Geothermal energy potential of urban heat islands (GEO-URB)

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Introduction

The European Union (EU) presented in 2018 a long-term strategy leading to a climate-neutral economy by 2050 in order to keep the global temperature increase below 2 °C. In this framework, a key role is played by the integration of alternative and renewable energy sources in city energy planning. In the heating and cooling sector, a considerable alternative to fossil fuel is the utilization of shallow geothermal energy (SGE). In fact, the human influences on climate change are significant in urban areas. Urbanization alters the land thermal properties, changes the energy budget at the ground surface, changes the surrounding atmospheric circulation characteristics, generates a great amount of anthropogenic waste heat, and leads to changes in the urban environmental system. The impacts of urbanization on the thermal environment are generally termed as Urban Heat Island (UHI) effects, whose consequences on the subsurface temperature (T) and environment are still poorly understood. Several studies proved that urban development can be expected to raise ground surface temperatures of the composite urban landscape by a noticeable amount (2–5 °C), because buildings, asphalt and concrete surfaces have higher mean annual surface T than grass and bare soil.

State of art

Groundwater, especially shallow groundwater, gains or loses heat from the ground surface, whose mean annual T is controlled both by climate change and by land use. On this regard, both long-term trends and seasonal cycles in surface air (SAT), subsurface (SST), ground surface (GST) and groundwater (GWT) temperature changes must be considered. As T fluctuations at Earth' surface diffuse downward, their amplitudes diminish exponentially with depth.

The induced large-scale thermal anomalies in the ground are called Subsurface Urban Heat Islands (SUHIs). Borehole T profiles reveal the accumulated energy by characteristic trends, where the urban heating induces a growing T towards the surface. The anomalous urban GST anomalies propagate both upward into the atmosphere and downward into the subsurface.

With the worldwide urbanization growing at an unprecedented pace, there is an urgent need to improve our understanding of the SUHI and its environmental, social, and economical consequences. As a result of the increasing interest in geothermal use, the extra heat stored in urban aquifers is considered an attractive thermal reservoir for space heating and cooling. This is really important for highly urbanized cities with higher heating demand compared to the surrounding countryside. Efficiently and sustainably extracting this large amount of energy will not only fulfill part of the energy demand in urban areas, but also play a positive role in slowing down urban warming, because of the reduction of greenhouse gas emissions.

Objectives

The overall aim of the "Geothermal energy potential in urban areas: use of shallow urban subsurface resources at city scale (GEO-URB)" Project is to define the geothermal energy potential in the Padua urban area. The long-term natural heat component and the anthropogenic heat contribution influencing the SUHI will be discriminated. Specific objectives are

a) to detect the urban thermal footprint on the ground by analyzing SAT, SST, GST and GWT records available in the metropolitan and rural area of Padua, assessing the long-term natural heat component with respect to the possible anthropic contribution;
b) to assess preliminarily the geothermal potential of the shallow urban ground, suggesting its exploitation by means of 'active' SGE solutions, like ground water heat pumps (GWHPs) or aquifer thermal energy storage (ATES), and 'passive' SGE solutions involving thermo-active ground structures (e.g. energy piles, diaphragm walls, concrete slabs) which extract energy conductively through embedded pipe loops;
c) to develop a multi-scale approach, where a first local assessment and planning of geothermal utilization is embedded in a district or even city-wide integrated energy management plan;

The thermal potential assessment defined by GEO-URB will provide a scientific basis for the development of application-oriented management tools on the city-scale and the city quarter scale. With the expected results, architects, city planners and potential users can acquire initial site-specific information on the technical feasibility of SGE use in the context of city development and construction projects. In addition, the assessment results will support spatial planning and can be integrated into urban energy plans, which foster the use of renewable energy and reduce the use of fossil fuels.

General information

A period of abroad experience for further study in the specific field of the PhD topic is planned in collaboration with experts from one or more international institutions, already cooperating with Dr. Di Sipio and Prof. Galgaro (i.e. Center For Renewable Energy Sources in Athens Greece, Universitat Politècnica de València Spain, Friedrich-Alexander-Universität in Erlangen-Nürnberg Germany).

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