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Impact of aquifer properties, well spacing and vertical offsetting of warm and cool plumes on ATES systems.

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Aquifer Thermal Energy Storage (ATES) can store and supply a high capacity of seasonal heating and cooling. Well-balanced and well-designed ATES systems provide a very efficient energy storage, up to around 70-90% and thereby play an important role in providing a sustainable, and low-carbon solution for heating and cooling. Factors affecting the efficiency and capacity of ATES deployments are mainly subsurface properties and related design decisions. We set up a framework to test the impact of a wide range subsurface and design parameters to deduce their impact on ATES system performance. Aquifer thickness, lateral permeability and permeability anisotropy are considered as main aquifer properties, and cool-warm well lateral spacing and vertical offsetting of cool and warm plumes as main design decisions. The thickness of the injection and production interval can be dictated by aquifer permeability variations and/or be chosen by varying screen length.

The parameters listed above are combined into dimensionless numbers, such as effective aspect ratio of the system and effective lateral spacing of wells to summarize and group different aquifers and possible ATES deployment designs. For a wide range of effective aspect ratios and effective well spacing ATES system behaviour is predicted by flow simulation and key performance indicators computed, including thermal efficiency, CO_2 savings, cool/warm plume sizes and stored energy density. The first two indicate the potential expected capacity of ATES systems. The latter provide recommendations for best use of land area, especially if multiple ATES systems are planned in areas with high concentration of cooling and heating demand. Given heating and cooling demand, specific aquifer conditions and land area available for use, the predicted behaviour metrics will help design optimal ATES deployments and show the potential for energy savings across multiple different settings.

Results indicate that ATES' bidirectional subsurface thermal storage nearly always produces more energy than unidirectional open-loop systems, even when thermal recovery is low. Only when cold and warm plumes are placed side-by-side, closer than half thermal radius apart, negative thermal efficiency occurs, and more energy is put in the system than extracted. However, placing cold and warm plumes at very small spacing is still efficient, when plumes are also offset vertically, and similar thermal behaviour as large lateral well spacing is achieved.