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A case study of thermal interaction at urban scale

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Due to the rise of awareness regarding the problem of climate change and greenhouse gas emissions, the European Union has increased its involvement in climate change mitigation policies. For this reason, investing in renewable energy sources has become urgent and mandatory.

Geothermal energy represents a large source of environmentally friendly energy with a low carbon footprint [1] and, thus, shows a high potential to help supply the thermal demands of buildings in urban areas which are usually characterized by a high-density population. However, especially in the shallow depths of urban areas, it is difficult to find natural undisturbed underground thermal conditions because of anthropic interventions. Moreover, these areas are being increasingly used for energy purposes, for example implementing shallow geothermal systems, as a proficient technology to provide clean thermal energy and supply thermal demands of buildings in both winter and summer seasons [2].

This abstract will focus on thermal interactions in urban areas with reference to the case of the city of Turin where, within the project of Metro Line 2 (ML2) currently at its outlined design stage, the thermal activation of both Cut&Cover and TBM tunnels and of metropolitan stations is envisaged, with the creation of an urban energy geostructure. This infrastructure will extend, in a first stage, in the central districts of the city for about 10 km with 1 depot, 13 stations and 14 shafts and will represent an essential milestone for the city transportation system, reaching decentralized areas and revolutionizing the surface space [3].

The subsurface in the central area of the city is characterized by sand and gravel deposits overlying, at approximately 40 m depth, clay layers, resulting in a very productive aquifer. Consequently, the geothermal and industrial use of water is of extreme importance [4] and more than 30 geothermal open loop systems are present, based on the public authorities databases. Together with a smaller number of geothermal closed loop systems, they exchange heat according to the user's seasonal cooling and heating demands, exploiting the subsurface resource. Moreover, anthropic entities such as underground car parks, urban tunnels and building basements exchange heat fluxes with the ground as well, affecting indirectly the aquifer and subsoil both hydraulically and thermally.

With the construction of the ML2 and the thermal activation of its structures, the actual conditions may be affected. It is indeed of interest to understand and evaluate the interaction between the ML2 and the other existing systems. To this extent, a 3D Finite Element numerical model with thermo-hydraulic coupling of the city area crossed by the first two ML2 lots was built by using the FEFLOW software [4]. Thanks to the interoperability of the numerical code and the Geographic Information System (GIS), it was possible to include in the model all the relevant information collected about hydrogeology, existing and planned geothermal systems and anthropic structures. Adequate material properties and boundary conditions were imposed (Figure 1(a)) on the basis of the data collected during the geognostic and hydrogeological survey campaigns of the outlined design. To reproduce the current thermally and hydraulically disturbed subsurface environment, the model was run to simulate a 5 years lifespan where all the existing systems are active and validated against available monitoring data. Subsequently the thermal activation of the ML2 was introduced and its effect on the subsurface was predicted for a period of 4 years.

Finally, through GIS processing, the results allowed to extrapolate thermal maps of the study area (Figure 1(b)). The modelling showed that the thermal alteration due to the ML2 is limited to the corresponding depths of its structures and downstream of the infrastructure. The central district of the city, where the largest number of existing geothermal systems are present, is the area that

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is shown to be most influenced and where the thermal plume of existing open loop systems may locally affect the thermal exploitation from the ML2 structures. It is also shown that open loop systems in the city impact massively the ground temperature more than the energy geostructures of the ML2 do.

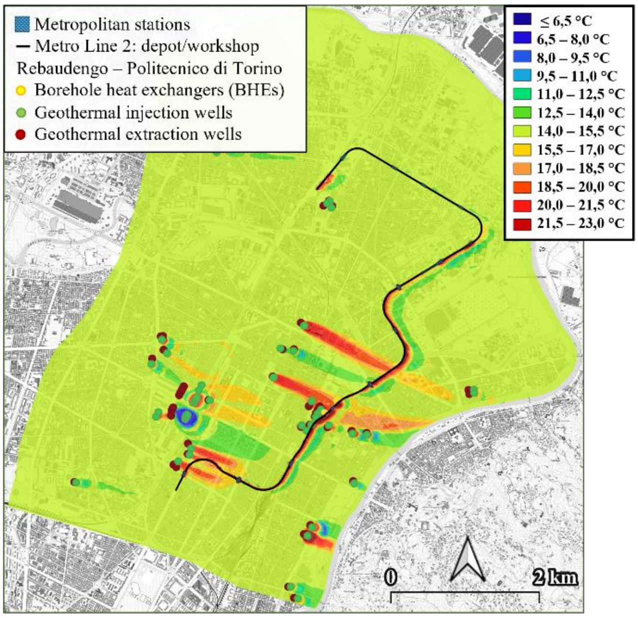

Figure 1: 3D FE model's hydraulic and thermal boundary conditions (a) and thermal map (at the TBM's depth) at the end of the last summer simulated for the ML2's thermal activation (b).

Contributor statement

Maria Romana Alvi: conceptualization, formal analysis, data curation, investigation, methodology, visualization, writing - original draft, writing - review and editing; Alessandra Insana: resources, conceptualization, investigation, supervision, writing - review and editing; Marco Barla: project administrator, funding acquisition, resources, conceptualization, investigation, supervision, writing - review and editing.

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