CARBON INTENSITY OF DEEP GEOTHERMAL HEAT IN SCOTLAND

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SUMMARY

We analysed the carbon emissions from deep geothermal heat using the Hill of Banchory feasibility study as a case study. Our analysis [1] found that:

- Deep geothermal systems in Scotland can produce very low carbon heat that is **compatible with Scotland's carbon emission reduction targets for 2045 and beyond**. Deep geothermal heat systems therefore offer a **long-term low-carbon heat option at scale.**
- The carbon intensity of deep geothermal heat is between **9.7** and **14.0 kg(CO_2e)/MWh_{th}**; this is ~5% of the value for natural gas heating.
- The carbon intensity of deep geothermal heat could be **reduced further** as follows:
  (a) *Direct emissions*:
  Drilling: replace diesel fuelled drilling apparatus with natural gas or electricity powered hardware.
  (b) *Indirect emissions*:
  Pump operation: decarbonise the power grid more rapidly than forecast, or substitute mains power with local renewable electricity to power pumps.
  Infrastructure: source lower carbon steel and cement.
  Land use change: design projects to minimise land use change emissions.

In Scotland, no commercial deep geothermal heat (or electricity) project has yet commenced production. Other countries with comparable geothermal resources such as the Netherlands and France now have well developed geothermal heat sectors based on long-term, stable, policy support.

BACKGROUND

The Climate Change (Emissions Reduction Targets) (Scotland) Act 2019 sets 2045 as the net-zero emissions target year for Scotland. Heat currently accounts for 47% of Scotland's emissions [2]. While Scotland's electricity network is rapidly decarbonising, the proportion of heat demand from renewable sources in Scotland was only 5.9% in 2017; which is the lowest in Europe [3].

Deep geothermal heat (DGH) has been proposed as a technology option that could provide a significant amount of low carbon heat, assisting in the transition away from fossil fuel heating in Scotland [2, 4].

DGH resources in Scotland can be accessed by drilling 1.5-3 km below ground and pumping hot ground-water (70-90°C) to the surface to be used for space or industrial heating. DGH resources are found in the granites of North East Scotland [5] and the deep sedimentary aquifers of the Central Belt [6].

In 2015 the Scottish Government's *Low Carbon Infrastructure Transition Programme* funded three DGH feasibility studies: two to assess potential for a granite-based heat resource and another to assess a sandstone-based resource [7]. The studies found **no technical barriers** to DGH exploitation in Scotland. However, as yet no commercial large scale deep geothermal project has commenced drilling in Scotland; the risk that the first borehole may prove unproductive is the primary barrier to progress. The Netherlands, which has geothermal resources similar to Scotland's Central Belt, have overcome this barrier by developing a long-term support and legal framework, including an insurance scheme, which is supporting growth of its DGH industry [8].

To determine the potential for DGH to contribute towards net-zero targets, then the carbon intensity of deep geothermal heat must be known. A recent collaborative project between the Universities of Glasgow and Strathclyde, in partnership with industry experts Hotspur Geothermal, aimed to address this gap by performing a life cycle analysis of a deep geothermal heat project in Scotland.

PROJECT OUTLINE

Our study aimed to quantify the life cycle greenhouse gas emissions associated with producing DGH in Scotland. The study used DGH project details from the Hill of Banchory Geothermal Project (which we refer to as the 'Banchory DGH project'), which was one of the three DGH feasibility studies funded by the Scottish Government's *Low Carbon Infrastructure Transition Programme*. The Banchory DGH project would source heat from granite rocks 1.5 to 3 km below ground, located 1 km to the North of the town of Banchory in Aberdeenshire. Heat would be transported between the DGH site and the town's existing (biomass-heated) district heat network via buried insulated pipes. The feasibility study found that the Banchory DGH project could produce around 400,000 MWh_{th} of heat over a 30-year lifetime.

In our work we considered the direct and indirect greenhouse gas (GHG) emissions (expressed as CO_2 equivalent emissions, CO_2e) associated with the development and operation of the Banchory DGH project. Our calculations accounted for GHG emissions from: land use change resulting from building the DGH infrastructure; drilling the boreholes; and from generating the power required to operate the pumps that extract and circulate the thermal waters over a 30-year lifespan. We also accounted for the indirect GHG emissions embedded in the manufacture and transport of the DGH hardware such as steel and cement. We did not account for the carbon embedded in the town's existing district heat infrastructure.

RESULTS

We found an upper estimate for CO_2e released over the project lifetime of 5,506 tonnes (t) CO_2e. The largest contributor to the upper estimate (1,678 t(CO_2e), 30% of the total) was the indirect GHG emissions from operating the pumps that extract and circulate the thermal waters. Our calculations assumed the pumps were powered by the UK electricity grid which was decarbonising over the 30-year lifespan at rates equivalent to energy emissions targets for 2030.

The remaining emissions primarily came from the building of the site, including:

- Indirect GHG emissions embedded in the steel casing of the geothermal boreholes: 1,296 t(CO_2e)
- Direct GHG emissions from powering the drill rig using diesel fuel: 1,243 t(CO_2e)
- Change in land use (from building on heath rather than grass or arable land): 841 t(CO_2e)
- Indirect GHG emissions embedded in the cement used to seal the boreholes: 360 t(CO_2e)

Other smaller emission sources included the indirect emissions embedded in the pipes used to transport heat, transporting the drill rig to and from the DGH site, and the fluids used for drilling the well.

The lower estimate for the CO_2e released over the Banchory DGH project lifetime was 3,806 t(CO_2e).

The calculated carbon emissions intensity of heat produced from the Banchory DGH project is 9.7–14.0 kg(CO_2e) per MWh_{th} which is 5-7% that of fossil fuel derived heat. Thus, **DGH offers very low carbon heat**.

Hypothetically, if all of Scotland's heat were delivered by DGH, heat provision would take up less than 5% of a net-zero national carbon budget as set out in the The Climate Change (Emissions Reduction Targets) (Scotland) Act 2019. However, the total DGH potential for Scotland is still unknown.

Our findings show that DGH should be considered as a technology option for reaching net-zero in Scotland.

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