Optimisation of geothermal resources in urban areas

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Optimisation of geothermal resources in urban areas

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Summary

Shallow geothermal energy has been experiencing a rapid growth due to the energy policies promoted by national and international agencies. Climate change challenges are indeed pushing to renewable, distributed and low-impact energy sources in the heating and cooling sector. This sector accounts for half of the primary energy consumption. The Shallow Geothermal Energy (SGE) systems are a promising solution due to the pervasive availability. Conversely, high initial drilling and investigation costs prevent a wider application. Uncertainty about the exchangeable heat represents another obstacle especially in densely inhabited areas where interactions with subsurface uses are common and complicate the quantification of the geothermal potential.

The aim of this Thesis is to contribute to the optimisation in the use of shallow geothermal resources in urban areas. Tools and technologies are developed able to identify and use the portions of the subsurface that allow for the maximum impact of SGE on the energy supply mix is performed.

Following the introduction about the technologies that enable the heat exchange with the soil, the research examines the available methods to qualitatively or quantitatively assess the geothermal potential. This allows to evidence how in urban areas the need arises for a sound evaluation that tackles the advection and dispersion contributes in the heat transfer. A specific adaptation was developed in this Thesis for a semi-analytical formula used for the quantification of the geothermal potential from Borehole Heat Exchangers (BHE) including these contributions. This allows to fully consider the hydrodynamic regime in areas where an aquifer is present.

This formula is hence included in the *rOGER* four step procedure that is proposed for the optimisation in the use of SGE. This process is based on the integrated use of Geographic Information System (GIS) and of numerical analyses. This combination leads to the definition of multiple key metrics useful for spatial planning.

Since land scarcity issues affect urban areas, horizontal exchangers are usually not employed and the first meters below the surface are underexploited. In this perspective, a novel energy wall system that can be externally applied to earth-contact surfaces of new or renewed buildings is proposed. The first prototype of the system was designed and installed in Turin as part of this study and equipped with a wide monitoring network. Thermal performance tests allowed to quantify the heat exchange rate during winter heating operation in the range of 15-24 W/m^2 while virtually not affecting the

thermal status of the subsoil except for the very narrow surroundings of the system. This suggests that potential superposition of this system with deeper SGE can be obtained.
Subsequently the method was applied to the specific settings of a central portion of Turin metropolitan area. The *rOGER* procedure was applied by building a Geographic Information System and setting up a detailed numerical model. Several sources were employed to populate the GIS. A trend in shallow geothermal energy use was defined and a scenario was built. A three-dimensional Finite Element thermo-hydraulic model was built to reproduce and predict the thermal and hydraulic regime. The built heritage influence was accounted by proper handling of the related information. Results were then post processed and allowed to evidence the high potential of the area and the preferential location for new installations.The results suggest that the potential can be more than doubled with respect to hydrostatic conditions when considering advective contribution with the formula proposed in this Thesis.
Local peaks values of the geothermal potential of up to 0.5 MWh/y per square meter were obtained. Superposition of BHE and energy wall potential suggest that up to 57% of the built heritage may fulfil its energy needs relying on SGE. The general validity of the method proposed in this Thesis was demonstrated by its application to the study area.