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Accelerating the economic utilisation of deep geothermal energy in Northern Ireland

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INTRODUCTION

Northern Ireland contains some of the UK's most prospective geology for geothermal energy, with several preserved Permian–Triassic sedimentary basins hosting Warm–Hot Sedimentary Aquifers (W-HSAs). These aquifers support geothermal heating and, where hot enough, power generation, in many countries, yet Northern Ireland, like most of the UK, has no deep geothermal developments. The UK's only example remains the Southampton scheme from the 1980s.

Drilling over several decades has confirmed the potential of the Permo-Trias W-HSAs. Since 2021, geothermal has been integrated into Northern Ireland's energy strategy, supported by a Geothermal Advisory Committee, new research on resource potential and deployment barriers, and major investment such as the £3m GeoEnergy NI project and a £18m PEACEPLUS-funded cross-border programme.

Despite this momentum, a first deep geothermal demonstration project has yet to emerge. Causeway Energies, has applied commercial and analytical methods from the oil and gas sector to identify viable opportunities. Its integrated assessments highlight a "Goldilocks zone" at 500–1500 m depth, where modern industrial heat pumps can efficiently lift temperatures by 60 K or more, enabling competitive, lower-risk geothermal heat without drilling to greater depths.

METHODS

We have explored the following geoscience, engineering and economic aspects of DGE in Northern Ireland:

1. Identification of the key geothermal system archetypes applicable in the region, with a focus on the Permo-Trias W-HSA play;
2. Integrated lithospheric heat flow modeling with stratigraphic depth maps, deriving play attribute maps of expected reservoir depth and temperature;
3. Examination of existing porosity, permeability, production test data, and geological parameters to highlight the key reservoir productivity controls of the play;
4. Finite element simulation modeling of potential open-loop doublets in the Permo-Trias Sandstones to predict thermal power potential for IHP use in the Deep Geothermal Heat Pump system/method;
5. Integrated feasibility studies for a range of client locations ad heating demands to illustrate benefits, costs and economic performance of a range of depth scenarios; and
6. Identification and mapping of key demand market sectors and locations that can utilize geothermal energy for heat.

RESULTS

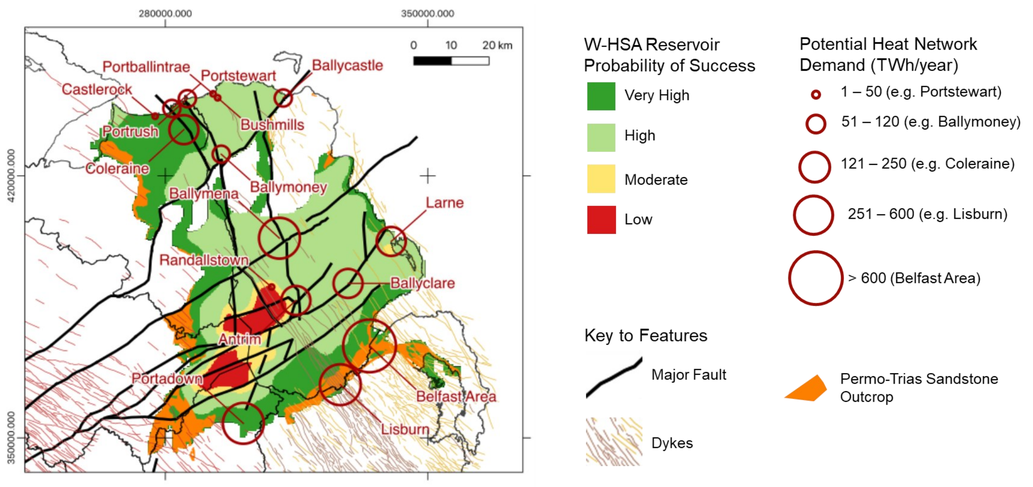


Figure 1: W-HSA Aquifer play fairway map for the Permo-Trias Sandstones in Northern Ireland. Probability of Success for sustainable flow rates (without EGS) illustrated in "traffic light" colour segments, based on depth to top Sherwood Sandstone and porosity-depth cutoffs . Town heat network demand is from (IDEA (2019) and the symbols are scale to a natural breaks (Jenks) distribution. Faults and dykes from Anderson et al. (2018) and outcrop of Permo-Trias Sandstone from Wilson et al. (2023).

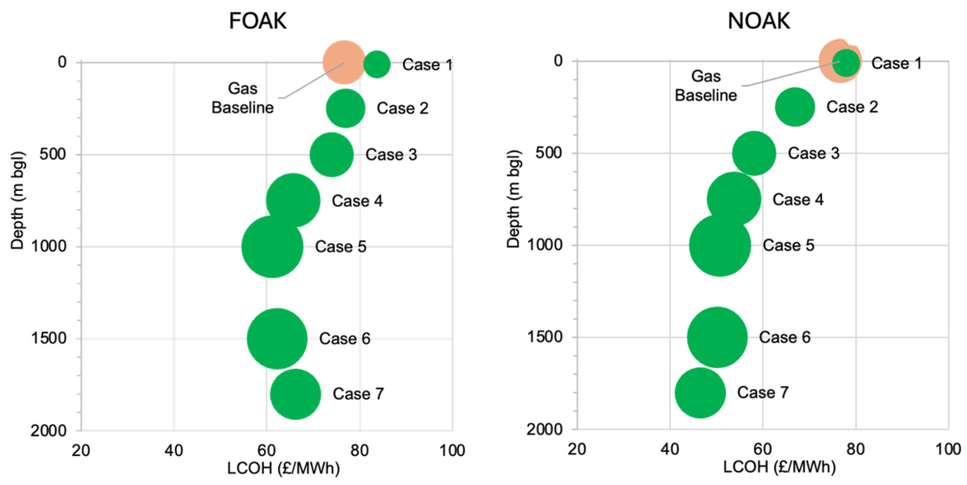
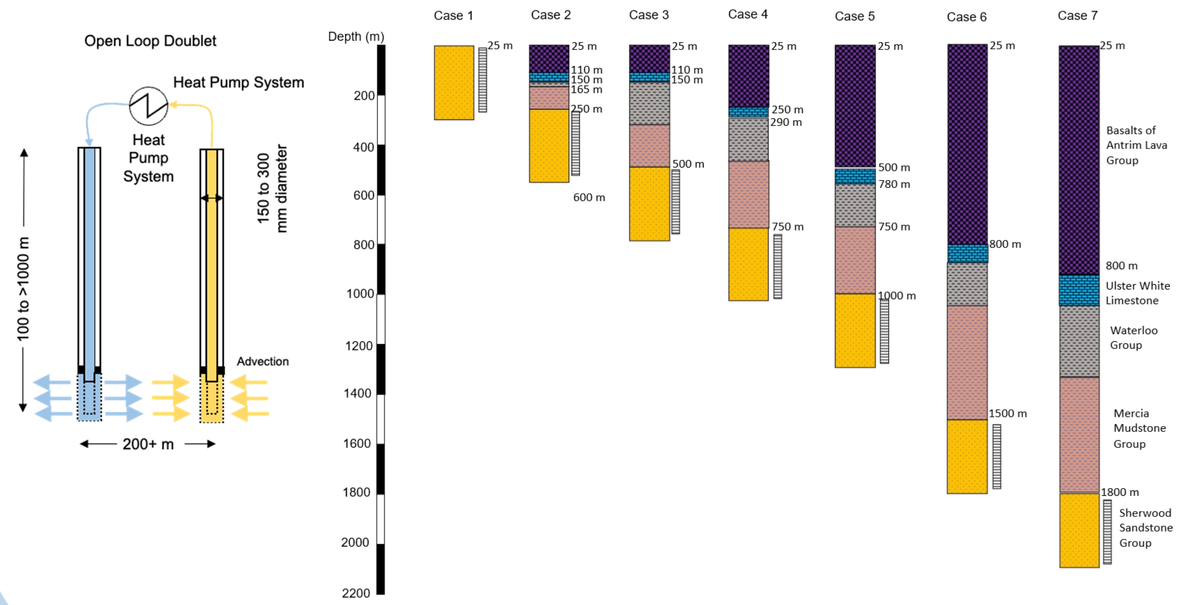


Figure 2: Levelised Cost of Heat (LCOH) variation with depth of reservoir. (a) First doublet in a new project area. (b) 20th doublet in a project area. First of a Kind (FOAK) economics included significant development expenditure (Devex) which is at risk capital deployed to reduce subsurface risk and uncertainty. Illustrative improvement to Nth of a Kind (NOAK) include reduction in devex and 20% reduction in drilling costs.

CASES FOR LCOH MODELING



DISCUSSION

- Thermal productivity of the W-HSA is controlled by temperature (thermal drawdown) and flow rates. Boosting by heat pumps makes up for resources that have temperatures lower than the required target temperature.
- Temperature modelling and interpolation to stratigraphic horizons allows for a more interactive approach to resource mapping relative to customer demand.
- Matrix porosity and permeability deterioration with depth, particularly deeper than 1400 m, may be offset by natural fractures but we currently depict yellow and red segments on the play map to be increasing risk.
- Emerging evidence that there will be significant horizontal anisotropy in the permeability at macro scale associated with faults/fractures with transmissivity increasing to parallel with the current principal horizontal stress.
- The presence of volcanic dykes and sills may both benefit the development of open loop doublets and be a risk to reservoir transmissivity and performance.
- Economics are controlled by the balance of capex and opex in Levelised Cost of Heat (LCOH) calculations. Opex is mostly electricity costs, so the Coefficient of Performance (COP) of the heat pump system is key. Higher temperature resource, if not accompanied by flow rate reduction, will allow both more thermal drawdown and a higher COP.
- Several cost factors may improve with project by project learning including drilling and heat pump performance.

CONCLUSIONS

- The geological controls including depth, thickness, productivity, temperature impact the key attributes of a Deep Geothermal Heat Pump abstracting heat by aquifer fluid flow in open loop doublets or pairs of abstraction and injection boreholes.
- These attributes, except for productivity, generally increase with depth so to a depth of 2000 m, where reservoir flow rate becomes higher risk, combine to improve the efficiency and power of the associated large heat pump system, more than offsetting the additional devex and capex of drilling deeper.
- The LCOH of the units are therefore competitive with the gas baseline and are 75% less emissions, the difference increasing with lower electricity carbon intensity.
- The ability to economically utilise W-HSA geothermal energy from a range of depths for the same higher target sink temperature implies a larger resource potential compared to a system/method for direct use without heat pumps.
- An overlay of prospective heat network demand on the pre-feasibility play map (Figure 1) highlights key leads for first development (FOAK) and some of the attributes to be assessed in feasibility and development.
- Risk and uncertainty reduction and cost improvements through learning and innovation within and between Deep GHP projects will serve to accelerate deployment from the first pathfinder projects.
- Further research will add more insight and value to Northern Ireland's geothermal opportunity. However, it is new data from design, appraisal and building the pathfinder projects that will refine the techno-economic description and hence value proposition of the sector in Northern Ireland and other regions in the UK and Ireland and elsewhere.

Acknowledgements

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REFERENCES

Todd *et al.* 2026. Technology innovation to accelerate the utilization of conventional deep geothermal energy: a case study from Northern Ireland. GeoEnergy, submitted. Please contact lead author for pre-print and reference list.

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