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Technical geothermal potential of urban subsurface influenced by land surface effects

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Changes in land use are probably one of the most notorious anthropogenic perturbations in urban environments. They significantly change the coupled thermal regime at the ground surface leading in most cases to increased ground surface temperatures (GST). The associated elevated vertical heat fluxes act at different scales and can influence the thermal conditions in several tens of meters in the subsurface. Urban subsurface thus often stores a higher amount of heat than less affected rural surroundings. The stored heat is regarded as a potential source of low-enthalpy geothermal energy to supply the heating energy demands in urban areas.
In this work, we explore the technical geothermal potential of urban subsurface via ground coupled heat pumps with borehole heat exchangers (BHE). This is tackled by semi-analytical line-source equations. The commonly used response factors or g-functions are modified to include transient land surface effects. By including this additional source of heat, the new formulation allows to analyse the effect of pre-existing urban warming as well as different exploitation schemes fulfilling standard renewable and sustainable criteria.
In our generalized reference scenario, it is demonstrated that energy gains for a single BHE may be up to 40 % when compared to non-urbanized conditions. For a scenario including the interaction of multiple BHEs, results indicate that it would be possible to supply between 6 % and 27 % of the heating demands in Central European urban settlements in a renewable way. The methodology is also applied to a study case of the city of Zurich, Switzerland, where the detailed evolution of land use is available.