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Estimating the CO_2 mitigation potential of horizontal Ground Source Heat Pumps in the UK

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By 2020, the UK will need to generate 15% of its energy from renewables to meet our contribution to the EU renewable energy target. Heating and cooling systems of buildings account for 30%-50% of the global energy consumption; thus, alternative low-carbon technologies such as horizontal Ground Couple Heat Pumps (GCHPs) can contribute to the reduction of anthropogenic CO_2 emissions. Horizontal GCHPs currently represent a small fraction of the total energy generation in the UK. However, the fact that semi-detached and detached dwellings represent approximately 40% of the total housing stocks in the UK could make the widespread implementation of this technology particularly attractive in the UK and so could significantly increase its renewable energy generation potential.

Using a simulation model, we analysed the dynamic interactions between the environment, the horizontal GCHP heat exchanger and typical UK dwellings, as well as their combined effect on heat pump performance and CO_2 mitigation potential. For this purpose, a land surface model (JULES, Joint UK Land Environment Simulator), which calculates coupled soil heat and water fluxes, was combined with a heat extraction model. The analyses took into account the spatio-temporal variability of soil properties (thermal and hydraulic) and meteorological variables, as well as different horizontal GCHP configurations and a variety of building loads and heat demands.

Sensitivity tests were performed for four sites in the UK with different climate and soil properties. Our results show that an installation depth of 1.0m would give us higher heat extractions rates, however it would be preferable to install the pipes slightly deeper to avoid the seasonal influence of variable meteorological conditions. A value of 1.5m for the spacing between coils (S) for a slinky configuration type is recommended to avoid thermal disturbances between neighbouring coils. We also found that for larger values of the spacing between the coils ($S > 2$), a slinky coil diameter (D) of 0.8m might be a better choice in terms of heat extraction rate. The fluid temperature of the pipe had a direct effect on the heat extraction rates of the system. The coefficient of performance of a heat pump did not remain constant and depended on the operating conditions and outdoor temperatures.

The outcomes of this study will allow us to give recommendations to installers and relevant government bodies concerning the optimal configuration of future installations of horizontal GCHPs at UK developments. Finally, long-term simulations with the coupled JULES-GCHP model, using high resolution (1 km) meteorological (historical and projected data), soil physical and land cover data over the entire UK-domain, will allow us to explore the effect that global warming will have on future surface and soil temperatures, as well as soil moisture contents, and therefore its impact on the energy demand of the buildings and the CO_2 mitigation potential of this type of renewable energy.