Geothermal Energy from a Notional 6km Deep Borehole Heat Exchanger in Glasgow

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Background

- Glasgow is rigorously pursuing a net-zero plan.
- There are talks on exploring the possibility of a 6 km geothermal well which is most likely going to be a deep borehole heat exchanger (DBHE).
- So far, the DBHE concept has been explored (and implemented) for space heating with most studies reaching a depth of <3 km.
- Few studies go as deep as 6km, and most focus on power generation.
- One study claimed that 3 MW_e can be generated from a 3 km well in Texas, US (Davis and Michaelides, 2009); others investigated 6 km abandoned oil wells for geothermal power generation recording a net electrical power of ~134 kW (Cheng et al., 2013; Alimonti and Soldo, 2016).
- What thermal power is obtainable in Glasgow using a 6 km borehole?

Deep Borehole Heat Exchanger Model

- A 6 km DBHE is modelled, where the central pipe produces fluid ('outlet') and the annular space injects fluid ('inlet') in a closed-loop system (Figure 1).
- A transient numerical model was developed on OpenGeoSys using the 'dual-continuum method' with finite elements.
- Dual-continuum method: DBHE is modelled using 1D finite elements while surrounding rock employs 3D prism elements.
- Homogenous design is adopted for parameterisation studies over one heating season – 6 months.
- Focus is on thermal power which can give initial estimates on prospects for electricity generation.

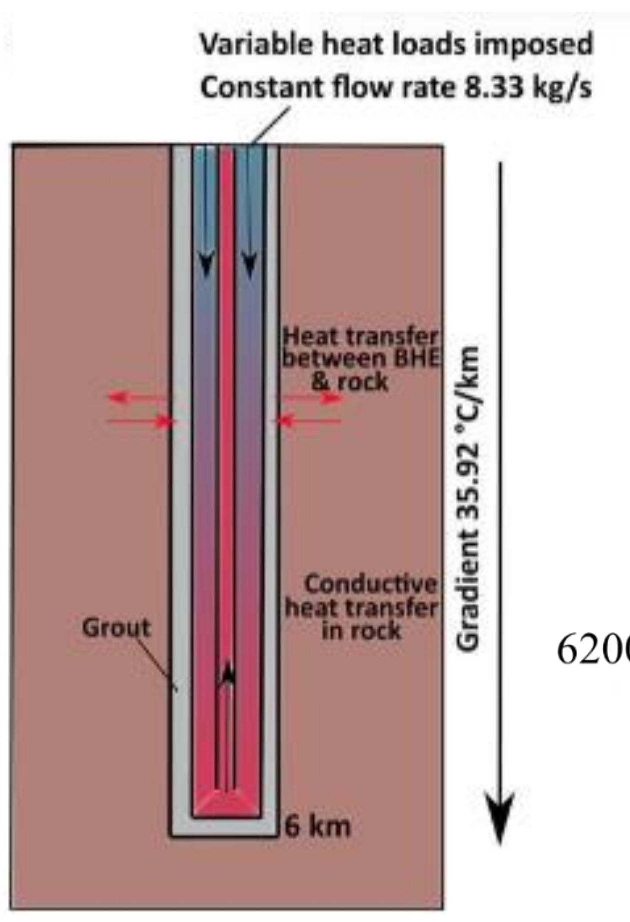

Figure 1: Schematic of a deep borehole heat exchanger (DBHE)

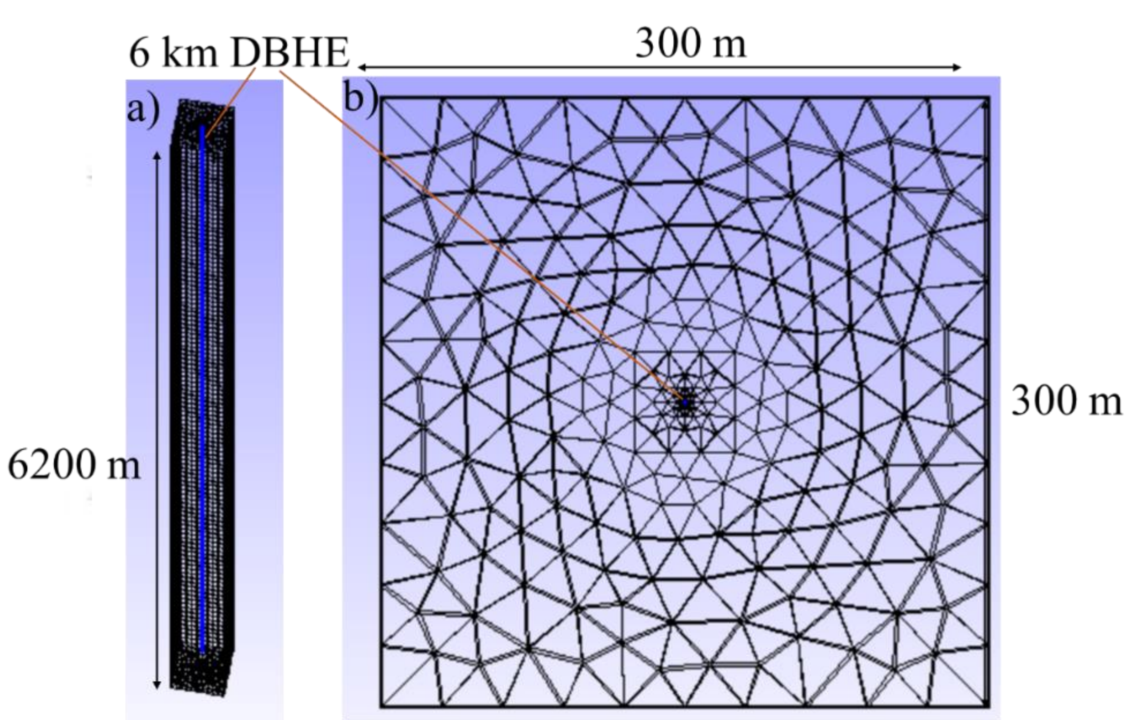

Figure 2: Geometry and mesh set-up

Model Set-up and Parameters

- Model (Figure 2) adopts a surface temperature of 10.17 ºC and a geothermal gradient of 35.92 ºC/km.
- Water is used as heat transfer fluid based on higher efficiency in relation to diathermic oil (Alimonti and Soldo, 2016).
- A base thermal conductivity of 2.5 W/(m·K) is used and then varied.
- A base mass flow rate of 8.33 kg/s is used and then varied.
- Constant heat load and constant inlet temperature boundary conditions (BC) have been adopted.

Acknowledgements

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Results and Discussion

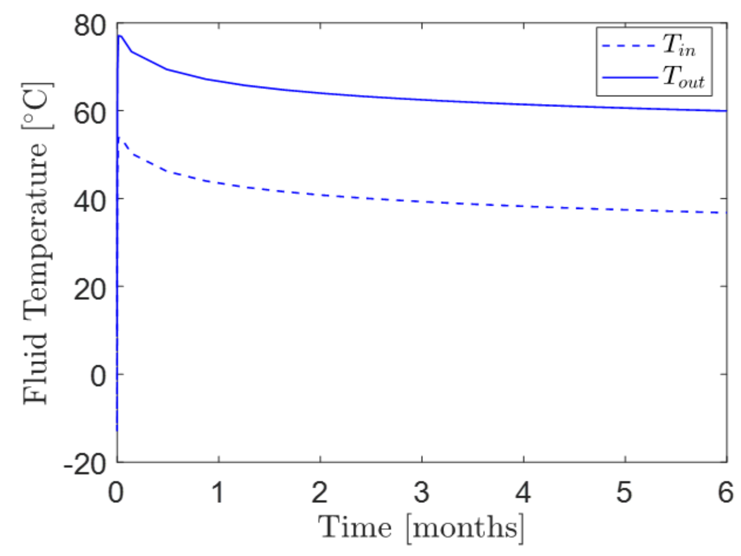

Figure 3: Fluid inlet (Tin) and outlet (Tout) temperatures for 800 kW load.

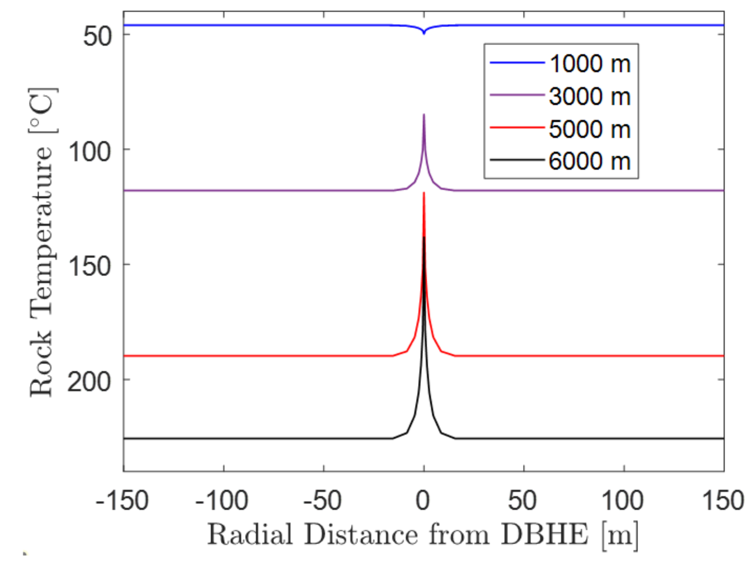

Figure 4: Rock temperatures for 800 kW load.

- After 6 months, outlet temperature (Tout) falls to 60 ºC due to thermal drawdown.
- For depths ≥ 3 km, heat is extracted, but there is heat gain for ≤ 1km.

Table 1: Fluid inlet and outlet temperatures after 6 months for different heat loads

Heat Load [kW]	150	200	500	700	800	1000	1200
Inlet Temp. [°C]	96.20	91.63	64.20	45.91	36.77	18.48	0.19
Outlet Temp. [°C]	100.55	97.43	78.69	66.19	59.95	47.45	34.96

- Assuming a minimum outlet temperature of 100 ºC for electricity generation, only 150 kW thermal power can be supplied. This increases to 500 kW for a cut-off of 74 ºC.
- Low thermal power relative to geothermal power plants which typically have ≥1 MW_e installed power (approximately 10% of generated thermal power).

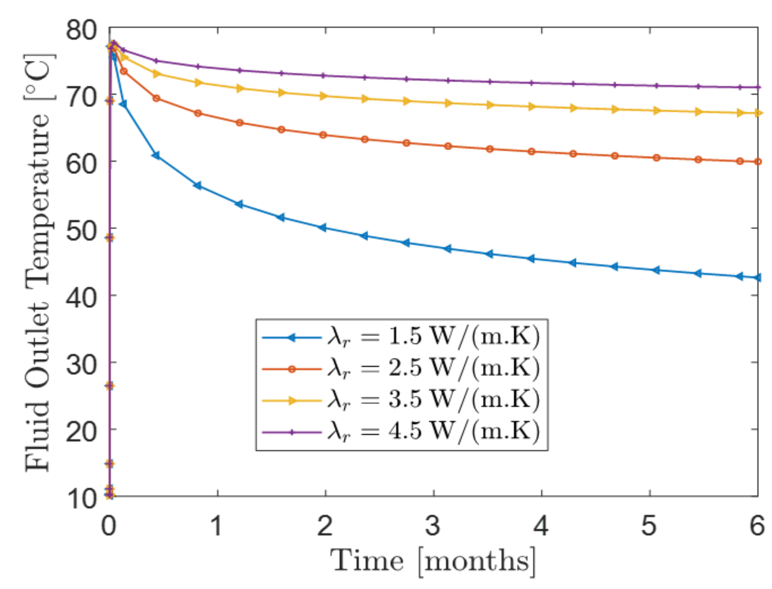

Figure 5: Outlet temperatures for varying thermal conductivity.

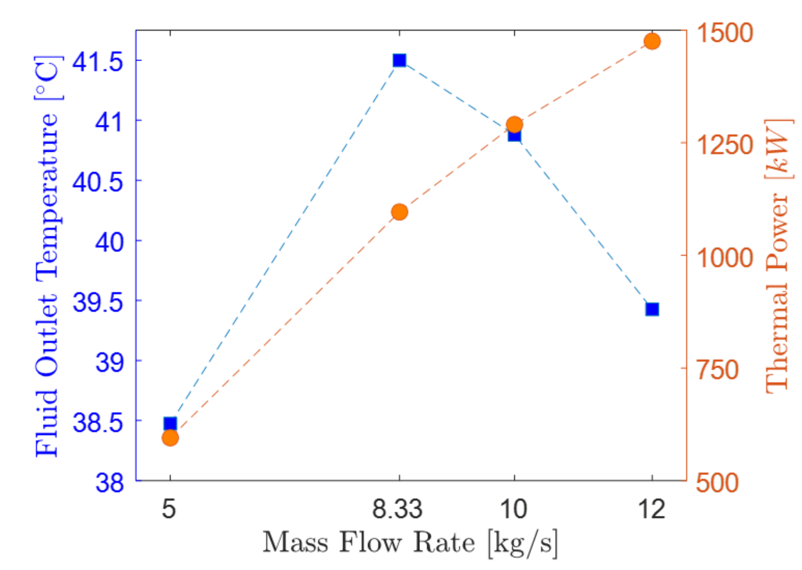

Figure 6: Thermal power with varying mass flow rate and an inlet temperature of 10 ºC.

- There is an increase in outlet temperature with increase in thermal conductivity.
- The optimum mass flow rate is 8.33 kg/s for an inlet temperature of 10 ºC.

Conclusion

- Using a cut-off outlet temperature of 100 ºC for electricity generation, around 150 kW thermal power can be supplied by the DBHE. A thermal power of 500kW can be obtained with a 74 ºC cut-off.
- Increasing the flow rate increases thermal output. However, the optimum flowrate is 8.33 kg/s with an inlet temperature of 10 ºC.
- Insulating the top part of the DBHE is likely to improve performance.
- Most geothermal power plants have installed capacities ≥ 1 MW_e electricity which cannot be supplied by a very deep DBHE despite the huge cost of drilling to 6 km.
- Drilling a 6 km conventional DBHE appears not to be viable economically; such DBHEs are probably more suited for repurposing infrastructure, such as oil and gas wells, which offsets drilling cost.
- Future work should incorporate lithological layering, isobutane as circulating fluid, and long-term operation of the system.

References

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