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Integrating experimental and numerical methods for a scenario-based quantitative assessment of subsurface energy storage options

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Within the framework of the transition to renewable energy sources ("Energiewende"), the German government defined the target of producing 60 % of the final energy consumption from renewable energy sources by the year 2050. However, renewable energies are subject to natural fluctuations. Energy storage can help to buffer the resulting time shifts between production and demand. Subsurface geological structures provide large potential capacities for energy stored in the form of heat or gas on daily to seasonal time scales. In order to explore this potential sustainably, the possible induced effects of energy storage operations have to be quantified for both specified normal operation and events of failure. The ANGUS+ project therefore integrates experimental laboratory studies with numerical approaches to assess subsurface energy storage scenarios and monitoring methods. Subsurface storage options for gas, i.e. hydrogen, synthetic methane and compressed air in salt caverns or porous structures, as well as subsurface heat storage are investigated with respect to site prerequisites, storage dimensions, induced effects, monitoring methods and integration into spatial planning schemes.

The conceptual interdisciplinary approach of the ANGUS+ project towards the integration of subsurface energy storage into a sustainable subsurface planning scheme is presented here, and this approach is then demonstrated using the examples of two selected energy storage options:

Firstly, the option of seasonal heat storage in a shallow aquifer is presented. Coupled thermal and hydraulic processes induced by periodic heat injection and extraction were simulated in the open-source numerical modelling package OpenGeoSys. Situations of specified normal operation as well as cases of failure in operational storage with leaking heat transfer fluid are considered. Bench-scale experiments provided parameterisations of temperature dependent changes in shallow groundwater hydrogeochemistry.

As a second example, the option of seasonal hydrogen storage in a deep saline aquifer is considered. The induced thermal and hydraulic multiphase flow processes were simulated. Also, an integrative approach towards geophysical monitoring of gas presence was evaluated by synthetically applying these monitoring methods to the synthetic, however realistically defined numerical storage scenarios. Laboratory experiments provided parameterisations of geochemical effects caused by storage gas leakage into shallow aquifers in cases of sealing failure.

Ultimately, the analysis of realistically defined scenarios of subsurface energy storage within the ANGUS+ project allows a quantification of the subsurface space claimed by a storage operation and its induced effects.

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