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Optimization of shallowest-depth geothermal heat collectors for sustainable energy production under variable saturation conditions and seasonal temperature fluctuations

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The increasing energy prices and technological progress in ground source heat pumps (GSHP) in recent years has substantially propelled the use of shallow geothermal energy in Germany. With the swiftly growing numbers of installed GSHP in urban areas, the optimal and sustainable use of shallow geothermal resources requires a thorough analysis and understanding of the key components and physical processes involved in the underground at different spatial and time scales. In particular, the question of possible thermal and/or thermo-hydraulic interaction of neighboring small-power (<30kW) geothermal facilities typical of single-family houses is most relevant. We address this question within the framework of the ongoing joint research project WärmeGut by studying the efficiency of shallow geothermal heat recovery in terms of avoiding negative thermal or thermo-hydraulic interferences between neighboring installations.

Using 3D finite-element numerical modelling and simulation, this work focuses on the impact that variably saturated flow and seasonably varying underground temperature have on several optimized pipe assemblage designs at different scales. Specially, we consider different shallowest-depth geothermal heat collector patterns and different soil thermal and hydrogeological properties. Taking into account the impact that varying saturation has on the soil thermal properties, we vary the location, depth, arrangement, pipes layout, and operational schemes to elucidate the controlling factors on the optimized sustainable use of shallowest-depth geothermal resources**.**

Employing COMSOL Multiphysics, we conduct a series of simulations intended to systematically analyze the complex thermo-hydraulic interaction between neighboring shallow geothermal installations under varying climatological conditions. Since there is no requirement by the German state geological surveys to provide any detailed modelling on the performance and thermal impact of small-power (<30kW) shallow geothermal facilities, we illustrate our simulation results in detail for a large range of parameter variation. We present in this work our most recent results.

This work is conducted within the joint research project WärmeGut "Flankierung des Erdwärmepumpen-Rollouts für die **Wärme**wende durch eine bundesweite, einheitliche

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