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Large-scale compressed air energy storage in porous media in a 100% renewable energy supply future

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Compressed air energy storage (CAES) in porous formations is one option to compensate the expected fluctuations in energy supply in future energy systems with a 100% share of renewable energy sources. Mechanical energy is stored as pressurized air in a subsurface porous formation using off-peak power, and released during peak demand using a turbine for power generation. Depending on share and type of renewable energy sources in the future, different storage capacities and storage power rates will have to be satisfied to compensate fluctuating nature of the renewable power supply. Therefore, this study investigates scenarios for subsurface compressed air energy storage using four potential future energy system development pathways. Because for CAES subsurface processes and power generation are strongly linked via reservoir pressure and flow rates, coupled power plant and geostorage model has to be developed and employed to evaluate potential operation conditions for such a storage technique.

In this study, a diabatic CAES is designed, with a three-stage compression and a two-stage expansion with heat recuperator in the power plant and a porous formation as a storage formation with 20 m thickness in an anticline trap structure at a depth between 700 and 1500 m. A withdrawal rate of 115 MW and a total stored energy of up to 348 GWh per year are derived from the future energy system scenarios. Scenario simulations are carried out by coupling the open-source thermal engineering TESP code and the multiphase-multicomponent ECLIPSE flow simulator using highly fluctuating load profiles with a time resolution of one hour. In addition to the diabatic CAES, two adiabatic concepts are considered for the same geostorage configuration.

Results show that nine vertical storage wells are sufficient to deliver the target air mass flow rates required by the power plant during 98% of the year. Flow rate limitation occurs due to bottom hole pressure limits either during the injection or the withdrawal phases, depending on the specific load profile of the future energy systems, as well as the prior operation conditions. Thus, our scenario simulation shows that one porous media CAES site can cover all expected load profiles and balance the expected offsets between energy demand and energy supply up to the GWh scale. Balancing of the energy system at the national level can be achieved by up-scaling of the results obtained in this study.