

Environmental Audit Committee inquiry into [Heat resilience and sustainable cooling](#)

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British Geological Survey organisation and expertise

The British Geological Survey (BGS) is a public sector organisation and the UK's premier centre for earth science information and expertise.

BGS is responsible for advising the UK government on all aspects of geosciences, as well as providing impartial geological advice to industry, academia and the public, with decades of corporate experience in the collection, collation, databasing, statistical evaluation, mapping and interpretation of geological and environmental data. We are the UK's principal provider of objective and authoritative geoscientific information and knowledge for wealth creation, sustainable use of natural resources, reducing risk, living with the impacts of environmental change and advising on the opportunities and challenges of the subsurface environment.

BGS has been undertaking research on UK geothermal potential and thermal energy storage since the 1970s, including the delivery of multimillion-pound UK Geothermal Energy Programme (1977–1984) (Downing & Gray, 1986) and the UK Hot Dry Rock R&D programme (1977-1991) (MacDonald et al., 1992) and more recent BGS research.

BGS recently contributed to updates of UK ground source heat pump industry best practice guidance (CIBSE AM17 and TM51) which includes integration of sustainable ground-coupled cooling technologies. We are a member of the Ground Source Heat Pump (GSHP) Association and provide geological appraisal services to the ground source heating and cooling industry through our GeoReports service and stakeholders through our enquiries service and projects.

BGS has also received £31 million of funding to build field infrastructure and research facilities for shallow geothermal energy and underground heat storage – the UK Geoenery Observatories (<https://www.ukgeos.ac.uk/>). Each observatory delivers a different body of knowledge relating to different geothermal systems including ground source heat pump systems and thermal energy storage (Cheshire), mine water geothermal (Glasgow) and integrated urban geothermal systems (Cardiff Urban Geo-Observatory).

BGS works closely with stakeholders from government, industry, and regulation in the UK and internationally to identify and advise on policy and regulation necessary to progress geothermal energy developments in the UK (1922 BEIS Backbench Committee, 2022). Our outputs include science briefing papers and reports, a POST brief and a deep geothermal white paper (Abesser et al., 2018; Abesser et al., 2020; Abesser & Walker, 2022; Abesser et al. 2023).

BGS is submitting evidence to this inquiry to summarise state of knowledge on use of the subsurface for sustainable cooling, highlight the potential opportunity as well as some of the research ongoing and needed towards more widespread deployment.

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Glossary

Aquifer: underground layers of water-bearing, permeable rocks that contain and transmit groundwater and from which groundwater can be extracted.

Boreholes: deep, narrow holes made in the ground, either vertically or inclined, often to locate water or oil.

Deep geothermal: term used widely to refer to systems at a depth of more than 500 m below the surface. In this document, the term is used to mean system that produce heat in the 50–200°C range of medium temperature (steam or water).

District Heating: communal heating systems that deliver heated water to a large number of homes and buildings via a heat network.

Groundwater: water that exists in pores and fractures in the rocks and soils beneath the land surface where it forms saturated zones (aquifers).

Heat network: a distribution system of insulated pipes that takes heat from a central source and delivers it to domestic or non-domestic buildings.

Heat pump: a device that transfers and “upgrades” heat from a colder space to a warmer space using mechanical energy. A ground source heat pump uses heat from underground.

Question 2. How can sustainable cooling solutions and adaptation strategies be implemented in such a way as to minimise overheating, reduce energy consumption and prevent overloading of the electricity grid during peak demand?

Ground-coupled passive and active cooling systems offer many benefits (reduced energy consumption, heat recycling, improved air quality) and work extremely well (ultra highly energy efficiency) when coupled with heat pumps and geo-exchange infrastructure such as ground source heat pump boreholes, energy piles, and thermal banks. A detail overview of current deployable technologies is provided by The Chartered Institution of Building Services Engineers (CIBSE) in AM17 Heat pump installations for large non-domestic buildings (2022). A bibliography of case studies highlighting long-term performance of ground-based heating and cooling systems deployed in the EU and US (3 from the UK) on a range of building types is presented in the IEA Heat Pumping Technologies Annex 52. The field trials found ground source heat pump systems generally work satisfactorily and were sustainable when correctly designed, implemented and maintained. There is evidence that free-heating/free-cooling technology (i.e., circulation only without a heat pump) can achieve Measured Seasonal Performance efficiency up to 1450%, compared with reversible heat pumps that typically achieve 100-800% efficiency in heating or cooling mode.

References

CIBSE AM17 Heat pump installations for large non-domestic buildings (2022) www.cibse.org/knowledge-research/knowledge-portal/am17-heat-pump-installations-for-large-non-domestic-buildings

IEA Heat Pumping Technologies Annex 52 <https://heatpumpingtechnologies.org/annex52/documents/>

Question 7. What role might reversible heat pumps (which can act as both heating and cooling systems) and other emerging technological solutions, such as the development of smart materials, play in meeting future cooling demands?

Reversible heat pumps incorporated into ground source heating and cooling systems have a potentially significant role to play in sustainable cooling, including for balancing 5th generation district heating grids. The high thermal capacity of soils, rocks and groundwater, means the subsurface can be used as a large heat store for cooling buildings.

In 'shallow geothermal' or 'ground source heat systems' boreholes/wells are drilled to between 10's – 300 m beneath the ground surface. In cooling applications, water is pumped from underground water bodies (aquifers) or abandoned, flooded mines (open-loop; see Figure 1), or a thermal transfer fluid is circulated through a closed pipe (closed loop; Borehole Thermal Energy Storage-BTES). Using heat extracted from buildings, IT servers, sewers or industrial facilities, a reversible heat pump/chiller is used to transfer heat to the circulated groundwater or transfer fluid, which is then returned underground. Temperature differences of up to around 10°C may be added to groundwater originally extracted at temperatures between 10-25°C. Using these technologies, the subsurface can be used as a high volume, highly deployable, low cost and low carbon thermal storage medium for passive or active cooling of buildings and other infrastructure.

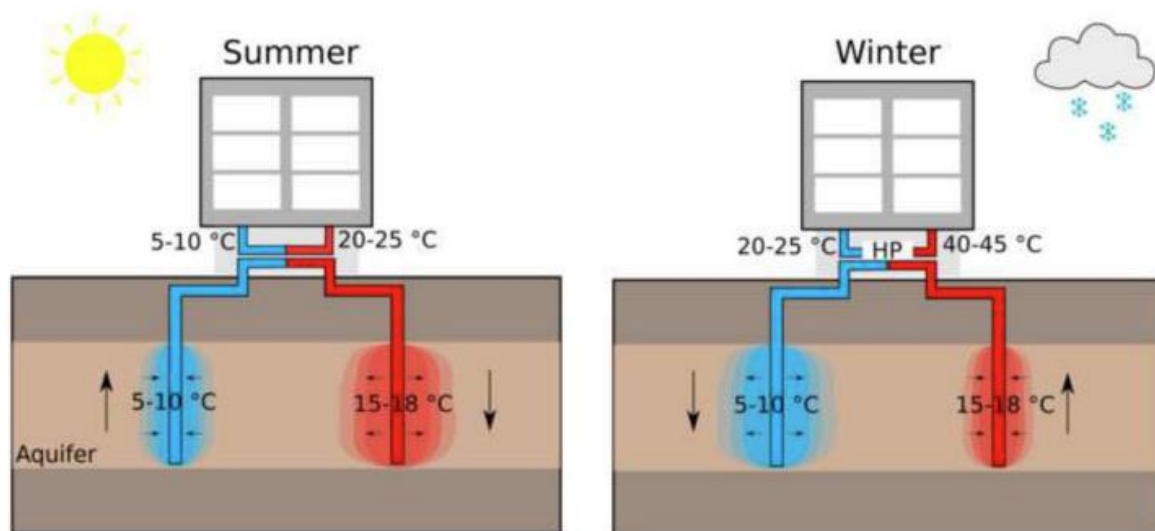


Figure 1 showing the working principal of aquifer thermal energy storage (ATES) system used for cooling in summer and heating in winter, from Regnier et al. (2022).

Integrated ground source heating and cooling systems are proved at a number of scales and in a number of subsurface geologies. These can be used for cooling and to store heat in summer months and use heat in winter months (interseasonal heat storage). The technology is deployable in a wide range of subsurface geologies across the UK, more details in Abesser and Walker (2022, section 1.1).

Examples where the technology is used for individual or multiple occupancy buildings include Portcullis House in Westminster which has passive cooling system that exploits groundwater in the bedrock under the building (CIBSE AM 17) and the Riverside Quarter in Wandsworth, London which uses groundwater for heating and cooling (IEA Heat Pumping Technologies Annex 47). A review of groundwater cooling systems in London (Ampofo et al. 2006) concluded that although good progress has been made on passive cooling systems, these are limited to new-build projects. For existing buildings, and those for which mechanical air conditioning cannot be avoided, low energy cooling capability using groundwater and open water can be incorporated to improve significantly overall efficiency. Groundwater is massively underutilised as a nature-based solution for low carbon cooling, as a review of aquifer thermal energy systems in the UK found only 11 operating systems (Regnier et al. 2023).

At larger scale, the subsurface can be used in heating and cooling networks where some buildings use heat and some use cool in an interconnected district heating/cooling loop, using the subsurface as a balance or baseload. Studies have concluded that networked heat pumps supplying multiple buildings have economic benefits (e.g Kensa, 2023). Large scale examples include the mine water energy

scheme and Heerlen in the Netherlands (<https://mijnwater.com/en/>; Verhoeven et al. 2014; IEA geothermal case study Heerlen) and 5th generation district heating and cooling networks (5G DHC; D2 Grids (2023) contains examples from Bochum and Paris-Saclay).

Environmental and sustainability considerations

Regulation and permitting of heating and cooling applications using the subsurface is varied depending on

- the technology used (open or closed loop)
- a number of factors such as the aquifer vulnerability, depth of the borehole, abstraction/re-injection flow rates etc.
- environmental regulator (Environment Agency, Scottish Environment Protection Agency, Natural Resources Wales, NI Environment Agency).

Potential environmental impacts may vary dependent on the temperature difference applied during cooling. The EA provides guidance for temperature differences and permitting ([Open Loop Ground Source Heating and Cooling Notification Form](#) page 2], whereas SEPA assesses based on site-specific impacts [[geothermal-october-2022.pdf](#) top of page 8].

There is potential for thermal interference between closely spaced heating/cooling ground source schemes in urban areas. For example, in central London where many GSHP schemes are within 250–500 m of each other (e.g. Fry, 2009). Interference risks can be mitigated by managing the deployment (wider well spacing locations, thermal loads, operational strategies, use of dry coolers at surface) of such systems. At minimum, this requires recording locations of ground source heating and cooling systems, including their thermal loads, management and monitoring of the system and their operations and reporting back to the regulator. Other long-term (10+ year) effects of repeated heating and cooling cycles on the subsurface environment and on resource sustainability such as chemical clogging and biofouling of aquifer rocks are not currently well understood.

Research and innovation infrastructures are available to increase the evidence base – the [UK Geoenergy Observatory in Cheshire](#) has extensive capability for ground source heating and cooling investigations in a sandstone aquifer, the [UK Geoenergy Observatory in Glasgow](#) in flooded, abandoned coal mine workings, and the [urban geo-observatory in Cardiff](#) is a network of boreholes in the shallow subsurface including monitoring around an operational ground source heat scheme at a nursery school building (Boon et al 2019).

BGS undertakes research into underground heat storage, including Aquifer Thermal Energy Storage (ATES) potential with Universities, working closely with Environment Agency and other EU projects (UKRI funded ATESHAC and SmartRes projects, EU MUSE and PUSH-IT projects) to inform subsurface thermal policy and regulation. This includes laboratory- to field-scale testing and modelling studies to evidence and better understand ground heat (and cold) storage capacity and monitor the environmental impacts such as thermal interference and saline intrusion into aquifers.

Another notable project is the ‘[Galleries to Calories](#)’ using the geobattery concept (Fraser-Harris et al. 2022) research in Midlothian, investigating cooling a computer data centre and storing/transporting the heat in abandoned flooded mine workings to increase the sustainability of ground source heat systems nearby.

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