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Global knowledge exchange - experiences and outputs from the IEA Geothermal Mine Water Energy Expert Group

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1. OVERVIEW

Net-Zero carbon emissions targets require significant progress to be made in the decarbonisation of heat, and many Governments have defined their ambitions to transform space heating of homes and buildings to clean energy sources. Seen as a global leader in terms of Net Zero Strategy, the UK strategy (2021) sets out that key decisions on the decarbonisation of heat are to be made by 2026. Heat and Buildings strategies (2021a,b) in the UK and its devolved nations indicate geothermal energy could be part of the solution to diversify the low carbon alternatives to fossil fuel heating, despite the low temperature resource available in countries like the UK.

At the same time, legacy from a previous era of high-carbon heating still exists in many countries in the form of abandoned coal mines. Upon closure and with the cessation of dewatering, the mines have become naturally flooded with groundwater which contains a useful low temperature energy resource for heating and cooling, and thermal energy storage. The energy resource can be abstracted through schemes that pump groundwater from the mines via boreholes, and once passed through a heat exchange/heat pump arrangement, can provide space heating and cooling for homes and businesses, before returning the water within a sealed loop to a different part of the mine system (Figure 1). Alternatively, old mine shafts may be used, or heat can be extracted from existing mine water management pumping schemes that discharge to surface water. Examples are given in Bailey et al. (2016); Banks et al. (2017).

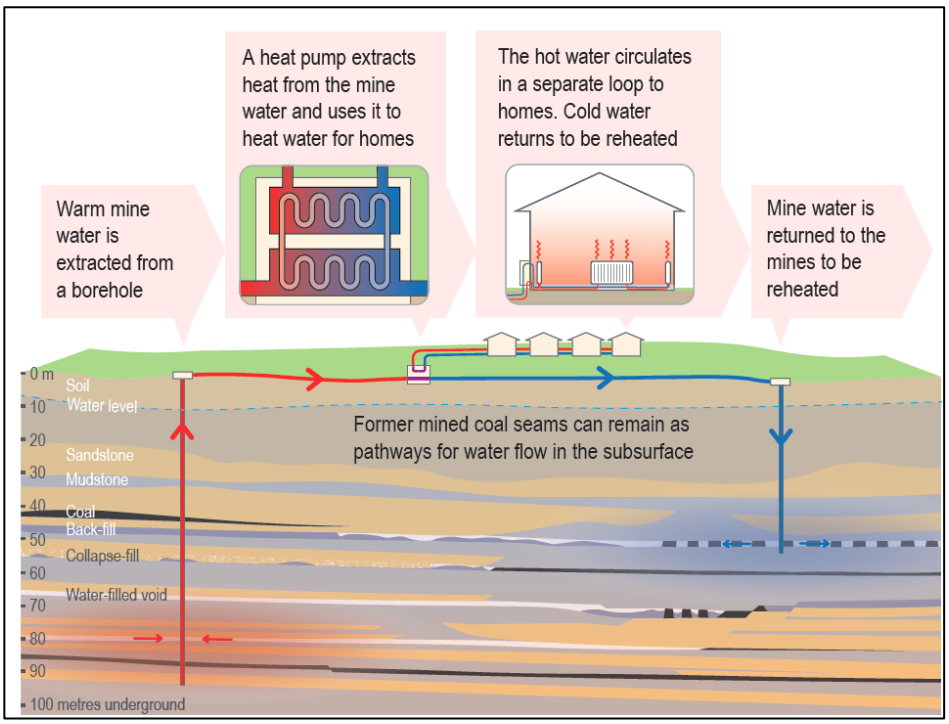

Figure 1 Simplified overview of abandoned, flooded coal mines in the subsurface utilised for shallow, low enthalpy mine water heat via abstraction and re-injection of groundwater, to heat homes and businesses ©BGS, UKRI 2021

Low temperature shallow geothermal heat recovery and seasonal thermal storage in abandoned coal mines offers a sustainable energy opportunity in a number of countries around the world. To date tens of successfully operating mine water geothermal and heat storage

schemes have proved the concept of using this energy source for heating and cooling of buildings (e.g. Verhoeven et al. 2014; Loredo et al. 2016; Walls et al. 2021).

2. EXISTING MINE WATER ENERGY SCHEMES

In the UK, pilot and small mine water heat schemes were active for 5-20 years at Crynant, Wales (35 kW; Farr et al. 2016), Lumphinnans and Shettleston, Scotland (both 65 kW Banks et al. 2009: Walls et al. 2021), Caphouse and Markham (Banks et al., 2017). Lack of expert contractors and the maintenance burden (e.g. clogging and build-up of ochre; loss of pressure) contributed to the closure of the Scottish schemes (Walls et al. 2021), highlighting the importance of growing the technical skills base in operational maintenance.

A number of larger mine water heat schemes are now in operation, construction or advanced feasibility in north-east England. Two mine water heat schemes c. 700m apart at Felling, Gateshead are used to heat a wine warehouse and bottling plant (Lanchester Wines 2.4 MW and 1.4 MW; Walls et al. 2021: Banks et al. 2022). Technical challenges include not encountering the anticipated mine voids; unexpected hydraulic responses and ochre scaling of the heat exchanger and corrosion by H_2S rich water (Stevens, 2021). The degree of thermal interference between these two schemes has yet to be empirically demonstrated (Walls et al., 2021).

Nearby, mine water heat recovery feeding into the Gateshead district heat network has commenced operations in 2023. With a 6 MW water source heat pump installed, this heat network will supply up to 1250 new homes, a care home, Gateshead International Stadium and other Council-owned buildings (Coal Authority online 2022) and has been funded by the UK government's Heat Networks Investment Project (HNIP). Also in north-east England, an existing small scale heat recovery scheme from the Dawdon mine water treatment scheme is also planned to be significantly expanded into a district heating network, supplying a new Seaham Garden Village of 1500 homes. It has a potential heating capacity of 6 MW (Coal Authority, 2020; Walls et al., 2021). A significant additional number of mine water heat schemes are in feasibility stages in England, Scotland and Wales, with NELEP (2021) reporting 42 schemes, that could provide 4500 jobs and 90,000 tonnes of carbon savings.

In Europe, a number of successful mine water heating/cooling/storage schemes have been in operation for tens of years (e.g. Heerlen, Netherlands, Verhoeven et al. 2014; Essen, Germany, Bracke and Bussmann, 2015; Mieres, Spain, Loredo et al. 2017) and a good number more are ongoing (e.g. Bochum, Germany; Heatstore, 2022; Hahn, 2022). A similar picture of active and decommissioned schemes exists in the USA (Korb 2012), Canada (Jessop et al. 1995) with further examples in Russia and China; the most recent summary is given in Walls et al (2021).

The mine water expert group is preparing case studies for successful heat schemes. It is also looking to document where lessons can be learnt to improve future outcomes, for example from unsuccessful boreholes. These are available at https://iea-gia.org/areas-of-activity/geothermal-heating-and-cooling/mine-water-geothermal-energy-group/

3. AT-SCALE MINE WATER ENERGY OBSERVATORIES AND FACILITIES

Any developing technology benefits from facilities to do research, innovate, and to monitor impacts (e.g. environmental changes) of the technology. In Glasgow, UK a flexible, at-scale infrastructure is available for academic and commercial researchers investigating low-temperature geothermal energy and thermal storage resources in abandoned and flooded coal mine workings at depths of around 50–90 m (Monaghan et al., 2021). It comprises 5 mine water and 7 environmental monitoring boreholes including with geoelectrical, fibre-optic and hydrogeological sensors. 4 mine water boreholes in a sealed, open loop can be used in a variety of abstraction and re-injection combinations, through three types of heat exchanger and with a heat pump/chiller of c. 200 kW with flow rates of 3/6/9/12 litres/second to simulate a heat user or thermal storage. More details for potential users are available at https://www.ukgeos.ac.uk/glasgow-observatory or on a video at https://youtu.be/vkvlG3ZaohI .

Also in the UK, at Gateshead the Coal Authority is currently establishing a 'Living Lab' comprising up to five monitoring boreholes around two mine water heat schemes at Lanchester Wines and the Gateshead Energy Company mine water heating network. The Living Lab will use a range of novel sensors to record and observe data on temperatures, water movement and water quality at different points within the mines as both of the schemes operate. Better understanding of how schemes operate and interact could in turn support the development of more mine water heat schemes elsewhere in Great Britain. In Bochum, Germany, the Heatstore project is creating a high temperature mine thermal energy (HT-MTES) storage pilot plant, see https://www.heatstore.eu/national-project-germany.html .

The mine water energy expert group will aim to draw in the significant learnings and data from these research/monitoring infrastructures and pilot facilities, in addition to mine water heating and cooling supply schemes.

4. CHALLENGES FOR MINE WATER ENERGY

Economics, regulation, policy making, awareness and social acceptance have been identified as remaining barriers to widespread utilization of mine water energy, as well as appropriate management of technical and environmental risks (e.g. NELEP, 2021; Environment Agency 2021; Townsend et al. 2021; Walls et al. 2021).

Several of the barriers can be overcome through knowledge exchange, scientific evidence and collaboration. The IEA Geothermal Technology Collaboration Programme has set up an international working group on mine energy within Working Group 14, starting in March 2022 and open to all interested in mine water thermal energy. The rationale for setting up this group is to use the UK's growing industry, academic and regulatory expertise and current interest to leverage global collaborations in the field of mine water

energy. By documenting case studies, successes and failures, the group will make progress towards raising awareness, summarizing lessons learnt and work towards standards and best practice guidance.

Specific challenge areas that the mine water energy expert group aims to address by knowledge sharing and collaboration are shown in Table 1.

Challenges	Examples	Mine water expert group initial contribution
Technical	1. High cost/risk in drilling/hydraulic testing boreholes to effectively recover heat from target 2. Sustainability: integrated heating and cooling 3. Environmental impacts and management (groundwater/surface water; gas movement; chemical and geomechanical/subsidence risks etc.) 4. Data availability	1. Borehole drilling/construction/testing risks/lessons learnt from several case studies 2. Case study on Heerlen and Bochum Heatstore 3. Drawing out common challenges and solutions from case studies, working towards standards and best practice 4. Listing data locations and open data sources
Operational	5. Maintenance requirements, cost-effective techniques for ochre build up, clogging, gas management, declining yield, corrosion of equipment etc.	5. Case study of operational maintenance
Regulatory	6. Lack of heat licensing 7. Sustainability/longevity of the heat resource, unknown impact of nearby schemes 8. Mineral and land rights ownership	6. Summary of regulation and licensing in different countries 7. Case studies from long operating schemes, demonstration and to improve confidence

Table 1

5. BUILDING PARTICIPATION IN THE MINE WATER ENERGY EXPERT GROUP

Two online mine water energy symposia in 2021 and 2022 achieved a global reach, with participants from over 35 countries. During the 2022 IEA mine water energy symposium participants undertook online polls and a discussion session and identified (i) sharing of mine water energy successes and failures (33/111 votes) (ii) awareness raising (38/304 votes), (iii) summaries of regulation, policy (21/111 votes) and (iv) data availability as significant needs that could be addressed by the expert group. With a call for volunteers, the group it was initiated by the active community in the UK in 2022 and includes representatives from national Government, regulators, The Coal Authority, the British Geological Survey, university researchers and commercial companies. This is now being extended by contacting mine water heat schemes internationally to draw in wider case studies and contributions.

6. INITIAL OUTPUTS OF THE MINE WATER ENERGY EXPERT GROUP

Given the momentum currently building with the mine water heat schemes under feasibility, construction and operation (section 2 above), a focus of the mine water energy expert group is initially to publish basic, accessible information in a central location on the IEA Geothermal webpages https://iea-gia.org/areas-of-activity/geothermal-heating-and-cooling/mine-water-geothermal-energy-group/ . As lack of data and awareness have contributed to the reluctance of private investors, public bodies etc. to move into geothermal energy, this information is a first step. Figure 2 shows the range of summary documents that have been volunteered as at December 2022.

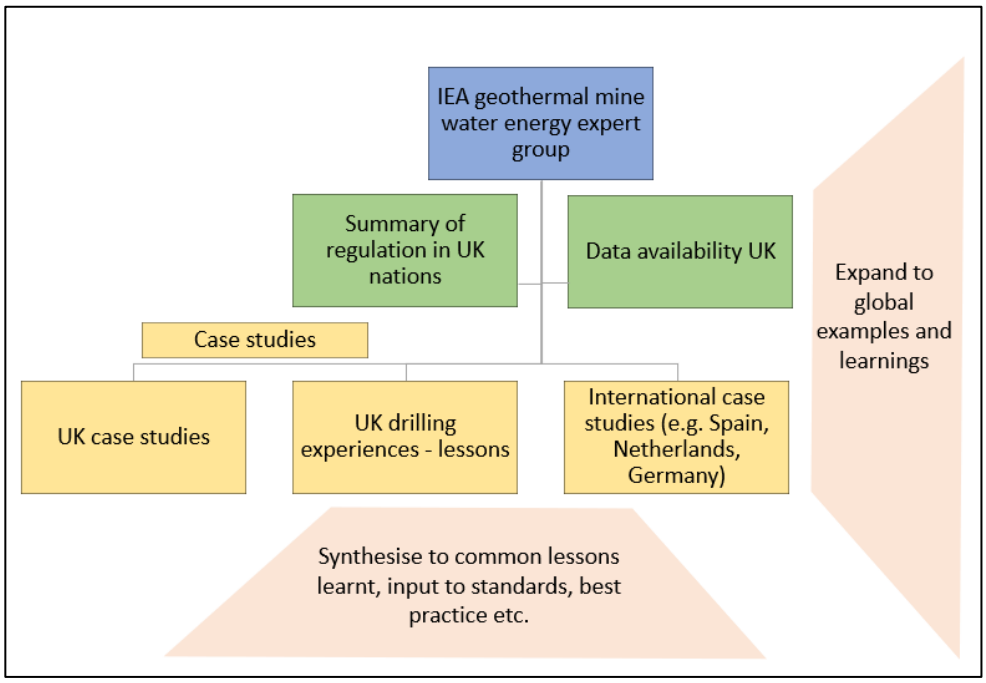

Figure 2: Case studies and short information documents volunteered for the mine water energy expert group

Next steps will be to include more international case studies and to synthesise information towards common themes such successes and failures in drilling, regulation and licensing regimes seen as exemplar, of relevance for determining standards or summarizing lessons learnt and best practice, leading to future cost-reduction and de-risking.

7. 2023 MINE WATER ENERGY SYMPOSIUM

The third mine water energy symposium in April 2023 was extended in length due to the number of speakers. In all, 215 attendees from 18 countries attended online, for 27 presentations and a discussion session.

Speakers from across industry, universities and regulators shared their knowledge and experience on a wide range of topics. One group of talks provided updates on mine-water energy schemes already in place or in the exploration stage from Germany, Spain, UK, USA and Canada. These talks demonstrated the size (hundreds of houses plus industrial or municipal buildings) of mine-water heat, cool and storage resources that are being used. An emerging theme was around successful integration with other technologies, for example solar-thermal and integration in fifth generation district heating and cooling networks.

Cutting-edge modelling of mine-water energy systems was illustrated in several presentations, applied to the size and sustainability of the heat resource as well as the geomechanical stability. Models were not theoretical; they were quantified using data from active mine-water schemes. The significant potential for further at-scale quantification, calibration and monitoring at the UK Geoenergy Observatory in Glasgow and the 'Living Lab' in Gateshead were also described. Experimental and analytical work examining changes in in-rock properties under heat and flow changes and geomicrobiological processes provided insight into controlling processes that could affect mine-water heat operations.

An important emerging theme at the 2023 symposium was investigating thermal storage in disused mines and shafts for balancing intermittent electricity supply, for use of waste heat (for example from data centres) and to maintain long-term sustainability of temperature. The significant scale of potential storage was also highlighted. Interesting discussions included considering whether thermal storage would improve the economic case for mine-water heat schemes.

A number of talks covered economic, social and regulatory aspects. Community ownership and participation for a just, place-based energy transition provided a different perspective to speakers covering the opportunities offered by government-led heat zoning that could provide certainty to investors. The role of raising awareness with appropriate groups (for example housebuilders) was highlighted and a new mine water heat resource map for Scotland was presented as a first step to guiding non-users to the opportunity.

Finally, a discussion followed presentations on an integrated regulatory and permitting regime in England, the needs of commercial operators and investors, and grant funding timelines for data and decisions. The symposium discussion ended with the aim of collectively articulating the data and regulatory needs for enhanced mine-water energy deployment and to raise awareness of these with decision makers.

8. CONCLUSION

The aim of this paper is to present initial progress and to encourage further international participation in the mine water energy expert group. A summary has been given of mine water geothermal in 2022/2023 particularly focused on a growing number of projects in the UK, the methods used to develop this international task on mine water energy, and the initial outputs gathered.

Please get in touch if you would like to join the IEA geothermal mine water energy expert group by emailing minewaterthermal_iea@bgs.ac.uk

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