confirm that the system can successfully extract heat from the ground, but there is room for improvement. One significant issue is that as heat is extracted and not returned, the ground heat eventually depletes, decreasing system efficiency over time. Also, because the system uses heat pumps to raise the fluid temperature at consumer sites, any reduction in efficiency can significantly impact the economics of the system. Furthermore, because the system is connected to the Danish electricity grid—which has a high carbon emission footprint—it also has room for environmental improvements.

These challenges could potentially be overcome by using locally generated renewable electricity and harnessing low ground temperatures to cool buildings during the summer. Despite these issues, the system is a viable alternative for areas with smaller populations where conventional district heating systems might not be suitable.

This study used four years' worth of system operation data to develop an investigative model with the help of the Modelica language. After cleaning the data, it was used as input for the model, which was then validated. However, there are still gaps that future research needs to address. For example, the economic analysis was based on 2018 prices, which may have changed significantly by now. Also, the format of the original data posed challenges in processing. Despite these limitations, this study provides a valuable foundation for decision-making and future energy efficiency and sustainability advancements.