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Quantifying the potential of Aquifer Thermal Energy Storage (ATES) for energy savings in the built environment

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Aquifer Thermal Energy Storage (ATES) is a building technology which can be used to seasonally store thermal energy in natural subsurface formations. In combination with a heat pump, ATES can reduce energy use for heating and cooling by more than half in larger buildings, while supporting the electrification of building energy systems. This has made the technology increasingly popular in Northern Europe. Furthermore, the climactic and subsurface conditions required for ATES can be found across Europe, Asia and North America.

The potential contribution of large-scale ATES use for urban energy efficiency has not yet been evaluated in the literature. This makes it difficult for analysts and policymakers to assess its potential on an equal basis with other energy-efficient technologies. Given that ATES performance is highly site-specific and sensitive to climate conditions, this requires a spatially-explicit analysis which accounts for local properties, as well as plausible future changes in operating conditions. This work therefore synthesizes existing data sources for building, climate and aquifer properties, to estimate the long-term energy savings which could be achieved from ATES use in 588 urban areas worldwide at the 2050 horizon.

Local energy demand for heating and cooling was first estimated using data from an ensemble of 8 Climate Model Intercomparison Project phase 5 (CMIP5) models, under the standard RCP8.5 and RCP2.6 future trajectories for greenhouse gas concentrations. These results were combined with forecasts for the energy intensity of building heating and cooling as a function of region and building type, and with forecasts for building floor space. Finally, energy savings from ATES were estimated across a set of plausible scenarios for ATES use, where ATES performance and adoption were assumed to be dependent on climate and subsurface properties. These scenarios were derived from current ATES adoption patterns and targets for the Netherlands.

Regionally-aggregated results indicate that the potential energy savings from ATES use would be largest in North America, with an upper bound of 490 PJ/year (or 7% of energy use in the commercial building sector in large metropolitan areas). Due to favorable climate conditions for ATES, the largest potential contribution of ATES to energy savings is found in Western and Eastern Europe (8-12% of commercial building energy use). Furthermore, although China is currently not a significant market for ATES, the analysis indicates that ATES could reduce energy use in large metropolitan areas by 420 PJ/year in a high-adoption scenario. However, with the exception of Eastern Europe and Russia, increased climate change tends to reduce the energy-saving potential of ATES by shifting energy demand towards cooling.