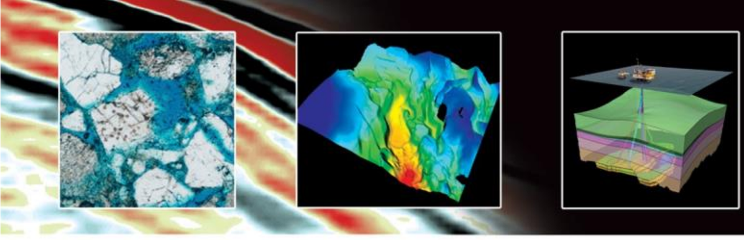

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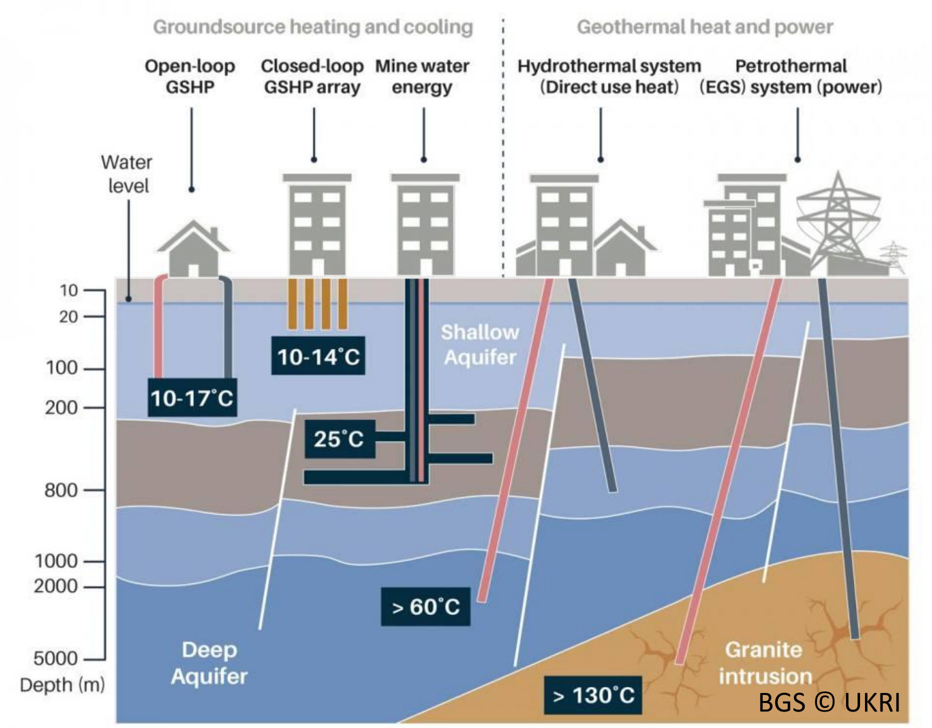
11th UK Geothermal Symposium

11th – 13th November 2024
The Geological Society, Burlington House, Piccadilly, London



- **The development of geothermal energy to provide sustainable baseload heat and power at different scales is moving at an unprecedented pace.**
- **The 11th UK Geothermal Conference aims to highlight the technical and scientific advances being made across the spectrum of geothermal exploration and development.**

Whether you are involved in exploration, development, policy or regulation, this symposium is for you. Broad themes may include, but are not limited to, shallow geothermal and heat pumps, minewater heat, subsurface geological studies, heat and power from granites and case studies from the UK and abroad. Additional areas of research such as the development of innovative technologies and solutions, mineral extraction from geothermal waters, and the potential environmental impacts of geothermal energy are also welcomed.

It remains an exciting time for the geothermal industry in the UK and this three-day symposium aims to showcase all aspects of research and development in this emerging industry. Join us on the third day of the conference for workshops and classes, where industry experts will delve into some of the most pressing hurdles facing the geothermal sector today.

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11th UK Geothermal Symposium

11th-13th November 2024

Hybrid Conference, Burlington House, and Zoom, BST

Final Programme

Day One	
08.30	**Registration**
08.50	**Welcome**
	Session One: Shaping the Future of Geothermal: Costs, Data, Networks, and Global Standards
09.00	**KEYNOTE: The evolving policy landscape and an overview of the latest research on costs of geothermal for heat and power in the UK** **Cantor Mocke, *Department for Energy Security and Net Zero***
09.40	**Supporting heat decarbonisation through new BGS geothermal data, maps and products** Alison Monaghan, *British Geological Survey*
10.00	**Enabling geothermal heat networks in the context of Heat Network Zoning** David Barns & Jessica Ryan-Smith, *Geosolutions Leeds, University of Leeds*
10.20	**Introducing the IADC Geothermal Well Classification: Global Guidelines for Deep Geothermal Well Construction** Kevin Gray, *Black Reiver Consulting*
10.40	**The National Geothermal Centre: Defining a geothermal roadmap to 2050** Charlotte Adams, *National Geothermal Centre (NGC)*
11.00	**BREAK AND POSTERS**
	Session Two: Practical Insights and Innovations in Geothermal Projects: From Mine Water Heating to Living Labs
11.30	**Operational findings from the UK's first multi-megawatt mine water geothermal heating schemes at Lanchester Wines** Sally Jack, *TownRock Energy*
11.50	**GeoEnergy NI - an example of an integrated approach to geothermal demonstration projects** Michael MacKenzie, *Department for the Economy*
12.10	**The United Downs Deep Geothermal Project: combining the generation of geothermal electricity and heat, with the extraction of critical raw materials** Ryan Law, *Geothermal Engineering Ltd.*
12.30	**Geothermal Campus – a living lab for geothermal research at the University of Leeds** Emma Bramham, *University of Leeds*
12.50	**Gateshead mine water "living lab"** Fiona Todd, *The Coal Authority*
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14.30	**Impact of aquifer properties, well spacing and vertical offsetting on ATES and Open-loop unidirectional systems** Carl Jacquemyn, *Imperial College London*
14.50	**Potential CO2 savings from widespread deployment of Aquifer Thermal Energy Storage across the UK** Matthew Jackson, *Imperial College London*
15.10	**BREAK AND POSTERS**
15.50	**Responsible deployment of Aquifer Thermal Energy Storage: A stakeholder approach to characterising societal desirability, opportunities and challenges** Ting Liu, *Imperial College London*
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16.30	**Evaluating the Impact of Chalk Aquifer Heterogeneity on LT-ATES Performance: A Case Study from London** Hayley Firth, *Imperial College London*
16.50	**WING Update** Rebecca Bolton, *WING UK*
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Day Two

08.30	**Registration**
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09.30	**A Local Hydrogeochemical Conceptual Model of the Midlothian Coalfield: Assessment of Risks Baseline Prior to Minewater Thermal Storage** Samuel Graham, *University of Edinburgh*
09.50	**Advancing Net Zero: Expanding Mine Water Geothermal Potential in Kent's Coal Mines** Mimi Bleakley, *ERCE*
10.10	**Investigating the potential impacts of climate change on mine water resources: Central Scotland as a case study** Clodagh Gillen, *University of Strathclyde*
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11.40 Virtual	**Reinjection of CO2-enriched spent fluids at the Kızıldere geothermal field, Turkey: A numerical modelling study** Ji-Quan Shi, *Imperial College London*
12.00	**InSAR for geothermal field monitoring: case studies from New Zealand** Nick Dodds, *SatSense*
12.20	**New Approach to Modeling Fractured Reservoirs for Geothermal Energy and Lithium Recovery** Tim Salter, *Baker Hughes*
12.40	**Use of Rockwash Geodata integrated cuttings analysis for characterisation of deep wells in granite basement – an example from United Downs wells UD-1 and UD-2** Douglas Langton, *Rockwash*
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14.20	**Ground source heating and cooling (GSHC) systems – evidence for regulation** Sian Loveless, *Environment Agency*
14.40	**Geothermal heat with every beat – the BODYHEAT project two years into operation** John Naismith, *TownRock Energy*
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16.00	**Core to field-scale thermal characterisation of the Sherwood Sandstone Group aquifer at UKGEOS Cheshire, UK** David Boon, *British Geological Survey*
16.20	**Numerical Modelling of an Exceptionally Well Instrumented Thermal Response Test in the UK Chalk Aquifer** Louisa Bahlali, *Imperial College London*
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Day Three

08.30	**Registration**
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09.10	**The potential benefits of technology transfer from the US to the UK to accelerate the development of Geothermal Energy in UK** Tony Pink, *Pink Granite Consulting Ltd.*

09.30	**Deep Geothermal Heat Pumps: megawatt-scale, sustainable heat supply that is cost competitive with fossil fuels** Huw Williams, *Causeway Geothermal (NI) Ltd & Agua Enodo Ltd*
09.50	**A pathway to simplifying modelling of single coaxial deep borehole heat exchangers (DBHE)** David Banks, *University of Glasgow*
10.10	**Investigating the Potential for a 6 km Deep Borehole Heat Exchanger to Supply Heat and Power in Glasgow** Tiorafi Muhammad, Christpher Brown, *University of Glasgow*
10.30	**Challenges and opportunities for binary cycles in geothermal power applications** Martin White, *University of Sussex*
10.50 Virtual	**Global database of hot sedimentary aquifer geothermal projects: De-risking future projects by determining key success and failure criteria in the development of a valuable low-carbon energy resource** Maëlle Brémaud, *University of Strathclyde*
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11:30	**SEPARATE REGISTRATION REQUIRED** **Workshop 1: Advancements in Geothermal Drilling: Best Practices and Emerging Technologies for High-Temperature Operations and Enhanced ROP** **Workshop 2: Optimising Geothermal Deployments**
13.00	**LUNCH**
14.00	**SEPARATE REGISTRATION REQUIRED** **Workshop 1(continued): Advancements in Geothermal Drilling: Best Practices and Emerging Technologies for High-Temperature Operations and Enhanced ROP** **Workshop 2 (continued): Optimising Geothermal Deployments**
15.30	**End of day two**

Posters Day 1
How good is your fracture model? Examining how interpreter experience and approaches affect fracture model variability Leila Evans, *University of Strathclyde*
Regional interpretation of Permo-Triassic aquifers in the Cheshire Basin, UK, for direct use geothermal energy David Johnstone, *University of Manchester*
Aquifer geothermal potential of Upper Devonian strata in the Midland Valley of Scotland Tim Kearsey, *British Geological Survey*
Innovative new closed loop horizontal well solution to universally harvest deep geothermal Energy Kim Gunn Maver, *Green Therma*
Aquifer lithology and fluid composition across potential geothermal production intervals Will Norfolk, *Newcastle University*
Community engagement for deep geothermal developments in the UK: an updated reflection on engagement for the United Downs Deep Geothermal Project, Cornwall Thomas Olver, *Geothermal Engineering Ltd.*
Levelised Cost of Heating Estimation of Deep Geothermal in Newcastle upon Tyne and North East England Daniel Samosir, *Newcastle University Alumni*
The Good, The Bad, and the Ugly Drillers Stuart Sinclair, *Consortium Drilling Limited*

Drilling geothermal wells with laser: Sci-Fi or new reality? Pawel Slupski, *University of Padua*
Cornish Lithium: Understanding lithium-enriched waters in Southwest England Jos Thio, *Cornish Lithium*
Posters Day 2
Modelling & Optimization of Geothermal Energy in the Gulf of Suez Amira Abdelhafez, *University of Manchester*
A new ground source heat pump installation and 'Living Lab' at BGS Headquarters, Nottingham, UK David Boon, *British Geological Survey*
Borehole exchangers as thermal batteries: towards a new standard in GSHP dimensioning Étienne Coudert, *Celsius Energy*
Geothermal Energy Collaborating with Fish Farms for Climate Adaption in East Africa Charles Ferguson, *Global Infrastructure Solutions Limited*
How far and how fast? Multiphysical monitoring of thermal plumes under mine water geothermal Andrés González Quirós, *British Geological Survey*
Assessment of shallow geothermal energy potential underneath Leeds Mohamed Gouiza, *University of Leeds*
Integration of photovoltaic-thermal captured heat within shallow geothermal networked heat pump systems Alister Henderson, *Kensa Engineering Ltd.*
Option of energy-free thermostat storage employing a near-surface aquifer system Arunangshu Mukherjee, *Manav Rachna International Institute of Research and Studies*
A feasibility study for the installation of mine water thermal energy storage (MTES) in an abandoned metalliferous mine in Cornwall, UK. Thomas Olver, *Geothermal Engineering Ltd.*
Evaluating the potential for heat storage in abandoned coal mine shafts in Scotland Zoe Shipton, *University of Strathclyde*
Air Source vs Mine Water: An appraisal of the preferred heat pump solution in former coalfield areas of the UK Sam Smith, *TownRock Energy*

The Energy Group of the Geological Society would like to thank the following for their support for this conference:

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ORAL ABSTRACTS
(In Programme Order)

Session One: Shaping the Future of Geothermal: Costs, Data, Networks, and Global Standards

KEYNOTE: Research on costs of Geothermal for heat and power in the UK

Cantor Mocke, Department for Energy Security and Net Zero

TBC

Supporting heat decarbonisation through new BGS geothermal data, maps and products

Alison Monaghan, British Geological Survey

In the 2023 deep geothermal White Paper 'unlocking investment at scale in the UK' recommendation 3 is around 'Improving data availability and accessibility', echoing similar recommendations over the years in geothermal roadmaps, policy papers and inquiry findings.

As part of its 2023-2028 strategy, the British Geological Survey (BGS) is working on a range on initiatives around UK geothermal data, maps, products and tools. For example, in April 2024 the first open, digital release of the legacy geothermal catalogue comprised 11,821 temperature, thermal conductivity and heat flow data points derived from 743 sites. BGS is working on making accessible a range of map information (e.g. thermal conductivity, heat flow, deep geothermal extent maps) and a geospatial platform for subsurface heat information. Tools are also being developed to provide pre-feasibility screening level information on geothermal opportunities. For example, BGS worked with NHS England and the Energy System Catapult on a tool for closed loop ground source heat screening for hospital sites.

Together these initiatives aim to help developers, Government and researchers to access impartial and definitive geothermal data and information, as well to identify areas of geothermal opportunity, to support heat decarbonisation in the UK.

Enabling geothermal heat networks in the context of Heat Network Zoning

David Barns, Geosolutions Leeds, University of Leeds

Heating accounts for approximately a third of the UK's greenhouse gas emissions. Low to medium temperature (<100°C) geothermal systems could provide a locally-sourced, reliable, and low-carbon energy for for heating and cooling buildings. The UK subsurface contains several Permo-Triassic and Palaeozoic sandstone and limestone aquifers, which have been previously assessed to contain several thousand Etajoules of heat in place.

The shallow (< 2 km msl) subsurface of Leeds, located in West Yorkshire in the central part of the UK, is made of highly faulted thick Carboniferous strata. The Lower Carboniferous Dinantian includes the fractured Pendleside Limestone aquifer at depths ranging between 900 and 1800 m. The Upper carboniferous Namurian Millstone Grit Group consists of multiple thick sandstone aquifers (up to 250 m thick), which outcrop in the north of Leeds and reach a depth of 1500 m in the South. Whereas the shallower Westphalian Coal Measures groups exhibit several sandstone aquifers (up to 50 m thick), reaching a maximum depth of 550 m.

To assess the geothermal potential underneath Leeds, we built a 3D geological model (x = 17 km, y = 15 km, z = 2.25 km) of the city subsurface and its physical properties, using legacy public data. Assuming a local geothermal gradient, we then calculated the total heat in place and the potential recoverable heat. Our estimates suggest that a total heat in place of over 30 EJ could be present within the various Carboniferous aquifers, which could yield a recoverable thermal power of 2.5-5 GW.

Introducing the IADC Geothermal Well Classification: Global Guidelines for Deep Geothermal Well Construction

Kevin Gray, Black Reiver Consulting

BODYHEAT is an innovative geothermal cooling and heating system built at SWG3. It was co-funded by the Scottish Government and principal advisors were TownRock and Harley Haddow.

SWG3 is a events venue in the west of Glasgow, where large music events are held hosting up to 1250 partygoers. BODYHEAT supplies cooling to these event spaces using indoor refrigeration units. The rejected heat, instead of being vented to the atmosphere, is stored in closed loop boreholes. The heat stored in the boreholes is recovered later and used to supply hot water and heating. The most intense cooling occurs during large events when there is high occupancy and high activity. During these times, the more energy that partygoers expend to enjoy the music, the more energy is captured by the system! As a result, the BODYHEAT name has gained considerable traction in the media, raising awareness of the potential of geothermal heating, cooling and storage.

The project faced multiple challenges, including: uncertain future cooling and heating loads; boreholes very close to two busy commuter train lines; co-location of a still-to-be-constructed community garden above the boreholes; project cost growth and the COVID pandemic.

Detailed geotechnical studies were carried out to confirm there would be no significant ground movement risks; header system and garden design were developed in parallel to protect the boreholes; and a low-cost data acquisition system was devised to monitor borehole and system performance.

The talk will show and tell the latest operational data with preliminary analysis of the system.

The National Geothermal Centre: Defining a geothermal roadmap to 2050

Charlotte Adams, National Geothermal Centre (NGC)

The UK has successfully decarbonised around 50% of its electricity generation over the past decade, however heat decarbonisation remains a persistent challenge. Heat production accounts for around 50% of our energy consumption and one third of our carbon emissions. Geothermal energy is well aligned to meet this challenge being one of the few low carbon technology options that combines versatility and scalability with continuous and controllable energy supply. Several European nations including France, The Netherlands, Germany and Hungary have similar geology and geothermal resources to the UK yet have significantly more installed geothermal capacity. This is in part due to them having produced strategy documents and support mechanisms that have accelerated the uptake of geothermal in their countries.

The National Geothermal Centre launched in January 2024 to supercharge uptake of geothermal across the UK. We are developing a geothermal roadmap that sets out aspirations for 10 GW of geothermal heat and 1.5 GW of geothermal electricity being produced by 2050. Alongside this we expect around 50,000 jobs will be created and around 10 million tons of CO2 emissions will be avoided annually. We now outline the pathways the UK will need to take to achieve these targets. The pathways align with key areas, identified during early conversations with sector stakeholders and include; regulation and licensing, technology and innovation, research and knowledge and integration with infrastructure. We are delighted to share our outline roadmap with you at the symposium and welcome collaboration and feedback for its future development.

Session Two: Practical Insights and Innovations in Geothermal Projects: From Mine Water Heating to Living Labs

Operational findings from the UK's first multi-megawatt mine water geothermal heating schemes at Lanchester Wines

Sally Jack, TownRock Energy

TownRock Energy (TRE) currently operates and maintains the UK's first multi-megawatt mine water geothermal energy schemes (MGES) in Felling, Gateshead. The MGES at Abbotsford and Nest Road each host an open-loop water source heat pump (WSHP) with combined heating capacities of 3.6 MW used to heat Lanchester Wines' food and beverage storage warehouses.

TRE present an update on the schemes at both Lanchester Wines' sites and detail the challenges, mitigations, and lessons learned from operating and maintaining the first large-scale MGES in the UK. We also present initial findings on the extent to which Lanchester Wines' schemes hydrogeologically interact with their neighbour, the Gateshead Council's scheme.

Legacy challenges associated with the MGES, particularly at Abbotsford Road were related to unfavourable water chemistry, overdesign of plant, and a poorly regulated configuration that ultimately led to poor system performance and operational challenges.

In recent years, TRE and Lanchester Wines have made efforts to address challenges at Abbotsford Road, optimising the existing plant and completing newly drilled boreholes, including a new abstraction borehole. Furthermore, TRE have worked cooperatively with relevant regulators and stakeholders to streamline the mine water geothermal permitting processes and ensure the schemes are operating under the correct permits. The latter required an understanding of interactive hydraulic behaviours between the two Lanchester Wines owned mine water schemes, and the Gateshead Council owned scheme, each of which access the same series of connected mine workings.

GeoEnergy NI - an example of an integrated approach to geothermal demonstration projects

Michael MacKenzie, Department for the Economy

In Northern Ireland, the geothermal energy sector remains nascent, despite its ability to provide low-carbon energy and security of supply to the region. Several reports have referenced the barriers to geothermal sector growth, including a lack of awareness of geothermal energy.

The GeoEnergy NI project is a public demonstrator project delivered by Government, that is assessing the potential for both shallow and deep geothermal in Northern Ireland by carrying out feasibility studies centred on two sites. It is gathering the data needed to enable projects to be taken forward and will increase our understanding of the potential role that geothermal energy can play in Northern Ireland’s green economy and future energy mix.

The shallow resources are being assessed through drilling and testing to characterise the open-loop and closed-loop potential of the Stormont Estate. Deep geothermal feasibility is being assessed utilising existing data and acquired new geophysics (seismic, gravity and magnetotellurics) for a site near Antrim.

Two of the project’s aims are to showcase and demystify geothermal energy, as well as to gain public support and social acceptance. These are being met by a tailored communications and engagement strategy, including the delivery of educational resources, a bespoke virtual reality programme and a mobile visitor’s centre. Communications work also allows for early engagement with relevant stakeholders, regarded as important for unlocking widescale deployment of geothermal.

This multi-disciplinary approach to geothermal demonstration has resulted in high-quality data being collected that will be used to inform evidence-based policy for geothermal energy in Northern Ireland.

The United Downs Deep Geothermal Project: combining the generation of geothermal electricity and heat, with the extraction of critical raw materials

Ryan Law, Geothermal Engineering Ltd.

The United Downs Deep Geothermal Project, developed by Geothermal Engineering Ltd (GEL) is nearing completion, with construction of the power plant set to complete in Q4 2024, and commissioning scheduled for early 2025. It will be the first geothermal power plant in the UK.

Drilling, testing and stimulation of the geothermal doublet (a 5,275 m production well and 2,393 m injection well) occurred between 2018 and 2021, and highlighted significant permeability within the target Porthtowan fault zone, as well as bottomhole temperatures > 180 °C, both essential to the generation of geothermal power and heat. Globally significant lithium concentrations (> 300 ppm) in the geothermal brines were identified.

GEL have explored the potential for the extraction of lithium from the United Downs deep geothermal brines. The first two phases of this project included a pilot study of direct lithium extraction (DLE) and a technical and economic feasibility study for the development of a demonstration plant. GEL are currently completing the third phase of this project, the design and construction of a demonstration scale lithium extraction plant. Construction of the plant will complete in early 2025. The plant will produce 100 tpa of lithium carbonate equivalent and the results will feed into a larger commercial scale expansion.

The United Downs Deep Geothermal Project is backed by Thrive Renewables plc and Kerogen Capital and has been supported by the European Regional Development Fund and Cornwall Council. Further projects are planned based on the United Downs model.

Geothermal Campus – a living lab for geothermal research at the University of Leeds

Emma Bramham, University of Leeds

The Geothermal Campus project by the University of Leeds forms part of its campus decarbonisation plans to reduce heating-related emissions on campus with heat from either air or geothermally-driven ground source heat pumps, distributed through a series of low temperature heat networks. Through exploratory drilling on campus, the project aims to assess the viability of key geothermal aquifers to better inform future phases of campus drilling.

With drilling completed in July 2024 and initial testing showing significant aquifer fluid flow, the project provides 2 sites for geothermal heat provision and investigation: a working open loop system providing heat into the University's Engineering cluster of buildings, and a secondary exploration site by the Environment buildings and central residences. Alongside a doublet of 150 m deep, reversible injection/abstraction water wells, the sites contain an array of strategically placed, instrumented 150 to 250 m deep exploration and monitoring boreholes (2 cored pilot wells and 4 thermal response testing (TRT) boreholes). This living research lab for geothermal energy allows us to model and observe the behaviour of geothermal reservoirs for heat, storage and cooling in the fractured sandstone Elland Flags and Rough Rock aquifers beneath campus.

Additionally, the urban location has enabled the multi-disciplinary team at Leeds, working across geoscience, engineering and social sciences, to develop impactful opportunities and collaborations to gain insight into the behaviour and responsible use of aquifers, not just beneath campus but across the wider urban environment, providing better constraint and more informed decision making for future geothermal endeavours across the UK.

Gateshead mine water "living lab"

Fiona Todd, The Coal Authority

The deep (>500 m) Sherwood Sandstone of Northern Ireland has some of the highest potential geothermal resources in the British and Irish Isles. This hydrothermal resource present at variable depths and although higher resource temperatures (>90°C) are sequestered to the deeper areas, the innovative use of Industrial Heat Pumps (IHPs) allows lower temperature geothermal energy to be upgraded and utilized in cost effective ways.

Where hydrothermal aquifers with flow rates sufficient to support open loop geothermal development are not present, Deep Borehole Heat Exchangers (DBHE) are a possible alternative, however, they are an order of magnitude less effective than open loop extraction.

We have developed thermal energy forecasts for the two main archetypes at 1 and 2 km depths in two conceptual locations in County Antrim. An open loop doublet targeting the Sherwood Sandstone is expected to deliver a thermal power through a IHP of 2.5 MWth (70 º C output) over 25 years from a 1 km deep Sherwood Sandstone interval. The same formation is predicted to deliver a thermal power of 1.6 MWth directly direct heat from a depth of 2 km.

The Levelised Cost of Heat (LCOH) of these open loop systems is on par with large scale gas boilers at 4 to 7 p/KWh. Coupled with potential 25% to 0% operational GHG emissions from geothermal system compared with the fossil fuel equivalent, there is a compelling case for this novel application which Causeway is pursuing with several clients in the UK.

Session Three: Optimising Aquifer Thermal Energy Storage (ATES): Efficiency, Impact, and CO2 Reduction Potential in the UK

Multi-scale imaging of the Triassic Sherwood Sandstone Group, NW England: impact of heterogeneity on aquifer thermal energy storage efficiency

Jingyue Hao, University of Manchester

The development of aquifer thermal energy storage systems (ATES) in the UK has potential for energy efficiency and CO2 reduction. Accurate prediction of aquifer response to injection and extraction cycles necessitates detailed characterisation of aquifer properties and heterogeneity that may influence system efficiency. This study employs petrographic, mineralogical and X-ray CT techniques to investigate mineralogy, microstructure, porosity, pore-distribution and structure, permeability, and potential fluid pathways in Sherwood Sandstone core material from the UK GeoEnergy Observatory field research site in Cheshire. Multiple scales of observation, from core- to pore-scale, have allowed the assessment of scales of heterogeneity in the aquifer. Based on mineralogical and petrographic data, the sandstone is characterized into (i) clay-lean, quartz-rich sandstone; (ii) clay-bearing, quartz-rich sandstone; and (iii) pebbly sandstone. Clay-lean, quartz-rich sandstone exhibits a well-connected pore network, yielding the highest permeability and porosity (up to 31.8% and 2135 mD). Clay-bearing, quartz-rich sandstone possesses a poorly connected pore network, resulting in low permeability (around 0.1 mD), making it a barrier within the aquifer. Pebbly sandstone is rich in calcite cements, and therefore also has low porosity and permeability (up to 17.7% and 1009 mD). Clay-lean, quartz-rich sandstone occupies 81% of the 100-meter core, while pebbly sandstone constitutes 10%, and clay-bearing, quartz-rich sandstone accounts for 7%. Heat transfer modeling indicates that heat dissipates more rapidly through clay-lean, quartz-rich sandstone and pebbly sandstone compared to clay-bearing, quartz-rich sandstone. This multi-scale characterisation enhances the understanding of fluid and heat flow in heterogeneous aquifer systems, providing valuable insights for optimizing ATES operations.

Impact of aquifer properties, well spacing and vertical offsetting on ATES and Open loop unidirectional systems

Carl Jacquemyn, University of Manchester

Aquifer Thermal Energy Storage (ATES) and Open-loop unidirectional shallow geothermal system can supply both heating and cooling. Both play an important role in providing a sustainable, and low-carbon solution for heating and cooling. Both use similar numbers of well pairs and have similar installation and operational costs. However, the seasonal reversal of ATES systems allows very efficient energy storage, up to around 70-90% for well-balanced systems. Here we explore a number of parameters of interest, including energy production and energy production per area for a suite of common aquifer properties and design decisions.

We set up a framework to simulate the impact of a wide range subsurface and design parameters to deduce their impact on ATES and Open-loop system performance. Aquifer thickness, lateral permeability and permeability anisotropy are considered as main aquifer properties, and well lateral spacing and vertical offsetting of screened interval as main design decisions. The thickness of the injection and production interval can be dictated by aquifer permeability variations and/or be chosen by varying screen length.

Results indicate that ATES' bidirectional subsurface thermal storage nearly always produces more energy than unidirectional open-loop systems, even when thermal recovery is low. Only when cold and warm plumes are placed side-by-side, closer than half thermal radius apart, negative thermal efficiency occurs, and more energy is put in the system than extracted. However, placing vertical offsetting of screen intervals between wells at very small spacing is still efficient, and similar thermal behaviour as large lateral well spacing is achieved.

Potential CO_2 savings from widespread deployment of Aquifer Thermal Energy Storage across the UK

Matthew Jackson, Imperial College London

Aquifer Thermal Energy Storage (ATES) is an underground thermal energy storage technology that provides large capacity (of order MWth to 10s MWth), low carbon heating and cooling to the built environment. Heating and cooling currently produces 23% of the UK's greenhouse gas emissions. ATES can be a key technology for the UK to meet its net zero targets. ATES offers a higher overall coefficient of performance compared to conventional, open-loop shallow geothermal systems: waste heat and cool is captured and stored underground as warm and cool water, so less electrical energy is required by a heat pump to provide heating, and cooling can be delivered directly without the need for a heat pump.

We demonstrate that ATES could make a significant contribution to decarbonising UK heating and cooling, but uptake is currently very low with eleven systems meeting <0.01% of the UK's heating and <0.5% of cooling demand. Despite the current low uptake, we show that the UK has large potential for widespread deployment of LT-ATES, due to its seasonal climate and the widespread availability of suitable aquifers which are co-located with urban centres of high heating and cooling demand. We estimate that ATES could supply 61 % of UK heating demand and 79 % of cooling demand. Widespread deployment in the UK offers a 16-41% reduction in carbon emissions for heating, and 86-94% reduction for cooling, compared to equivalent ground- or air-sourced heat pump systems. A key barrier to increasing uptake is lack of awareness of the technology.

Responsible deployment of Aquifer Thermal Energy Storage: A stakeholder approach to characterising societal desirability, opportunities and challenges

Ting Liu, Imperial College London

Exploring the societal challenges associated with the adoption of Aquifer Thermal Energy Storage (ATES) for low carbon heating and cooling is crucial for facilitating socio-technical innovation and scaling up nationwide deployment. Here, we build on a Responsible Innovation framework to assess the social desirability, opportunities, and limitations of ATES expansion in the UK. We conducted 14 semi-structured interviews with a representative set of stakeholders comprising heating and cooling suppliers, consumers, regulators, and researchers associated with ATES and renewable energy in the Greater Manchester Metropolitan area, a region with significant potential for ATES development. The findings offer insights into several key areas: perceived multifaceted benefits in the local economy, environment and energy efficiency; reputation of ATES and associated confidence risks; regulatory hurdles, legislative mismatches, licensing complexities, and infrastructure challenges of ATES deployment. These insights contribute significantly to the discourse on strategic views towards a sustainable energy transition and stakeholder engagement in renewable energy projects. This study proposes policy recommendations focusing on improving market awareness of ATES, promoting industry-specific education and knowledge sharing, facilitating stakeholder engagement from a top-down perspective, leveraging collective expertise and commitment across different stakeholders, as well as advocating tailored legislative and regulatory measures to uphold a British standard for ATES. Central to our findings is the emphasis on value-inclusive design of ATES systems that align with social desirability and local priorities such as affordability, safety, reliability, inclusivity, responsiveness, and sustainability, to facilitate the responsible deployment of ATES.

Evaluation of the fracture slippage potential in Low Temperature Aquifer Thermal Energy Storage systems

Andre Efsion, Imperial College London

Evaluating the mechanical stability of near-well regions is crucial for the effective implementation of Low Temperature Aquifer Thermal Energy Storage (LT-ATES) systems. LT-ATES operates in shallow aquifers having temperatures below 30 oC, and typically extracts relatively hot water for heating whilst injecting spent cold water at 5-8°C in winter and extracts relatively cold water for cooling whilst injecting spent hot water at 14-18°C in summer. Despite the small temperature contrasts involved, near-well regions in naturally fractured aquifers are subjected to some thermal effects, in addition to fluid pressure changes. Changes in shear and normal stresses due to this thermal effect may induce fracture slippage, modifying the fracture aperture and thus the permeability. Fracture slippage can also generate micro fractures or damage zones in its vicinity, allowing fluid migration to other formations.

A thermo-hydro-mechanical (THM) model of a LT-ATES system was constructed using COMSOL Multiphysics to simulate cyclic water injection and extraction operations, and stress changes associated with temperature and fluid pressure changes. The Coulomb failure stress changes (ΔCFS) were calculated to evaluate the potential for fracture slippage around cold and hot wells. The model considers cyclic field operations during a period of 10 years, as well as the injection and extraction rate and temperature variations based on seasonal heating and cooling demands. The ATES system simulated is based on the UK Geoenergy Observatories (UKGEOS) Cheshire site, utilising extensive lithological and fracture characterisation data from borehole logs and follow up laboratory studies. This research is carried out as part of the EPSRC funded Aquifer Thermal Energy Storage for sustainable decarbonisation of Heating and Cooling (ATESHAC) project, Grant No EP/V041878/1.

Evaluating the Impact of Chalk Aquifer Heterogeneity on LT-ATES Performance: A Case Study from London

Hayley Firth, Imperial College London

The Chalk aquifer is a highly heterogeneous dual porosity system, with high-permeability zones formed by fracturing and/or karstification within a low-permeability matrix. Many London boreholes show a high-permeability flow zone at the Chalk's top, yet industry models often assume a homogeneous aquifer, leading to simulated warm and cold plumes having simple cylindrical geometry around wells. This study examines the impact of aquifer heterogeneity on ATES system performance through an operational LT-ATES installation with four well doublets. Preliminary interpretations indicate a well-balanced energy ratio of 0.09 and thermal recovery of approximately 40% for warm wells and 25% for cold wells.

Using a Surface-Based Modelling (SBM) approach, we develop an ensemble of 3D models to capture subsurface uncertainty. Flow and heat transport during operation are simulated with the Imperial College Finite Element Reservoir Simulator (IC-FERST). Models are calibrated using Nelder-Mead methods against pressure transient data and inflow logs. Operational temperature and flowrate data are subsequently employed in thermal simulations using the calibrated models.

Findings reveal significant impacts of heterogeneity on warm and cold plume formation. High-permeability intervals cause pancake-shaped plumes, increasing conductive heat loss and lowering thermal recovery, which is expected to improve over time as surrounding rock temperatures change. Due to low heating and cooling demand, the system predominantly uses a single well doublet. Additionally, thermal interference between warm and cold wells arises from laterally extensive plumes.

The study underscores the necessity of recognizing and modelling subsurface heterogeneity for effective ATES operation, influencing future planning and design of ATES systems globally.

WING UPDATE

Rebecca Bolton, WING UK

TBC

Session Four: Exploring Mine Water Geothermal Energy: Characterization, Challenges, and Opportunities for Sustainable Heat

Drilling into shallow coal mine workings for heat: importance of characterising the rocks

Stuart Jones, Durham University

Coal extraction (Durham and Northumberland Coal Fields) has largely taken place using the pillar and stall method. For mine geothermal prospects, the majority of flow will occur through open stalls, which will have very high permeabilities and porosities. However, pillars and temporary supports that were designed to sustain the weight of overburden can over time fail resulting in mine roofs to collapse. Furthermore, the occurrence of goaf (backfilled mine waste), caving's, localised dissolution and lithological heterogeneity of the Carboniferous coal measures are important to appraise as they will significantly affect the capacity and flow properties within mine workings. This research has investigated former coal mine anthropogenic deposits along the Northumberland coast at Whitley Bay and integrated with borehole and core data sets from the local region. The project has undertaken extensive detailed fieldwork with sedimentological field data collection focusing stratigraphically on the Upper Carboniferous (Westphalian) High Main coal seam. Detailed permeabilities, porosities and petrography were collected from different lithologies in the field. The research demonstrates how any collapse, spalling of the roof and backfilled roadways will have very low permeabilities (> 0.01mD to 0.001mD) but low to moderate porosities (~3-8%) compared to the surrounding lithologies and may act as long-term barriers to flow. Closely associated and laterally connected sandstones and siltstones frequently have much higher permeabilties (~100-300mD) and porosities (~15-25%). Older mine workings that have experienced greater degrees of compaction and anthropogenic heterogeneity may be less viable as geothermal reservoirs. The findings presented establish one of the first data sets that can be used for modelling of geothermal prospects in former coal mine workings.

Challenges in Characterizing Mine-Water Baseflow and Heat Transport Using Tracer Tests in the Galleries to Calories Project

Alejandro Perez, University of Edinburgh

The performance of potential mine-water waste-heat storage schemes is significantly influenced by the effect of groundwater flow on thermal transport. This issue is explored in the "Galleries to Calories" project using analytical and numerical modeling, as well as field tracer tests. Numerical simulations of coupled fluid flow and (conservative) mass transport in a 3D domain indicate that, at a local scale (< 200 m), a set of three monitoring boreholes could confirm the groundwater flow direction, which is locally controlled by void connectivity. On a larger scale, the high flow through these voids could result in travel times for the dye tracer of less than a year for monitoring locations more than 1 km from the injection point. However, the dispersive nature of the mine-water system leads to very low-concentration signals that are challenging to detect at these proposed monitoring locations. Consequently, the design and proposal of large-scale open-loop schemes for heat storage could be hindered by the lack of calibration data for predictive heat plumes in numerical models.

A Local Hydrogeochemical Conceptual Model of the Midlothian Coalfield: Assessment of Risks Baseline Prior to Minewater Thermal Storage

Samuel Graham, University of Edinburgh

The Galleries to Calories research project led between seeks to establish a field test site to assess the viability of flooded coal mine workings as part of a regional scale heat battery. We plan to target the Roslin and Burghlee collieries to the SE of Edinburgh. The collieries underlie the catchment of the river Esk.

Minewater interactions poses risks surface water quality. Heat storage places additional sources and sinks, with consequences for geochemical fluxes (sources), transport (pathways), and the wider environment (receptors). A detailed field campaign has been ongoing since May 2023 to establish local baseline in the vicinity of the geobattery test site in terms of water physiochemistry and hydrochemistry.

We present the results of this study, combing new geochemistry with earlier work establishing a structural conceptual model of the workings. Our results ground-truth earlier hypotheses as to potential source-pathways and receptors, and translate this into a fuller understanding of the actual relationships between the collieries and their neighboring water bodies. In particular we highlight possible controls on chemistry in the Kill Burn related to interactions with Burghlee colliery, and interactions between Bilston Glen shaft and the neighboring Bilston Burn. Faulting-related influences on the geochemistry of the North Esk are also explored. Our results allow us to move beyond a merely conceptual understanding of the system, to a position of making some initial predictions for changes to surface water chemistries that could occur in response to various degrees of change to current surface-groundwater interactions. This can inform further monitoring required for safe management of a regional scale heat battery scheme. The results are also presented.

Advancing Net Zero: Expanding Mine Water Geothermal Potential in Kent's Coal Mines

Glyn Pugh, ERCE

In 2023, Mimi Bleakley presented the results of a desktop study on the geothermal potential of coal mine water at the Snowdown mine workings in Kent. Building on the success of this initial project, ERCE has extended its research and engaged in discussions with local stakeholders regarding the practical applications of coal mine water geothermal energy in new developments.

Our expanded scope now includes an integrated desktop study to assess the geothermal potential at two additional major collieries in Kent: Betteshanger and Tilmanstone. These sites are in proximity to several villages and the town of Deal, offering significant opportunities to utilise geothermal heat for upcoming developments, including a planned leisure and heritage centre near Betteshanger and an industrial/business park near Tilmanstone.

This study aims to evaluate both the practical and economic feasibility of leveraging coal mine water geothermal energy to minimise the environmental footprint of new and existing infrastructure in the region. By demonstrating the potential for geothermal energy in these areas, we seek to contribute to the reduction of carbon emissions and the promotion of sustainable energy solutions in Kent.

Investigating the potential impacts of climate change on mine water resources: Central Scotland as a case study

Clodagh Gillen, University of Strathclyde

TBC

The Opportunities and Challenges of the Mine Water Heat Resource in Cornwall

Tony Bennett, EGS Energy Ltd. And Southwest Geothermal Alliance

The use of abandoned flooded coal mines as a source of renewable thermal energy is well established in the UK and a number of successful projects are in operation. However, abandoned metal mines also offer a considerable resource. During the 18th and 19th centuries Cornwall exploited vast quantities of copper and tin and for many decades was the richest and most extensively mined region in the world. Over 2,000 mines were active at various periods and this has left a legacy of extensive flooded mine workings, many of which are greater than 300 m deep. The Southwest Geothermal Alliance has developed a database of mine shafts in Cornwall that are over 300 m deep and has undertaken several feasibility studies into the potential use of mine water heat to supply existing residential and commercial buildings. The geology and the mining methods used in the Cornish metal mines presents a different set of conditions from those encountered in coal mines, which means that different approaches have to be considered for evaluating the resource and the methodology of heat extraction. This presentation outlines some of the challenges and opportunities associated with evaluation and with the feasibility of cost-effective utilisation of this resource. Several heat extraction scenarios and case studies for using mine water heat in Cornwall are presented, which illustrate some of the specific strengths and weaknesses of this form of geothermal energy.

Session Five: Advanced Techniques in Geothermal Reservoir Imaging, Monitoring, and Modelling

The potential of Large-N passive seismology to image meter scale reservoir heterogeneity

Mark Ireland, Newcastle University

The production of geothermal energy requires the abstraction, and conventionally reinjection, of water. The geochemical composition of waters and the nature of rock/water interactions is vital to understand scaling and mineral precipitation in both wells and surface infrastructure. Increasingly there is a recognition that the mineral end element components of produced fluids could also be extracted.

To better understand the range of groundwater geochemistry, including critical minerals and potentially toxic elements, we have collated a dataset of over 3000 water sampling occurrences with data from the BGS Geothermal Catalogue and the EA Water Quality Archive. The data are geographically located and have depth, formation and lithology information, and geochemical data such as pH, major/minor ions, and dissolved metals. Multivariant analysis was used to determine the subsurface distribution of critical minerals and potentially toxic elements in relation to rock lithology and depth.

Examples of the information that can be derived from the data are, for example, there are 21 sample locations that show dissolved Cd concentrations over the 1.5 µg/l maximum allowable EQS, and 50 sample locations with Li concentrations greater than 100µg/l. However, of the data available approximately two thirds are shallower than 500 metres and one sixth had no depth assignment.

Further analysis of this data will provide greater understanding of the fluid composition, across a range of depths and geologies where geothermal energy projects may be developed, and longer term improve our understanding of factors controlling the relative enrichment of minerals and elements.

Reinjection of CO_2-enriched spent fluids at the Kızıldere geothermal field, Turkey: A numerical modelling study

Ji-Quan Shi, Imperial College London

The Kızıldere geothermal field, located in the East of Büyük Menderes graben in Western Anatolia, was discovered in 1968 as the first site with potential for geothermal energy in Turkey. Operated by Zorlu Energy, the two geothermal power plant units at Kızıldere currently has 245 MWe installed capacity, with wells drilled at 500 – 3,500 m reservoir depth and at 220 – 245 oC reservoir temperature. The geothermal fluid at Kızıldere is produced from carbonate rocks and carries a significant amount of dissolved CO_2 (over 3% by weight depending on depth), which is mostly exhausted to the atmosphere as non-condensable gas during power generation. Geothermal fluid production for the geothermal power plants has been accompanied by reinjection of spent fluids back into the geothermal reservoir.

SUCCEED (Synergetic Utilisation of CO_2 storage Coupled with geothermal EnErgy Deployment) is an industrial project which aims to research and demonstrate the feasibility of utilising produced and subsequently vented CO_2 for re-injection into the reservoir to improve geothermal performance, while also storing the CO_2. This study presents the development of a dynamic reservoir model representing the Kızıldere geothermal field and model calibration against field natural state well temperature and pressure profiles. The calibrated dynamic model is then used to simulate geothermal production and reinjection of CO_2-enriched depleted fluids. Reservoir simulations in this research have shown that reinjection of CO_2-enriched spent fluids has the potential to re-establish the geothermal reservoir CO_2 content, thus reducing CO_2 emission, while having the advantage of further maintaining reservoir pressure.

NSAR FOR GEOTHERMAL FIELD MONITORING: CASE STUDIES FROM NEW ZEALAND

Nick Dodds, SatSense

Injection and extraction of fluids in the subsurface for geothermal energy and mineral extraction purposes results in pore fluid pressure perturbations. These perturbations at depth result in ground motion at the surface that can be measured with millimetric precision using radar satellites (InSAR). With satellite revisit times at days to weeks and a data archive spanning over a decade, InSAR can be used to measure both dynamic short-term and steady long-term surface movements related to geothermal operations. These spatial and temporal observations can be inverted to reveal valuable insight into properties of the subsurface for geothermal applications.

SatSense in partnership with GNS Science have processed InSAR data from 2015 to present over the entirety of New Zealand. We present case studies from geothermal fields across New Zealand, where geothermal power accounts for 25% of the total energy supply. We present how patterns of movement at the surface can be used by operators to manage reservoirs and optimise their geothermal energy recovery strategy. We present how InSAR can be used by operators to manage and report their subsidence footprint at scale. Finally we present how monitoring movement at the surface can be used to manage related critical infrastructure such as pipelines.

New Approach to Modeling Fractured Reservoirs for Geothermal Energy and Lithium Recovery

Tim Salter, Baker Hughes

The geothermal resource potential of the Hell's Kitchen area of the Salton Sea Geothermal Field (SSGF) was evaluated through geological assessment, well modeling, and reservoir simulation to deliver a natural-state matched dynamic reservoir model for estimating geothermal power and lithium production.

A 3D geomodel centered around the development area was constructed from ground level down to a base depth that equals a nominal 370°C isotherm. The temperature model distinguishes the high geothermal gradient thermal cap from the near isothermal reservoir that is clearly demonstrated in most wells. Geochemical properties for the resource defined the key inputs to flow simulation of lithium rich and lithium depleted brines. The main reservoir faults define linear trends likely to host upflow of fluid from the base of the reservoir.

A Discrete Fracture Network (DFN) model was developed to provide the fracture and fault derived permeability to the dynamic flow model. The DFN model is comprised of large-scale faults that are described deterministically and smaller scale structures that are described stochastically. Stress-permeability coupling is dynamically computed during DFN model development.

To model flow and transport on the regional scale over time, the properties of the network of discrete fractures were upscaled for dynamic fluid modeling to explore well engineering scenarios for optimal production. In a base-case forecast scenario, the total enthalpy production rate reached 1076 kJ/kg. Cumulative elemental lithium production modelled reaches 1.58E5 tonnes over the 30 years.

Use of Rockwash Geodata integrated cuttings analysis for characterisation of deep wells in granite basement – an example from United Downs wells UD-1 and UD-2

Douglas Langton, Rockwash

The United Downs Deep Geothermal Project wells UD-1 (5275 m MD) and UD-2 (2393 m MD) were completed in 2019 and provide an unparalleled insight into the deep geology of the Cornubian Batholith. 50 g samples of wet ditch cuttings from UD-1 (509 samples) and UD-2 (240 samples) were washed, photographed and underwent pXRF and magnetic susceptibility analysis (plus selective sample XRD analysis) at Rockwash Geodata. The purpose was to determine the effectiveness of semi-automated analysis, typically applied to wells in sedimentary basins, to a basement granite geothermal play. Compositional changes in the granites reflect: (1) Early Permian magmatic processes and pluton construction, that exert a first-order control on the distribution of the heat-generating elements (U, Th, K) and (2) post-Permian wall-rock alteration (kaolinisation and hematisation) associated with the development of the fault-controlled geothermal reservoir. Variations in U, Th and K, and hence heat generation, are effectively demonstrated and, together with Nb/Zr and Rb/K ratios, confirm the presence of multiple granites with differing compositions. Agglomerative hierarchical clustering of PCA scores from the XRF data provides a granite classification consistent with XRF lithotyping. The use of brightness and red channel optical analysis provides a first-order constraint on major ‘cross-course’ fracture zones. Trace element analysis indicates zones of restricted fracture-controlled W, Sn, Zn, Cu, Mo and Ni, Co, Pb, As, mineralisation, particularly in the upper part of the wells. Overall, these additional datasets provide a deeper insight into the basement granite reservoir that complements manual cuttings analysis during drilling.

Session Six: Integrating Renewable Technologies: Innovations in Shallow Geothermal and Heat Pump Systems

Integration of photovoltaic-thermal and passive cooling rejected heat within shallow geothermal networked heat pump systems

Alister Henderson, Kensa Engineering Ltd.

TBC

Ground source heating and cooling (GSHC) systems – evidence for regulation

Sian Loveless, Environment Agency

TBC

Geothermal heat with every beat" – the BODYHEAT project two years into operation

John Naismith, TownRock Energy

BODYHEAT is an innovative geothermal cooling and heating system built at SWG3. It was co-funded by the Scottish Government and principal advisors were TownRock and Harley Haddow.

SWG3 is a events venue in the west of Glasgow, where large music events are held hosting up to 1250 partygoers. BODYHEAT supplies cooling to these event spaces using indoor refrigeration units. The rejected heat, instead of being vented to the atmosphere, is stored in closed loop boreholes. The heat stored in the boreholes is recovered later and used to supply hot water and heating. The most intense cooling occurs during large events when there is high occupancy and high activity. During these times, the more energy that partygoers expend to enjoy the music, the more energy is captured by the system! As a result, the BODYHEAT name has gained considerable traction in the media, raising awareness of the potential of geothermal heating, cooling and storage.

The project faced multiple challenges, including: uncertain future cooling and heating loads; boreholes very close to two busy commuter train lines; co-location of a still-to-be-constructed community garden above the boreholes; project cost growth and the COVID pandemic.

Detailed geotechnical studies were carried out to confirm there would be no significant ground movement risks; header system and garden design were developed in parallel to protect the boreholes; and a low-cost data acquisition system was devised to monitor borehole and system performance.

The talk will show and tell the latest operational data with preliminary analysis of the system.

Comparative subsurface aquifer modelling: a Geothermal Campus case study

Arka Sarkar, University of Leeds

Geothermal Campus is an initiative by the University of Leeds as part of its campus decarbonisation plans. To target reduction in emissions related to space heating on campus, a series of smaller low temperature heat networks connected to 'Energy Centres' are planned, utilising the existing high temperature steam distribution heat network. Energy Centres are supplied by either air or ground source geothermal heat pumps, the latter targeting warm aquifer fluid. Phase 1 of this project will cover the Engineering cluster of buildings and a hall of residence with drilling undertaken Q1-Q2 2024. The drilling campaign involves a mix of exploration and monitoring boreholes (two 250 m depth cored pilot wells, three 150 m thermal response testing, TRT, boreholes, and one 250 m TRT borehole). Production infrastructure will include a pair of 150 m depth reversible injection and abstraction water wells targeting the Carboniferous Elland Flags Formation aquifer sandstone. The monitoring boreholes are all being permanently installed with fibre-optic monitoring cables for both distributed -acoustic and -thermal sensing (DAS & DTS respectively). TRT conducted post drilling will be concurrently monitored via DTS to contrast bulk thermal results against DTS readings taken at greater vertical spatial resolution downhole. TRT results suggest the impact of groundwater fluid flow, with DTS testing used to help delineate this impact as well as help constrain any compartmentalisation of the target aquifer. Given the difficulty of active seismic surveying in a built environment, this information when coupled with downhole geophysics and core from the pilot wells will help better inform future phases of campus drilling.

Core to field-scale thermal characterisation of the Sherwood Sandstone Group aquifer at UKGEOS Cheshire, UK

David Boon, British Geological Survey

The thermal properties of UK aquifers are important considerations for the effective design of geothermal systems. We focus on the Triassic Sherwood Sandstone Group (SSG), a principal aquifer underlying several major cities in the UK that represents a considerable heat source for heat pump systems, aquifer thermal energy storage, and deep geothermal plays.

Multi-scale thermal property evaluation of the fluvial Chester Formation of the SSG within a 30x30 m wide by 100 m deep rock volume at the UK Geoenergy Observatory (UKGEOS) research facility in Cheshire, has been undertaken using core plugs and insitu tests in boreholes. Advanced thermal response tests (A-TRT) were conducted in four 100 m deep vertical closed loop boreholes. The loops were instrumented with fibre optical distributed sensing cables (FO-DTS) inside the pipe and on the tremie pipe, and digital thermistor cables (DTC) on the outside of the loops determination of effective thermal conductivity down the entire well. Hybrid FO cables in 13 wells were actively heated to undertake enhanced TRT (E-TRT) to further characterise well thermal and flow properties. The field site gives insight into the influence of lithological and mineralogical variations and fractures in a rock unit widely considered to be dominated by intergranular flow. Thermo-physical data derived from 200 x 1 inch diameter core plugs is compared with field-scale measurements. The results enhanced the site geo-model and support regional-scale heat flow modelling in the Manchester-Warrington area. The results are also relevant to hot sedimentary aquifer (hydrothermal) reservoir analogue studies for the Permo-Triassic sandstones.

Numerical Modelling of an Exceptionally Well Instrumented Thermal Response Test in the UK Chalk Aquifer

Louisa Bahlali, Imperial College London

The Chalk aquifer hosts > 50 open-loop shallow geothermal systems across the south and east of the UK. Yet the development and migration of thermal plumes in the aquifer during operation of these systems remains poorly characterised. The Chalk aquifer comprises a highly heterogeneous, dual porosity system, with high-permeability zones formed by fracturing and/or karstification within a low-permeability matrix. Groundwater flow velocities at pumped and ambient conditions can be highly variable across these zones, resulting in spatially complex plume geometries. This increases the risk of poor system operation caused by thermal interference between wells within the same installation, and between neighbouring installations as deployments become more numerous.

We report numerical modelling of a Thermal Response Test (TRT) in the Chalk aquifer at a test site in Berkshire, UK. The TRT involved an exceptional level of instrumentation and monitoring, including distributed temperature sensors installed in offset boreholes and the tested borehole, surface and cross-well electrical resistivity tomography, and seismic monitoring. The aim of the TRT was to image the thermal plume as it developed around the borehole to determine the impact of aquifer heterogeneity. Using the open-source IC-FERST code, we simulate the TRT where a closed-loop heating tube provided 7.7 kW of heat. Early results demonstrate that high ambient groundwater flow, focussed in specific high permeability zones, efficiently removes heat from the borehole, transporting it downstream to develop a thermal plume with complex geometry that is strongly controlled by heterogeneity. Work is ongoing to integrate the thermal-hydrogeological model results with geophysical imaging.

Session Seven: Unlocking Geothermal Potential: Innovations in Exploration, Technology Transfer, and Sustainable Heat Solutions

Customer driven geothermal exploration approaches for industrial hubs and district heating

Dave Waters, Paetoro Consulting UK Ltd.

The proliferation of geothermal research and development in the last 20 years has been remarkable.

Throughout this diverse evolution, use of hydrothermal resources in large city-scale district heating networks has increased in scale and sophistication. The cities possessing >100MWth geothermal district heating systems are approaching double digits. Techniques for exploration and drilling in urban environments are advancing, and risk decreasing as urban plays are better understood. Urban scale district heating – with additional cooling options, remains an underrated geothermal success story in 2024.

Simultaneously, deployment of geothermal resources in large industrial hubs collecting both energy resources and energy customers, is an incipient phenomenon that is greatly underexploited. Early initiatives in Iceland, and China, are changing this paradigm from looking at geothermal projects in isolation to regarding them as part of a wider energy portfolio. Large industrial hubs are compatible with both the risk and the capital expenditure involved. Nevertheless, to take advantage of geothermal resource in such hubs requires early planning and placement suitable for resource use. Such planning is non-trivial and a key obstacle.

For all the improvements in lower enthalpy hydrothermal deployments, risk associated with well-scale variation in reservoir quality remains largely irreducible for individual development and operational wells. Chances of success are typically in the realm of 70-80%. This necessitates an especially devised approach to commercial project risking distinct from other subsurface resources. It also requires a different prioritisation of drilling-based exploration relative to geophysically -based pre-drill techniques, when targeting geothermal plays fundamentally different in their geometric constraints.

The potential benefits of technology transfer from the US to the UK to accelerate the development of Geothermal Energy in UK

Tony Pink, Pink Granite Consulting Ltd.

Over the last 3 years, through major investment grants from the US Department of Energy and a significant pivot by Oil and Gas companies, the development of Enhanced Geothermal Systems (EGS) and now Super-Hot Rock (SHR) Geothermal systems. These investments have led to a number of technological breakthroughs in drilling technology, completion development and geothermal reservoir creation. These technologies and processes are easily transferable to the UK Geothermal industry. The adoption of these technologies could significantly accelerate the development of the UK Geothermal industry and drive down the cost of development making Geothermal energy even more attractive when compared to Nuclear and fossil fuels. The US has also continued to drive down the cost of wells in sedimentary basins. Transferring the knowledge gained from factory drilling on land in the US could bring massive financial benefit in developing the Geothermal heat market in the UK. The presentation will provide an overview of the benefits of technology transfer and discuss the various technologies and their relative merits in the hard basement opportunities and in sedimentary basin heat market.

Deep Geothermal Heat Pumps: megawatt-scale, sustainable heat supply that is cost competitive with fossil fuels

Huw Williams, Causeway Geothermal (NI) Ltd & Agua Enodo Ltd

The deep (>500 m) Sherwood Sandstone of Northern Ireland has some of the highest potential geothermal resources in the British and Irish Isles. This hydrothermal resource present at variable depths and although higher resource temperatures (>90°C) are sequestered to the deeper areas, the innovative use of Industrial Heat Pumps (IHPs) allows lower temperature geothermal energy to be upgraded and utilized in cost effective ways.

Where hydrothermal aquifers with flow rates sufficient to support open loop geothermal development are not present, Deep Borehole Heat Exchangers (DBHE) are a possible alternative, however, they are an order of magnitude less effective than open loop extraction.

We have developed thermal energy forecasts for the two main archetypes at 1 and 2 km depths in two conceptual locations in County Antrim. An open loop doublet targeting the Sherwood Sandstone is expected to deliver a thermal power through a IHP of 2.5 MWth (70 º C output) over 25 years from a 1 km deep Sherwood Sandstone interval. The same formation is predicted to deliver a thermal power of 1.6 MWth directly direct heat from a depth of 2 km.

The Levelised Cost of Heat (LCOH) of these open loop systems is on par with large scale gas boilers at 4 to 7 p/KWh. Coupled with potential 25% to 0% operational GHG emissions from geothermal system compared with the fossil fuel equivalent, there is a compelling case for this novel application which Causeway is pursuing with several clients in the UK.

A pathway to simplifying modelling of single coaxial deep borehole heat exchangers (DBHE)

David Banks, University of Glasgow

Numerical modelling is commonly applied to simulate the performance of coaxial deep borehole heat exchangers (DBHE), but it can be resource-intensive. Simpler, transparent analytical models and nomograms would be valuable to planners, developers and geologists for evaluating thermal output. Beier's (2020) analytical computational model was used to produce nomograms of geothermal heat yield from two generic designs of DBHE, by varying depth and rock thermal conductivity, and assuming a geothermal gradient (25°C / km) and fluid circulation rate (5 L/s). Continuous 25-year heat yields for thermal conductivities of 1.6 to 3.6 W/m/K range from 27 to 55 kW for a 1000 m DBHE and 165 kW to 281 kW for a 3000 m DBHE. Effective borehole thermal resistance (Rb,eff) increases strongly as DBHE depth increases, due to increased internal heat transfer between upflowing and downflowing fluid. Beier (2020) simulations correspond well with industry-standard (Earth Energy Designer) software for shallow 200 m coaxial BHE and modestly underestimate (2-4%) OpenGeoSys numerically modelled thermal yields for 1000 to 3000 m deep coaxial DBHE. Temperature evolution in the Beier (2020) model closely approximates an analytical "line heat source" approach. Simple spreadsheet "line source" analytical models (allowing variable heat loads via use of superimposed step-functions) are thus plausible for DBHE simulation, presupposing that a credible value of Rb,eff can be assigned to the system. Future research should thus focus on methods for forward quantification of Rb,eff from information on borehole construction materials/dimensions and fluid flow rates/conditions.

Banks et al. (2024) doi: 10.1144/qjegh2023-162; Beier (2020) 10.1016/j.applthermaleng.2020.115447

Investigating the Potential for a 6 km Deep Borehole Heat Exchanger to Supply Heat and Power in Glasgow

Tiorafi Muhammad, University of Glasgow

Glasgow is striving to achieve net-zero targets as detailed in the Glasgow Climate Plan. Geothermal energy can support this goal by contributing to sustainable energy generation within the city. However, there is significant risk associated to deep geothermal development as subsurface data is limited, and it is unlikely there will be sufficient conditions at depth to allow for conventional exploitation. Deep borehole heat exchangers (DBHE) can eliminate the reliance on natural permeability by forming a closed-loop geothermal system. Within a coaxial DBHE, fluid is circulated down the annulus, exchanging heat through the borehole wall via conduction before being pumped to the surface through a central pipe. This study aims to predict the thermal response of the subsurface under operating conditions for a notional coaxial DBHE in Glasgow with stratigraphy consisting of Carboniferous to Silurian strata. OpenGeoSys was used to model heat transfer in the DBHE, applying a ‘dual-continuum’ finite-element approach.

Imposing a heat load of 800 kW with a constant mass flow rate of 8.3 kg/s will result in the temperature of the inlet fluid being 56 °C, while the outlet fluid temperature is 79 °C after 25 years of operation. Increased flow rates lead to higher outlet temperatures, while improving the insulating properties of the inner pipe (i.e., vacuum insulated tubing) can achieve an outlet temperature that is 39 °C higher than a high-density polyethylene central pipe. Overall, DBHEs to depths of 6 km can provide substantial thermal energy but have low potential for power generation.

Challenges and opportunities for binary cycles in geothermal power applications

Martin White, University of Sussex

A binary power cycle, or organic Rankine cycle (ORC), system provides a means to convert heat extracted from low- and medium-enthalpy geothermal resources into electricity. Given the high cost of constructing geothermal reservoirs, the binary power cycle should be designed to generate the maximum amount of power to ensure the most optimal economic performance of the overall system. Thus, further advancements in binary power cycles to extend power production capabilities beyond the current state-of-the-art offer a route to improving plant economics. This talk will first summarise the current state-of-the-art in binary power cycles, including a discussion on the current limitations and challenges. This will be followed by a discussion of the potential performance improvements that can be unlocked by two-phase expansion, in which a mixture of liquid and vapour, rather than superheated vapour, is expanded in the expander. The concept has potential to improve power output in geothermal applications but has not been realised due to issues with the identification of suitable expansion machines. However, in recent years, one of the current authors has pioneered a new concept that could achieve two-phase expansion using conventional turbines. Previous studies for industrial waste-heat recovery indicate an increase in power of up to 30% compared to conventional ORC systems [1]. Therefore, the final part of this talk will explore the potential of this concept for large-scale geothermal applications.

[1] White, M., 2021, “Cycle and turbine optimisation for an ORC operating with two-phase expansion”, Applied Thermal Engineering, 192, 116852. https://doi.org/10.1016/j.applthermaleng.2021.116852

Global database of hot sedimentary aquifer geothermal projects: De-risking future projects by determining key success and failure criteria in the development of a valuable low-carbon energy resource

Maëlle Brémaud, University of Strathclyde

TBC

POSTER ABSTRACTS

How good is your fracture model? Examining how interpreter experience and approaches affect fracture model variability.

Leila Evans, University of Strathclyde

TBC

Regional interpretation of Permo-Triassic aquifers in the Cheshire Basin, UK, for direct use geothermal energy

David Johnstone, University of Manchester

This study is a play-based exploration assessment of two siliciclastic aquifers in the Cheshire Basin, northwest England, the Triassic Sherwood Sandstone Group and the Permian Collyhurst Sandstone Formation. The geothermal aquifers in this study form part of a sedimentary sequence deposited in a Permo-Triassic extensional half graben, known as the Cheshire Basin.

This study has utilised four interlinked workflows that combine to determine aquifer presence, -temperature, -quality, and -geothermal potential (Figure 1):

1. Aquifer presence, depth, and thickness. Well-seismic tie, Seismic TWT interpretation and depth conversion.

2. Aquifer temperature. Data gathering, temperature calibration and mapping.

3. Aquifer quality. Core analysis data from Cheshire Basin and the adjoining East Irish Sea Basin (EISB) has been used to identify porosity-depth and porosity-permeability trends in the aquifers of interest. Transmissivity maps are the product of permeability and thickness maps.

4. Mapping the Geological Chance of Success.

By integrating the predicted temperature and transmissivity maps for both aquifers, a target zone is defined which meets the cut-off criteria, a minimum temperature of 40°C, and minimum transmissivity of 4Dm (Figure 2). Values of domestic heat demand greater than 5kWh/m2 have been extracted from the heatflow dataset of Taylor et al., (2014b), and overlaid onto this target area to indicate areas of significant domestic demand.

Core data From the EISB wells shows that depositional facies, and a variable diagenetic overprint strongly control aquifer quality. The actual net thickness of suitably permeable aquifer within the plays of interest across the Cheshire Basin is therefore unknown at present, but is estimated using a net:gross ratio derived from analogue wells in the EISB. Uncertainty remains therefore in the prediction of the porosity and permeability at the depths required for direct use heat.

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Aquifer geothermal potential of Upper Devonian strata in the Midland Valley of Scotland

Tim Kearsey, British Geological Survey

Despite the high geological uncertainty, the hot sedimentary aquifer presents significant opportunity for a decentralised heat supply in central Scotland, coincident with some major population centers.

We present the first regional-scale estimation of the ‘hot sedimentary aquifer’ (or ‘hydrothermal’) heat-in place for the potential geothermal energy source of sandstone-dominated strata of central Scotland has been made. Including describing the lithology and rock properties of the target units now classified as Upper Devonian in age – the Kinnesswood Formation and Stratheden Group, the construction of an updated 3D geological model of depth and thickness, as well as values and assumptions input to the potential geothermal energy source estimation.

Compared to other UK geothermal opportunities (e.g. Permo-Triassic sandstones Worcester Basin, Eastern England) the heat-in-place values are large due to the greater depth and unit thickness combined with moderate porosity values, though the geological uncertainty is higher.

Innovative new closed loop horizontal well solution to universally harvest deep geothermal Energy

Kim Gunn Maver, Green Therma

To efficiently harvest deep geothermal energy universally an innovative closed loop horizontal well solution is proposed, which can be implemented in any geological setting as there is no requirement for fluids to circulate through a geological formation. This is unlike the doublet hydrothermal solution, which has specific geological requirements.

The geothermal well is drilled to a depth of 3-5 km depth with an up 5 km horizontal section utilizing oil field drilling technology and completed with a pipe-in-pipe concept with the inner pipe having a double wall with a continuous vacuum.

The fluid will flow within the outer pipe spacing and along a geological formation in the horizontal section of the well. In this process, the fluid is heated and then returned to the surface in the inner dual vacuum pipe at the toe of the well with minimal heat loss by being similarly to a thermoflask.

Without continuous vacuum 30-40% of the energy harvested is lost on the journey to the surface.

There is no downhole maintenance of equipment and the maintenance of the surface equipment is minimal as the circulation fluid is not exposed to damaging formation fluids.

A reliable and constant production of a heated fluid is possible to harvest constant energy from this deep geothermal solution that can be designed to last 50-100 years with virtually no CO_2 emissions. The solution can be connected to district heating and cooling systems and have industrial applications.

Aquifer lithology and fluid composition across potential geothermal production intervals

Will Norfolk, Newcastle University

The production of geothermal energy requires the abstraction, and conventionally reinjection, of water. The geochemical composition of waters and the nature of rock/water interactions is vital to understand scaling and mineral precipitation in both wells and surface infrastructure. Increasingly there is a recognition that the mineral end element components of produced fluids could also be extracted.

To better understand the range of groundwater geochemistry, including critical minerals and potentially toxic elements, we have collated a dataset of over 3000 water sampling occurrences with data from the BGS Geothermal Catalogue and the EA Water Quality Archive. The data are geographically located and have depth, formation and lithology information, and geochemical data such as pH, major/minor ions, and dissolved metals. Multivariant analysis was used to determine the subsurface distribution of critical minerals and potentially toxic elements in relation to rock lithology and depth.

Examples of the information that can be derived from the data are, for example, there are 21 sample locations that show dissolved Cd concentrations over the 1.5 µg/l maximum allowable EQS, and 50 sample locations with Li concentrations greater than 100µg/l. However, of the data available approximately two thirds are shallower than 500 metres and one sixth had no depth assignment.

Further analysis of this data will provide greater understanding of the fluid composition, across a range of depths and geologies where geothermal energy projects may be developed, and longer term improve our understanding of factors controlling the relative enrichment of minerals and elements.

Community engagement for deep geothermal developments in the UK: an updated reflection on engagement for the United Downs Deep Geothermal Project, Cornwall.

Thomas Olver, Geothermal Engineering Ltd.

As the first geothermal power development in the UK, the United Downs Deep Geothermal Project, developed by Geothermal Engineering Ltd (GEL), continues to provide a unique case study for community engagement activities around deep geothermal projects in the UK. Furthermore, GEL have begun to disseminate information focused on the development of a lithium extraction plant at United Downs. As construction of the powerplant nears completion and development of the lithium extraction plant progresses, an updated perspective on engagement can be provided.

Community engagement at United Downs, conducted largely by two full-time members of staff, includes the identification of key community groups, the dissemination of information onsite and at community functions and work with local schools. Both visual and written resources are used, with accessible versions provided where possible. GEL have developed online learning resources and are working to improve engagement over social media. The United Downs project has been able to progress without demonstrations or mass complaints and has been met largely with positive attitudes and support from local communities. This highlights the importance of proactive, clear and transparent community engagement to the development of future geothermal projects.

As GEL start to implement the United Downs geothermal model at other sites across Cornwall, learnings from past activities will be implemented to improve methods of engagement. Developing the quality and styles of communication and dissemination will aid in the acceptance of future projects, aid the GEL’s ability to deal with potential challenges and ensure future engagement is as effective as possible.

Levelised Cost of Heating Estimation of Deep Geothermal in Newcastle upon Tyne and North East England

Daniel Samosir, Newcastle University Alumni

Located in a temperate climate, the UK has significant heating demand, especially during winter. The combustion of fossil fuels for heating contributes 17% of greenhouse gas emissions, ranking third after surface transport and industry (North & Jentsch, 2021). These emissions exacerbate global warming, underscoring the urgency of the Paris Agreement's goal to limit global temperature rise to 1.5°C by 2025. The UK Government aims for net zero emissions by 2050, necessitating a shift from fossil fuels to renewable energy for heating (BEIS, 2021).

North East England, with 13.1% of households in fuel poverty (Department for Energy Security & Net Zero, 2023), predominantly relies on natural gas for heating (87.25%) (ONS, 2020). Newcastle upon Tyne, the largest metropolitan area in the region, faces growing heating demand from both domestic and commercial sectors, including universities and offices. Geothermal energy, a renewable source that extracts thermal energy from the earth, emerges as a viable alternative to fossil fuels.

This dissertation investigates the feasibility of utilising deep geothermal energy for heating in Newcastle and North East England. It calculates the Levelised Cost of Heating (LCOH) based on data from past and proposed deep geothermal projects. Using a multidisciplinary approach, it reviews theories for LCOH calculation, performs deterministic estimations, and compares results with data from other projects globally.

The analysis shows that deep geothermal energy is cost-competitive with other heating methods. Projects like Newcastle Helix, Town Moor, and Gateshead QEH demonstrate varying LCOH values due to factors such as heat generation and investment costs. The UK's policies, such as mandating large heat users to connect to district heating networks, can promote geothermal adoption and reduce LCOH. Integrating technological research and supportive subsidies is crucial for making deep geothermal energy a viable replacement for conventional heating methods.

The Good, The Bad, and the Ugly Drillers

Stuart Sinclair, Consortium Drilling Limited

As the UK intensifies its pursuit of sustainable energy, onshore geothermal drilling emerges as a key opportunity. This presentation explores the successes, challenges, and prospects within this sector through the lens of Consortium Drilling Limited (CDL), a premier onshore drilling contractor.

The Good: CDL has positioned itself as a leading onshore drilling contractor in the UK, offering tailored solutions for geothermal projects. CDL's commitment to innovation and environmental stewardship is evident through significant investments in automation and advanced drilling technologies that minimise environmental impacts while maximising efficiency. With a C-suite team having over a century of combined experience, CDL effectively navigates the complexities of onshore geothermal drilling, contributing significantly to the UK's net zero ambitions.

The Bad: Despite the considerable geothermal potential beneath the UK, progress has been slow. Challenges such as regulatory uncertainty, high CAPEX, and insufficient government support have impeded the development of onshore geothermal projects. However, recent advances, including the Eden Project, United Downs, and other operators receiving funding to deliver geothermal heat to NHS hospitals, demonstrate the sector's growing potential and the importance of strategic support.

The Ugly: The time for decisive action is now! To fully unlock the potential of onshore UK geothermal resources, stronger government backing, streamlined regulations, and targeted financial incentives are crucial. Industry stakeholders, policymakers, and investors must urgently collaborate to overcome barriers and accelerate timelines. CDL calls on the industry to unite in advocating for the changes needed to ensure geothermal energy becomes a cornerstone of the UK's sustainable energy future.

Drilling geothermal wells with laser: Sci-Fi or new reality?

Pawel Slupski, University of Padua

The potential of geothermal resources is currently constrained by existing drilling technology. To address this issue, the DeepU Project is investigating the application of laser and cryogenic gas for drilling deep wells (>4 km) to realise a U-shaped closed-loop geothermal heat exchanger. Here, we present the latest results from laboratory-scale laser drilling experiments utilising a newly designed and manufactured drilling system. This technology includes a 30kW laser source and optics, a drilling string, a drilling head, a flushing system and a few secondary systems necessary for successful rock penetration. We examined the laser-rock interactions, such as thermal spallation, melting and vaporisation. These phenomena were investigated using advanced analytical techniques like thermography, photogrammetry, and electron microscopy to understand the physical nature of the drilling process. Subsequently, we evaluated the feasibility and efficiency of the laser drilling, allowing for a direct comparison with traditional mechanical drilling methods. Our work has demonstrated that laser drilling technology is a promising alternative, capable of reducing well completion costs while being environmentally friendly. In the near future, it may not only unlock the true potential of deep geothermal resources but also reduce cost of drilling for all geothermal systems and deep storages.

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Cornish Lithium: Understanding lithium-enriched waters in Southwest England

Jos Thio, Cornish Lithium

Since 2019, Cornish Lithium has drilled six exploration boreholes in Cornwall to depths of <2 km to intersect fault structures based on 3D geological models created using historical mining records and geological mapping data. Sampling of these holes reveals lithium concentrations of ~100 mg/L and geothermal gradient of <45°C/km with fluids encountered throughout the permeable fracture network.

Here we present wireline data and images of relevant core intervals from a selection of our exploration holes to provide a greater understanding of the regional fracture network and help define the thermal and lithium resource found in the SW England.

Following positive exploration results at Cross Lanes Farm, which included the drilling of an exploration borehole, permeable structures have been identified and confirmed as having the potential for commercial lithium extraction. As a result, we are now planning a demonstration project in the area, which will include the construction and operation of a geothermal lithium production facility and the development of two additional 2 km deep wide-diameter boreholes, one serving as a producer the other as an injector.

Investigating Geothermal Potential using a global E&P database

Matthew Turner, S&P Global Ltd.

Geothermal Energy is a renewable energy resource that has been steadily increasing globally in installed capacity in recent years. In 2020, geothermal global installed capacity and power generation were reported to be 15,950 MWe and 95,098 GWh/yr, respectively (Huttrer, 2021). Global installed capacity is predicted to rise to 54 GW by 2050, with a global potential capacity of 318 GW (SPG, 2020; 2022). S&P Global has been building a database of geothermal energy and using it to study the potential for geothermal energy generation at many locations around the globe. Within the E&P International database, ~ 231,000 wells contain bottom-hole temperatures and ~ 7,000 fields contain geothermal gradients. More recently, a further ~ 40,000 geothermal data points have been added to the database. This large and extensive database was used to analyse geothermal potential in a number of basins globally at various depth intervals the results of the studies are presented in this presentations.

The S&P Global Upstream International Database contains data covering most of the world including parts of the conterminous United States and Canada. It contains information on nearly 800,000 wells, over 30,000 fields, producing from some 68,000 reservoirs. Historically the S&P Global dataset is compiled into separate databases covering North America (Enerdeq), Canada (Accumap) and the rest of the world (International) giving complete global coverage. The E&P International database holds information on over 40,700 lithostratigraphic units from 5,335 geological provinces, with stratigraphic charts available for every sedimentary basin, representing the geological history from basement to the surface.

Modelling & Optimization of Geothermal Energy in the Gulf of Suez

Amira Abdelhafez, University of Manchester

Geothermal energy in Egypt represents a significant untapped renewable resource that can reduce reliance on conventional power generation. Exploiting these geothermal resources depends on depth, temperature range, and geological characteristics. The intracontinental rift setting of the Gulf of Suez (GoS)-Red Sea rift is a favourable tectonic setting for convection-dominated geothermal plays. The geothermal gradient across the GoS ranges from 24.9 to 86.66 °C/km, with a heat flow of 31-127.2 mW/m². Surface expressions of convective heat loss emerge along the gulf flanks as hot springs (e.g., Hammam Faraun) accompanying deeper geothermal resources. These thermal anomalies are driven mainly by the local tectonic configuration. Characterizing the structural framework of major faults and their control on reservoir properties and subsurface hydrothermal fluid circulation is vital for geothermal applications in the gulf. The geothermal play systems of the GoS depend on structural and lithological properties that contribute to heat storage and vertical transport. Potential geothermal reservoirs include the Nubia sandstones, which, due to their thickness, continuity, and contact with hot basement rocks at a mean depth of 3 km, create an extensive reservoir for geothermal fluids. To develop these geothermal resources for energy production, defining the permeability anisotropy of the reservoir due to faults and facies variation is a crucial step in our study, particularly evaluation of influence on thermal breakthrough and production rates.

A new ground source heat pump installation and 'Living Lab' at BGS Headquarters, Nottingham, UK

David Boon, British Geological Survey

The Natural Environment Research Council (NERC) has a target for its estate to decarbonise its heating by 2030 and achieve Net Zero by 2040. The space heating of two office buildings on the BGS Keyworth Campus have been decarbonised using a ground source heat pump system comprising 28 closed-loop boreholes installed to 225m and 6 x 60kW heat pumps.

The project started in summer 2023 with a 231m thermal response test (TRT), followed by a tendering process, planning permission, then the main drilling phase over a 6-month period with completion and system commissioning in late 2024.

The project includes a geothermal 'Living Lab', featuring in-ground monitoring of 5 of the borehole heat exchangers (BHE) using hybrid fibre optical cables for distributed temperature sensing (DTS), distributed acoustic sensing (DAS), and electrical resistivity tomography (ERT). The monitoring system enables direct and indirect mapping and numerical modelling of daily thermal changes that occur during heat extraction and recovery periods. The ground loop flow and return temperatures are continually monitored. On the secondary side, the heat pump electrical consumption, building flow and return temperatures and flow rates are monitored, enabling calculation of seasonal performance factors (SPFH1-4). One borehole was cored to 240m, proving 215m of Mercia Mudstone Group on Sherwood Sandstone. Geophysical logging, core scanning and other analyses are being performed to support geoscientific research and public outreach.

This case study is an example of a commercial-scale GSHP system successfully retrofitted into in a mixed-age public sector campus fitting the buildings with new emitters.

Borehole exchangers as thermal batteries: towards a new standard in GSHP dimensioning

Étienne Coudert, Celsius Energy

TBC

Geothermal Energy Collaborating with Fish Farms for Climate Adaption in East Africa

Charles Ferguson, Global Infrastructure Solutions Limited

I will be sharing perspectives on geothermal infrastructure as a new avenue to explore in Eastern Africa that is combined with sustainable fish farming utilising the hot water from the drilled wells.

The solution to Africa's energy crisis is geothermal energy which is freely available in the East African Rift Region due to geological natural resources similar to Iceland.

This is an untapped natural resource with more than 20000 plus Mega Watts available for harvesting .Currently, only about 900 Megawatts of installed geothermal electricity capacity exists in the region, with power plants in Ethiopia and Kenya. This is an unexploited growth market about to take off.

The geothermal power plants will be combined with fish farming in ponds. Climate change will never really effect this type of food production and you could utilise the same earth moving equipment to dig the ponds to save costs.

This creates a sustainable energy and food solution. It will create growth, stability and security for East Africa for centuries to come.

It is expected that surplus power from the project will be exported to the Southern African Power and Pool (SAPP) and this will generate foreign exchange for the countries involved.

The fish produced will be used to feed the malnourished in this geographic area.

This is the cleanest renewable energy that can be produced on the planet and these geothermal plants can be operated for 24 hours a day.

Fish Production from nearby ponds.

AI has an important role to play with the geothermal water. The water taken from the well at 90°C is mixed with colder water into the fish pond for an optimal pond temperature of about 28°C which is maintained year round for the fish to thrive.

Smart monitoring systems can be utilised with aquaculture. These systems can employ various sensors, cameras, and data analytics tools to continuously collect real-time data on water quality, temperature, oxygen levels, and fish behaviour.

How far and how fast? Multiphysical monitoring of thermal plumes under mine water geothermal

Andrés González Quirós, British Geological Survey

Mitigating risks associated with the long-term sustainability of geothermal operations is dependent on improved understanding of the rate and magnitude of thermal changes in the subsurface. New multiphysical monitoring results from experiments performed at the UK Geoenergy Observatory in Glasgow during the first year of operation aimed to quantify how far and how fast thermal plumes move in complex mine water systems.

The point high-resolution information collected by downhole loggers was combined with the distributed temperature sensing and electrical resistivity tomography collected with cables located outside the boreholes casing. The combination of the three techniques provides a unique capability for temporal and spatial multiphysical monitoring of the transport of heat in the subsurface, both by groundwater advection in the flooded mine, or through conduction around the boreholes. More specifically, the DTS data show variable rates in the heat transfer with depth directly related to lithological changes. The time-lapse inversion of electrical resistivity shows the extent of the cool thermal plume from the injection borehole, extending both laterally farther in the mine workings, and upwards showing some processes of heat transfer between the mine and the overlying rock mass. The data has been combined with targeted numerical modelling to obtain refined estimates of the hydraulic and thermal properties.

These new insights, along with ongoing at-scale research, provide valuable information about the spatial and temporal scales of thermal migration in flooded mines, and a more in-depth knowledge of the relevant factors controlling the transport of heat in these complex systems.

Assessment of shallow geothermal energy potential underneath Leeds

Mohamed Gouiza, University of Leeds

Heating accounts for approximately a third of the UK's greenhouse gas emissions. Low to medium temperature (<100°C) geothermal systems could provide a locally-sourced, reliable, and low-carbon energy for for heating and cooling buildings. The UK subsurface contains several Permo-Triassic and Palaeozoic sandstone and limestone aquifers, which have been previously assessed to contain several thousand Etajoules of heat in place.

The shallow (< 2 km msl) subsurface of Leeds, located in West Yorkshire in the central part of the UK, is made of highly faulted thick Carboniferous strata. The Lower Carboniferous Dinantian includes the fractured Pendleside Limestone aquifer at depths ranging between 900 and 1800 m. The Upper carboniferous Namurian Millstone Grit Group consists of multiple thick sandstone aquifers (up to 250 m thick), which outcrop in the north of Leeds and reach a depth of 1500 m in the South. Whereas the shallower Westphalian Coal Measures groups exhibit several sandstone aquifers (up to 50 m thick), reaching a maximum depth of 550 m.

To assess the geothermal potential underneath Leeds, we built a 3D geological model (x = 17 km, y = 15 km, z = 2.25 km) of the city subsurface and its physical properties, using legacy public data. Assuming a local geothermal gradient, we then calculated the total heat in place and the potential recoverable heat. Our estimates suggest that a total heat in place of over 30 EJ could be present within the various Carboniferous aquifers, which could yield a recoverable thermal power of 2.5-5 GW.

Option of energy-free thermostat storage employing a near-surface aquifer system

Arunangshu Mukherjee, Manav Rachna International Institute of Research and Studies

Our understanding of the occurrence and movement of groundwater and the knowledge of aquifers' character plays a significant role in its utilization through development and management. It has been observed aquifers at near-surface depths globally remain under thermostat conditions year by year. Such a condition can be useful to develop energy-free perpetual temperature storage. Further, the spatial variability in groundwater temperature often provides an option to choose a suitable storage temperature range based on requirements. The ambient groundwater temperature of a particular place will also be a decisive factor for the type of product to be stored under natural thermostat conditions. The thickness of the aquifer, its depth from the earth's surface, annual groundwater level fluctuation range, and type of aquifer are important parameters that govern the commercial viability of the proposed thermostat storage. Therefore, a comprehensive hydrogeological investigation of the aquifer is a prerequisite for developing such facilities.

The presented work continues our previously published research on hard rock aquifers dominated by fractured porosity. This paper discusses the behavior of soft rock aquifers that possess inter-granular porosity and gives a comparison with hard rock aquifers to highlight the difference in the mechanism. Such differences can be captured and documented by analyzing the data of high-frequency automatic water level and temperature recorders fitted in purpose-built piezometers. The recharge discharge mechanism details support building proper storage space within aquifers of the required nature and dimension.

Groundwater science is still evolving and concepts developed for soft rock aquifers with inter-granular porosity are often applied to fractured hard rock aquifers. However, a substantial difference occurs between aquifer recharge discharge mechanisms within naturally formed fractured and granularly porous media. The very high heterogeneity of hard rock aquifers produces unique hydrographs that show clear and loud responses to the recharge discharge process. The comparatively more homogenous soft rock aquifers produce uniformity in hydrographs with subdued responses to the recharge discharge process. This is due to the diffusivity of fluid within the individual aquifers.

The existing functional difference between soft rock aquifers and hard rock aquifers can additionally be highlighted by monitoring the groundwater temperature of near-surface aquifers. The thermostat nature observed within the near-surface aquifers can provide season-after-season and year-by-year a constant temperature storage space, further, spatial temperature variations of groundwater can be used to select a commercially suitable specific temperature range. Spatial variations in groundwater temperature are a function of the background geothermal gradient and ambient temperature at the land surface. The background noise is largely observed in all the groundwater temperature curves, providing an apparent thickness to the curve line. . Comparatively, inter-granular porosity shows higher noise levels than fractured media. The noise of fractured media generally remains much smaller than 0.1°C whereas with granular porosity it remains over 0.2°C always and even shows up to 0.5°C. It has been observed that a substantial lag exists between the recharge level peak and temperature peak. The response of the aquifer system toward temperature is slower and much more balanced than the groundwater level this adds to newer dimensions of understanding.

The geothermal property of groundwater is being explored in several ways however, the fundamentally different thermostat nature of near-surface aquifer is proposed for its utilization for the first time. It is to conclude a concept of aquifer-based energy-free thermostat storage is introduced for its global utilization with the added advantage of spatial temperature variability of groundwater.

A feasibility study for the installation of mine water thermal energy storage (MTES) in an abandoned metalliferous mine in Cornwall, UK.

Thomas Olver, Geothermal Engineering Ltd.

Heating and cooling drives approximately half of the European energy demand, which is largely met by the burning of fossil fuels. To decarbonise heating and cooling, the development of renewable production and storage technologies is required. Storage technologies will address the seasonal mismatch between heat demand and production. The PUSH-IT project is working to develop mine water, borehole and aquifer thermal energy storage technologies, for storage of water up to 90°C.

Mine water thermal energy storage (MTES) utilises flooded, abandoned mines, extracting and injecting heated or cooled water to meet seasonal heating or cooling demands and store thermal energy. Mine water geothermal is still a relatively new concept in the UK, with a small number of recent installations in abandoned coal mines. To date, there are no mine water geothermal installations in UK metalliferous mines and no MTES has been developed. Geothermal Engineering Ltd (GEL) and the British Geological Survey (BGS) are undertaking a feasibility study to explore the potential for high-temperature MTES in conjunction with the United Downs geothermal power plant in metalliferous mines in Cornwall. The feasibility study will include a hydrogeological assessment of the mines and the creation of conceptual and numerical models to evaluate different operational scenarios. Social and environmental aspects will be evaluated, and a planning and regulatory route identified. The results will inform future development at United Downs and provide a resource for future mine water geothermal projects in Cornwall.

The shallow geothermal potential of Permian rocks beneath Belfast, Northern Ireland

Rob Raine, Geological Survey of Northern Ireland

Whilst the well-known, highly productive Triassic sandstone aquifer (Sherwood Sandstone Group) underlies much of the city of Belfast, thinner but more permeable sandstone aquifers of Permian age are also expected beneath this. Although largely untested beneath the city, records from Permian sandstones at Comber (~12 km ESE) and from boreholes drilled ~8 km SW of Belfast in the 1970s and 1980s, indicate that rocks of this age are likely to also underlie Belfast. These sandstones may have potential for open-loop geothermal heating, cooling and thermal storage.

Across Belfast and the wider area of the Lagan Valley, stratigraphy and reservoir quality of the Permian rocks are poorly understood, primarily because there are few boreholes in the city that have penetrated deep enough to adequately test these rocks. There are virtually no outcropping strata on which to base a study, and the handful that do exist are not representative of subsurface characteristics.

This study considers existing borehole records from an adjacent sedimentary basin (Newtownards Trough) and the rest of the marginal Larne Basin along the present-day Lagan Valley and examines the reservoir quality and distribution of reservoir rocks. The existing data is supplemented by a new cored borehole at Stormont (~6.5 km E of the city centre) that provides a link between boreholes in these two geological basins. Fresh core of the entire Permian succession, supplemented with borehole geophysical logging, were obtained in May 2024 from GeoEnergy NI's shallow feasibility study, part of the Department for the Economy's geothermal demonstrator project.

Evaluating the potential for heat storage in abandoned coal mine shafts in Scotland

Zoe Shipton, University of Strathclyde

TBC

Mine Water vs Air Source Heat Pumps: a head to head between two low carbon heating solutions Sam Smith, TownRock Energy

In recent years, numerous private and public sector institutions across the UK have implemented ambitious and admirable Net Zero targets, for which the transition from fossil fuels to low-carbon heating and cooling will play a fundamental role. With various low-carbon technologies available it is important to conduct a detailed, site-specific options appraisal to select the preferred solution.

Air Source Heat Pumps (ASHP) are an increasingly popular solution, for both domestic and industrial applications. The relative maturity and lower capital expenditure of ASHP technology often leads to developers and investors opting for ASHP over alternate low-carbon solutions, such as Mine Water Heating Systems (MWHS).

MWHS harness low-moderate temperatures from water in flooded abandoned mine voids, which are widespread across major populated areas in the UK. The high flow rates and constant temperatures which these systems offer means they can deliver multi-megawatts of both heating and cooling. Despite these advantages, MWHS have been a relatively underutilised low-carbon heating and cooling solution in the UK to date.

This presentation presents learning from recent TownRock Energy (TRE) projects, assessing the suitability of each technology on a case-by-case basis with regards to local hydrogeological conditions, as well as the practicalities of system installation and operation. Due to the inherent uncertainty associated with subsurface projects, the crucial importance of robust subsurface analysis is emphasised in the assessment of MWHS suitability. The technical assessment is supplemented by techno-economic and carbon emissions forecasting, to give a holistic view of integrated lifetime cost and emission profiles of each technology.