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Co-production of Geothermal Energy and Lithium in Cornwall, UK: Continued Development of the United Downs Geothermal Project

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ABSTRACT

The United Downs Geothermal Project, developed by Geothermal Engineering Ltd (GEL), has demonstrated power generation from a geothermal resource in the UK. The geothermal power plant developed at United Downs provides an important case study for the development of future projects both in Cornwall, and the wider UK.

With increases in global demand for lithium-ion batteries forecasted in the coming decade, largely driven by decarbonisation of the automotive industry through increased EV vehicle use, alternative and low carbon lithium resources, including lithium-rich brines, are being explored.

Globally significant lithium concentrations (> 300 ppm) have been identified in deep geothermal brines at United Downs. Furthermore, the brine compositions are optimal for the development of lithium extraction methods. GEL has conducted a number of studies exploring the potential for lithium extraction in conjunction with power production. The first phase was a pilot study of direct lithium extraction from the United Downs deep geothermal brines, which was followed by a technical and economic feasibility study for the development of a demonstration plant. In Spring 2025, GEL completed the third phase of this study, the design and construction of a 100 tonnes per annum (Lithium Carbonate Equivalent) demonstration scale lithium extraction plant. Technology providers were assessed, and the extraction process was tailored for the United Downs brine composition. Data collected throughout development and testing will feed into future commercial expansion.

Co-production of geothermal energy and lithium provides opportunity for a UK source of lithium products, reducing import reliance and reducing the environmental impacts associated with other methods of extraction and shipping.

1. INTRODUCTION

Construction and commissioning of the UK's first geothermal power plant, located in United Downs, Cornwall, was completed in 2025. Since conception, the primary aim of the United Downs Geothermal Project was to demonstrate geothermal power production in UK, whilst providing proof of concept for the utilisation of fractured granites in Cornwall for geothermal projects in Cornwall. Successful completion of this phase of the project will de-risk future projects across Cornwall and the UK. The project has been developed since conception by Geothermal Engineering Limited (GEL).

The granites and deep, saline ground waters in Cornwall are often characterised by high concentrations of lithium (e.g., Miller, 1864; BGS, 2020). During testing of the deep geothermal waters at United Downs, globally significant lithium concentrations were identified. Akin to a number of other high profile geothermal settings worldwide, the fractured granites in Cornwall hold potential for the co-production of power, heat and lithium.

Globally, the production of lithium is dominated by the mining of hard rock deposits in Australia and China (lithium rich pegmatites or sedimentary deposits), and evaporation from Salar brines in South America (Energy Institute, 2024). Both methods of extraction are associated with high carbon emissions, pollution, and waste material production, in addition to the large consumption of chemical reagents, land, and water (e.g., United Nations 2020).

Beyond production of raw materials, the subsequent processing and production of downstream products largely takes place in China, prior to shipping worldwide (IEA, 2024). This intercontinental transit of lithium products further increases the net carbon emissions of the final product.

Increases in the forecasted demand for lithium has driven the extractive industry to evaluate non-traditional sources of critical minerals, including geothermal brines. The viability of recovering lithium from geothermal brines is increasing as technical advancements are made in extraction techniques, policy shifts towards low carbon and environmentally sensitive mineral extraction (e.g., European Parliament, 2022) and governments seek to onshore production. Extraction of critical minerals as a downstream product of geothermal power and/or heat production can increase the revenue available for a given project (Weinand et al., 2023). Furthermore, utilisation of renewable, clean geothermal heat and power in the extraction process can minimise carbon emissions (Razmjou, 2024). Ultimately, a low- or zero-carbon lithium product can be recovered. The use of geothermal electricity and heat onsite will also reduce the operational expenditure of the extraction process.

The extraction of lithium from geothermal waters would reduce the total land footprint used and water consumption relative to evaporative extraction from Salar brines and allow for reinjection of 'spent' brine into the hydrogeological system, maintaining reservoir pressure.

Extraction of lithium directly from solution is collectively referred to as 'direct lithium extraction', or 'DLE'. A range of DLE techniques have long been in development, which has only quickened as demand for extraction has increased, however, these techniques are often suited to geothermal waters of specific composition and properties, showing comparatively poor recovery across a wider range of compositions (Farahbakhsh et al., 2024). Overcoming the complex compositions of geothermal brines and low technology readiness levels (TRL) of many DLE technologies has been a challenge for many projects.

Despite these challenges, a small number of projects globally have either implemented or are approaching on-site implementation of DLE technologies at small scale, and a smaller number produce lithium from brines in commercial quantities (e.g., Nicolaci et al., 2023). One such project is the United Downs Project, where the development of lithium extraction from deep geothermal waters post power production is progressing.

2. GEOLOGICAL CONTEXT

The Ordovician-Devonian granites that extend across much of the southwest of England (Cornwall and Devon) provide significant geothermal resources (Abesser et al., 2023). Elevated heat flows and geothermal gradients are driven by enriched concentrations of radiogenic isotopes. The near-surface granitic deposits provide potential for both fractured hydrothermal reservoir development (utilising naturally permeable fault and fractures zones) and engineered geothermal systems.

The granites and associated saline ground waters in Cornwall have long been recognised as possessing enriched lithium concentrations.

All granites outcropping across Cornwall contain varying proportions of lithium bearing micas. A number of granite bodies contain high lithium zinnwaldite and lepidolite micas (BGS, 2020).

High levels of lithium were identified in subsurface thermal springs in the United Mine workings by Miller (1864). Enriched lithium concentrations in saline groundwaters in Cornwall have been suggested to owe to the congruent reaction of lithium rich mica within the granite (e.g., Edmund et al. 1988).

3. GEOTHRMAL MODEL AT UNITED DOWNS

The United Downs Project has demonstrated geothermal power production through the utilisation of a fractured crystalline geothermal reservoir.

Two deviated wells were drilled into the Porthtowan Fault Zone (PTFZ), a zone of NNW-SSE aligned 'cross course' faults and fractures. A 5,275 m (MD) production well (UD1) and a 2,3939 m (MD) reinjection well (UD2) both intersect the targeted PTFZ (Figure 1). The PTFZ aligns with the maximum horizontal stress in the region and is often associated with permeability in the subsurface (e.g., thermal springs in mine workings). Furthermore, the PTFZ can be identified at the surface in close proximity to the outcropping Carnmenellis Granite.

A description of the drilling programme and well design is presented in Reinecker et al. (2021).

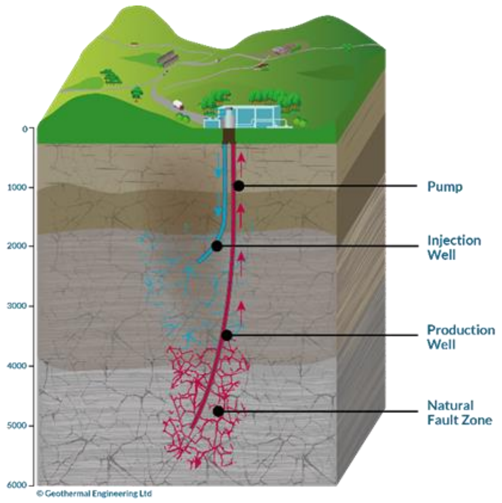

Figure 1: A schematic diagram presenting the geothermal model installed at United Downs. A production well was drilled to 5,275 m MD and an injection well to 2,393 m MD.

UD1 allows hot geothermal waters to be pumped from depth using an electronic submersible pump, installed to a depth of 1400 m. UD1 intersects the fault zone between 4,100 m and 4,700 m, in the 8 ½" open-hole section of the well. UD1 is cased to 4000 m. Post power production, 'spent' geothermal waters are reinjected via UD2, into a shallower zone of the PTFZ.

The geothermal model (Figure 1) was based on observations from the Hot Dry Rocks Research Programme (Parker, 1999) that 70 % of water injected into the Carnmenellis Granite (at Rosemanowes Quarry) was lost to the pressure-induced downwards opening of natural fractures. Reinjecting at shallower levels will also increase residence times of ‘spent’ brine in the reservoir.

4. UNITED DOWNS DEEP GEOTHERMAL WATERS

After the completion of drilling at United Downs, the wells were tested to assess reservoir properties. Testing confirmed the presence of high temperature geothermal waters (180 °C) and an inherent permeability of natural fractures within the target structure at depth. Testing was followed by a period of low-pressure stimulation to improve reservoir properties.

During testing, geothermal waters sampled from UD1 were analysed. This is the deepest water sample taken from within the granite in Cornwall to date and has allowed for direct comparison to groundwater and mine water compositions.

The deep geothermal waters contain significant lithium concentrations (290 - 330 mg/l). High lithium concentrations are coupled with comparatively low levels of total dissolved solids (TDS) (Table 1).

Despite lithium rich saline waters being identified as early as the mid-1800s, the testing of fluid compositions at United Downs confirmed greater levels of lithium enrichment within higher temperature fluids at greater depths within the granite.

Table 1: Comparison of United Downs deep geothermal brine composition with notable geothermal brines globally. International brine compositions were compiled by Sanjuan et al. (2022), and the sources of each data for each line are noted within the table.

Location	Reservoir type	Temperature (°C)	TDS fluid (g/l)	Li (mg/l)	References
United Downs, Cornwall, UK	Fractured granitic reservoir	180	31 – 42	290 - 330	This study.
Campi Flegrei, Mofete, Italy	Volcano-sedimentary reservoir.	380	516	480	Pauwels et al. (1991), Buonasorte et al. (1993), Sanjuan et al. (2022)
Cesano Geothermal Area, Italy	Carbonate reservoir adjacent to young alkaline-potassic volcanic centre	350	230 – 290	220 – 380	Pauwels et al. (1991), Buonasorte et al. (1993), Sanjuan et al. (2022)
Salton Sea, Southern California, USA	Series of deltaic sediments adjacent to young volcanic area.	340 – 360	260 – 265	200 – 215	Elders and Cohen (1983), Williams and McKibben (1989), Sanjuan et al. (2022)
Groß Schonebeck, North German Basin, Germany	Rotliegend, Lower Permian sandstone and volcanic units.	220	212 – 269	180 – 237	Regenspurg et al. (2010, 2015), Sanjuan et al. (2022)
Groß Schonebeck, North German Basin, Germany	Upper Muschelkalk fractured and karstified limestone/dolomite reservoir	210	55 – 62	143 – 162	Stober (2014), Sanjuan et al. (2022)
Upper Rhine Graben, Germany/France	Triassic Buntsandstein red sandstone overlying granitic basement.	190 – 250	104 - 121	1159 – 210	Pauwels et al., 1993, Sanjuan et al. (2016), Sanjuan et al. (2022)
Soultz-sous-Forets	Granitic basement.	200 – 250	93 – 107	161 – 190	Sanjuan et al. (2016), Sanjuan et al. (2021), Bosia et al. (2021), Sanjuan et al. (2022)

5. DEVELOPMENT AND TESTING OF GEOTHERMAL LITHIUM EXTRACTION

Following the initial testing of the geothermal waters pumped from UD1, GEL have collaborated on, and led a number of projects assessed the potential for, and developed the capability to extract of lithium form the United Downs geothermal waters, alongside power production.

5.1 Pilot Study

The first project phase involved collaborating on a pilot study of an ion exchange DLE technology (part of the

Geo[3] Project), utilising sampled geothermal waters from the initial testing of UD1.

5.2 Feasibility Study

After the initial pilot study, GEL conducted a part grant-funded (UK Department of Business and Trade Automotive Transformation Fund, Feasibility Study Round 3) technical and economic feasibility study to assess the potential for development of a larger demonstration-scale lithium extraction plant at United Downs.

The principle aims of the study were to test a range of DLE technologies (working directly with a range of commercial partners and technology providers) to assess the capability of different extraction methods and the respective scalabilities, as well as developing a business case for a demonstration scale plant. The study also included the identification of potential off takers, the securing of land for a future demonstration plant and early-stage community engagement.

Ultimately, a number of preferred commercial DLE providers were selected for further evaluation, potential UK offtakers were identified and MoUs signed, land was identified and secured for development of the demonstration plant, and a strong foundation of information was prepared for a thorough and robust approach to community engagement as the project progresses.

5.3 Demonstration Plant Development

GEL have most recently completed a third phase of development, the design and construction of a 100 tonnes per annum (tpa) demonstration-scale lithium extraction plant. This project built on the previous feasibility study and was part funded by the UK Department of Business and Trade Automotive Transformation Fund: Scale Up Readiness Validation scheme.

The development of the demonstration plant included the extensive testing of two previously selected DLE technologies (building on the previously conducted feasibility study) prior to final selection, the design of the complete extraction process, completion of a mass and energy balance and assessment of overall CAPEX and OPEX. After design, all plant equipment was procured, and the demonstration plant was constructed on the United Downs site.

Upon extensive testing of selected DLE technologies, an adsorption-type DLE technology was selected for use at United Downs.

The chosen DLE technology showed high levels of extraction during testing, with low levels of impurities. Furthermore, adsorption DLE technologies possess comparatively high TRLs relative to other techniques and have shown commercial viability. Adsorption DLE utilises water as opposed to acid when rinsing lithium from the resin post extraction, preventing degradation of the resin over time, therefore lowering the OPEX of the extraction technique. Use of water also minimises the need for chemical reagents during extraction (reducing the overall environmental impact).

Ultimately, the demonstration plant has been designed to produce lithium carbonate. Construction and commissioning of the demonstration plant took place in early 2025, and GEL have begun full scale testing, the results of which will inform future scale-up.

Throughout this project, a wide range of stakeholder engagement was conducted, including high levels of political engagement, working with local and national government to communicate the needs of the growing critical minerals sector in Cornwall, as well as engaging with organisations throughout the whole supply chain. This is in addition to ongoing community engagement around United Downs.

Figure 2: A photograph of the exterior of the 100-tpa lithium extraction plant during construction.

5.2 Community Engagement

Community engagement conducted in all stages of project development has built on the community engagement framework developed by GEL (e.g., Charman et al., 2023) during drilling and development of the power plant at United Downs.

Throughout the development of the demonstration plant, a range of communication methods have been utilised, including hosting site visits, tours and open days, visiting schools and attending/speaking at community events. Engagement resources and dissemination material has been consistently updated to reflect project progress.

Throughout the demonstration project alone, GEL took part in over 80 community events, including 19 school visits and the hosting of 6 open days. In total, during this project, over 3000 individuals were engaged across all events.

6. FUTURE DEVELOPMENT

The United Downs has demonstrated the potential for the co-production of geothermal power and lithium in the UK and plans to scale this up to commercial levels of extraction in the coming years. Current testing of the 100-tpa demonstration plant will directly inform commercial scale-up of extraction, utilising a greater proportion of brine post-power production. Upon scale-up, GEL are targeting production of 1000 – 1500 tpa of lithium carbonate equivalent (LCE) at United Downs.

The geothermal concept at United Downs is repeatable across similar geological structures **(**fault zones**)** across Cornwall and the wider southwest UK. With extensive faulting spanning the region and the favourable alignment with the background tectonic stress (e.g., Heath, 1985; Brereton et al. 1991), similar reservoir behaviour is expected across the county. High lithium concentrations are anticipated in localities across Cornwall owing to similar reservoir geology.

GEL has gained planning permission for two further sites in west Cornwall, Manhay and Penhallow, which are fully permitted and await drilling and development. Manhay and Penhallow will build on learnings from United Downs, employing a geothermal doublet to produce a forecasted gross output of 4.9 mW. Both sites hold potential for lithium extraction upon confirmation of the available resource. A number of additional prospective sites are in earlier phases of development

Beyond lithium, GEL are involved in earlier stage research and development to explore the potential for low-carbon extraction of additional critical minerals from the deep geothermal waters in Cornwall.

7. CONCLUSIONS

GEL have completed a 100-tpa demonstration scale lithium extraction plant at the United Downs deep geothermal site in Cornwall. Testing progressing at the site will contribute to full commercial scale up. Development of full-scale extraction at United Downs and a number of other key sites in Cornwall will provide the first geothermal lithium production in the UK.

The co-production of geothermal power and low-carbon lithium products at United Downs will not only economically strengthen the project and aid in the de-risking of future deep geothermal projects across Cornwall, but the project also provides a clear step onshoring lithium production in the UK. Successful scale-up to commercial extraction at United Downs and other sites across Cornwall would aid in placing the UK at the forefront of European low-carbon critical mineral production.

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