2023_39_ESE_Pain: AI modelling of underground water for heating buildings

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The project mainly focuses on energy efficiency and control of the underground water that is available beneath our cities for heating and cooling. Furthermore, in this project, we will also be able to optimise the hot water energy usage and storage under our buildings, with the aim of minimising energy use from electricity and generating a healthy and comfortable living space indoors. The longer-term implications for the welfare of the local and other communities are immense, both directly through energy supply, reduced pollution (water and air) and climate change impacts and, indirectly, through economic impacts.

Underground water beneath our cities offers the potential to store large quantities of energy for heating our buildings. It can also provide an energy buffer for weather-based renewable energy systems such as wind and solar energy. This can work by storing the excess energy in the subsurface when there is excess renewable energy production. When required, the stored hot water is pumped to the surface and used to heat our buildings. The cool water from this process is also stored in the subsurface and reused, thus minimising energy loss.

Artificial Intelligence is having a large impact on techniques developed for modelling of computational physics problems. The project will use fast-running yet accurate surrogate models and also leverage a recent development which allows standard numerical discretisations to be implemented in AI libraries by setting the weights of neural networks analytically (with no training required). The combination of these techniques will allow a range of models to be explored, including developing efficient physics-informed neural networks.

The project will involve 3 parts: (i) prediction of the flow underground; (ii) data assimilation to help determine the water temperatures and geology underground from sensor measurements; (iii) control of the underground resource by extracting an optimal amount of hot water as well as storing hot water underground. For (i) we will use new rapid running AI surrogate models as well as AI models formed by analytically specifying the weights of the neural networks. The key point is that these neural networks or AI models enable optimisation for data assimilation and control using the optimisation engines built into AI libraries e.g. the ADAM optimiser. Therefore, data assimilation and control become more tractable for challenging problems of practical interest.