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Storage of Solar Thermal Energy in Geothermal Boreholes Installed in Unsaturated Soils

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Abstract

In the last decade, extensive research has been performed to investigate the thermal response of Borehole Thermal Energy Storage (BTES) systems, an innovative approach to provide heating and cooling of buildings through geothermal boreholes installed in the shallow subsurface. Despite their successful use in practice, high initial upfront costs and low efficiency due to groundwater flow necessitate further research to enhance BTES systems. This involves a better understanding of the effect of heat transfer mechanisms when storing the thermal energy in BTES systems and their implication on community resilience including the limits of extractable heat for design purposes. This study focuses on the coupled thermo-hydraulic response of a BTES system installed in the vadose zone where the soil is unsaturated. Investigation of BTES systems in unsaturated soils requires complex mathematical models that consider coupled heat transfer and water (liquid and vapor) flow and its effect on the thermal properties of soils. This research highlights how the coupled heat transfer and water flow processes and coupled thermo-hydraulic constitutive properties of soils may be exploited to enhance heat injection and heat retention in an array of geothermal borehole heat exchangers. Results from laboratory and field experiments and numerical simulations which can crucially contribute to the sustainable thermal energy strategies and the design are presented. Overall, the results from the numerical simulations and experiments confirm the good performance of SBTES system in the vadose zone, which supports considering coupled heat transfer and water flow when simulating the BTES systems is vital.