Department for Energy Security & Net Zero

Cover Note

UK Geothermal Energy Review and Cost Estimations

June 2025

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Contents

Introduction

This cover note accompanies the report commissioned by Department for Energy Security and Net Zero (DESNZ) to Arup titled "UK Geothermal Energy Review and Cost Estimations". The work ran for 12 months concluding in December 2024. This was updated by DESNZ in May 2025 to incorporate hurdle rate estimates obtained through a DESNZ commissioned project across renewable power generation technologies[1], which included geothermal energy.

DESNZ conducted pre-publication engagement with a small representative group of industry stakeholders. The stakeholders were chosen to ensure technical expertise across geothermal power and heat generation. Insights from this engagement have informed the content of this cover note.

The purpose of this note is to provide a clear context for readers of the report by:

- outlining the research's purpose, scope, and assumptions;
- exploring areas for future updates to this research; and
- outlining its intended use.

Project Scope

The purpose of this analysis was to update geothermal electricity generation cost estimates and to provide DESNZ's first estimates for heat generation costs. It includes a revision of the technical assumptions that underpin these cost estimates and reflect the UK context.

Geothermal energy refers to the heat naturally stored beneath the Earth's surface. It offers a dependable, continuous, and low-carbon source of renewable heat that operates independently of weather conditions. In this report geothermal energy covers use for power, heating and cooling, whist also considering lithium extraction from geothermal waters. An overview of geothermal can be found within Annex A of the report.

Key Points

- This research represents the most in-depth assessment of geothermal energy generation costs in the UK to date. It includes the first levelised cost for heat published by DESNZ and the first for power since 2016, as well as a carbon intensity assessment.
- Geothermal energy generation is a relatively established technology in both heat and power projects worldwide. Whilst ground source heat pumps are in relatively widespread use across the UK, the use of other geothermal generation technologies – particularly for power generation and deep heat generation – are nascent with a small number of operational projects.

[1] https://www.gov.uk/government/collections/energy-generation-cost-projections

- The costs presented in the research are averaged across sites in order to provide a benchmark for a generic project. Given the uncertainty associated with the costs and technical assumptions specific project costs could differ significantly from these.
- The research shows that costs of geothermal energy generation are currently relatively high compared to other established renewable energy sources (e.g. wind and solar for power and air source heat pumps for heat).
- However, the research shows that geothermal energy generation costs are likely to decrease further and potentially compete with established renewable technologies. The timing and extent of cost reductions remains uncertain but will be influenced by factors such as technological learning rates as well as the availability of funding support.
- The potential for a geothermal project to provide multiple valuable outputs, for example heat and power, or heating and cooling, can also significantly reduce costs.
- The report does not factor in the possible wider benefits of geothermal energy generation. These include increased energy security by reducing reliance on intermittent sources, avoiding grid upgrade costs were providing heating, supporting a just transition through transferring skills from the oil and gas sector and small land footprint.
- This research adds to the evidence base to inform government policy decisions on geothermal energy generation. There are still areas where further evidence is required to further improve the evidence base.
- We welcome feedback on any aspect of this research, including the collation of updated costs and assumptions going forwards. Please email geothermal@energysecurity.gov.uk.

Approach and Assumptions

Analytical Approach and Data Considerations

This research estimates generalised levelised costs and technical assumptions for a selection of shallow ground source heat pumps and deep geothermal technologies in the UK. It draws on published data and insights from UK and international stakeholders, with a focus on UK applicability. For deep geothermal, a literature-based geological evaluation of representative sites and industry-standard modelling was undertaken.

The levelised costs presented are specific to the input parameters assessed. As the analysis is not site-specific, the results are not directly applicable to individual projects. Instead, they are intended to serve as a benchmark for the generic project. Site-specific costing should be undertaken separately.

This research represents the most in-depth analysis to date on levelised costs and technical assumptions for geothermal energy generation in the UK. The report is underpinned by transparent data practices, with sources clearly cited and methodologies openly described. Some data used is commercially sensitive and was provided under confidentiality agreements. To protect proprietary information, individual stakeholders are not identified, and data has been anonymised and averaged where appropriate.

Assumptions

This section discusses are the key assumptions that have been identified to have the biggest impact on the results outlined in the main report.

Geothermal Technologies

A selection of geothermal technologies that are commercially available in the UK were selected to capture the breadth of different technologies, both in how they operate and at what depths. DESNZ recognises that the report does not cover all geothermal technologies, for example emerging technologies (e.g. Next Generation Geothermal[2] and ambient loop systems) and some commercially available technologies, such as Enhanced Geothermal Systems or Underground Thermal Energy Storage[3]. Some of these other technologies may result in lower levelised costs of geothermal generation, for example if they can increase the energy capacity output, reduce capital costs or enable revenues for cooling and storage.

Technology Maturity

This research categorises technologies into two technology maturity levels: First of a Kind (FOAK) and Nth of a Kind (NOAK). FOAK refers to technologies being deployed at scale for the first time, typically involving greater uncertainty, higher risk, and therefore higher costs. NOAK refers to technologies that have been deployed multiple times, benefiting from operational experience and economies of scale, which generally results in lower costs. In the UK shallow ground source heat pumps number in the hundreds, reflecting NOAK status. Whereas for other shallow geothermal technologies, such as mine water heat, and for all deep geothermal technologies, there are limited operational UK sites reflecting early-stage FOAK[4]. Within both categorisations appropriate learning rates are evaluated. In this research technology maturity was modelled through changes to operational hours, changes to costs associated with learning rates and the scale of the geothermal plant[5].

Technology maturity projections suggested that geothermal costs could come down over time, making them more competitive with other renewable technologies. This also highlighted that learnings can be drawn from international geothermal projects, for example improvements in drilling technology that can reduce the overall costs, and innovations in geothermal technologies that can further expand the scope of geothermal energy generation. While some

[2] https://iea.blob.core.windows.net/assets/cbe6ad3a-eb3e-463f-8b2a-5d1fa4ce39bf/TheFutureofGeothermal.pdf
[3] DESNZ has conducted separate research on Thermal Energy Storage, which includes UTES, and which is planned for publication in [Summer 2025].
[4] Gateshead for mine water heat, Eden for deep geothermal heat and United Downs for geothermal power.
[5] For shallow geothermal FOAK assumed reduced operational hours and high construction costs. For deep geothermal for heat and power is that scaling up from a single doublet for FOAK to multiple for NOAK is assumed.

learning can be drawn from international geothermal projects, deep geothermal systems assessed in this research are highly dependent on local geology[6]. As local geology varies significantly across and within UK regions, improvements arising from greater understanding of specific geological formations relies on UK experience.

End User Scenarios

For the Levelised Cost of Heat (LCOH) analysis, end-user scenarios were modelled to reflect potential use cases for geothermal heat in the UK given that heat is inherently a localised solution.

In contrast, the Levelised Cost of Electricity (LCOE) analysis is assumed to operate at baseload[7] and did not model end-use scenarios, as electricity generated from geothermal sources can be transmitted via the national grid and used wherever the grid reaches.

District heat networks were selected as representative end users for geothermal for heat and two temperatures for heat delivery were modelled: 55 °C representative of fourth-generation low temperature district heat networks[8] and 85 °C as per higher-temperature third generation district heat networks. However, the modelling does not include the cost of the heat network distribution infrastructure. It focuses solely on the cost of generating and upgrading the temperature at the geothermal plant, if necessary, to meet the required end-user temperature.

For shallow geothermal, an additional scenario was modelled to capture a dual use end-user scenario[9] where both heating and cooling can be supplied. This additional dual use scenario was not modelled for deep geothermal systems as they are likely to only provide heating in the near term[10].

DESNZ acknowledge that these do not reflect all potential end user scenarios. Some users may be able to utilise heat below 55°C for example, unlocking further opportunities and decreasing costs associated with the need for a heat pump.

Averaging of data

Inputs were averaged to provide indicative, rather than site-specific, levelised costs estimates. Low, medium and high ranges were modelled for all inputs for the levelised costs estimations based upon on the available data. This section draws on deep geothermal as an example to demonstrate considerations in relation to averaging inputs.

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[6] DESNZ acknowledge that emerging geothermal technologies such as Next Generation Geothermal is less dependent on local geology.

[7] Constant and reliable source of electricity/heat, typically running all hours excluding when down for maintenance.

[8] Fourth generation represents those that provide low temperature heating. Fifth generation represent heat networks those that provide ambient/heat and cooling. Cooling in this research is only considered in the hospital scenario and not considered in the low temperature DHN scenario.

[9] In the research this is named a hospital scenario but could be related to any end use case where heating and cooling is needed.

[10] Deep geothermal cooling is possible with adsorption or absorption chillers; however, these have not yet been extensively commercially deployed.

The deep geothermal assessment for this study was based upon seven sites across the UK, with the aim to capture 1) the entirety of the UK, 2) the breadth of geological conditions for geothermal in the UK (e.g. both sedimentary and granite aquifers) and 3) a range of subsurface depths. The geological assessment in Annex A feeds into the model by providing values which are used to calculate heat or power capacity for a specific geothermal technology. The geological assessment was necessary as several geological factors[11]drive the amount of usable heat for geothermal energy generation. Averaging of the values to calculate heat or power capacity means the capacity used in the model may be lower than at an individual site with more favourable geological conditions. Those locations would deliver a higher capacity and therefore a lower levelised cost (see Figure 1 for an illustration). Equally, less favourable conditions would result in higher levelised costs than the average.

Several other parameters are also contingent on heat assumptions so assumptions for this are highly influential on the estimated levelised costs.

Additional revenue offsets

Additional revenue generation from other products (e.g. from lithium, cooling, and heating) offer important benefits (see Figure 1), such as increasing projects viability. Additional revenues generated are however uncertain. The viability and scale for each project can vary due to the local geology, system design and end-use integration. For example, lithium is a promising additional revenue but still a nascent revenue stream which therefore makes it difficult to identify when these revenues can be realised for future geothermal projects. There are also methodological challenges in estimating revenues; this research utilised avoided cost methodologies[12] and literature-based proxies which can oversimplify or overestimate potential returns. Some assumptions have been made in this study, but further work will be necessary to ensure the benefits of these additional revenues are achieved.

Hurdle rates

The hurdle rate assumed for geothermal energy generation projects has significant influence on overall cost. A hurdle rate represents the minimum project internal rate of return (IRR) at which an investment will proceed and reflects the risk of a project. Hurdle rates will vary depending on the characteristics of a specific project and its financing arrangements. The context in which DESNZ uses cost estimates generally require that a hurdle rate would reflect the return required over the life of the project: a ‘whole-of-life’ hurdle rate and consistent with published LCOE for power technologies, such as in DESNZ’s Generation Costs Report[13]. This differs from the return that may be required at a specific stage of project development. Conceptually, a whole-of-life hurdle rate represents the weighted average of the returns required at different stages of a project’s lifecycle.

[11] Geological factors such as temperature at depth, rock type and structures, depth and thickness of resource and fluid flow rates.
[12] Avoided cost methodology assumes that the revenue is equivalent to the cost that would otherwise have been experienced using an alternative source of heat, such as a gas boiler system.
[13] https://www.gov.uk/government/collections/energy-generation-cost-projections

For deep geothermal systems, the drilling phase is high-risk where uncertainty is greatest. However, once drilling is complete and production is demonstrated, project risk decreases and the geothermal well is considered a constant and reliable energy source, with this latter phase the significantly higher proportion of overall project lifetime. To reflect this lifecycle risk profile, a whole-life hurdle rate for a generic geothermal project of 10.1% is used for deep systems based on 2025 DESNZ Generation Costs research[14] We note previously a hurdle rate of 18.8% was quoted in the 2018 Europe Economics assessment[15] and inferred to be more reflective of the shorter high-risk drilling phase. The same hurdle rate is assumed for both deep geothermal for power and for heat. To develop the hurdle rates the Contracts for Difference (CfD) scheme and Government grants in place as of 31st December 2024 are taken into consideration for power and heat respectively. In the UK, deep geothermal heat would be likely to face a lower degree of development of construction risk due to a reduction in uncertainty at shallower depths than for power, but a higher degree of price risk due to the absence of a CfD. This would point to some balancing out and a broadly similar risk rating for both power and heat projects and assuming the same hurdle rate being reasonable within the level of uncertainty.

For shallow geothermal systems, where drilling depths are lower and subsurface conditions are generally better understood, a reduced whole life hurdle rate of 7.5% was applied. Similarly to deep geothermal, there is a higher risk drilling phase (potentially lower than deep geothermal) and then a reduced risk once drilling is complete and production is demonstrated.

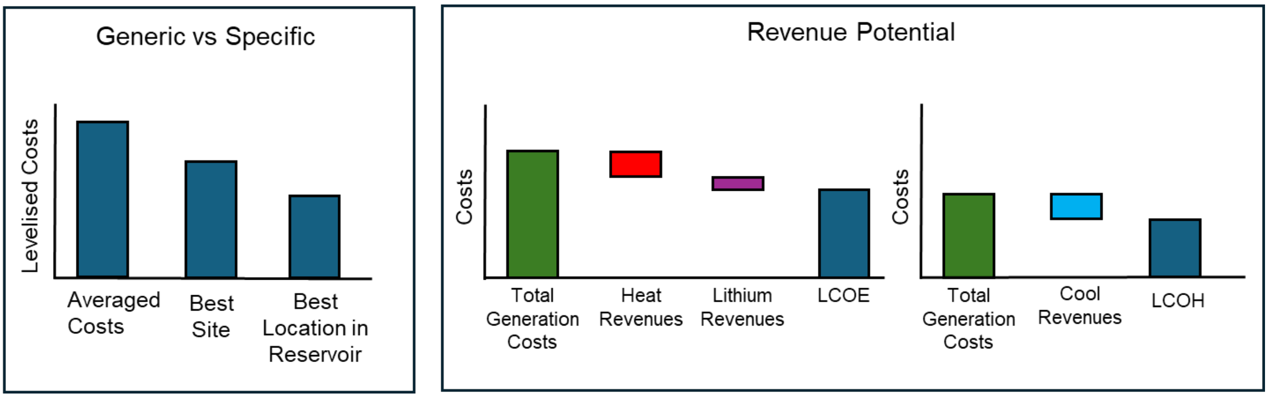

Figure 1 Schematic illustrations of the choice of the generic site and revenue potential.

Potential Future Updates

This section is primarily informed by stakeholder input gathered from a subset of stakeholders during a pre-publication workshop. It highlights overarching themes rather than all the detailed

[14] https://www.gov.uk/government/collections/energy-generation-cost-projections
[15] https://www.gov.uk/government/publications/cost-of-capital-update-for-electricity-generation-storage-and-dsr-technologies

points raised and does not represent a comprehensive assessment of all potential future updates.

The research report itself was based on the best available data as of the research in 2024 and input was requested from a wide range of stakeholders. The uncertainties in the data gathered have been reflected in the ranges modelled (low, medium and high) and can be explored within the underlying models. The discussion below, informed by workshop attendees, has not been incorporated into the research report but provides additional context around the uncertainty.

Most of these variables can be changed readily in the underlying models as we receive a greater body of UK information.

Some workshop attendees also felt that when referring to a particular technology, the terminology was not sufficiently specific in the report. The research report provides definitions and categorises systems into shallow (<500m) and deep (>500m) for LCOH, and by aquifer type for LCOE but DESNZ recognises that geothermal systems vary widely by depth, technology, and subsurface interaction. Potential future work that incorporates project specific parameters may utilise more nuanced classifications of geothermal technologies.

Some workshop attendees identified operational hours, hurdle rates, decommissioning costs, energy outputs and flow rates as underestimates. These assumptions have differing effects on levelised costs. For example, some attendees felt that under favourable conditions heat and power capacities could be higher than the assumptions used and therefore result in an overall reduction in levelised cost. Decommissioning costs were also excluded from shallow geothermal technologies; if included this would increase the overall levelised cost.

Some workshop attendees identified fixed operation and management costs for deep geothermal technologies, construction costs and revenue offsets as overestimates. For example, some believed that construction costs for some technologies could be lower depending on the location and drilling techniques used which would decrease the estimated levelised cost.

We expect that the research report accounts for some of these over and under estimations by the use of averaging, in particular for heat or power capacities and drilling costs and reflects the best available data at the time of compilation. However, these assumptions will benefit from additional evidence when this becomes available and readers should consider this when reviewing the report.

Looking Ahead

This research is an early assessment of the levelised costs of geothermal energy in the UK. The technical and cost assumptions could be improved in the future with site specific data and as geothermal deployment in the UK matures. This research uses hypothetical scenarios, averaged inputs and assumptions and results are not applicable to all sites but can provide a benchmark for future geothermal projects in the UK. DESNZ recognises geothermal as an emerging technology in the UK, that levelised cost trajectories are uncertain and more favourable technical and cost assumptions may be evident depending on the trajectory.

DESNZ plans to use this research to understand the uncertainties and sensitivities across all input parameters. In doing so we can look to where research, innovation and policy interventions can support reductions in costs, increase speed of delivery and productivity to mature the geothermal industry in the UK. An example of the use of this research is the inclusion of selected relevant aspects in the UK Geothermal Platform commissioned by DESNZ to the British Geological Survey, which illustrates the geothermal potential in the UK.

We encourage stakeholders to provide data, assumptions and information which can improve the work that has already been done as part of this research project. If you would like to provide any data, please contact geothermal@energysecurity.gov.uk. We can also discuss, where appropriate, data sharing agreements for any data shared.

We want to thank Arup for the work and effort put into this research and the subsequent engagement. We would like to thank all stakeholders who fed into the research and also those involved in the pre-publication workshop.

This publication is available from: www.gov.uk/government/publications/uk-geothermal-energy-review-and-cost-estimations