Geophysical Research Abstracts
Vol. 17, EGU2015-6731, 2015
EGU General Assembly 2015

Planning ATES systems under uncertainty

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Aquifer Thermal Energy Storage (ATES) can contribute to significant reductions in energy use within the built environment, by providing seasonal energy storage in aquifers for the heating and cooling of buildings. ATES systems have experienced a rapid uptake over the last two decades; however, despite successful experiments at the individual level, the overall performance of ATES systems remains below expectations – largely due to suboptimal practices for the planning and operation of systems in urban areas.

The interaction between ATES systems and underground aquifers can be interpreted as a common-pool resource problem, in which thermal imbalances or interference could eventually degrade the storage potential of the subsurface. Current planning approaches for ATES systems thus typically follow the precautionary principle. For instance, the permitting process in the Netherlands is intended to minimize thermal interference between ATES systems. However, as shown in recent studies (Sommer et al., 2015; Bakr et al., 2013), a controlled amount of interference may benefit the collective performance of ATES systems. An overly restrictive approach to permitting is instead likely to create an artificial scarcity of available space, limiting the potential of the technology in urban areas.

In response, master plans – which take into account the collective arrangement of multiple systems – have emerged as an increasingly popular alternative. However, permits and master plans both take a static, ex ante view of ATES governance, making it difficult to predict the effect of evolving ATES use or climactic conditions on overall performance. In particular, the adoption of new systems by building operators is likely to be driven by the available subsurface space and by the performance of existing systems; these outcomes are themselves a function of planning parameters. From this perspective, the interactions between planning authorities, ATES operators, and subsurface conditions form a complex adaptive system, for which agent-based modelling provides a useful analysis framework.

This study therefore explores the interactions between endogenous ATES adoption processes and the relative performance of different planning schemes, using an agent-based adoption model coupled with a hydrologic model of the subsurface. The models are parameterized to simulate typical operating conditions for ATES systems in a dense urban area. Furthermore, uncertainties relating to planning parameters, adoption processes, and climactic conditions are explicitly considered using exploratory modelling techniques. Results are therefore presented for the performance of different planning policies over a broad range of plausible scenarios.