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Efficient Urban Geothermal Heating with a Compact Diagonal Borehole Heat Exchanger Array: Seasonal Performance and Configuration Insights

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Underground Thermal Energy Storage (UTES) technologies are essential for advancing low-carbon heating and cooling systems, particularly in urban areas where space constraints and retrofitting challenges pose significant barriers. In this study the performance of a system of novel coaxial diagonal borehole heat exchangers (BHE) is analyzed during September–December 2024.

The Home Smart Energy (HSE) system, implemented in Medemblik, Netherlands, features a nine-borehole diagonal array arranged in a circular configuration. The boreholes are drilled at a 60° or 45° angle to depths of up to 40 meters, operating in a closed-loop coaxial setup. A brine mixture of water, operates with a flow rate of 3100 l/h, and 14% glycol lowers the freezing point below 0°C, allowing the system to supply higher capacities. The heat pump extracts the heat from the BHE's, supported by solar thermal collectors to charge the BHE's in summer, ensuring efficient year-round heating. An extensive monitoring framework, including Distributed Temperature Sensing (DTS), provides detailed insights into system performance during operation.

The HSE system demonstrated consistent performance under varying configurations and conditions. With all nine boreholes active, the system achieved a seasonal Coefficient of Performance (COP) ranging from 3.8 to 5.2, with daily energy outputs averaging 125 to 220 kWh/day. During December 2024, tests were conducted using three boreholes in different configurations at a reduced flow rate of 2800 l/h. These tests showed that borehole arrangement moderately influenced system performance, with the adjacent configuration achieving slightly higher energy outputs and COP, compared to the dispersed configuration.

The system also demonstrated significant energy cost savings of €954 during November and December 2024, attributed to a reduction in gas consumption by over 700 m³ compared to the previous year. These findings confirm that diagonal shallow co-axial borehole arrays are a scalable and sustainable UTES solution, offering substantial energy savings and CO reductions in dense urban settings.

Keywords: UTES, diagonal boreholes, geothermal energy, COP, solar thermal storage, urban

heating, thermal recovery.

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