Record of proceedings

UK Geoenergy Observatories Glasgow

Geothermal Energy Innovation Workshop

Monday 3rd June 2019, 10am to 4.30pm

University of Strathclyde, Technology Innovation Centre, Glasgow

Contents

1. Introduction

In June 2019, the Natural Environment Research Council (NERC), the University of Strathclyde, and the British Geological Survey invited scientific researchers and innovators to a one-day workshop in Glasgow to investigate the innovation required to unlock geothermal energy in the UK.

Participants were invited to map how these innovation requirements could be taken forward at new research facilities becoming available through a £31m investment in two UK Geoenergy Observatories.

One of the observatories is a site in the Glasgow City Region focussed around minewater heat. The UK Geoenergy Observatory in Glasgow will be site for learning about the geology and demonstrating new products. The research and innovation activities will provide more certainty around policy and regulation, as well as opportunities for stakeholder engagement and showcasing consumer demand.

Participants at the geothermal energy innovation workshop discussed the following topics:

1. geothermal research
2. technical innovation
3. policy needs
4. stakeholder engagement

This document provides a record of the discussions during the day and includes data from the facilitated sessions and from post-workshop feedback. This document is being released for the research & innovation community under the UK Geoenergy observatories open data policy.

The data, information and knowledge gained from the workshop will be used to inform the UK Geoenergy Observatories innovation strategy and stakeholder engagement strategy.

2. Overview of workshop outcomes for UK geothermal innovation

Unlocking geothermal energy in the UK requires innovation in four key areas. These are:

1) De-risking the geological and thermal site model

Provision of robust scientific data on sub-surface geology and thermal properties will reduce risk for potential investors in geothermal energy projects. Opportunities include:

- Data: Obtaining the basic data sets, particularly core and wireline data; Data analysis and data innovation
- New (open access) tools for subsurface visualisation e.g. interactive 3D to 4D mapping/modelling
- System models e.g. to assess heat, productivity, short circuiting
- Methodology and process: best practice to assess subsurface structure and temperature using measured data.
- Energy data and thermal power: e.g flow rate of water at a given temperature.
- Tools for the assessment of ground motion risk during water extraction/injection
- Proven compatible unique tracer test approaches for geothermal resource assessment

2) Reducing capital costs

The up-front capital cost must be brought down to unlock the market. Innovation opportunities include:

- Technological solutions for faster/more efficient/cheaper drilling and well completion
- More accurate and better integrated site investigation technologies
- Combined installations with other energy sources
- Optimising surface engineering layout through pipes and pump testing

3) Reducing operational costs

Optimisation of operations (e.g. monitoring and remediation) will ensure the longevity of projects through, for example:

- Costed engineering solutions + predictive tool for different classes of geochemistry
- Infrastructure innovation and systems integration.
- Development of better models for infrastructure costing that take account of lessons learned at the UK Geoenergy Observatories
- Optimisation of pressure control to prevent air incursion/degassing and pipe fouling
- Recovery of valuable by-products e.g. metals in solution, particulate matter
- Monitoring and intervention: data analysis and data innovation
- Remediation of Fe (III) ppn in pipes/pumps in situ via: Chemistry management; Additives; Pipe coating

4) Non-technical challenges

- Financing of geothermal projects
- Policy development
- Regulation
- Consumer markets

A key learning from the workshop discussion and feedback was that multiple geothermal demonstration sites are needed to prove concepts and unlock investments: i.e. learning by doing.

Delivering demonstration sites is beyond the scope of phase one of the UK Geoenergy Observatory in Glasgow: the site is not a fully integrated geothermal demonstrator. The UK Geoenergy Observatories delivery team, project board and external governance groups should consider the following questions:

1) Can the Glasgow Observatory become, or be integrated into, a demonstration project beyond the project lifetime?
2) How can the project team work with the stakeholder community to develop a geothermal demonstration site and what is the UK Geoenergy Observatories' role in this?

3. Event format

3.1 Background and aims of the event

The workshop focussed on the innovation required to underpin the development of geothermal energy resources in the UK and introduced the UK Geoenergy Observatories as a potential enabler.

UK Geoenergy Observatories is a £31 million UK government capital investment to create world-class, subsurface energy-research test centres. Of particular relevance to the June 2019 innovation workshop is the Glasgow Observatory, which aims to study low-temperature geothermal energy from the flooded mine workings below the Glasgow City Region.

The workshop included presentations on the Glasgow Observatory offer, how innovators can access the sites and potential routes for funding research and innovation.

The delivery of UK-wide geothermal resources into the energy system requires cross-sector collaboration and innovation. Opportunities range from deep geothermal to shallow mine water geothermal with innovation needed in heat resource characterisation, site investigation, design of engineering infrastructure, construction and maintenance of facilities, sensors for better control of the geosphere-engineering hardware system, data analytics to support stronger regulatory compliance and innovation in public engagement.

This workshop brought people together from different sectors including companies across the geothermal supply chain, regulators, and academics in related fields to develop an understanding of the innovation requirements for a future UK geothermal industry. The day consisted of a number of presentations and breakout sessions.

The day was held at, designed and facilitated by the University of Strathclyde, with support and input from the BGS and NERC; and utilising Mentimeter interactive audience engagement software.

3.1 Summary of attendees:

NERC publicised the innovation event via its regular stakeholder information update (Listserver), which contains several thousand contacts.

Of those contacts, 67 people signed up to attend. They break down into the following segments:

Sector	**Headcount**
Industry	23
Academia	27
Government departments, regulators & government agencies	4
Event organisers, BGS and GSAG (Geoscience advisory board)	13

3.2 Event objectives

The event objectives were to:

1) Explore the challenges and opportunities for geothermal in the UK.
2) Encourage the exchange of perspectives, knowledge, understanding, and experiences to date around geothermal energy in the UK.
3) To map the range and breadth of innovation needs for effectively delivering and successfully regulating a geothermal industry. Identify where current knowledge is well established and where there are gaps and if these gaps can be addressed by the Glasgow Observatory.
4) Introduce and provide an overview of the UK Geoenergy Observatories and in particular the Glasgow Observatory.
5) Understand how the Glasgow Observatory can help participants' organisations, what their interest would be in the site and how they might engage with the project.

4. Summary of presentations

Presentations were given to inform discussion of the innovation challenges for geothermal energy. These included:

- Professor Zoe Shipton, Professor of Engineering Geology at the University of Strathclyde (introduction to the workshop)
- UKRI NERC head of productive environment Dr Beth House (setting the scene)
- BGS UK Geoenergy Observatories science director Dr Mike Spence & BGS Glasgow Observatory science lead Dr Alison Monaghan (the observatories)
- Town Rock Energy managing director David Townsend (industry perspective)
- The Coal Authority Innovation Manager Jeremy Crooks (regulator perspective)

The observatories

Dr Mike Spence gave an overview of the UK Geoenergy Observatories including the BGS core scanning facility and the Glasgow and Cheshire Observatories. He summarised the opportunities and how to access the Observatories for research and innovation. Dr Alison Monaghan introduced the Glasgow Observatory and the research and innovation questions it could be used to address. The borehole and monitoring infrastructure and data acquisition were described, along with the timeline for the construction and operational stages.

Industry perspective

David Townsend presented on the challenges and opportunities for geothermal, identifying a range of political, economic, social, and technological challenges: not least of which is awareness-raising with government decision makers and gaining public acceptance. He saw many opportunities particularly in former mining areas and identified the need for demonstrator projects to move the industry forward. There is a need to act now: not only for the UK energy mix, but as other nations are already moving on this and quick progress is needed to secure the UK's competitive advantage.

Regulator perspective

Jeremy Crooks highlighted the significant UK opportunities for minewater energy systems. He noted that the Coal Authority manages large volumes of minewater that could be utilised for geothermal heating schemes. Roadways are seen at the main drilling target, with a key objective being to circulate minewater through fractured rock or collapsed wastes in longwall mines. Jeremy noted the pride in coalfield communities. Lack of regulation on heat resource ownership and utilisation was identified as a major barrier to resource development

5. Summary of workshop sessions

The University of Strathclyde, with support from NERC and BGS, facilitated a series of workshops in the afternoon: with delegates grouped to ensure sectors were represented equally within each grouping. A summary of each workshop discussion is included here:

5.1 What are the challenges and opportunities in delivering geothermal into the energy mix?

The challenges and opportunities set out by workshop participants is included in Appendix A, and these are highlighted in yellow. The key themes that emerged from this session were:

1) Regulation and Policy
2) Financial
3) Systems and Integration
4) Awareness and consumer demand
5) Site specific technical risks
6) Infrastructure
7) Learning by doing
8) Data management

5.2 What are the innovation needs for effectively delivering and successfully regulating a geothermal industry?

The challenges identified in facilitated session 1 were ranked in order of priority by the participants (Figure 1) and these are set out in Appendix A, highlighted in green.

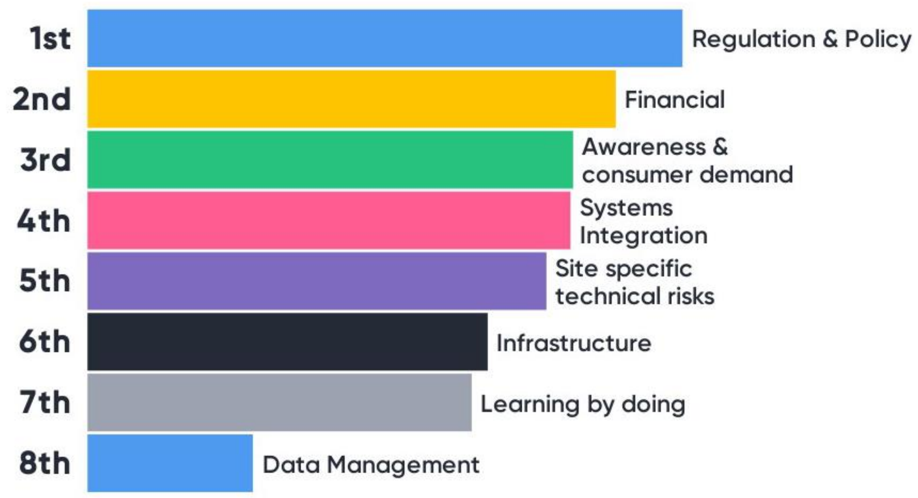

Figure 1 Mentimeter result on ranking of challenges for geothermal by the participants.

5.2.1 Key comments from participants:

1) A key consideration in moving UK geothermal forward is the need for an increased number of successful heat networks to increase the confidence of consumers and investors: more systems are needed in the right places.
2) Need for long-term heat supply agreements with e.g. housing associations, local authorities, prisons, hospitals etc.
3) Need for policy development to support investment in heat networks; greater consumer interest and awareness would facilitate this.

Participants recognise that there is limited scope for the UK Geoenergy Observatories to innovate around the financial/policy challenges identified as a top priority for geothermal.

Participants ranked the opportunities that could be addressed by the UK Geoenergy Observatories (Figure 2).

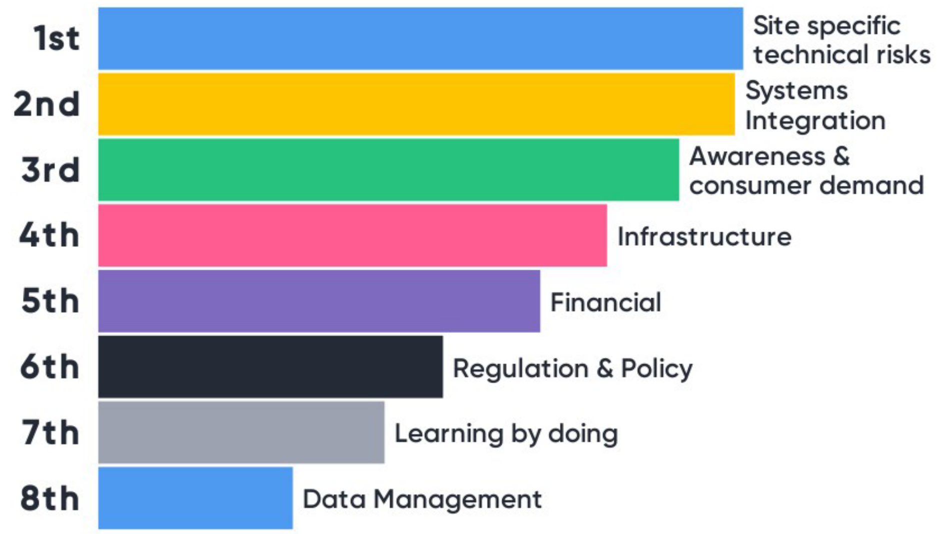

Figure 2 Mentimeter ranking of challenges for geothermal, prioritised on UK Geoenergy Observatories research topics.

5.3 How can the UK Geoenergy Observatories help?

Participants highlighted areas of innovation that could be stimulated with the UK Geoenergy Observatories and these are set out in Appendix A in orange. The mind map shown in Figure 3 highlights participant responses to the workshop question.

Figure 3 Mentimeter mind map summarising innovation topics UK Geoenergy Observatories is best placed to address

5.4 Summary of UK Geoenergy Observatories innovation opportunities

Throughout the workshop, participants identified the following innovation opportunities around the UK Geoenergy Observatories.

Access/Site/Focal point
Additives
All into one open access space
Barriers and gaps
Chemistry management
Collaboration
Combined installations
Communicate/publicise to engineers/sensor development
Communication
Costed engineering solutions for different classes of minewater chemistry:
Data analysis
Database of solutions + predictive tool for unknown geochemistries

Demonstrator
Derisking
Development of better models for infrastructure costing that take account of lessons learned at the UK Geoenergy Observatories
Development of tools for the assessment of ground motion risk during water extraction/injection
Discussion steering committee
Expanding the Glasgow Observatory to include heat connection to district heating
Faster/better/cheaper drilling and well completion techniques
Funding
Heat
Interactive 3-4D map/model (open access)
Make tests public
Methodology and process best practice to assess mine temperature using measured data
Model validation
Monitoring
New product development
New tools for visualisation of subsurface
Operative regime
Optimisation of pressure control to prevent air incursion/degassing and pipe fouling
Optimisation of pressure control to prevent air incursion/degassing and pipe fouling
Pipe coating
Pipes and pump testing
Productivity
Proven tracer testing approaches for mine-water geothermal resource assessment
Recovery of valuable by-products e.g. metals in solution, particulate matter
Remediation of Fe (III) ppn in pipes/pumps in situ
Resource appraisal
Sensible funding mechanism: NERC / EPSRC
Short circuiting
Smaller wells
Suite of compatible unique tracers
Synergy between group
System models – validate simple models across site
Technological solutions for improved efficiency
Technology
Temporal changes
Use of heat/coolth

6. Post event feedback

Feedback forms were distributed to all participants during the event to capture reflective feedback. The information provided within the feedback forms is summarised in this section.

6.1 Question 1 - What would your interest be in the UK Geoenergy Observatories?

As a demonstrator

1. Heat balancing system – supply, storage, demand
2. Commercial application of GSHP and minewater
3. To de-risk geothermal investment
4. Characterise the minewater systems
5. Simple (UK-wide) map of minewater geothermal resource and developing evidence base and technical information and cost.
6. Water chemistry for flow direction/recharge inflation/deflation risk.
7. Research. How to usefully constrain hydraulic conditions in abandoned mines that we know nothing locally about.
8. Improving understanding of sub-surface processes, chemistry and flow and physics. Micro-macro by-products etc.
9. Potentially using it to test my minewater heat flow and geo-mechanical model – model verification of potential surface subsidence risks.
10. Understand the physics of heat flow and fluid flow in flooded mine workings.
11. Understanding how to limit uncertainties in subsurface mechanical and fluid flow properties.
12. Geological risk in mine geothermal potential, with a particular interest in the fluid flow and mechanics of both the abandoned workings and faults and fractures within the sedimentary structures.
13. Potential activities related to heat transfer/storage that may require subsurface activities within the borehole that can be monitored by the established sensors.
14. Chemistry changes in the bottom-hole chemistry over time.

Data innovation

1. Infrastructure innovation and systems integration innovation and access to all sorts of data associated with geothermal energy.
2. Energy data – flow rate of water temperature. Thermal power.
3. Provide robust scientific data on sub-surface geology to reduce risk for potential investors in geothermal energy projects.
4. Data: Obtaining the basic data sets, particularly core and wireline data.

Collaboration

1. Possible collaborations with oil and gas companies looking to diversify.
2. Collaboration with UK Geoenergy Observatories key universities and BGS in grant calls.
3. Promoting and refining geothermal research in the UK. Increasing awareness and confidence in geothermal as a resource.
4. Influencing the plans for the Glasgow Observatory to maximise its influence in promoting minewater geothermal industry in Scotland and UK.

Public Engagement

1. Disseminate information that can be interpreted by non-technical users.
2. Organise stakeholder events.
3. Engaging through a Centre for Doctoral Training (CDT) project I am sponsoring – an interdisciplinary study to understand the barriers and opportunities for minewater heat.

Consultancy and technical services

1. Related to minewater-sourced heat pump systems. Specifically drilling and pumping test supervision, groundwater sampling, pumping test analysis, pumping equipment specification.
2. Consultant in district energy systems
3. Renewables consultancy.
4. Feasibility studies for geothermal heat projects in UK (and overseas).

6.2 Question 2 - What does your organisation do?

3D seismic
Basin analysis
Borehole characterisation
Design, installation, monitoring and maintenance of ground source heat pump (GSHP) system (closed loop, open loop water source combined GSHP/CHP)
Develop effective and efficient systems for utilising geothermal energy to meet end users' needs
Develop intelligent integrated systems
Development contractor for design and execute stages of projects
Efficiently utilise low-grade heat
Energy and technology companies
Environment monitoring and geothermal modelling along with various environmental assessment capability (and research)
Geochemistry
Geothermal heat modelling / Environmental monitoring
Government funded innovation support agency – targeted at oil & gas but expanding remit into other forms of energy production
Innovation organisation
Petrophysics
Renewable energy consultancy, supporting clients in all stages of project development
Research
Research and teaching
Research: geo-energy
Supports public, private sectors and academia in delivering low carbon energy innovation
Universities
We fund, build, operate and maintain heat pump LED low carbon energy systems: e.g. V&A Dundee

6.3 Question 3 - How would you like to potentially use the site?

For research

1. For academic collaboration, PhD supervision. To establish/collaborate in CDT/DTP proposals.
2. I am interested in studying the recovered core along with flow rates at different stratigraphic horizons.
3. I would be very interested in using the site as a living laboratory with field scale observations (plus possible borehole activities)
4. I would be keen to know what tests are being planned by other users as their data may help my research.
5. Systems development
6. Later on for cascade system development and community level.
7. Analyse data produced. Calibrate systems models.
8. Obtain system information.
9. Community and decision maker/government engagement.
10. To showcase minewater geothermal clients, local authorities and developers to demystify.
11. As a means of providing materials/education for specialists working in private sector renewables
12. Obtain any knowledge gained that can be extrapolated to minewater heat projects in general.
13. Use it to point people to (clients/stakeholders) in as far as the site has easily accessible facilities (visitor centre style, case studies) that may help demystify.
14. Sensor development
15. Testing novel sensors. Would be interested in modelling/testing heat production.

As a demonstrator

1. Heat extraction as part of district heating system. Seasonal heat storage. Precipitation conditions change through time.
2. Explore the potential for mines to deliver flexibility services to the rest of the energy system.
    1. *Demonstrate the energy systems that we develop.*
    2. *Use the measured collected data for further innovations.*

Data analysis

1. Use the data to further analyse our technology.
2. As a facility for gathering field data.
3. New product development
4. Use as a test site for innovations/new products.
5. UK map of geothermal opportunities with access to underlying data.

De-risking

1. (already using) for subsurface de-risking / Pump and tracer tests (proper rates)
2. Question 4 - How would you like to engage with the project?
3. Be kept informed of progress on regular basis.
4. For research.
5. Later on for cascade system development and community level.

Community engagement

1. Already engaged with the UK Geoenergy Observatories directly through Zoe S (GSAG)
2. Connection of the Glasgow Observatory to Clyde Gateway development *(=district heating loops)* where we are client engineer
3. Funding bids to use site infrastructure
4. Involvement with heat characterisation
5. Working collaboratively with the academic research community and others
6. Infrastructure development technology roadmap development
7. Interested to see how it progresses
8. Happy to act as a liaison to the oil and gas industry.
9. Possible knowledge transfer
10. Placements/industry clients. Research projects. Policy placement.
11. All of interest depends on question/project
12. As much as possible – using it as a test site – data analysis
13. Use as a means of promoting geothermal as a positive/promising source of heat
14. Maintain contact through workshops
15. By email
16. Hopefully influence project design access project data
17. Obtain system information
18. Informed and involved in stakeholder events
19. Become more involved and use the UK Geoenergy Observatories as part of my future research plans and post-doc fellowship proposal application (understanding the role of bed & sub-bed scale heterogeneity on fault and fracture networks with a particular interest in coal measures)
20. I am keen to engage both from a scientific view point and also on the planned borehole use and public communication plans

7. Summary of outcomes

The big challenges for innovators and companies are around regulation, policy and finance, particularly in relation to the surface aspects of heat/cold supply.

For example, the ownership and licensing of heat/cool resources and prices for heat supply on 10+ year timescales.

Aspects such as the cost and risks associated with drilling were also highlighted, and would benefit from a Government-type insurance scheme.

Other subsurface and technical risks were recognised to be important but ranked with lower priority.

It was noted, however that many of the financial and policy issues could be resolved more easily if technical risks and uncertainties around geothermal energy were reduced.

7.1 Opportunities for the Glasgow Observatory

Key opportunities highlighted in the workshops are listed below. The replies were not limited to innovation.

Access/Site/Focal point
Collaboration
Communication and Public Engagement/ Engaging decision makers
Data analysis and data innovation
Development of technology
Fundamental science.
Maximise influence in promoting minewater geothermal industry in Scotland and UK.
New product development
Promoting and refining geothermal research in the UK. Increasing awareness and confidence in geothermal as a resource.
Sensor development
Systems development
To de-risk geothermal investment

7.2 Research

Additional opportunities were identified that are outside the scope of the UK Geoenergy Observatories funding for the Glasgow City Region.

For example, it was noted that many of the highest priority challenges for geothermal, such as financial and integrated systems with heat networks require a demonstrator scheme (i.e. a scheme that supplies heat/cold to customers). While this is not achievable with the current funding, additional funding may allow this in future.

Several participants noted the importance of a minewater demonstrator facility and made suggestions as to where this could be achieved, including locally in Clyde Gateway at Dalmarnock.

7.3 Overview: challenges and opportunities for research and innovation for geothermal in the energy mix

An interesting outcome from the workshop was that major innovation is required around aspects less tangible than a new component or technical process – around awareness of geothermal, creating consumer demand and public acceptance.

It was highlighted that raising awareness of opportunity in Government and local government was key. A great deal could be done with awareness raising of shallow geothermal by improved regulation, recording and knowledge exchange: an example was given of the large number of heat pumps already installed in shallow subsurface across the UK, but with no register so the size of this resource is not widely known.

Overall the workshop highlighted that there are many challenges and opportunities for geothermal in the energy mix, many of which are not technical challenges that be addressed by the innovation of new equipment or processes.

Notwithstanding the above, it was noted that there are significant opportunities for innovation in heat resource characterisation, well installation approaches, engineering infrastructure, maintenance of facilities, and sensors.

The workshop outcomes tie into themes well recognised by the geothermal community. For example, on the ownership of geothermal heat (see the BGS policy paper); and more widely themes in workshop feedback that has informed the 2019 EPSRC decarbonisation of heating and cooling grant call.

In terms of raising awareness and platforms for innovation in geothermal and decarbonising heat, Scottish Enterprise published a demand analysis study with a focus around the Glasgow Observatory and the adjacent Clyde Gateway fifth generation district heating network. Key recommendations include creating a focal point for mine energy innovation. Linking back to the NERC workshop, such a hub or focal point could address the challenges identified around awareness raising, increasing confidence and integrated systems (different temperature heating loops supplied by a number of heat sources). On a more technical level, similar areas of innovation as covered at the NERC workshop are highlighted e.g. development of sensors and downhole technologies, drilling cost reduction, transfer of skills from the oil and gas sector etc. in the Scottish Enterprise report.

7.4 Demonstrators

As summarised above, many participants stressed that a mine energy system demonstrator or demonstrators were needed to break many of the financial/commercial and awareness barriers and to enable innovation integrated systems (surface infrastructure, heat supply, cascading systems etc.).

A demonstrator site would provide real data to address key uncertainties in finance, risk and policy models: and so encourage more widespread interest in, and activity around, minewater geothermal.

While demonstrators are outside the scope of the Glasgow Observatory, many research and innovation questions listed by participants are critically dependent on installation of ‘geothermal infrastructure’ (i.e. pipes and pumps to enable abstraction/re-injection). These are planned for

Phase two of the Glasgow Observatory, following the current Phase one characterisation and monitoring infrastructure. An advantage of the Glasgow Observatory is that experiments will be able to be performed flexibly: e.g. on heat pulses, de-clogging etc. that no demonstrator tied in to supply heat or cool would be willing to accommodate.

7.5 Funding

Feedback from the workshop highlighted the need for clearer funding and funding routes for research and innovation stemming from the UK Geoenergy Observatories and for geothermal generally, taking cognisance of the cross-sector nature of challenges.

For example the crossover between subsurface, engineering/systems and social sciences and areas such as regulation of heat (subsurface), regulation of heat supply/district heating and various policy incentives (surface).

7.6 Next Steps

The outcomes of this workshop will feed into the UK Geoenergy Observatories innovation strategy, which will address the key opportunities and challenges for innovation identified in the workshop.

8. Appendix A - Workshop summaries

8.1 Colour codes

Pink groups of challenges in identified first (four) breakout groups

Yellow – challenges and opportunities for geothermal into the energy mix

Big Orange – main 8 groups of challenges identified by facilitators

Green notes - innovation needs

Orange – where can UKGEOS help

Notes have been typed up in the clusters as they were on the wall

FINANCES

FINANCIAL	COST CHALLENGES
Treasury *link to the numbers Buy in from decision makers	Best practice on drilling costs and risk sharing knowledge
Challenge: A cohesive strategy for government investment	Retro fitting cost challenges
Proof of concept Demonstrators Commercial viability	CAPEX on wells Look to oil and gas financing models for wells
Understanding the perception of risk within industry and investment community How will they gain confidence in the opportunities	Driving costs down to be competitive with other sources of energy
Connecting innovate UK to minewater geothermal	CAPEX - reduce
Financial models that work	High upfront CAPEX
Funding for longitudinal datasets – before and during	Reducing business (investment) risk
Investor funding issues – overcoming initial capital without crippling long term commitments	Low cost of natural gas
Transition from gas CHP – GT (hybrid cars)	Cost per KW/hr
Challenge: commercial – Getting heat to customers	No private investment
Heat as a commodity – who owns the heat?	CAPEX, elec costs for heat pumps
	Proximity to heat users Access to low carbon electricity Risk/ROI
	Up front capital costs Unlimited knowledge of subsurface Public understanding of perception of drilling impacts

SITE SPECIFIC TECHNICAL CHALLENGES

BASELINE	GEOLOGICAL RISK AND KNOWLEDGE BASE	GEOLOGY AND HYDROGEOLOGY AQ CHEM	RESOURCE	MINE INTEGRITY, GEOMETRY	CHEMISTRY
Baseline monitoring for liability Environmental Microseismic Subsistence	Innovation Data Reporting Unity	Innovation – Make it easy somehow and up to date	Forecasting the resource – heat/water chemistry	Low temperature	Water chemistry – surface + groundwater
Could you enhance the current connectivity between mines at 2 different depths to make your resource more efficient?	Subsurface control of flow regime in flooded workings	Live update model to forecast/highlight risk	Resource definition – certainty of supply	Uncertainty in the internal structure of collapsed workings	Risk of ochre clogging
	Seismicity	Breakdown risk "bitesize" to different stakeholders	Metal extraction from minewaters as a resource	Storage of heat in mine workings	Water chem understanding and prediction – sustainability
	Mechanical/ chemical response of operations	Useful for operators/decision makers and also comms tool	Numbers! Quantifying the opportunity	Challenge: Identify active connected corridors between mines	Challenge/operations How to deal with methane or other core product carried in the water to surface
		Challenge correlation between groundwater		Using mines for energy storage and delivering system flexibility	How do you inhibit mineralisation and clogging

		contamination and heat		services with associated additional value streams	
		Life cycle assessment of projects to de-risk and prioritise investment Work includes Energy update Site specific issues Project specific schemes		How do you demonstrate that any subsidence or other environmental issues are not related to your system? LIABILITY	
		Investigate link between water and heat. This would help identify sites with deeper potential		Emphasis on energy losses – how to mitigate	
		Understanding of thermal recharge rate and energy storage behaviour		How interconnected are mineworking – at different depths and spatially?	
		How minewater flow changes geothermal gradient?			
		Environmental impacts eg. water quality + disposal + dissolved gas (CH_4 degass)			

1. Effect of injection on ground levels – clay swelling – pressure changes
2. Tools for quantitative risk assessment of subsurface installations
3. Faster/better/cheaper drilling and well completion techniques, smaller wells, combined installations
4. Provisions of UKGEOS findings to support effective regulation

DATA MANAGEMENT (KNOWLEDGE EXCHANGE)

Information available on geothermal resources, maps, flowrates, chemistry, depths. Linked to success stories of where it has worked or opportunities (like a hydrocarbon play map approach)
Integrating datasets (not hard, just needs doing)
Method of transfer – heat to electricity
Data management collation – knowledge from other industries
3rd party instrumentation UKGEOS should create a call for well owners who are willing to have their wells instrumented to share the data on portal (cheaper than BGS funded wells) Extends geographical and geological coverage

AWARENESS	CONSUMER DEMAND
Lead the story before projects begin – Geothermal opps	Co-operation and communication amongst all relevant stakeholders Public
Transfer / adapt ideas and tech from other industries eg. O&G	Geotherm to support heat suppliers District heat (developers want to build and go) – Local/Gov Big energy companies – certainty around price of heat – characterise mine types
UKGEOS marketing materials – things that are easy to share on social media Benefits to economy Green	Regulation eg. No gas boilers from 2025
Public opinion	Media/comms campaign – HEAT
Marketing to Stakeholders	Creating simple minewater shared loop DHN Commercial model for housing developers
Teach energy issues and geothermal in schools – public acceptance and knowledge	Creating demand for low grade heat
Demystifying the subsurface – Induced seismicity	Minewater a must
Challenge: Social acceptance of a radical change in energy use	Attracting end users
Visitor centre	Commercial model for developer to quickly get a return on return on DH - Developer wants to know they will sell their houses
Will it be associated with fracking/drilling issues?	
Convince the public this is safe - Engagement with public early in projects	Inspiring community groups to pioneer small commercial demonstrators
Viral video on minewater heat – Children interview miners	Appropriate grant/subsidy
Connecting communities to the narrative – It's such a strong positive message	Cost reduction
House survey reports	
Publicly accessible data	
STEM Education Schools	
Mandated heat network	

VR/Apps
Local public engagement Focus on demand Low temp heat uses
Horticultural exemplar Greenhouse local use

PUBLIC
Right people here?
Public acceptance
Exploring the appetite for engagement amongst the many different ‘publics’ that exist
Mine theme park
Visualisation of heat/waste
Visual tools to aid understanding
Challenge: Perceived subsidence risk from messing with mine temperatures.
Minewater viewed as an asset – low carbon source of energy to tackle fuel poverty
Gaining acceptance for geothermal energy by population at large
Even if the science is proven, how does adoption happen if earthquakes or groundwater contamination are accused?

Natural Environment Research Council | British Geological Survey — Expert | Impartial | Innovative

SYSTEMS INTEGRATION

CASCADE	STORAGE	DEVELOPMENT/LIFE-SPAN	3D INTEGRATION AND COMPETITION	HEAT STORAGE	MULTIPLE RENEWABLES AND THE WIDER ENGINEERING DESIGN
Smart systems	Developing standard procedure in heterogeneous systems	Timing! Need conversations on buildings years ahead of construction Tools Tools to quickly assess viability of a mine into part of a system	Linking to district heat networks	Horticulture Vertical farms (LEDs Give off heat) - Poly tunnels Berries Tomatoes Fish farming	Temp of DHNs at the moment all high T loops minewater will be at lower T Switching
Cascading heat	Ice batteries	Upskilling training SME etc	Renewables – Powered MW-SHPs	Co-generation of heat and cooling using MW – SHPs	“Subsurface tank” – how to create from a mine.
Transition from gas CHP to geothermal	Storage of energy – increase efficiency of current renewables	Potentially infinite supply	Use of existing mine water treatment schemes as a quick win	How to turn theory (use energy resource in minewater) into practical systems	Value of system increase with collaboration Difficulty with introduction of 3rd party to work with UKGEOS
Smart systems	Combined minewater treatment and geothermal schemes	Ensuring a long productive lifespan	Building and linking local heat or power distribution systems – Needs investment	Storage to ensure continuity Electrical energy as waste heat Cooling	Reduce energy losses Increase efficiency

Opportunities Cascade!! Use more heat Community led Off grid	Links to other systems Renewables Storage End users	Certification of suppliers Very strong monitoring required		Smart systems/learning systems Switching	Mines as a heat transfer system
Hybrid systems (offset electricity)	Switching "plug and play grid"	Utilisation at depth - mineworking		Flexibility services Commercial innovation Technical part is around linking existing components and self learning	
Integrating reasonable power to offset the electricity costs of heat pumps	Living lab (EON) Industrial site			Local VS centralised grid Distributed system operators	
	Storage to ensure continuity Electrical energy as waste heat Cooling			Create energy repositories or stores	
				Smart heat balancing	
				House roof heat local storage	
				Integrated Heating Cooling Water treatment Water supply for districts	

INFRASTRUCTURE	HOW CAN UKGEOS HELP
Distribution systems and end users	Improving efficiency by technology Communicate/publicise to engineers/sensor development Barriers and gaps Make tests public Synergy between group Discussion steering committee
Transition from gas CHP to geothermal	Expanding UKGEOS to include heat connection to district heating (Dalmarnock) Sensible funding mechanism – NERC – EPSRC?
Infrastructure required to enable large scale use	Methodology and process best practice to assess mine temperature using measured data
Delivery of low enthalpy heat to existing housing stock	Chemistry cost – engineering tool kit: Database of Predictive tool of unknown geochemistries Costed engineering solutions to each chemistry
End user (home scale) accessibility	All into one open access space
Publicly owned easy access DHN (district heat network) Glasgow DHN – UKGEOS GGERFS should include a DHN in Glasgow to which their own and 3rd party experimental and demo projects can supply heat (and cool) with simple commercial arrangements – ref Hamburg!	Faster/better/cheaper drilling and well completion techniques Smaller wells Combined installations
Integrated in/out (smart) system	Interactive 3-4D map/model (open access)
Scale of Infrastructure	Remediation of FE (III) PPN in pipes/pumps in situ:- Chem management Additives Pipe coating Monitoring Operative regime Temporal changes

INFRASTRUCTURE	HOW CAN UKGEOS HELP
Community Industrial Centralised	Infrastructure costings and lessons learned Timeline Barriers
Shared loop new build heat network	Seismicity associated with extraction/injection
Baseload heat users	Recovery of valuable by-products eg. metals in solution, particulate matter
Commercial model	System models – validate simple models across site
Building fabric	Optimisation of pressure control to prevent air incursion/degassing and pipe fouling
Standards Supply Heat network construction	New tools for visualisation of subsurface
Boreholes Financing regulation	Resource appraisal Heat Productivity Short circuiting Model validation
Retrofitting DHN to older buildings	System for effective tracer testing of mine-workings Use of heat/coolth Suite of compatible unique tracers
Monitoring technology (thermal sensors) across the whole system	
Is there an alternative heat carrier than water?	
Above ground distribution network	
Combined energy sharing system Commercial solar PV – Domestic Domestic minewater thermal	

REGULATION AND POLICY

Legislation
Regulatory/planning – Roadmaps, simplified system and best planning
Clarity of licensing regime
Owning of heat regulations
Gaining government support
Challenge/opportunity – meeting carbon targets (decarbonisation)
Energy poverty
Emissions accounting
Opportunity: reduced cost of heat for areas of fuel poverty
Challenge: who takes on the long term liability? Can a public organisation led ESCO pay out in a worst case scenario?
Challenges: Current legislation. Statutory duties associated with local authority. Funding (innovation)
Divide Coal Authority role Currently CA is regulator for minewater projects CA also develops its own projects Conflict of interest? Slows implementation?
Loss of RHI in 2021 will prevent most heat pump projects from going ahead – replacement needed ASAP

Licensing the subsurface (smoothly)

Code of practice (compulsory)

Reporting as standard and open access to high quality

LEARNING BY DOING

Demonstration and implementation
Stakeholder collaboration
Need for commercially viable demonstrators – Fracking without the name
What are the issue in Heerlen
Involve energy companies – Shell, Statoil, SSE who are all moving to 100% renewable projects Knowledge transfer Finance opportunities Integrated power systems