Modelling Borehole Thermal Energy Storage using Curtailed Wind Energy as a Fluctuating Source of Charge

Christopher S. Brown[1,*], Thibaut Desguers[2], Andrew Lyden[2], Isa Kolo[1], Daniel Friedrich[2] and Gioia Falcone[1]

*christopher.brown@glasgow.ac.uk
[1]James Watt School of Engineering, University of Glasgow, Glasgow, G12 8QQ.
[2]School of Engineering, University of Edinburgh, Edinburgh, EH9 3DW, United Kingdom

Introduction

In the UK, net zero carbon targets have been set to reduce emissions of carbon dioxide and other greenhouse gases by 2050. Renewable resources have the potential to contribute to this goal, but their energy supply fluctuates and does not always coincide with demand. Methods of thermal energy storage can, therefore, be considered to help decarbonise the heating sector. Borehole heat exchangers can be used for heating, cooling and thermal energy storage by circulating fluid within a u-tube heat exchanger (Figure 1). This work evaluates the potential to use curtailed wind as a source of charge via air sourced heat pumps for borehole thermal energy storage for the King's Buildings at the University of Edinburgh. The key aims were to i) compare whole-systems and subsurface modelling solutions for discrepancy, ii) evaluate heat flux in the subsurface, and iiii) test the influence of groundwater flow on heat recovery.

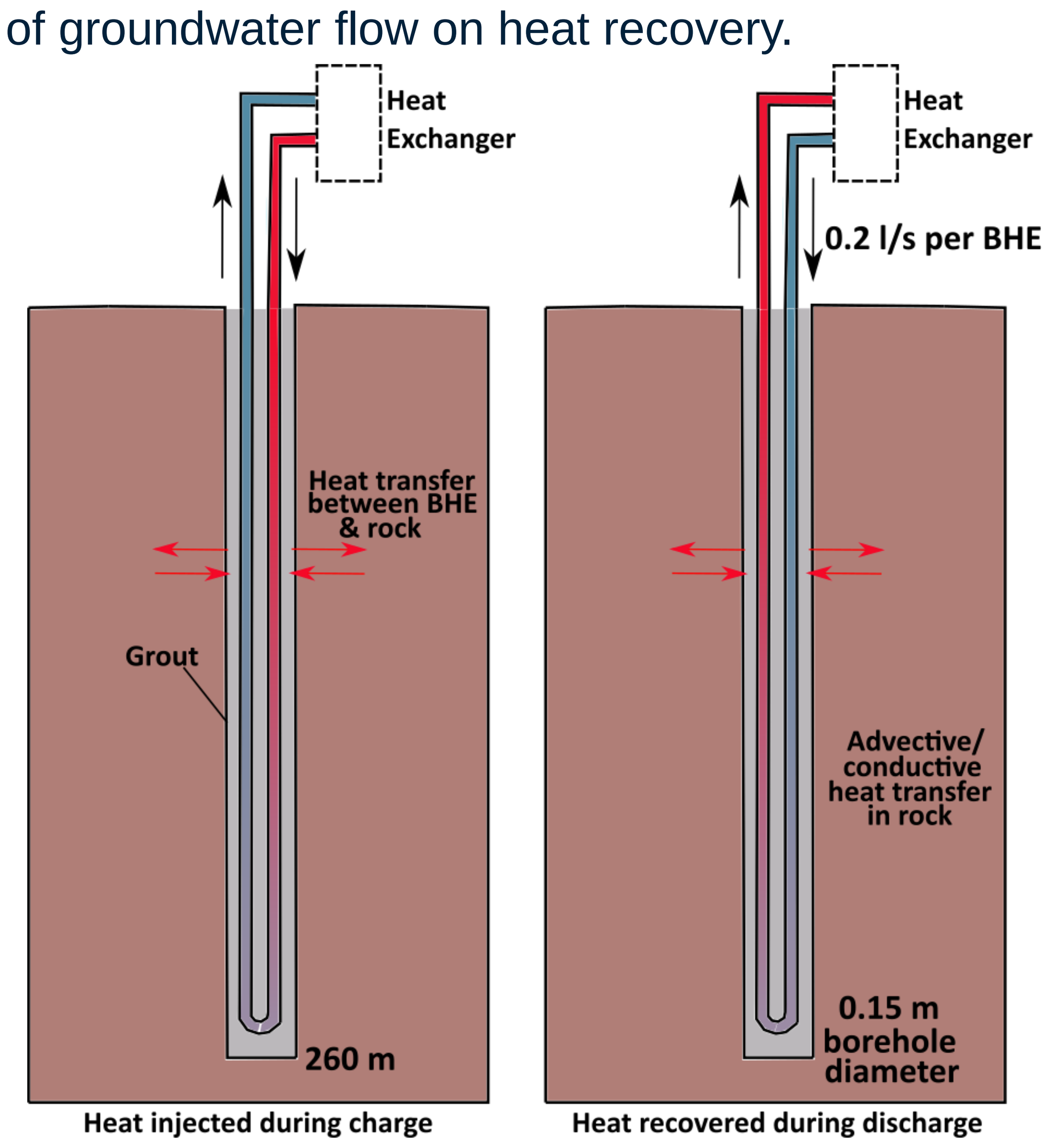
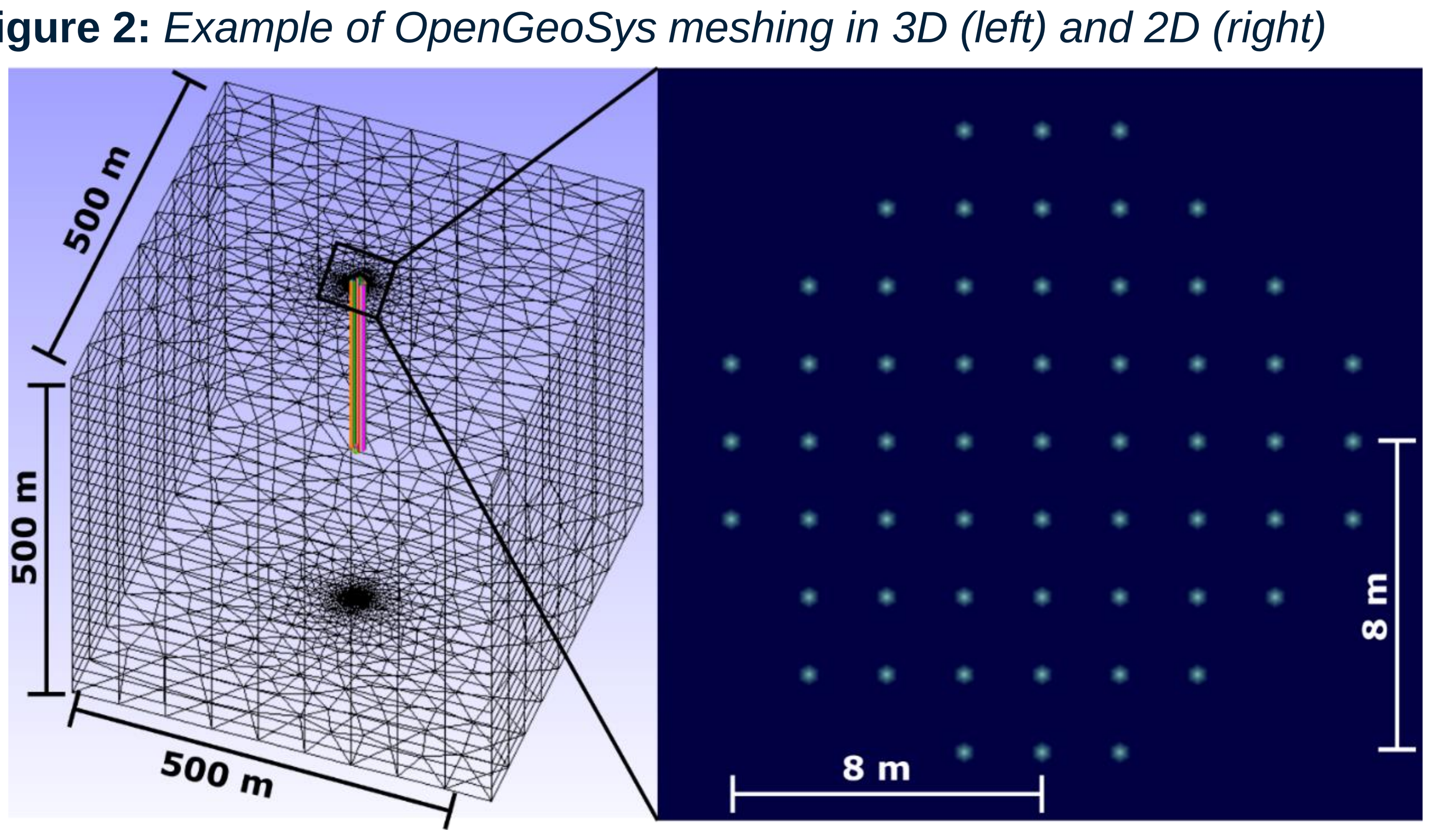


Figure 1: *Schematic of a borehole thermal energy storage system during charge and discharge. Note only one borehole shown out of an array.*

Methods

Curtailed wind data was taken from above the SCOTEX (B6) boundary and modelled to supply the King's Buildings at the University of Edinburgh which consists of 35 buildings with a peak thermal power demand of 9.62 MW in winter and peak daily energy demand of 157 MWh. Modelling was undertaken to evaluate the potential recovery of heat stored via air source heat pumps. Data was modelled on TRNSYS (whole-systems model), before utilizing this in a subsurface model on OpenGeoSys software. OpenGeoSys is a finite-element software capable of modelling intricate subsurface details, such as groundwater flow, which TRNSYS cannot model. Simulations were undertaken for 2 years.

Figure 2: *Example of OpenGeoSys meshing in 3D (left) and 2D (right)*



Acknowledgments

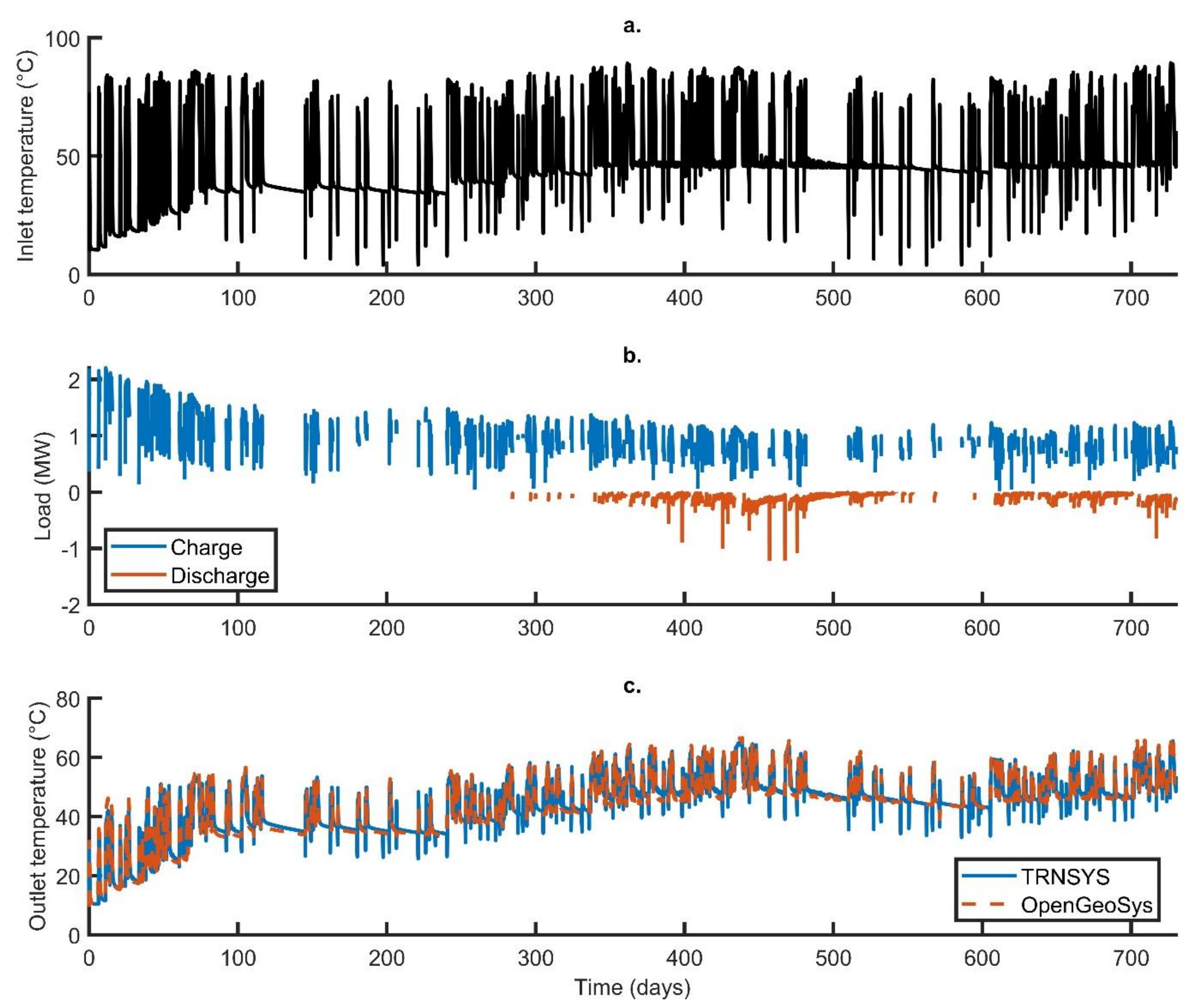
This work was supported by the UK Engineering and Physical Sciences Research Council (EPSRC) grant EP/T023112/1. The funding source was for the INTEGRATE (Integrating seasoNal Thermal storagE with multiple enerGy souRces to decArobonise Thermal Energy) project.

Results

TRNSYS and OpenGeoSys show good comparison with outlet temperature generally within 2 ºC of each other (Figure 3). Detailed evaluation of the subsurface in a conduction only setting highlights:

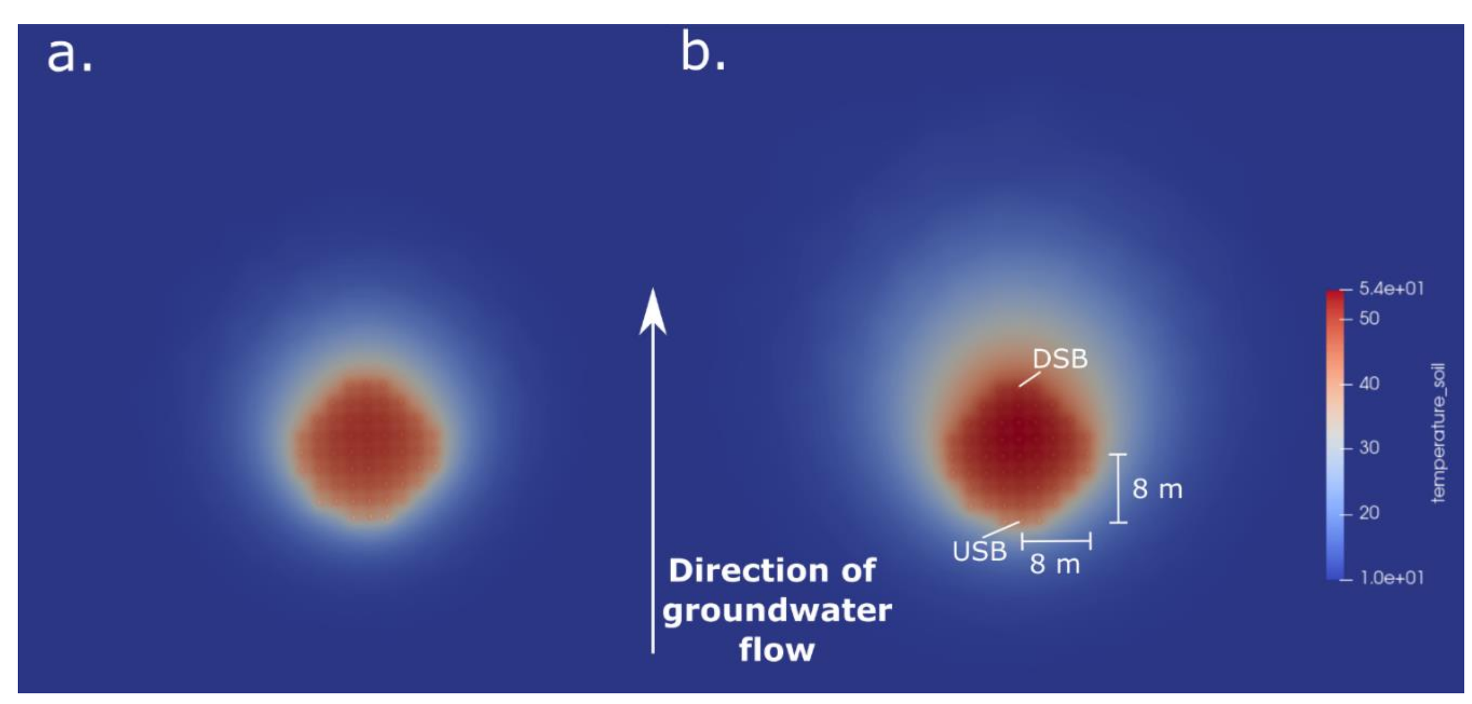
1) Charge dominates the first 100 days as the system warms without recovering heat due to a district heat network limitation in the system.
2) Highest thermal load imposed was 2.18 MW.
3) More warming towards the centre of the array.
4) Discharge increases between day 350 and 550 with peak loads of 1.2 MW drawn from the thermal store.

Figure 3: *(a) Inlet temperature, (b) thermal loads and (c) outlet temperature.*



A Darcy velocity of 1e-7 m/s was imposed on the system (Figure 4), resulting in increased thermal losses. Heat was transported up to 40 m from the array. Discharge temperature decreased by up to 5 ºC (4 kW per borehole).

Figure 4: *2D slices at ground level for (a) 1 and (b) 2 years.*



Conclusions

1) Comparison of borehole thermal energy storage models on TRNSYS and OpenGeoSys show minimal discrepancy. Although the latter requires far longer computational time.
2) Numerical modelling allows the integration of detailed geological parameters (i.e., groundwater flow).
3) Groundwater flow impacts system performance as it removes heat stored during charge, reducing the efficiency.

Scan this QR code to find a full version of our paper:

Brown, C.S., Desguers, T., Lyden, A., Kolo, I., Friedrich, D. and Falcone, G., 2023, February. Modelling Borehole Thermal Energy Storage using Curtailed Wind Energy as a Fluctuating Source of Charge. In *Proceedings of the 48th Workshop on Geothermal Reservoir Engineering, Stanford, CA, USA* (pp. 6-8).