Sustainability and impact of Groundwater open loop and closed loop Heat Pump Systems in urban areas

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Shallow geothermal resources provide an enormous potential for emission-free energy and are already today a significant contributor among the renewable energy resources. Traditional use of geothermal energy has been limited to particular regions, but the resource is available worldwide, although scientific and technical solutions are at crux of making the resource exploitable.
Italian urban areas are characterized by centuries-old infrastructure: 35% of the Italian buildings stock is built before 1970 and about 75% is thermally inefficient. Besides, an important portion of buildings' energy consumption, from 60% to 80%, is attributed to space heating. In this context, defining a sustainable path to pursue 33.9% of energy consumption from renewable sources in the heating sector in 2030 is essential. Groundwater Open-loop and closed loop heat pumps, currently represent one of the most suitable technologies to be applied in the heating and cooling of buildings in Italian urbanized areas. However, different environmental aspects must be considered to minimize the impact of these systems on the subsurface and aquifers. As a consequence, for allowing the diffusion of geothermal systems, urban planning instruments cannot disregard the knowledge about geological and hydrogeological urban and regional settings.
Accurate modelling capabilities, and educated human resources, are prerequisites for the deployment of shallow geothermal energy extraction in a commercial setting. The main objective of this proposal is to develop a Decision Support System, based on AI - Machine learning approach to assess the energy exchanging potential in urban areas, with particular focus on a case study of a district of buildings of the University of Padua, evaluating the possible induced environmental impacts and benefits. To achieve this, will be developed and applied a comprehensive quantitative understanding of the mathematics and physics of ground thermal energy exchanging processes associated with different possible plant solution, both for open-loop and closed-loop systems. The possible short-circuit and hydraulic and thermal interferences risk and consequences will be evaluated by a detailed numerical modelling approach.
The primary aim of the research project, therefore, consists on develop simulation technology (in collaboration with experts of Trinity College in Dublin and Glasgow University, where is planned to spent a period of 3-6 months of the phd work), as well as fundamental AI based analysis, associated with heat disequilibrium and radial conductive/convective mixing phenomena, which may be introduced by significant energy exchange with the underground. Looking further, the project aims at quantitative understanding of the dominant processes of the fully coupled physical system, including forced convection in the geological formation and coupling to geological processes.
The modelling analysis will be supported by a real geothermal plant implementation, permitting the models calibrations and validations.
The project will be developed in collaboration with the UNIPD Sustainability Directorate (inside the project HESI, United Nations Higher Education Sustainability Initiative, and the Network of Italian Universities for Sustainable Development. The Phd will strictly links also with the Municipality of Padova City, and in particular with the 2ISECAP project, where the City of Padova decided to join the European network of Smart and Climate Neutral Cities. In April 2022, Padova has been included in the short list of 100 cities committed to achieve the climate neutrality by 2030.

The Phd activities will be support by additional funds assigned to Fina and Prin 2022 Projects