



Best practices for the sustainable management of the shallow geothermal energy resource in urban areas: insights from the case study of the City of Milan

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Recent EU directives and national regulations have encouraged the development of shallow geothermal energy as a renewable, low-emission source. Many cities in Europe are located in suitable areas with high geothermal potential and are therefore experiencing strong growth in the application of this technology for heating/cooling. On the other hand, densely populated urban areas experiencing a rapid development of shallow geothermal applications require appropriate tools to monitor and model the associated effects on both the quality and quantity of the available resource.

This work presents the case study of the metropolitan area of Milan, where the total number of geothermal wells (GWHP) has increased significantly in the last 5 years, covering a total thermal energy demand (including heating and cooling) from about 40 to 400 GWh/a. This very rapid growth and the resulting criticalities motivated the technical agencies and the stakeholders to improve the management of the shallow geothermal resource, which was addressed in the following steps.

- 1) Define common requirements for the development of a database of shallow geothermal installations, including the hydraulic and thermal regimes of the systems, and identify essential monitoring objectives for a better management of the subsurface low enthalpy thermal resource;
- 2) Study the cumulative impact of the existing geothermal systems in the entire Milan metropolitan area, delineating thermal capture and thermal disturbance zones using large-scale analytical and numerical models;
- 3) Assess the hydrogeological and subsurface thermal budgets on a regular grid basis to highlight the most critical areas in terms of hydrogeological (due to systems without groundwater reinjection) and thermal stresses (due to highly thermally unbalanced configurations).

The development of these tools and the implementation of a semi-automatic updating procedure aim to streamline the management of new requests with a quantitative view of the current exploitation of the geothermal resource in the Milan metropolitan area. Moreover, the implementation of future demand scenarios will improve the sustainability and reduce the risks of existing and planned systems.

