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The potenential for thermal energy from Tunnels beneath Manchester and Crewe: a case study

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The first section of high speed railway in the UK was built between London and the Channel Tunnel (High Speed 1 or HS1) and has been operating since 2007. Current construction of High Speed 2 (HS2) Phase One will take the network from London to Birmingham with Phase Two sections between Birmingham and Manchester due to be built by 2035. The University of Leeds have been working with HS2 Limited to identify the most suitable locations for use of tunnel sourced thermal energy, to gain an initial idea of likely scale of the thermal resource, as well as consider financial viability. Attempts to incorporate heat transfer pipes for thermal activation of tunnel linings in the UK [1] had previously not been successful due to a combination of economics and insufficient programme time to permit necessary stakeholder engagement and accommodate the design and construction changes. With awareness and policy support for green energy growing in the last decade, HS2 Phase 2b represents a significant opportunity to (i) commence the design process sufficiently early to encourage adoption of an energy tunnel solution; (ii) develop a novel case study of energy geostructures used with district heating networks. A summary of the key findings of this study are given below.

Tunnels at Crewe and Manchester will comprise twin bored running tunnels, 8.8m and 7.5m in diameter, supported by precast segmental linings, and 6.8km and 12.8km in length, respectively. The ground conditions vary along the length of the proposed route, including sequences of glacio-fluvial deposits and/or glacial till overlying Triassic bedrock of the Mercia Mudstone or Sherwood Sandstone Groups. The glacial tills and Mercia Mudstone can be assumed to have a thermal conductivity of approximately 2 W/mK, but much higher values may be appropriate for the Sherwood Sandstone depending on the horizon, fracture characteristics and groundwater flow conditions. As well as the ground thermal and hydrogeological conditions, the size of the thermal resource within and around the tunnels will depend significantly on the internal air flow and temperature conditions. Using design charts [2, 3], heat transfer rates of between 12 W/m^2 and 25 W/m^2 were chosen for sensitivity analysis.

These outline heat transfer rates were applied to 500m long lengths of tunnel that could be accessed from the four tunnel portals and from either side of six ventilation shafts that will be constructed along the route. This suggested that each portal could provide sufficient thermal energy to supply up to 500 homes, with each ventilation shaft having double that capacity. Final resource size would depend on the detailed tunnel ventilation design, as well as outcomes of ground investigation which are currently in progress.

Early consultation with stakeholders along the route suggested a genuine enthusiasm and appetite for future consumption of tunnel sourced thermal energy. However, a route to implementation including outside stakeholders remains challenging and requires new approaches. In the UK, the government is in the process of designating heat network zones [4], and implementation of these zones in the future will make it easier to supply properties adjacent to the tunnel route with thermal energy. Heat networks already being developed in Crewe and in Manchester could also be potential future customers for tunnel energy. In addition, anchor loads could be developed related to hospitals, university buildings and social housing estates that have been identified close to the route of tunnels. However, careful planning is required to ensure alignment of construction and public sector decarbonisation plans.

While the greatest environmental and social benefit could be drawn from using the tunnel heat beyond the boundary of the HS2 project, without detailed information about future customers and their energy demands it is hard to determine the financial viability

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for this scenario. Therefore costs and benefits of adopting energy tunnels connected to ground source heat pumps were determined for the case of providing heating and cooling for self consumption within station buildings, over station development and other structures related to railway operation. These were compared with adoption of air source heat pumps (ASHPs) as a suitable counterfactual given operation of the scheme will not take place for a further ten years or more, when use of gas boilers is not expected to be permitted. For these conditions, the geothermal activation of the tunnel linings was shown to generate positive financial returns, subject to economic uncertainties such as interest rates, inflation and energy prices. Energy tunnels were able to deliver heat at lower costs compared with ASHPs when real interest rates (interest rates minus inflation, a measure of the real cost of borrowing) are below 4%. For context real interest rates in the UK are currently negative as inflation is greater than the Bank of England interest rate. Assuming interest rates at 3.5%, Figure 1 shows the sensitivity of payback time for energy tunnel construction to key input parameters. Additionally, a Monte Carlo analysis for 20,000 simulations found that 80% of cases would return a positive net present value, 75% of cases would deliver an internal rate of return over 3.5% and payback in under 30 years.

Taken together, the economic indicators, the size of thermal resource and positive stakeholder engagement suggests that the option to deploy energy tunnels should be developed further as the scheme design proceeds. Technically this would include specific ground investigation for thermal and hydrogeological parameters, tunnel ventilation design, and determination of energy demands. These steps also need to be accompanied by careful alignment of the design and construction programme with extensive liaison and coordination with offtakers, and parallel heat network development, substantially increasing the challenge of implementation.

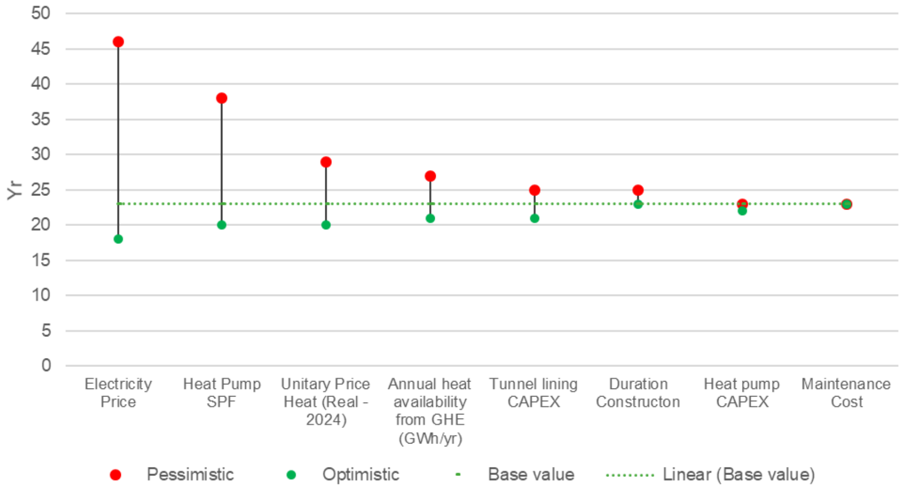

Figure 1: Sensitivity analysis of input conditions on payback time.

Contributor statement

David Barns: Investigation, Methodology, Project administration, Writing – Original Draft, Writing – Review & Editing. Fleur Loveridge: Conceptualization, Funding acquisition, Methodology, Supervision, Writing – Original Draft, Writing – Review & Editing . Tristano Sainati: Formal analysis, Methodology, Visualization, Writing – Review & Editing. Liam Duffy: Conceptualization, Funding acquisition, Writing – Review & Editing. Heather Donald: Funding acquisition, Project administration. Zoe Edmonds: Project administration.

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References

[1] Nicholson, D. P., Chen, Q., de Silva, M., Winter, A. & Winterling, R. (2014). The design of thermal tunnel energy segments for Crossrail, UK. *Proceedings of the Institution of Civil Engineers - Engineering Sustainability* 167, 118–134.
[2] Dornberger, S. C., Rotta Loira, A. F., Zhang, M., Bu, L., Epart, J-L. & Turberg, P. (2022). Heat exchange potential of energy tunnels for different internal airflow characteristics. *Geomechanics for Energy and the Environment* 30, 100229.
[3] Di Donna, A. & Barla, M. (2016). The role of ground conditions on energy tunnels' heat exchange. *Environmental Geotechnics* 3, 214–224.
[4] BEIS (2021) Proposals for heat network zoning. https://www.gov.uk/government/consultations/proposals-for-heat-network-zoning.