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Using distributed model predictive control to manage subsurface thermal interactions for Aquifer Thermal Energy Storage (ATES)

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Aquifer Thermal Energy Storage (ATES) is an increasingly popular technology which can be used to seasonally store thermal energy in the subsurface. This can significantly reduce the consumption of energy for space heating and cooling in larger buildings, when combined with a heat pump. However, the adoption of ATES by building owners puts pressure on available subsurface space in dense urban areas. The spatial planning of ATES requires a minimum clearance between neighboring systems to avoid thermal interactions; in the Netherlands, some cities already have a scarcity of space for new systems, limiting the energy savings which could be delivered. This situation is in part caused by the overallocation of subsurface space under current methods for ATES planning and operation.

In this context, previous work using an idealized case study has shown that cooperative ATES operation could support more efficient spatial planning, by dynamically managing thermal interactions between neighboring systems in response to operating conditions. This work extends this approach for a realistic case study of ATES operation in the city of Utrecht, in the Netherlands. This case is simulated using a coupled agent-based/geohydrological environment, under 5 different scenarios for spatial planning (representing different layout guidelines for ATES systems).

In addition, a distributed stochastic model predictive control (DSMPC) approach is used to impose coupling constraints on the stored thermal volumes of neighboring ATES systems. Compared to a case without coordination, the dynamic management of thermal interactions with DSMPC can significantly improve the energy savings obtained per unit of subsurface volume allocated for ATES, without penalizing the thermal performance of individual systems. Furthermore, the DSMPC controller provides comparable computational performance, with runtimes scaling linearly with the number of simulated systems.