



GEOHERMICA Initiative & CETPartnership TRI4
Workshop in Dublin 10/10/2023

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G2C – Heat GeoBattery

Using abandoned flooded coal mines to store and transport waste heat



Project partners



Co-funded by:
 Scottish Enterprise, Scotland
 Geological Survey Ireland (GSI)
 Department of Energy (DoE) USA
 European Union

Plus significant own contributions
 from project partners.

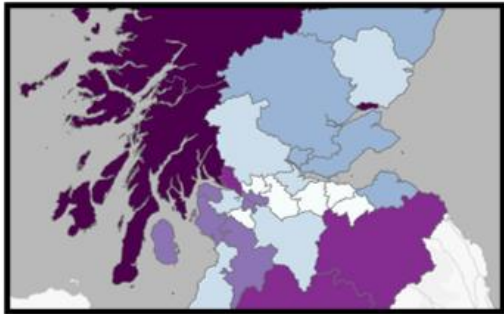
Cooperation partners



Concept

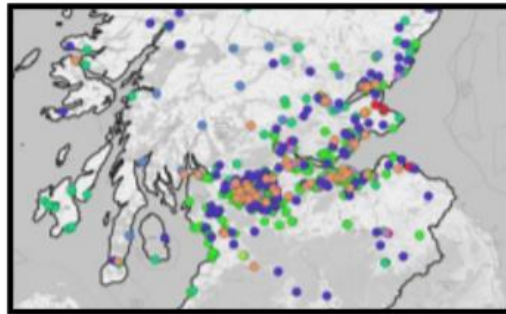
1

Waste Heat & Fuel Poverty in the Heart of Scotland



- **600,000** households face fuel poverty in Scotland
- Up to **1 in 4** households in the central belt of Scotland.

<https://www.gov.scot/publications/scottish-house-condition-survey-2018-key-findings/pages/6/>



- **1,677 GWh** of waste heat across ~1000 locations
- **121,000** households equivalent of heat

<https://www.climateexchange.org.uk/media/4481/waste-heat-sources-for-heat-networks-scotland-final-nov-20.pdf>



- Mine workings underly heat demand
- Potential for thermal storage and transfer

<https://mapapps2.bgs.ac.uk/coalauthority/home.html>

Flooded mine workings = thermal resource



Fig. 84—Falling in of a 10m.

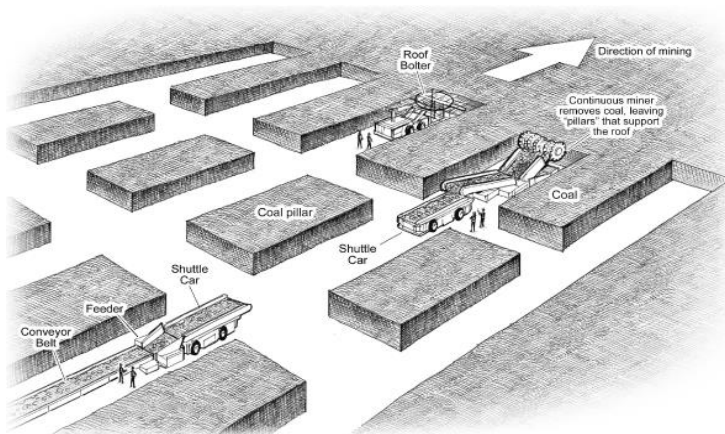
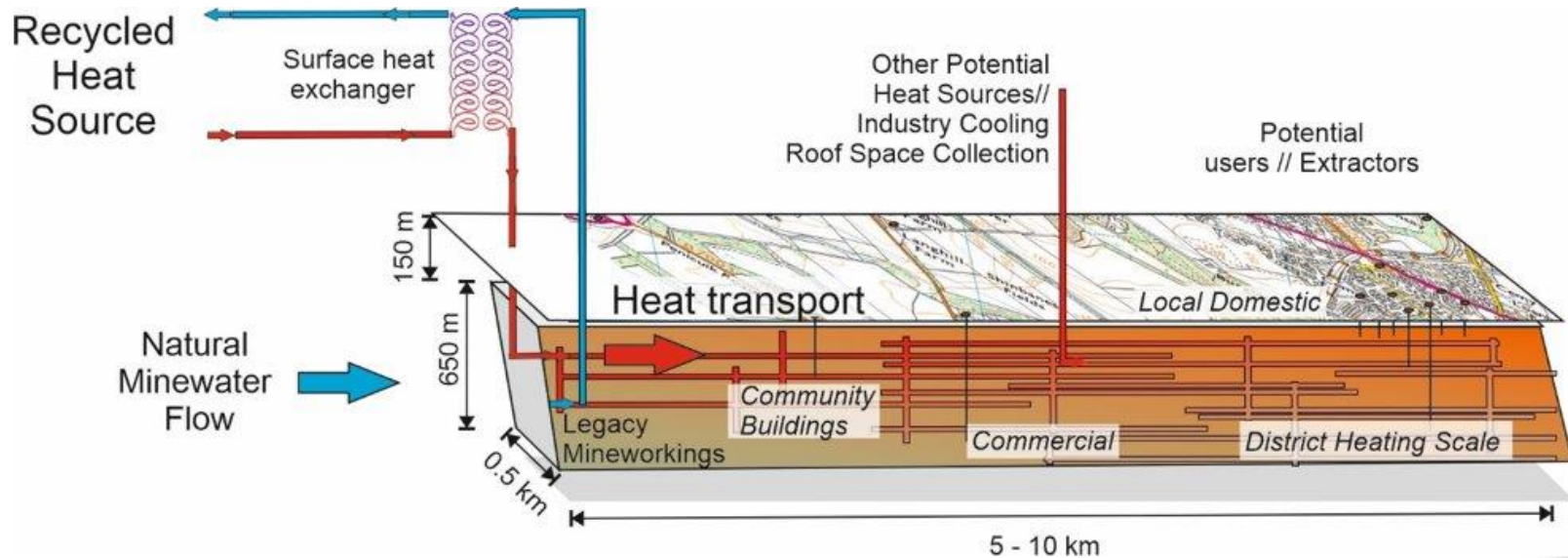


Photo © British Geological Survey
GeoScience Ref P001520 - Blindwells Opencast Site, Tranent, East Lothian

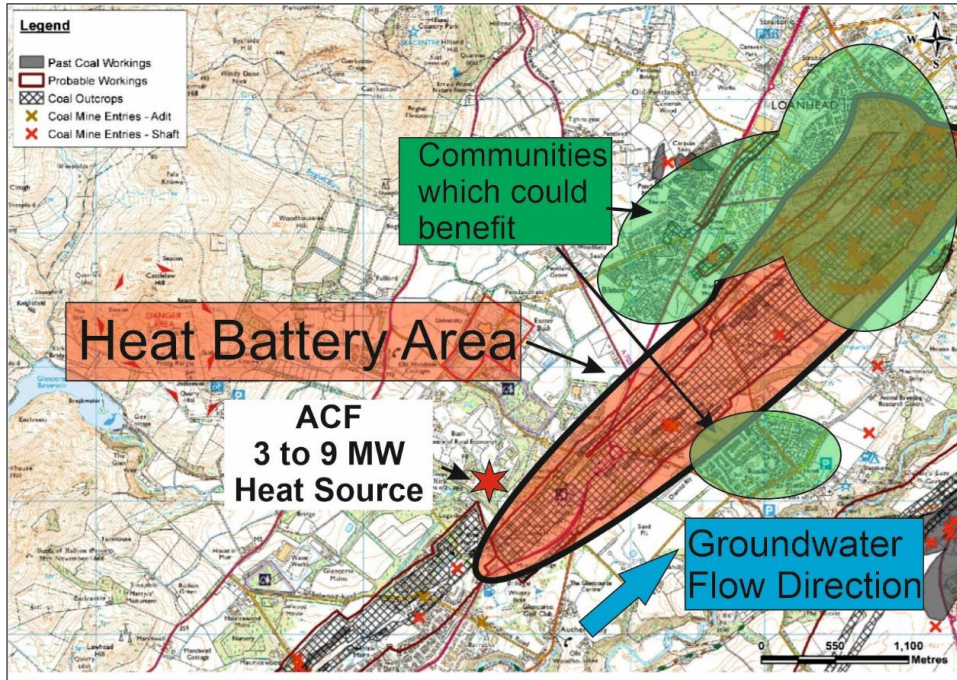
GeoBattery Concept



Site

2

Heat Battery Location

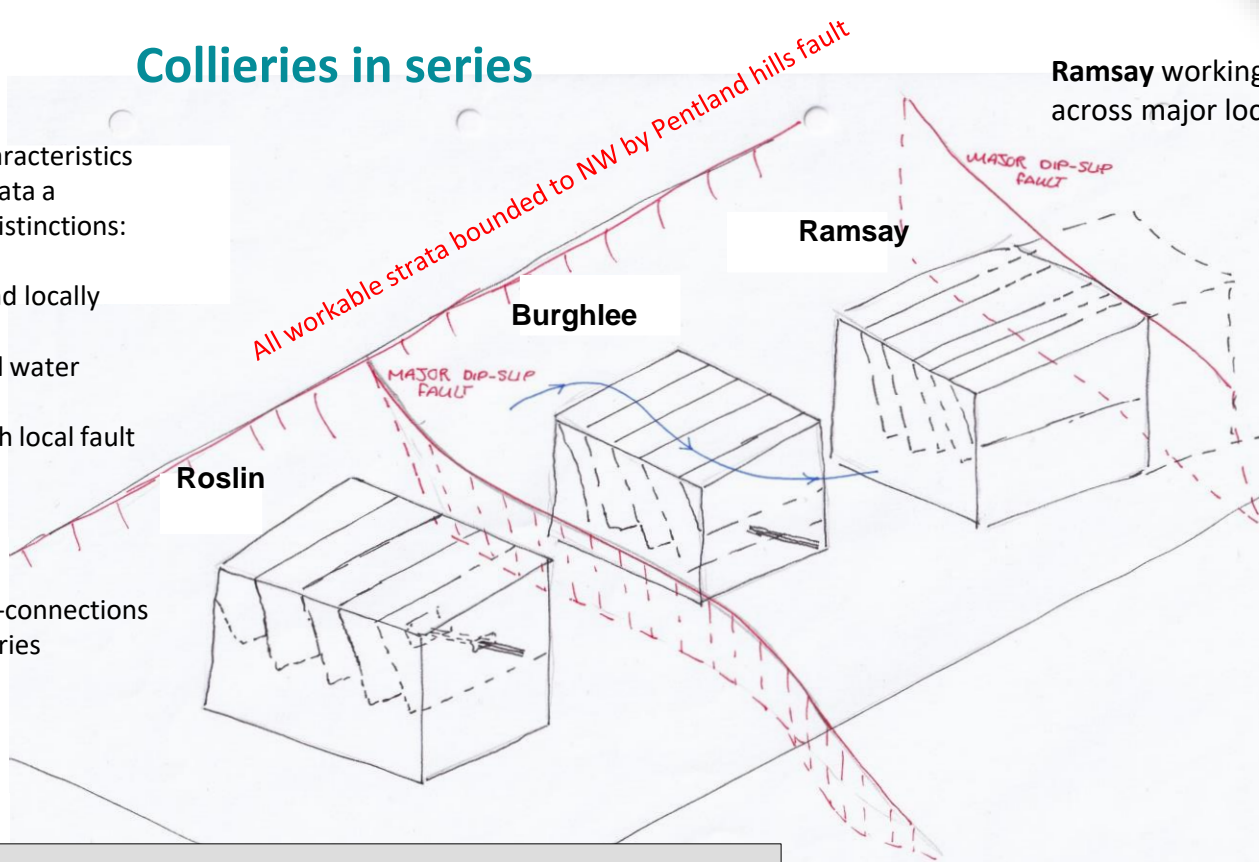


Collieries in series

Conceptually similar characteristics (they mine the same strata a similar way) but some distinctions:

- Roslin** – Mines up to, and locally through, Regional fault
- Burghlee** – Crosses local water course
- Ramsay** – Mines through local fault

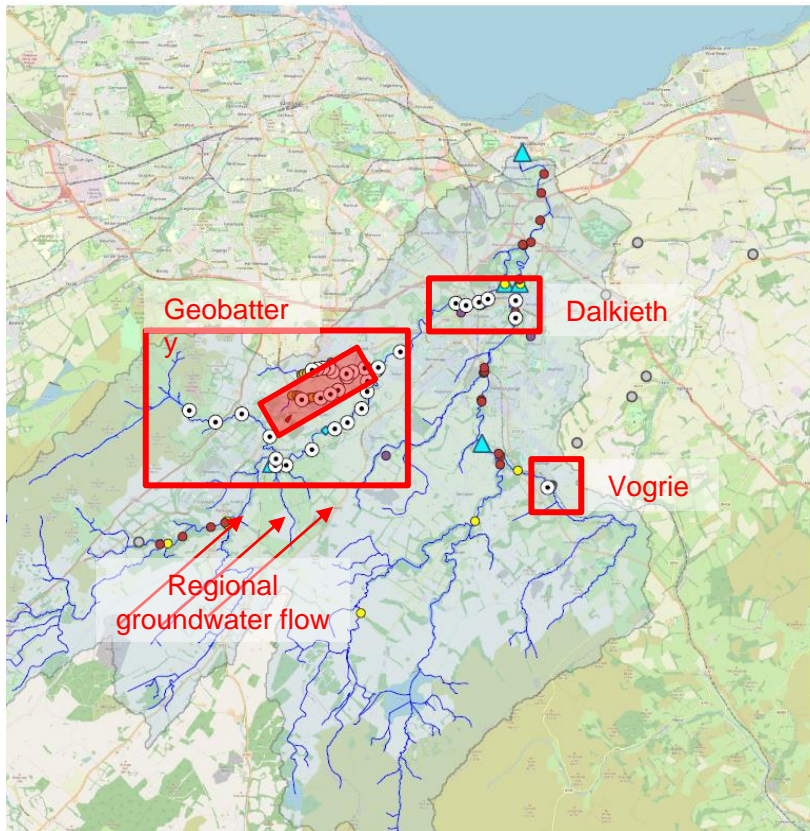
There are local through-connections between all three collieries



Ramsay workings continue across major local fault

Boundary conditions

- Pentland Hills fault** – zero-flow gradient (due to impermeable igneous bedrock in the footwall)
- NW-SE faults** – contrasting conductivity, but should be still somewhat transmissive to fluid
- Bilston burn** – Fixed head boundary condition (permeable bedrock in streambed – decent maintained flow even in drier times (limited field visits so far))



Legend

Hydrochemistry

- Baseline chemistry points (quarterly)
- Baseline hand-probe points (monthly)
- BSc project sample points
- Discharges
- Coal Authority monitoring points
- SEPA monitoring points

Hydrology

- ▲ Gauging station (National River Flow Archive)
- Catchment of Musselburgh gauge (19007)
- Water courses above Musselburgh gauge

- GeoBattery 'footprint'

Context/Rationale

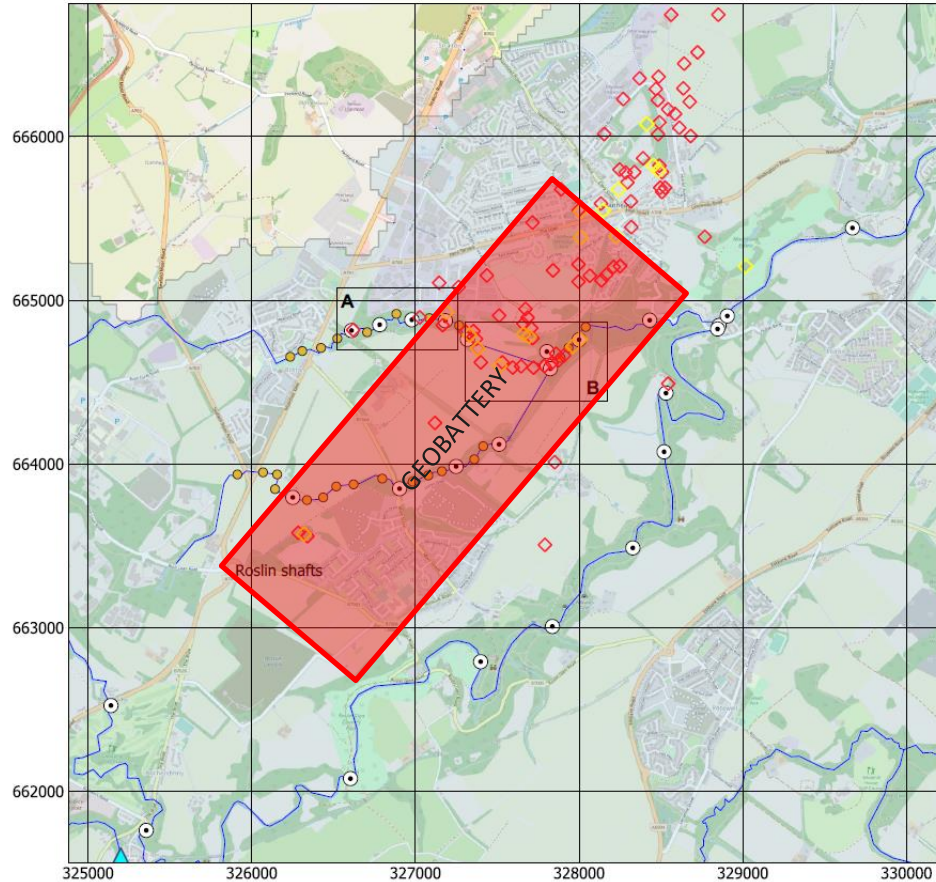
Geobattery footprint covers ~5km²

Interacts locally with a number of watercourses

Historic, shafts/adits near watercourses could be activated

Potential interactions minewater discharges in Dalkeith and Vogrie

Known Historic Shafts/Adits



Coal Authority

- ◊ CA (Adits)
- ◊ CA (Shafts)

G2C Baseline Points

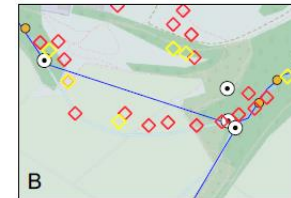
- ⊙ Chemical analysis
- Hand probe

Hydrology

- WatercourseLink



A number of shafts are present as sunken ground in the Bilston Burn. These are not shown on Burghlee colliery plans from CA - implying they target shallower levels



Numerous old shafts and adits are present in the Bilston burn, however most have been buried by the waste from Bilston Glen colliery. The Bilston burn goes into a tunnel here.

Monthly Measurements

Full field campaigns for June – September completed

Handprobe Ultrameter Measurements

- Oxidation-Reduction Potential
- Electrical conductivity
- pH
- Temperature
- Total Dissolved Solids

Quarterly Measurements

Full chemical sampling for meteorological Summer (June) and meteorological Autumn (September) complete

Water Sampling and Lab Analysis

- Ca Mg K Na (all dissolved unless otherwise stated)
- SO_4^{2-} NO_3^- Cl^-
- Dissolved Fe, Mn (field filtered at $0.45\mu\text{m}$, immediate preservation with conc. HNO_3)
- Total Fe, Mn (unfiltered, immediate preservation with conc. HNO_3)
- Alkalinity
- pH, conductivity (for QC against ultrametre)

Isotopes

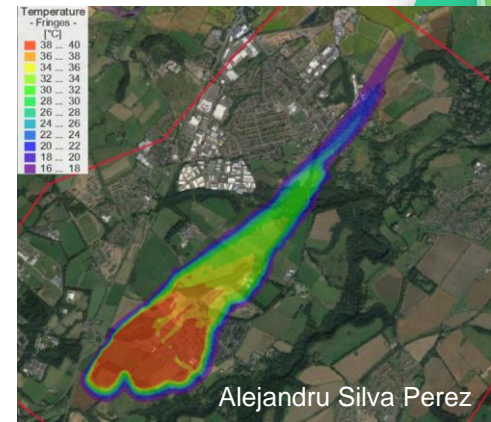
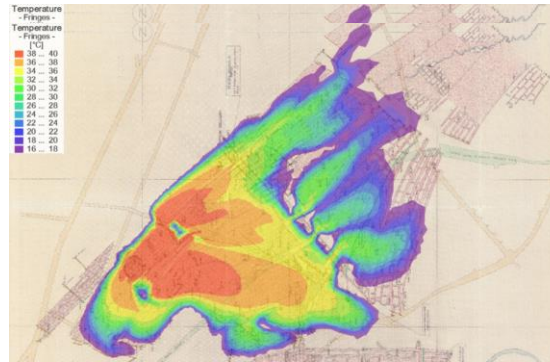
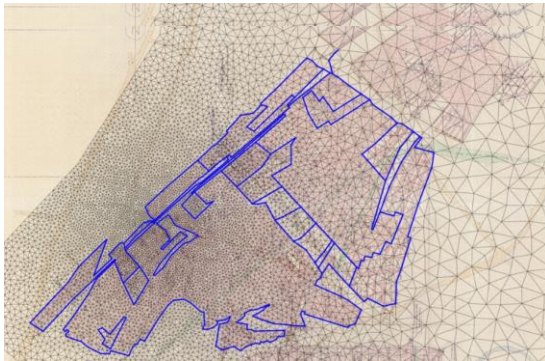
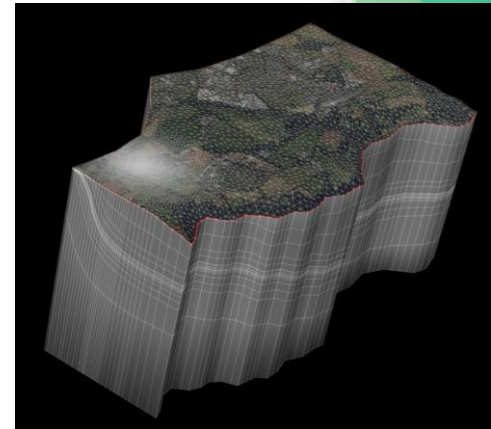
- ^{34}S , ^2H and ^{18}O from known minewater discharges to fingerprint seasonal variations in source

Simulation

3

3D T-H Numerical Model

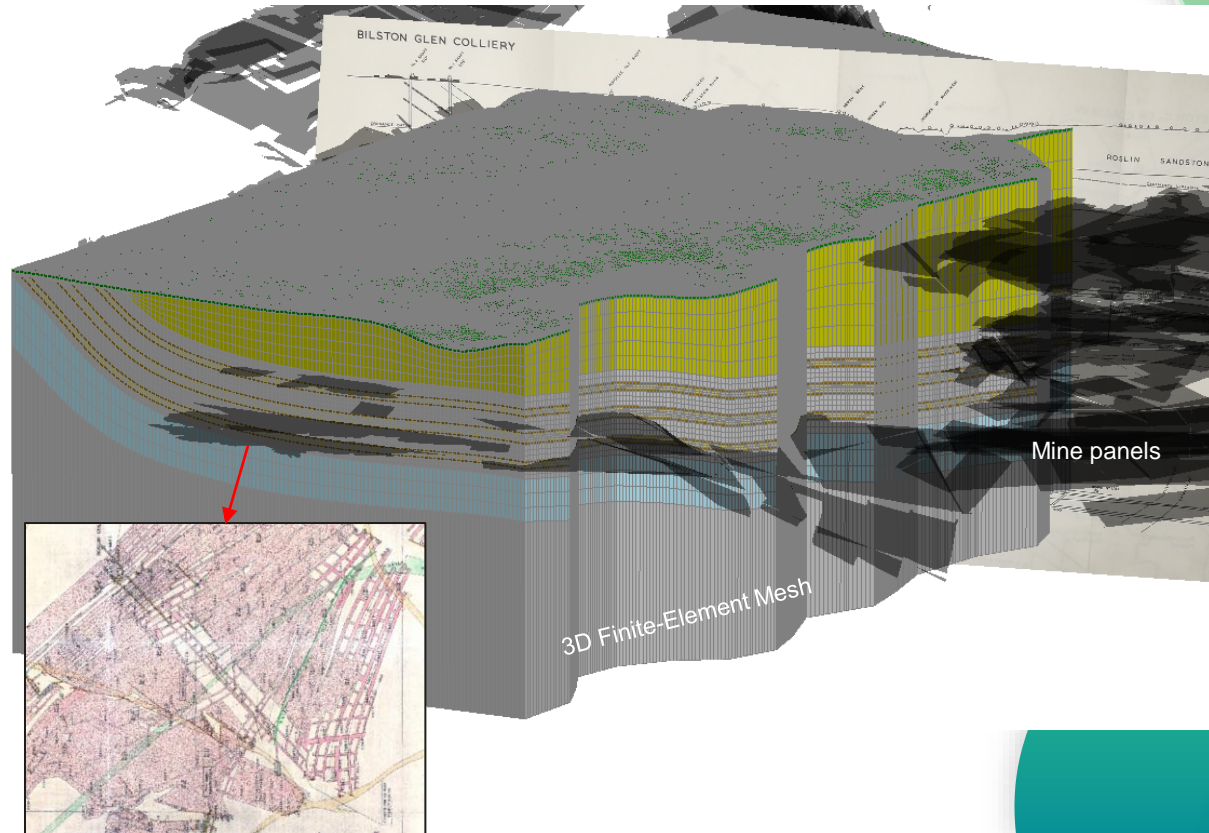
- A 3D model of the G2C area has been built in *FEFLOW* with the mesh structure created in the *Leapfrog* Geological Model
- Initial Thermo-Hydraulic simulations have been conducted to evaluate the potential heat plume extension in the subsurface
- The main stalls (rooms) and roadways are represented by discrete elements connecting nodes (initially) modelled through Darcian flow
- The results of pumping tests carried out in the Glasgow UKGEOS were used to define the hydraulic conductivity ranges assigned to the model voids
- Parametrical uncertainty will be assessed by the definition of individual zones representing distinct architectural units around mined panels
- The initial results (40y simulation) show the main role of roadways for subsurface thermal transfer, and the heat plume extending towards the town of Loanhead



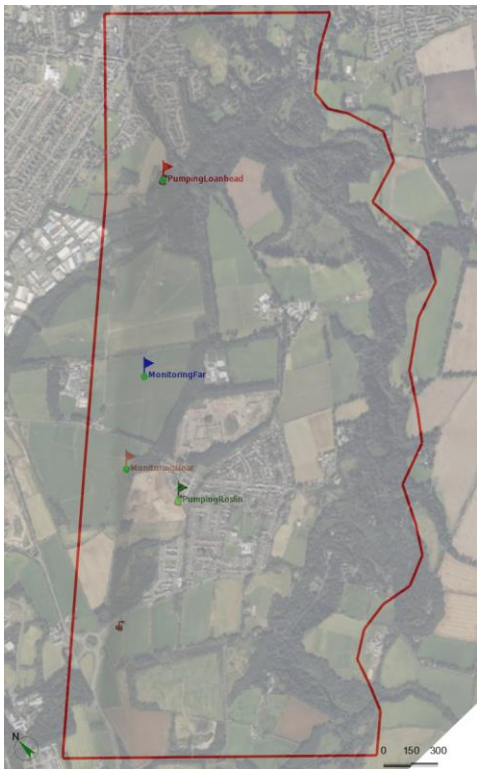
Subsurface Data Interpretation for 3D Model Creation

Geological Model
(*Leapfrog*): Interpretation of historical mine plans, cross-sections and surface geology maps.

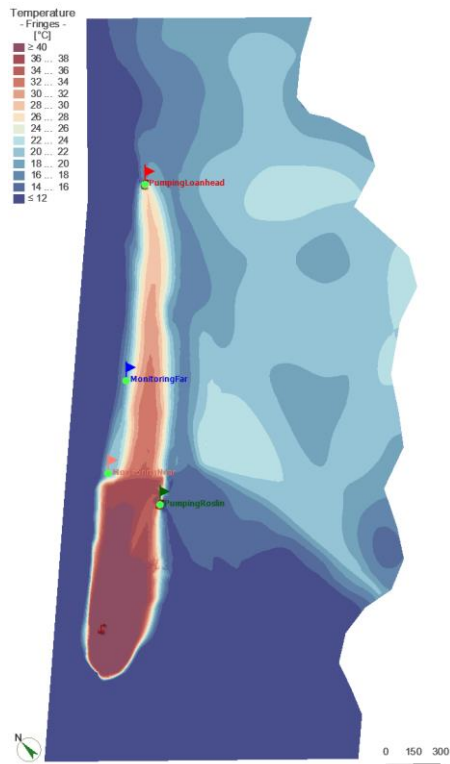
Finite-Element Mesh
(*Feflow*): Discretization of geological structures into 3D element mesh with 1D embedded features (roadways)



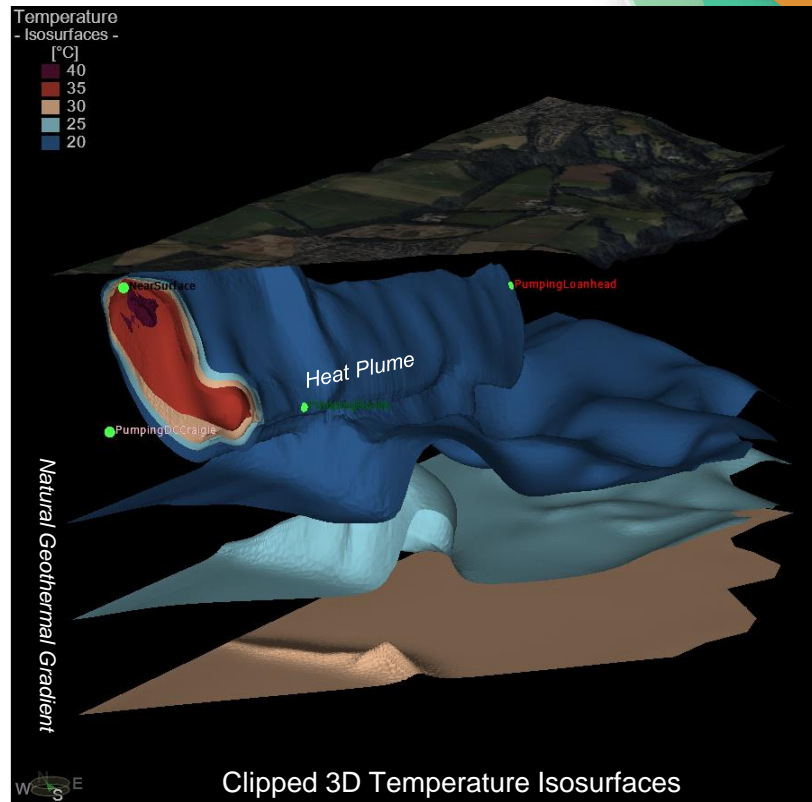
3D Numerical Model Area and Initial Results



Numerical Model Extension



Planar view of heat plume in Peacock coal seam

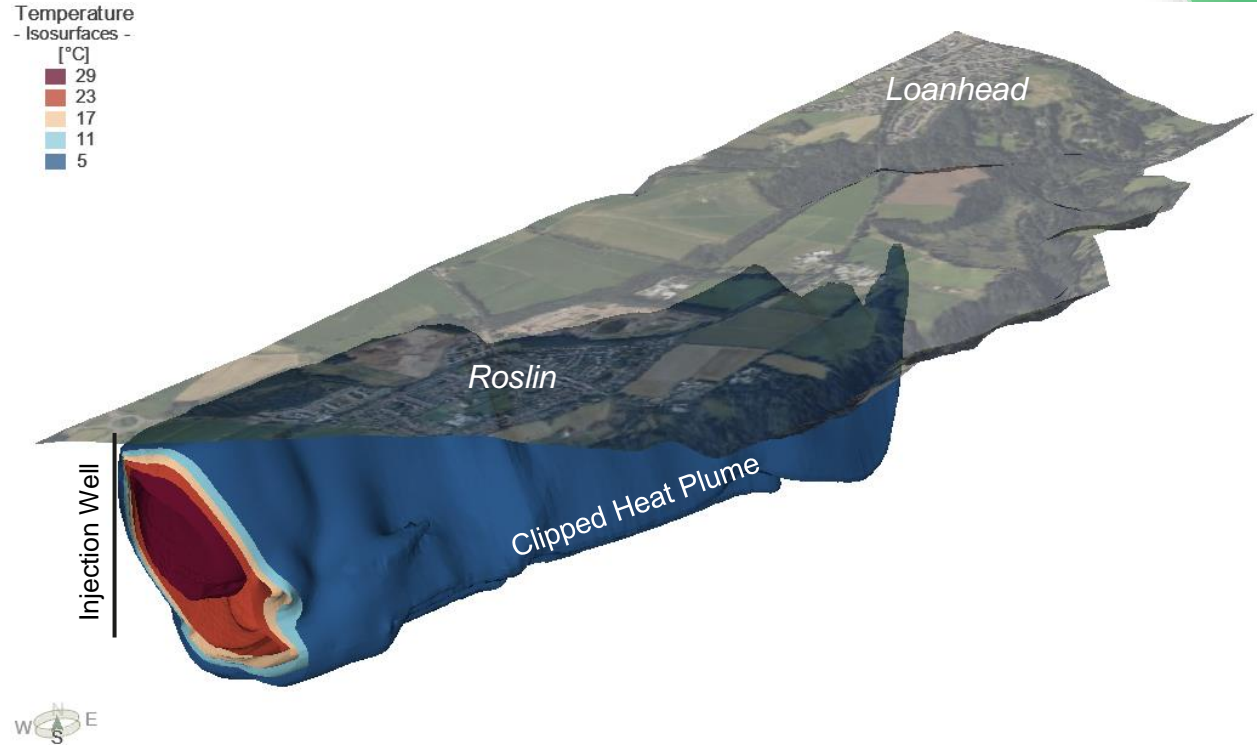
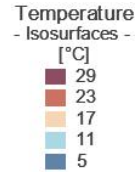


Clipped 3D Temperature Isosurfaces

Thermal Anomaly (Heat stored in the subsurface)

Results of thermo-hydraulic model developed to simulate heat transport in flooded mine workings.

Initial operational scenario simulated including open-loop systems (i.e. extraction wells in Roslin and Loanhead).



Execution

4

G2C – Heat GeoBattery - Aims

1. Feasibility Study for ACF Cooling Using Mine Water

- Quantification of Waste Heat Available
- Abstraction & Discharge Locations Identified
- Cost Engineering
- Environmental & Social
- Risk Assessment

2. Development of the Experimental Field Site

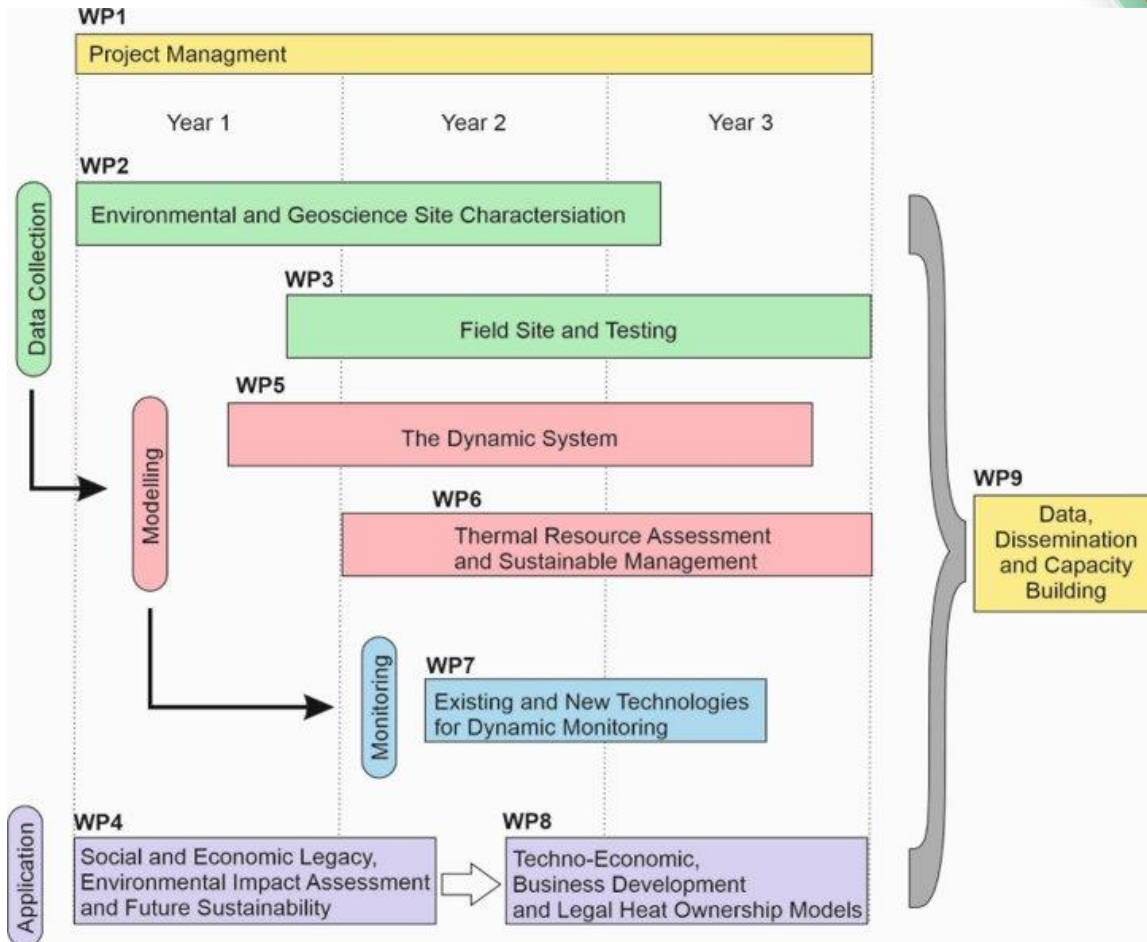
- Baseline Monitoring
- Borehole drilling:
 - 1 x abstraction borehole
 - 1 x discharge borehole
 - 1 x monitoring borehole
- Hydraulic and Tracer Tests
- Local Monitoring

3. Modelling, Monitoring and Making It Happen

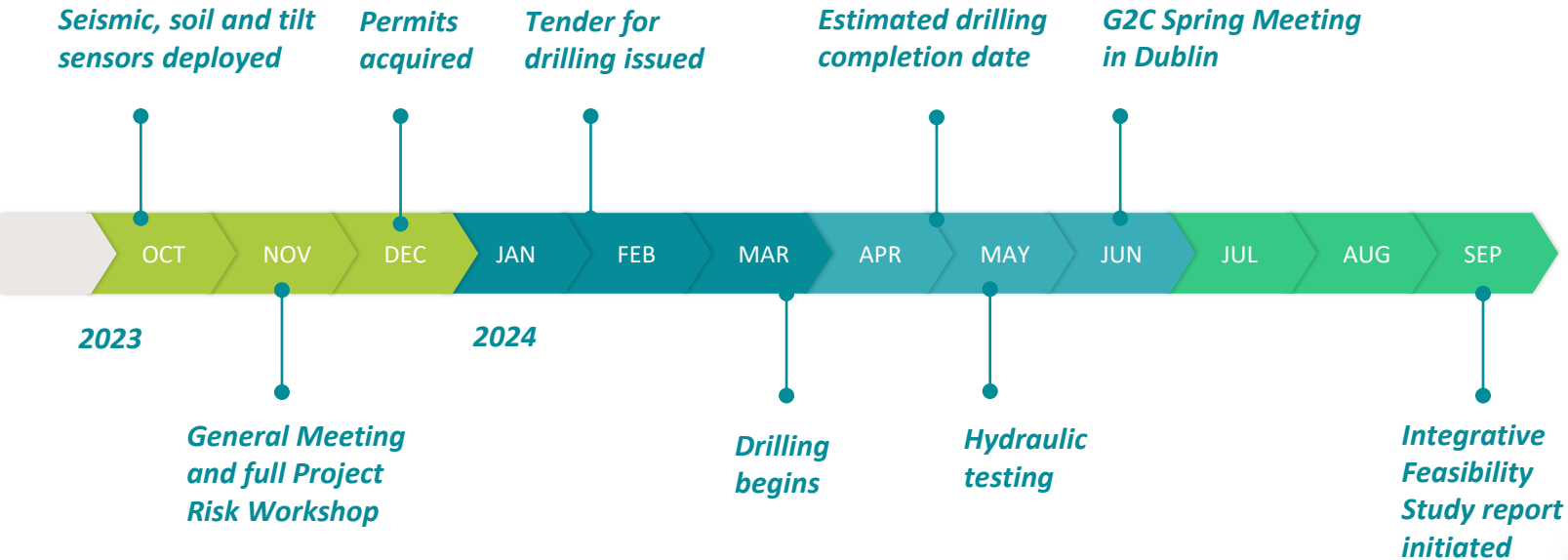
- Heat Discharge
- Heat Storage
- Heat Transport
- Heat Recovery
- Heat Ownership
- Regulation & Policy
- Techno-economic Case

Year 1 Activities:

- Conceptual Model Developed
- Hydraulic Model Developed
- Baseline Monitoring Programme
- Stakeholder & Risk Mapping
- Spring Meeting in Edinburgh with All Partners
- Transnational Collaboration Agreement Signed



Year 2 Timeline



Outcomes

- Outline techno-economic modelling tool for the Heat GeoBattery concept
- UK and Scottish Governments policy and regulatory recommendations for the use of mine workings as thermal stores
- Guidance on potential application of Heat GeoBattery concept to European & United States of America flooded mineral mines
- Best Practice Guidelines from G2C project for future projects

Part of a Wider Vision

- Heating accounts for 45% of the UK's energy use: market value of £45bn pa
- 66% of the mine water sites in the Central Belt of Scotland: £550m pa by 2031
- 81% of the most deprived communities live above coalfields.
- Conversion of the UK's £2.4b pa ex-coal mine liability to a £10bn asset
- Enhanced sense of place and pride for local ex-mining communities

Thank you!

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