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The impact of heated basements on the performance of borehole GHEs

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Increasing urban development is leading to a growing demand for subsurface utilisation. As more infrastructure is built into the subsurface, heat from tunnels, sewers, and basements, among others, alter the thermal state of the ground, acting as sources and sinks of heat, leading to a net-increase of underground temperatures, a phenomenon known as the Subsurface Urban Heat Island (SUHI) [7-8]. This additional heat can have impacts on, for example, health and maintenance of underground structures, increased ventilation costs for underground spaces, and quality and quantity of groundwater flow [1,2]. However, this additional heat in the subsurface can also be harvested by ground-source heat pump (GSHP) systems to provide heating to buildings [3-6], operating more efficiently due to the higher ground temperatures and reducing these temperatures through operation, thus mitigating the risks and impacts of SUHI.

This work demonstrates how heated basements can contribute to the operation of GSHP systems to provide heating. The area of Downing College, located in central Cambridge, UK, is used as a case study site, investigating how much of the college's heating demand a number of geothermal boreholes could provide, when the heat from the building basements is taken into account and when it is not. Measured gas consumption data from the college are used to estimate the heat demand. The geology of the site is obtained by importing historical borehole records for the wider Cambridge area into the British Geological Survey (BGS) Groundhog® Desktop Geoscientific Information System and constraining the domain using BGS generated superficial deposit and bedrock geology maps, thus producing a 3D lithological profile for the region*, while the hydrological conditions were obtained using measured water level time-series data, from water wells in the area, curtesy of the Environment Agency. A total of 88 boreholes are considered, placed symmetrically in the college courtyard, between the main buildings. Typical single U-loop borehole configurations are used with pipes of 32 mm outer diameter. Acknowledging that the effect of heated basements is greater in shallower regions of the subsurface, two typical borehole length values are considered: 50 m, providing about 40% of the required heating load, and 100 m, providing 100%. The operation is simulated over 50 years, using a full 3D numerical model coupling heat transfer, groundwater flow, and pipe flow governing equations, created in COMSOL Multiphysics®. The temperature of the heated basements is assumed to be maintained at 18 °C throughout the simulation. During the first 10 years, the GHEs are not operating, to allow heat accumulation in the ground to occur from the heated basements, following which, 40 years of operating GHEs are simulated.

The results of the simulations suggest that an increase in performance occurs when heated basements are present. For all scenarios, the fluid temperatures keep decreasing over time, as the ground temperature around the boreholes keeps decreasing, making it more difficult to extract heat. Over the 50 years of simulation, the fluid temperature reaches a minimum of -3.20 °C and -2.13 °C for the 50 m GHEs, and 4.52 °C and 3.88 °C for 100 m GHEs, in both cases the first value being the simulation with heated basements and the second without. The COP values over time are presented in Figure 1-right, showing the difference in COP between the cases with and without heated basements increasing over time for both 50 m and 100 m GHEs, for the former at a higher rate.

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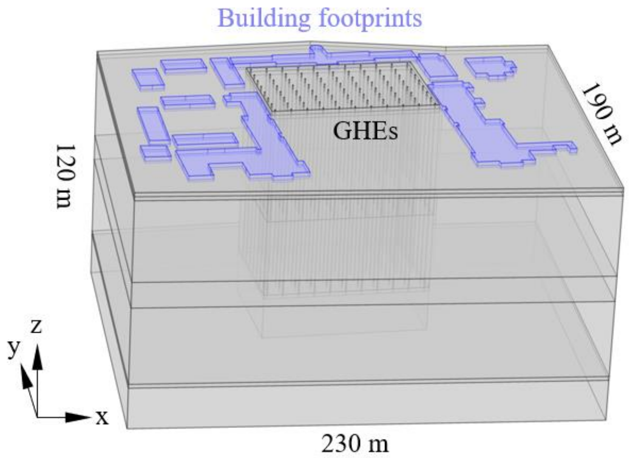
This increase corresponds to the increase in the average fluid temperature between the cases with and without heated basements, also shown in the figure, and reaches a maximum difference of about 0.08 for the 50 m GHEs and 0.05 for the 100 m GHEs, corresponding to a fluid temperature difference of about 1.10 °C and 0.65 °C, respectively. These figures correspond to a reduction in operating costs (assuming an electricity rate of £0.34 per kWh) of £17,352 for 50 m GHEs and £18,197 for 100 m GHEs. While for this case these values are relatively small considering 40 years of operation, the fluid temperature difference suggests that more energy can be extracted by the GHE borheoles when heated basements are present, especially for shorter boreholes, and thus potential savings could be obtained by reducing the number of GHEs.



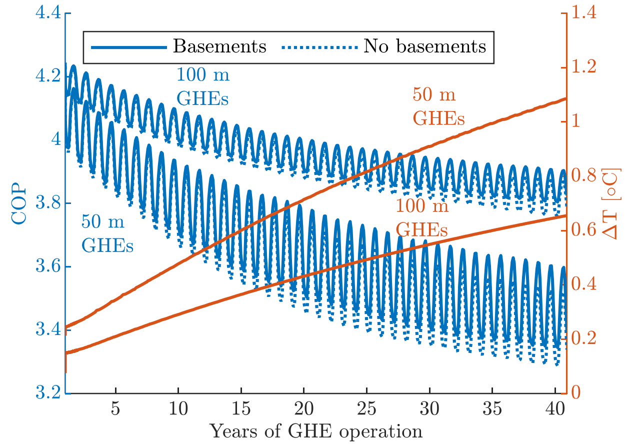


Figure 1: The left panel shows the numerical model of Downing College in Cambridge, UK, highlighting the building footprints and the borehole GHE field. The right panel shows results of the simulations (starting from the time the GHEs start opearating), in terms of the COP and average fluid temperature difference over time for the examined scenarios.

Data Availability Statement

*To undertake the subsurface modelling, the hydro-thermal properties of all materials were estimated based on the available literature, which is too long to include herein. A complete list will be made available in the near future in an upcoming journal publication by the authors.

Contributor statement

N. Makasis and M.J. Kreitmair: Conceptualisation, Formal Analysis, Investigation, Methodology, Visualisation, Writing. R. Ward: Data curation, Writing – Review and Editing. R. Choudhary: Conceptualisation, Supervision, Funding Acquisition, Writing – Review and Editing.

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