Quantification of storage capacities and withdrawal rates for high-temperature heat storage in the subsurface

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Thermal energy storage is one option of storing energy from renewable sources to overcome seasonal disparities between heat production and heat demand. In the subsurface, heat can either be stored in borehole thermal energy storage sites (BTES) through borehole heat exchangers or in aquifer thermal energy storage sites (ATES) through open well doublets. Using high temperatures of up to 90°C allows to achieve high temperature gradients and high energy densities and thus large storage capacities at high storage rates.

This works investigates the resulting induced thermal and hydraulic effects and quantifies storage dimensions, capacities as well as storage and recovery rates by numerical scenario simulations.

Results show that heat recovery of a BTES site mainly depends on the number of heat exchangers used as well as on the thermal conductivity and hydraulic permeability of the storage formation. Recovery rates increase with increasing heat exchanger number and with increasing thermal conductivity. In contrast, high permeabilities in combination with high operation temperatures may induce convective flow and heat transport in the storage formation, which may cause efficiency decrease and larger regions of thermal impact.

Using ATES, heat is stored by advective heat transport which is mainly controlled by the pumping rates of the well doublet and the storage formation hydraulic permeability. At high permeabilities and temperatures, induced convection also occurs in these systems, which reduces storage efficiency and enhances heat emissions to neighbouring formations. Higher permeabilites hence lead to an increase of the region of thermal impact and thus to increased heat losses with lower recovery rates.