DECARBONISING HEAT WITH GEOTHERMAL ENERGY

A policy and technology explainer from the Geological Society

The Geological Society

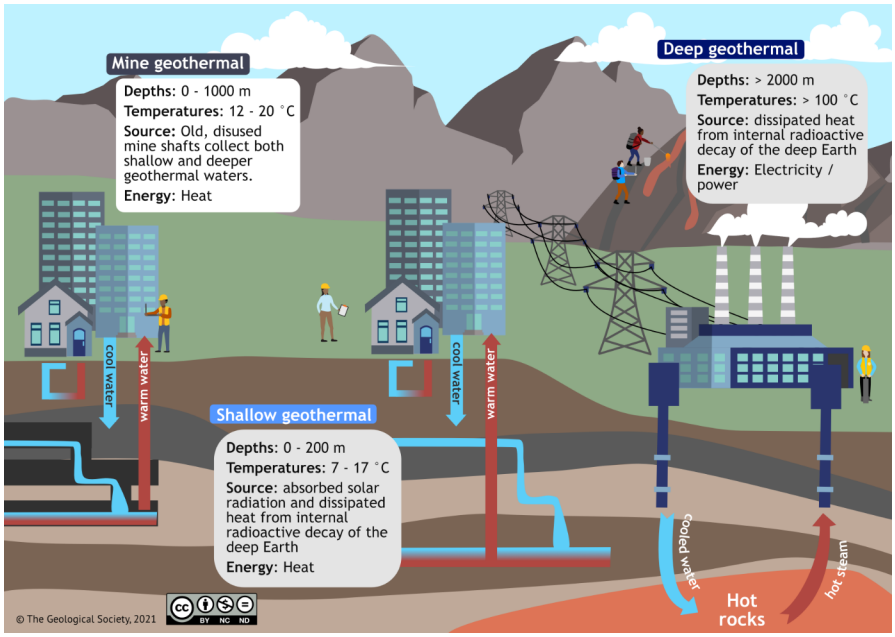

Figure 1 - Geothermal energy is heat energy stored beneath the Earth's surface. Geothermal energy can be harnessed directly for heating and cooling purposes or it can be used to generate clean electricity using steam and turbines. Through geological assessment, engineering, monitoring and data analysis geoscientists play an essential role in developing and implementing geothermal technologies across the globe.

The decarbonisation of heating and cooling, electricity production, industry and transport is essential to meet both UK and international climate change targets, and as part of the drive towards net zero carbon emissions. Geoscience has an important role to play in realising these goals.

In the last decade, the UK has successfully decarbonised half of its electricity demand by switching to renewable or low carbon sources (Ofgem, 2020). However, decarbonising heating in homes, offices, industry and public spaces remains a significant challenge. Gas and oil boilers are carbon-intensive forms of heating, and utilising widely available low-temperature heat from the ground instead could significantly lower the carbon footprint of the heating sector (Figure 1).

Conservative estimates of the geothermal resources of the UK indicate there is around 200EJ, or the equivalent of delivering 100 years of supply based on the UK's 2015 heat demand (Gluyas et al., 2018).

The UK Government Heat and Buildings Strategy (2021) recognises the value of utilising geothermal heat coupled with heat pumps and in district or network heating schemes in order to deliver low-carbon heating and cooling on a national scale.

With commitments in place to improve the affordability of the entire geothermal heat system, and pledges to invest in research and innovation to improve adoption, heat from the Earth could help decarbonise our heat demand in a much more prominent way in the future.

Heat from the ground

Geothermal energy is heat stored in the rocks and fluids under the surface of the Earth. They are heated predominantly by natural radioactive decay combined with residual heat from Earth's formation, with a much lesser contribution from solar radiation in the shallow subsurface.

High temperature geothermal energy, generated at depths greater than 500m, can be used to generate electricity in power stations and delivers heat as a by-product. Deep geothermal energy exists in Iceland, Indonesia and New Zealand and there may also be potential for it in some areas of the UK, such as in Cornwall, the North Pennines and in Scotland. Aside from in these areas, the majority of the UK is not hot enough to sustain the generation of geothermal electricity, but is well-suited to harnessing geothermal energy at much shallower depths (and lower temperatures) in the form of heat (Figure 1).

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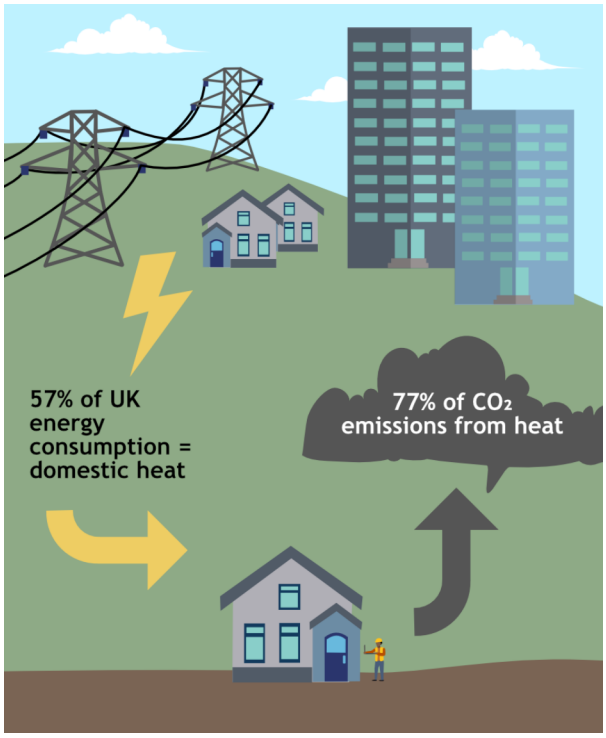

Figure 2 - Carbon emissions from heat and energy consumed for heat in UK households (Data: Committee on Climate Change, 2016).

The shallowest geothermal energy, also known as ground source heat, is absorbed into the ground from solar radiation and is stored and transported by fluid flow in the top 200m of the crust.

Heat from solar radiation is supplemented by highly dissipated geothermal energy from the deep Earth, also known as 'true geothermal'. Ground source heat exchange systems can extract this energy from the ground to control temperatures in low-volume spaces, and this technology is already being used in parts of the UK. A deep geothermal heat scheme in Southampton supplies water at 72°C from a 1.8 km deep sandstone aquifer. This system has been delivering heat for over 25 years.

Towards the UK's Net Zero Strategy

To help mitigate the most dangerous effects of climate change, the UK has committed to Net Zero carbon dioxide emissions by 2050. Achieving this target will require huge reductions in the carbon emissions from the UK's heat sector, which accounts for more than half of the UK's annual energy consumption. In 2016, 23 million homes in the UK used gas for their heating, accounting for 77% of the country's carbon emissions from heat (Committee on Climate Change, 2016 / Figure 2).

Geothermal energy is considered renewable since the Earth eventually replenishes the heat that is extracted. The timescales of replenishment depend on a number of factors, and geothermal reservoirs require sustainable management, just like any subsurface resource.

Many of the technological components used in geothermal systems such as pumps, boreholes, and heat exchangers are widely used for alternative applications such as water abstraction, in fossil fuel operations and other geotechnical projects and are therefore proven and readily available. However, necessary raw materials and a skilled workforce will be required to implement the infrastructure needed to deliver geothermal heat on a greater scale.

The future of sustainable cooling

Extreme heat and heatwaves will become increasingly common in the future, even under optimistic climate change scenarios. In the UK, summers are expected to regularly exceed 40°C, even if global warming is limited to 1.5°C, creating challenging living and working environments.

On a the global scale, demand for air conditioning is expected to triple by 2050, requiring a proportional increase in energy for temperature regulation. Air cooling units are expected to drive the second greatest demand for electricity after industry by 2050 due to a combination of population growth, rising global temperatures and increases in global development. Ground source heat pumps, can use geothermal energy to cool houses and other small spaces, transferring the heat back into the ground, thus offering a low-carbon option for both heating and cooling that is currently under-exploited.

Geothermal and Levelling Up

Geothermal heat has the potential to offer a more sustainable domestic heating option for many households and industries currently reliant on carbon-intensive gas heating and cooling. Utilising the heat from abandoned mine workings can deliver a 75% carbon saving when compared with gas heating under the right conditions.

Shallow geothermal heat from the water in disused mine workings could deliver a more sustainable heating option for thousands of homes in Britain. The water in disused mine workings generally remains at a constant temperature and is well insulated by surrounding rock. In comparison with more variable air temperatures, this reliable heat source can be exploited using heat pumps and heat exchangers to offer continuous and reliable baseload for space heating. Analysis from the Coal Authority and the British Geological Survey indicates that one quarter of the UK population live above disused mine workings with the potential to offer geothermal heat (The Coal Authority, 2021).

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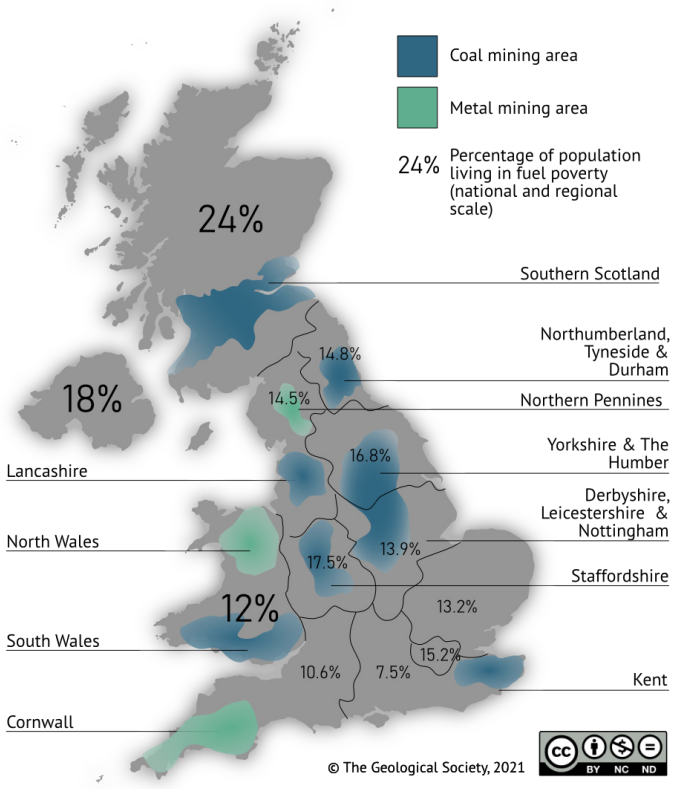

Figure 3 - The co-location of fuel poverty and major disused mine workings with potential to deliver heat in the UK. Fuel poverty definitions vary by country. In 2020, 13% of households in England were classed as fuel poor (see graphic for county-level data), 25% in Scotland, 12% in Wales, and 18% in Northern Ireland (Data: House of Commons Library: Fuel Poverty, 2021).

Geothermal systems can also supply district heating schemes, whereby a number of domestic, commercial and public buildings are connected to a single heating source.

The geographical availability of shallow geothermal heat from disused mine workings intersects with communities most affected by fuel poverty, many of which are in areas that are in receipt of the Government's Levelling-Up Fund – such as towns in Lancashire, Yorkshire and Staffordshire. This presents an opportunity for geothermal heat to deliver on the Government's policy to boost investment and economic growth far beyond the South-East (UK Government, 2022) while also delivering on the Net Zero Strategy to decarbonise a large proportion of energy emissions from heat in these locations. Regions where mining was prevalent during the UK's industrial revolution have the greatest opportunity to access these resources (Figure 3).

While challenges remain around the replacement and retrofitting of existing gas heating infrastructure and the complexities of permitting, licensing and ownership of geothermal heat, these can be ameliorated through regulation and permitting designed to support more widespread utilisation of subsurface heat.

Policy challenges and opportunities

There remain several challenges to overcome with respect to scaling up and growing the geothermal industry in the UK. The most immediate barriers to deployment of geothermal energy for heat are the relative cost and availability of fossil energy alternatives and the uncertainty around support schemes and grants to drive investment into the industry.

There is no established process, or single regulatory body, responsible for permitting and licensing for geothermal projects in the UK. A permitting system that establishes ownership and rights to underground and produced heat, and regulations that govern fluid abstraction and re-injection, considering geological risk and subsurface management, would be a welcome catalyst for the industry.

Availability of skilled and experienced geoscientists to work in the industry given the current student enrolment crisis affecting the geosciences will be of particular concern in the medium to long term.

To facilitate the immediate and rapid up-scaling of the geothermal heat industry in the UK the following areas will need to be considered:

- Access to and ownership of the subsurface and any heat produced
- Improved communication of perceived risks
- Assurances around the cost of drilling
- Understanding of resource certainty (e.g. evolution of temperature with time)
- Capacity for retrofitting
- Financial insurance
- Social license to operate
- Minimised risk of environmental impacts
- Effective waste management

Whilst there are challenges to be overcome before we see widespread deployment of geothermal in the UK, there are a number of recent projects that show that most barriers can be overcome on a project-by-project basis with the right support.

Geothermal: in practice and in demand

There are case studies throughout the UK and EU where individuals, businesses or groups have turned to the heat in the ground as an affordable, reliable, and low-carbon energy source. From farmers in the Netherlands, to the bioplastics industry in Scotland – the number of industries and individuals that have benefited from geothermal heat is growing.

In 2020, **Germany's** government introduced drilling rebates for the installation of ground source heat pumps for replacing oil heating systems with geothermal. This support will likely drive individual and small-scale investment in geothermal heating systems.

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There are numerous operational geothermal projects in the **Netherlands**, including geothermal heat from shallow mine workings, and recent support from the Dutch Government is expected to stimulate this growing industry further. The Dutch 'Geothermal Heat Action Plan (2020)' offers risk insurance, subsidised software and information access, a grants scheme, and support with permitting for new geothermal projects across the Netherlands - with the aim of generating 150,000 households worth of power through geothermal resources by 2020. To achieve a 40% emissions reduction by 2030, the Netherlands aim to scale up their provision of geothermal loop systems from 17 in 2018, to 75 in 2025, and eventually 175 in 2030 - which equates to 570,000 homes on a geothermal district heating grid.

Belgium's first deep geothermal power plant will be constructed in Flanders with the aim to deliver heat and power to 5000 homes in the region. Belgium has a licensing system in place for geothermal schemes (2009) and a government insurance system offering pay-outs to negate the risk that comes with exploration which supports the exploitation of such resources.

The skills, knowledge and data gained from this array of international projects will help to unlock future investment and development in geothermal as the UK strives to achieve Net Zero.

About The Geological Society

The Geological Society of London is the UK's national society for geoscience, providing support to over 12,000 members in the UK and overseas. Founded in 1807, we are the oldest national geological society in the world. We provide professional support to our members, as well as impartial scientific information and evidence to policy makers and the public.

Geoscience and policy

As the national forum for the debate and development of cutting-edge Earth science, the Geological Society has a special responsibility to communicate this science and its importance to society, the Government, the media, other scientific communities and the general public.

Our Policy Team engages with Parliament, Government, industry and academia to fulfil this purpose. Find out more at **www.geolsoc.org.uk/decarbonisation**.

Geoscience skills: understanding what's going on underground

Geoscientists are skilled and experienced at monitoring and managing the ground beneath our feet. During geothermal exploration, extraction and continued management, geoscientists will:

- **Evaluate** – survey and assess any geothermal resources and sites to ensure that they have suitable characteristics and geology.
- **Monitor** – review and study the ground to ensure stability, performance, safety and sustainability.
- **Remediate** – minimise any environmental effects and ensure responsible stewardship of the subsurface especially in relation to conflicts of use.
- **Predict** – model and estimate of the likely impacts of resource extraction by understanding subsurface behaviour and any response to change.

Understanding and carefully working with the environment beneath our feet will be especially important when exploiting heat resources in densely populated areas where the shallow subsurface can be crowded with other infrastructure. Shallow geothermal projects have much lower risks than deeper, hotter geothermal systems, and numerous projects operate without significant environmental issues.

References and further reading

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This document has been reviewed for content and scientific accuracy by our Decarbonisation Working Group.