CARBON INTENSITY OF LOW-ENTHALPY GEOTHERMAL HEAT

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1. SUMMARY

1.1 Globally, low enthalpy (i.e. low temperature, <100°C) geothermal resources are widespread and could offer a valuable long-term source of low carbon industrial or domestic heat. The question is, *how low carbon is low enthalpy geothermal heat?*

1.2 We analysed the carbon emissions from low enthalpy deep geothermal heat using the Hill of Banchory feasibility project as a case study. **The project constraints represent many typical low enthalpy heat prospects, and the methodology we develop can be readily adapted to suit individual projects**.

1.3 Our analysis [1] found that:

- Low enthalpy deep geothermal systems can produce very low carbon heat that is **compatible with long-term carbon emission reduction targets**. 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.

2. BACKGROUND

2.1 Countries are setting ever more stringent targets for reducing greenhouse gas emissions. Recently in Scotland, The Climate Change (Emissions Reduction Targets) (Scotland) Act 2019 set 2045 as the net-zero emissions target year. While Scotland's electricity network is rapidly decarbonising, the proportion of heat demand from renewables in Scotland was only 5.9% in 2017; which is the lowest in Europe [2].

2.2 Many low-enthalpy deep geothermal heat (LDGH) resources are known in Scotland. Here we define LDGH resources to be 50-90°C at 1-3+ km below ground, and which do not require heat pumps to raise the temperature for surface use of the heat.

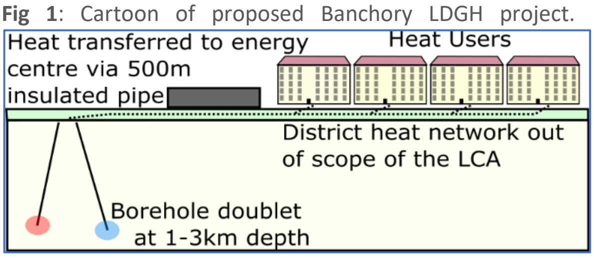
2.3 To determine the potential for low-enthalpy deep geothermal heat (LDGH) to contribute towards net-zero targets, then the carbon intensity (i.e. carbon footprint) of deep geothermal heat must be known. However, when conducting a geothermal feasibility study (in Banchory, North East Scotland), we found no publicly available information on the carbon footprint of LDGH.

3. PROJECT OUTLINE

3.1 To address the knowledge gap, our study aimed to quantify the life cycle greenhouse gas emissions associated with producing LDGH. We used project details from the Hill of Banchory Geothermal Project (which we refer to as the 'Banchory LDGH project'). However, the results are relevant to any equivalent LDGH project.

3.2 The Banchory LDGH project (cartoon Fig 1 below) would source heat from granite rocks 1.5 to 3 km below ground. Heat would be transported between the LDGH site and the town's existing (biomass-heated) district heat network via buried insulated pipes. The feasibility study found that the Banchory LDGH project could produce around 400,000 MWh_{th} of heat over a 30-year lifetime.

Fig 1: Cartoon of proposed Banchory LDGH project.

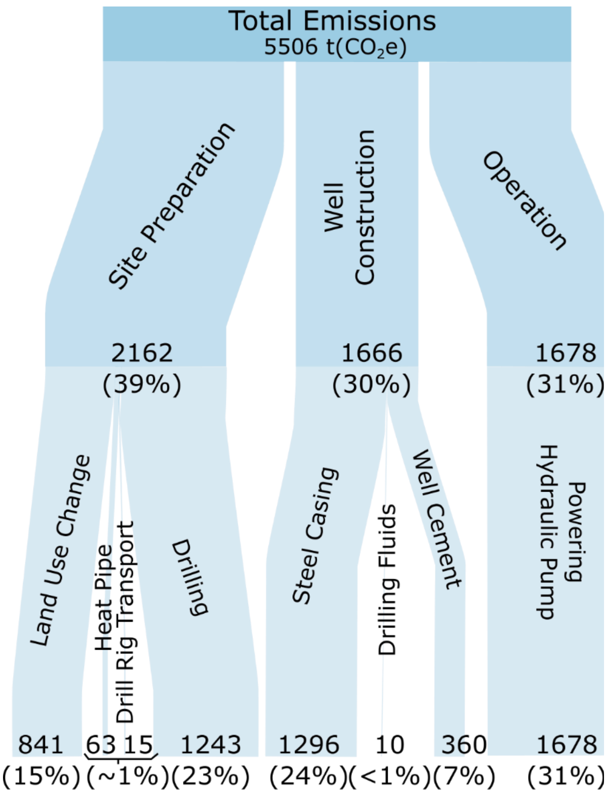


3.3 In our work we considered the direct and indirect greenhouse gas (GHG) emissions (expressed as CO_2 equivalent emissions, CO_2e) associated with the development and operation of the Banchory LDGH project. Our calculations accounted for GHG emissions from: land use change resulting from building the LDGH 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 LDGH hardware such as steel and cement. We did not account for the carbon embedded in the town's existing district heat infrastructure.

4. RESULTS

4.1 We found an **upper estimate for CO_2e released over a LDGH 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. We assumed the pumps were powered by an electricity grid which was decarbonising over the 30-year lifespan towards carbon intensities of <100 kg(CO_2e).

Fig 2: Schematic showing the sources of GHG emissions for the three stages of project lifecycle, and the contribution of these sources towards carbon footprint. Emissions associated with project decommissioning is out of scope.



4.2 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)

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

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

4.4 The calculated carbon emissions intensity of heat produced from the LDGH project is **9.7–14.0 kg(CO_2e)** per MWh_{th} which is 5-7% that of natural gas derived heat. Thus**, LDGH offers very low carbon heat**. Although the intensity is highly dependent on the quantity of heat produced over the life of the LDGH.

Our findings show that LDGH is a widespread resource which should be considered to achieve future GHG emission reduction targets.

REFERENCES

1. McCay, A.T., Feliks, M.E. and Roberts, J.J. (2019). Life cycle assessment of the carbon intensity of deep geothermal heat systems: a case study from Scotland. *Science of The Total Environment*, *685*,p.208-219. https://doi.org/10.1016/j.scitotenv.2019.05.311
2. Annual Compendium of Scottish Energy Statistics. May 2019. Scottish Government