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Optimising the thermal use of groundwater for a decentralized heating and cooling supply in the city of Munich, Germany

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Shallow geothermal energy can contribute to a regenerative supply of urban heating and cooling loads and hence, reduce primary energy consumption and greenhouse gas emissions. In the city of Munich, which hosts a very productive shallow aquifer, conditions are outstanding for the thermal use of groundwater. Therefore, already more than 2800 shallow geothermal systems are installed and due to better economic incentives, numbers are rising. Thus, the future development of this already intensely used urban aquifer holds challenges to avoid conflicting uses, but also opportunities to build synergies and balance the energy budget.

However, fostering a sustainable development is only possible with knowledge about the dynamic hydraulic and thermal behaviour of the groundwater and its anthropogenic and natural influences. Currently, this information is missing on a city scale as a decision basis for the responsible growth of thermal groundwater use. As a consequence, water authorities have to become increasingly restrictive when granting licenses to cope with preventive drinking water protection. Therefore, tools for the thermal management of aquifers are needed to enable resilient decision making.

The project GEO.KW (2019-2021), funded by the German Ministry for Economic Affairs and Energy, took up this challenge and develops a flexible management and optimisation tool for the thermal use of groundwater. As pilot area for an implementation, Munich offers a dynamic and well-monitored hydrogeology. The tool's core element is the coupling between a thermal-hydraulic groundwater model and a linear optimisation model for distributed energy systems. This interdisciplinary approach, allows us to include the heat storage potential of the aquifer and study the coverable heating and cooling demand depending on the thermal resource at high temporal and spatial resolution. The optimisation integrates all regulatory restrictions of water resource management, like temperature or extraction limits, and comparatively analyses conventional heating and cooling systems alongside with thermal groundwater use. As cost factor in the optimisation, greenhouse gas emissions and economic cost is evaluated.

The development focuses on using highly parallelised open-source codes and efficient code

coupling. The numerical groundwater simulation is performed with *PFLOTRAN*, a code specifically built for scalability on supercomputers. It is coupled to the linear optimiser *urbs* through the minimally invasive coupling library *preCICE* and the simulations are performed on the *SuperMUC-NG* in Garching, Germany. Since the parallelisation of optimisation problems is not straightforward, a decomposition procedure is introduced to assure performance with high resolution models.

The optimisation tool and associated methods will also be applicable to other urban areas. Thus, it will offer the decision support for an optimised growth of thermal groundwater use to assure its contribution to emission-free and decarbonised heating and cooling of cities.