Geophysical Research Abstracts
Vol. 18, EGU2016-15052, 2016
EGU General Assembly 2016

Hybrid modelling for ATES planning and operation in the Utrecht city centre

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Aquifer Thermal Energy Storage (ATES) systems can significantly reduce the energy use and greenhouse gas emissions of buildings in temperate climates. However, the rapid adoption of these systems has evidenced a number of emergent issues with the operation and management of urban ATES systems, which require careful spatial planning to avoid thermal interferences or conflicts with other subsurface functions. These issues have become particularly relevant in the Netherlands, which are currently the leading market for ATES (Bloemendal et al., 2015). In some urban areas of the country, the adoption of ATES technology is thus becoming limited by the available subsurface space. This scarcity is partly caused by current approaches to ATES planning; as such, static permits tend to overestimate pumping rates and yield excessive safety margins, which in turn hamper the energy savings which could be realized by new systems.

These aspects are strongly influenced by time-dependent dynamics for the adoption of ATES systems by building owners and operators, and by the variation of ATES well flows under uncertain conditions for building energy demand. In order to take these dynamics into account, previous research (Jaxa-Rozen et al., 2015) introduced a hybrid simulation architecture combining an agent-based model of ATES adoption, a Matlab control design, and a MODFLOW/SEAWAT aquifer model. This architecture was first used to study an idealized case of urban ATES development. This case evidenced a trade-off between the thermal efficiency of individual systems and the collective energy savings realized by ATES systems within a given area, which had already been suggested by other research (e.g. Sommer et al., 2015). These results also indicated that current layout guidelines may be overly conservative, and limit the adoption of new systems.

The present study extends this approach to a case study of ATES planning in the city centre of Utrecht, in the Netherlands. This case is particularly relevant due to a combination of dense ATES development and complex subsurface conditions. An agent-based model of ATES adoption was thus parameterized to represent historical development patterns in the area over the 1998-2015 period, as well as plausible future adoption dynamics under a range of socio-technical uncertainties. An existing geohydrological model (Deltares, 2009) was used to represent local subsurface conditions.

Preliminary results from this case study indicate that the idealized dynamics obtained in the previous case can also be observed under more realistic conditions; the geographic constraints introduced by building plot layouts and other spatial features tend to further constrain the adoption of new systems, emphasizing the risk of a scarcity of space under current layout guidelines. Furthermore, order effects appear to play a more significant role for system efficiency than in the idealized case. Earlier adopters thus tend to benefit from higher thermal efficiency due to the transient development of thermal bubbles, which could make older systems more robust to thermal interactions. In order to better understand the relationships between these processes and the operation of ATES wells under uncertainty, the case study will be extended by incorporating a Model Predictive Control approach for simulated ATES operation.

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