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Evaluating the sustainability of low enthalpy geothermal applications in a subsurface heat island

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Low enthalpy geothermal applications such as ground coupled heat pumps (GCHP) and groundwater heat pumps (GWHP) are an attractive low-carbon solution for heating and cooling of buildings. Their efficiency depends on the subsurface thermal properties (e.g. thermal conductivity, heat capacity) and the hydrogeological/thermal regimes (e.g. groundwater flow, depth of the water table, temperature profile). The geothermal potential is an indicator used to quantify and compare the ability to exchange heat with the subsurface/groundwater according to specific technologies. Even though it has no unique definition, it is often obtained as a combination of the subsurface hydrogeological/thermal properties and the thermal regime and, by means of GIS techniques it can be spatialized to obtain geothermal potential maps.

The subsurface thermal properties vary in space according to the geological setting, while the hydrogeological and thermal regimes can vary both in space and time according to the fluid and heat budgets of the aquifers. However, despite few studies consider the variability of the geothermal potential in time due to possible variations of the hydrogeological and thermal regimes, it is essential to evaluate the efficiency of geothermal systems in a changing environment such as subsurface urban heat islands. The hydrogeological/thermal regimes are not stationary, especially beneath big cities where land and subsurface uses control the elevation of the water table and the shallow subsurface thermal regime. Moreover, the heating and cooling demand of buildings may vary due to climate change effects such as global warming and atmosphere urban heat island.

The potential to exchange heat with the subsurface in the Milan metropolitan area was estimated from hydrogeological and thermal regimes simulated by a fluid-flow/heat-transport city-scale numerical model, calibrated on the current state. Several scenarios were generated changing the boundary conditions according to projected changes of (I) the air temperature (based on RCP 2.6, 4.5 and 8.5 scenarios), (II) the groundwater head, (III) the land use/city size and (IV) the geothermal uses (based on the increment of installations and changes of the thermal demand), to estimate the changes and the seasonal variability of the subsurface temperature at different depths in different zones of the city. Finally, the future variations of the thermal potential were estimated for heating and cooling seasons combining the scenarios-projected subsurface temperatures with the hydrogeological and thermal properties, also considering the variation of heating and cooling thermal loads.