Geothermal Energy Use, Country Update for United Kingdom

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ABSTRACT

The exploitation of geothermal resources in the UK continues to be slow. There are no proven high temperature resources and limited development of low and medium enthalpy resources. However, in the reporting period 2013-2016, there has been a continuing resurgence of interest in all aspects of geothermal energy in the UK. New geothermal assessments and reports have been produced, and several deep aquifer projects, minewater projects, deep co-axial projects and EGS/HDR projects are at various preliminary stages.

In terms of real activity "in the ground" in this reporting period, a deep coaxial heat exchanger trial has been undertaken, and ground source heat pump installations have continued, albeit at a lower rate of growth than had been hoped for. "Geothermal" seminars and conferences have been held. Activity surrounding the potential of geothermal in Scotland has continued to grow.

There has been increasing recognition both at European and at UK national levels of the importance of delivering secure low carbon sources of heating. There is growing interest in the installation of district heating networks in the UK, some of which may make use of deep geothermal heat, or larger scale ground source heat pumps

1. INTRODUCTION

In a worldwide context, the exploitation of geothermal energy in the UK remains small. The geological and tectonic setting precludes the evolution of high enthalpy resources close to the surface and only low to moderate temperature fluids have been accessed by drilling in sedimentary basins in the south and northeast of England. Elevated temperature gradients and high heat flows have been measured in and above some granitic intrusions, particularly in southwest England. These granites were previously the site of the UK Hot Dry Rock programme in Cornwall. More recent work at the Eastgate and Newcastle boreholes in northeast England also suggests higher than anticipated temperature gradients and hence increased focus on the possible application of geothermal heat in that region.

The comprehensive work by the British Geological Survey, (reported by Downing and Gray, 1986) is still the definitive reference to the geothermal prospects of the UK. For a background to material provided here, readers are referred to earlier UK Country Updates provided for the GRC International Symposia on Geothermal Energy (Garnish 1985, Batchelor 1990) the IGA World Geothermal Congresses (Batchelor 1995, Batchelor et al 2005, 2010, 2015) and EGC 2013 (Curtis et al 2013).

2. POLICY / INSTITUTIONAL

The UK renewed its association with the IEA-GIA in 2011. The contracting party is the UK Department for Energy and Climate Change (DECC). The UK is participating in three Annexes; Annex III- Enhanced Geothermal Systems, Annex VIII- Direct Use of Geothermal Energy and Annex X - Data collection and Information.

Two major legislative drivers continue to assist in driving forward interest in geothermal activity in the UK. The first is the European Union's RES Directive or 20/20/20 campaign. The UK has agreed a 15/20/20 commitment, which translates into 30% renewable electricity and 12% renewable heat by 2020. While the UK is on target to deliver on renewable electricity, it has fallen far behind on the renewable heat and transport targets. The second legislative driver is the 2008 UK Climate Change Bill – the first in the world, that commits current and future UK governments to publicly declared CO_2 reduction targets.

These overarching drivers translate into lower level legislative drivers such as the energy/carbon components of the Building Regulations, and planning requirements for new buildings. To assist with the achievement of these targets, a number of financial support schemes are in place. As well as ongoing support for mainstream renewable electricity generation (through Renewable Obligation Certificates (ROCs) and Contracts for Difference (CfDs)), enabling legislation was passed in 2008 to allow for feed-in-tariffs (FITs) for both small scale electricity generation and for renewable heat. The latter is the Renewable Heat Incentive (RHI) scheme which applies to biomass, solar thermal, and heat pump technologies. After four years of evolution and development, the RHI for domestic and non-domestic installations has been operating in this reporting period. Unfortunately, it appears that the tariffs for biomass and borehole based GSHPs have led to a disproportionate fraction of the non-domestic RHI being taken by biomass installations (>90%). This has had a negative impact on the growth of GSHPs in the UK. There is currently a consultation underway by DECC to review the operation of the RHI. Announcements are expected later in 2016 that will see changes to the scheme from April 2017. Given the requirement to accelerate the adoption of renewable heat, it is hoped that the incentives for GSHP systems will be modified.

Legislation for deep geothermal development has been slow to catch up with the renewed level of interest in the sector. There is still no official licensing scheme for deep geothermal development in the UK. At the time of writing this report, the Department of Energy and Climate Change is revisiting this topic.

3. GEOTHERMAL UTILISATION

3.1 Medium / Low Enthalpy Aquifer Projects

The City of Southampton Energy Scheme (Smith 2000) remains the only exploitation of low enthalpy geothermal energy in the UK. It is owned and operated by Cofely District Energy, now part of ENGIE. The scheme was started in the early 1980s when an aquifer in the Triassic Sandstone containing 76^{o}C fluid was identified at approximately 1800m in the Wessex Basin. Construction of a district-heating scheme commenced in 1987 and this has since evolved and expanded to become a combined heat and power scheme for 3,000 homes, 10 schools and numerous commercial buildings. (see: http://www.energiecites.org/db/southampton_140_en.pdf). While gas fired CHP now supplies the majority of the district energy scheme's low-carbon heat, money from DECC's Deep Geothermal Fund has been provided to allow for the replacement of the original hydraulically driven downhole pump with a modern electro-submersible pump. At the time of writing the new pump is planned to be installed by the end of 2016.

The hot springs at Bath have long been a tourist attraction among the Roman architecture of the ancient city. After their extensive refurbishment they continue to be popular

(http://www.thermaebathspa.com/)

During this reporting period, continuing investigative work has been carried out on the 1820m (drilled depth) borehole that was drilled at “Science Central” in Newcastle-upon-Tyne. Temperature and permeability measurements on the borehole have revealed a temperature of 73°C but the porosity of the Fell Sandstone at depth was significantly less than was hoped for, with the result that the well will not produce significant flow. Further details of this borehole were described for EGC2013. (Curtis et al 2013)

Based on the work in Newcastle, Cluff Geothermal has continued with preparatory work and investigations at Shiremoor and more recently at Bishop Auckland. Cluff are advising the Auckland Castle Trust on the use of a deep geothermal scheme to provide a district heating system that exploits the permeability and heat present at depth in the Butterknowle fault

In July 2012 GT Energy announced that it was working with a major utility on a proposal to develop deep geothermal heat projects in Manchester and several other UK cities. In December 2012 the Manchester project received its Ground Investigation Consent (GIC) from the Environment Agency (EA) which was followed by the granting of a 24 year water abstraction licence in January 2013. The project has obtained planning permission for the geothermal element of the project which involves the drilling of two 3200m deep boreholes in the Ardwick area of Manchester. The objective is to deliver heat to around 6000 homes and businesses in the locality. GT Energy continues to work on other projects across the UK. These projects are expected to feed into urban district heating schemes. As these are relatively uncommon in the UK, it is interesting to note that DECC have recently announced funding for the development of urban district heating networks as part of their support for the development of low-carbon heat.

In 2014 it was announced that the city of Stoke would receive £20 million for the development of a geothermal based district heating scheme. In addition, Cheshire East Council held an open day in June 2014 to solicit interest in the Crewe Deep Geothermal Energy Project. This arose out of a resource identified by the SKM work (SKM2012).

During 2015 Wychavon District Council (Worcestershire) held a tendering process which called for an investigation into the potential use of deep geothermal heat to supply a new district heating scheme.

In Scotland a number of feasibility studies on the use of deep geothermal heat have been supported by the Scottish Geothermal Challenge Fund (under the Low Carbon Infrastructure Transition Programme). The fund was aimed at consortia working together to benefit local communities, achieving measurable and sustainable carbon reductions with proper consideration of the impacts on the local environment. In June 2015, the Scottish Government awarded £185,000 to four feasibility studies to investigate the geothermal potential of sites in Fife, North Lanarkshire, Aberdeen City and Aberdeenshire. All studies are complete with final reports being in the public domain.

In Fife a feasibility study was undertaken by a consortium comprising: University of St Andrews, Ramboll Energy Ltd, Town Rock Energy, British Geological Survey, Resource Efficient Solutions LLP, Eden Estuary Energy Ltd, and Iain Todd. This study investigated the geothermal potential of a brownfield site at Guardbridge, Fife. The system would incorporate a heat network and be based on a 1200m deep geothermal well that is anticipated to supply 5-20l/s at temperatures of ~25°C. The economic model used to assess the viability of a heat network that could use this resource assumed that the geothermal well could supply around 50% of site needs and deliver 0.42MW of heat (with the remainder being provided by biomass).

The Hill of Banchory project was undertaken by the Hill of Banchory Geothermal Energy Consortium comprising Hill of Banchory ESCo Ltd, Jigsaw Energy, University of Glasgow, British Geological Survey, Ramboll Energy, Town Rock Energy, University of Aberdeen. The project investigated the feasibility of a deep geothermal energy system to complement a pre-existing heat network that serves the Hill of Banchory area. The study investigated the potential for one or more geothermal doublets drilled into the underlying Hill of Fare granite pluton. From field observations and previous studies, it was calculated that a borehole 2000-2500m deep would reach temperatures of 65°C - 82°C. The study concluded that the geothermal system would be competitive against fossil fuel alternatives and that the system would offer CO_2 savings of around 71,000 t over a thirty year period of operation.

3.2 Deep Coaxial Projects

In Autumn 2014 a deep co-axial heat exchanger demonstration was run in one of the boreholes at the site of the Rosemanowes Hot Dry Rock project in Cornwall. The project was funded by DECC and carried out by Geothermal Engineering Ltd (GEL) and consisted of running1800m of polypropylene pipe into the 35 year old pre-existing borehole to form a co-axial heat exchanger (Law et al 2014). The heat exchanger was fitted with an 1800m fibre optic real time temperature sensor, and was connected to a Thermal Testing Rig built for the project, which provided a variable, dummy load. A testing programme was run to establish the operating characteristics and potential viability of the system. Once completed, the plastic pipework had to be removed from the borehole, dismantled and stored. Discussions are currently underway at a number of other sites for the possible installation of more of these systems to deliver time varying heat demands to adjacent buildings. The next co-axial project that is closest to implementation is on the site of a renovated, open-air, lido on the south coast at Penzance in Cornwall. Other potential projects that are being negotiated include a site near Crewe in Manchester.

In Scotland, a feasibility study into the use of a similar co-axial system for the Aberdeen Exhibition and Conference Centre has been undertaken by Geothermal Engineering Ltd, Ove Arup and Partners and the University of St Andrews.

This study investigated the potential for a deep geothermal single well (DGSW) to serve the Exhibition Centre and pioneered the potential for this technology to reduce the risk, cost and timescale associated with conventional geothermal doublet development. The DGSW would comprise a 2km well incorporating a pump and pipe-in-pipe formation whereby hot water is drawn up through the pipe from the bottom of the well and the heat is recovered using a heat exchanger. The cooled water is returned to the top of the well. Short duration, peak heat outputs (determined from the field trials in Cornwall) from each DGSW are expected to be between 400 and 600kW.

3.3 EGS / HDR Projects

In February 2016 the UK government issued a call on behalf of Cornwall Council inviting bids for funds to be used in the development of a deep geothermal system. These funds have been secured via the European Regional Development Fund from the European Structural and Investment Funds (ESIF). Combined with £2.4 million of matched funding from Cornwall Council, the total amount of public funding available is £13 million. Applicants were specifically invited to make proposals that included the drilling of a commercial scale demonstration well in Cornwall. The call closed in June 2016.

In previous UK Country Update papers (Curtis et al 2013, Batchelor et al 2015) brief descriptions have been given of projects that are among those expected to bid for this funding. These projects have already identified and secured potential sites in Cornwall and have planning permission. It is anticipated that a decision on which bidder will be selected to enter detailed negotiations with the funding agency will be announced prior to EGC 2016. It is hoped that drilling of the borehole will commence during 2017.

A recent paper published in the open source journal Geothermal Energy provides an up-to-date overview of the Cornubian geothermal province and incorporates data from recently acquired airborne gamma ray measurements. (Beamish, Busby 2016)

3.4 GSHP Activity

The background to GSHP activity in the UK up to 2013 and 2015 respectively is provided in the two earlier Country Update papers (viz for EGC 2013 (Curtis et al 2013) and for WGC 2015 (Batchelor et al 2015))

Along with installation activity, a number of parallel supporting activities have continued. The UK Ground Source Heat Pump Association (www.gshpa.org.uk) has held technical seminars and has continued to develop new technical standards. At the time of writing, the three published standards are for Vertical Closed Loop Boreholes, Shallow systems and Thermal Piles.

As reported for EGC 2013 and WGC 2015, GSHP activity in the UK has been badly affected by a combination of factors and there has been a very significant downturn in the number of installations per year. During this reporting period, the Renewable Heat Incentive (RHI) for both domestic and non-domestic heating installations (solar, biomass and heat pumps) finally came into full operation. This is beginning to encourage the adoption of domestic GSHPs, but in the non-domestic sector biomass installations are collecting in excess of 90% of the RHI funding. In November 2015 it was announced, following a major budget review, that the RHI scheme will continue up to 2020 in order to encourage the uptake of renewable heat. However, the scheme is once again under review and a revised approach is expected to be announced later in 2016 and implemented in Spring of 2017. It is anticipated that it will take several more years to recover to the installation rate of about 4000 GSHP systems / year that had already been achieved by 2009. This will make the desired target rates for 2020 and beyond very difficult to achieve without a rapid expansion of a well trained and experienced GSHP installer base.

4. MINEWATER.

There is increasing interest in geothermal systems based upon minewater within abandoned mine workings. Although minewater generally offers lower temperatures (typically 12-20^{o}C) the uncertainty associated with fluid flow is much reduced in a mined system. The cooler temperatures may also be used directly or with a heat pump to provide space cooling and heating respectively. The Heat Networks Delivery Unit (HNDU) was established by DECC in 2013 to assist local authorities in the development of heat networks by providing funding for feasibility studies. To date there have been six rounds of funding and some of the funding has been used on projects that have considered abandoned mines as the heat source. Two case studies are briefly described here but there is little information on the outcomes of these projects currently within the public domain.

In 2014 Copeland Borough Council secured £180,000 of HNDU funding to investigate the potential for a heat network for the Whitehaven area. This has included an investigation of abandoned mines in the Whitehaven area as a source of heat.

In 2016 Stoke-on-Trent City Council was awarded £107,000 of HNDU funding towards the development of a flagship district heating project that will include using water from abandoned mines in the North Staffordshire coal field where the minewater is unusually hot (up to 43^{o}C) in some areas.

Aside from the pre-existing minewater heating schemes in Scotland (Shettleston and Lumphinnans) some smaller single installations have taken place.

Alkane Energy have been extracting minewater from Markham colliery in Derbyshire at rates of 2-3l/s and temperatures of 15^{o}C since 2011. (Athresh et al 2015). The minewater is abstracted from and returned to the existing mine shaft and is fed open loop through a 20kW heat pump which supplies heat at 60^{o}C to an adjacent office block. This trial was carried out in conjunction with a wider project funded by Innovate UK and undertaken by Nottingham Trent University in conjunction with Alkane Energy who have calculated that a 30km^2 area within the Nottinghamshire Coalfield could produce sufficient heat for 45,000 homes.

The Coal Authority completed the installation of a pump and treat minewater treatment scheme at Dawdon Colliery, County Durham in 2009. Flows of 100l/s are pumped to maintain water levels within abandoned mines in East Durham. The water temperature is 20^{o}C. A small portion of the treated water (1.5l/s) is used in conjunction with a heat pump to provide heating for a site office. Problems due to ochre fouling were observed at the site. This was because aerated minewater was being put through the heat network. The problem was alleviated by intercepting the flow for the heat network prior to it being aerated during the treatment process.

In Scotland, the Geothermal Energy Challenge Fund supported a feasibility study to investigate a scheme using water from an abandoned mine (Kingshill Colliery) in North Lanarkshire to provide district heating for a rural area with social deprivation in the vicinity of the village of Allanton. The geothermal potential was estimated at 258 or 71 years of heat extraction at rates of 0.63MW and 2.3MW respectively. Potential options for the site include extracting minewater from depths of around 340m near or at the colliery shaft, extracting heat from it and then releasing it to a local watercourse following treatment or installing a production and two injection wells to intercept workings at around 380m that will allow spent water to be returned underground.

In Wales, the SEREN Project (2010-2015) was led by the Geoenvironmental Research Centre at Cardiff University in partnership with the British Geological Survey (BGS). SEREN is a European Regional Development Fund (ERDF) research project, aimed at developing innovative engineering technologies for commercial applications in low carbon energy delivery. The project included an assessment of minewater potential in South Wales and concluded that mine waters in the region have an average temperature of 13.4^{o}C, and a potential heat output of 63MW, enough to heat 13,000 homes. In 2014 a minewater heat pump scheme was installed at Crynant which provides 40kW of space heating and hot water. (Farr et al 2016)

The major minewater projects described in the 2005 Country Update report (Batchelor, et al 2005) at Midlothian in Scotland and at Camborne in Cornwall have not come to anything. More recently, the British Geological Survey has been carrying out increasingly detailed studies into the resource in the minewater underneath Glasgow.

There are no technical barriers to putting the old mine workings back to work in sustainable developments to provide heating, hot water and cooling. However, the issues of surface and subsurface ownership, licences for abstraction and discharge, the control of pollution and the potential claims of mineral owners all need resolution for any particular project.

5. MEETINGS AND PUBLICATIONS.

The level of interest in all things geothermal in the UK is reflected in recent symposia/meetings held on the subject and a number of generic papers on the subject.

In October 2014 The BritGeothermal Partnership and EGS Energy organised the fourth UK Geothermal Symposium to formally launch the BritGeothermal Partnership and review current progress in the field of geothermal energy development.

In December 2014, Cornwall Council, supported by other local UK authorities with an interest in geothermal energy, hosted the first Deep Geothermal Local Authority event at the Eden Project in Cornwall.

6. CONCLUSIONS

With the increasing pressure to develop secure, low carbon, sustainable energy sources for the delivery of both electricity and heating, there has been a revival of interest in geothermal energy in the UK. This ranges from the prospect of seeing activity in Enhanced Geothermal Systems returning to Cornwall in the very near future, through to growing numbers of GSHP installations throughout the UK. In addition, the geothermal resource surveys and review work carried out in the 1980's is now being turned into potential low and medium enthalpy heating projects particularly in the midlands and northeast of the UK.

The next five years will prove to be critical for geothermal developments in the UK. Hopefully the recent decline in the growth rate of GSHP installations will be reversed through the stabilisation and timely management of the Renewable Heat Incentive scheme. A permanent deep co-axial heat exchanger should be installed and operating. At least one of the proposed EGS systems should have completed the drilling of a deep borehole in Cornwall, and one or more of the proposed deep heat or minewater schemes in the North East, Midlands or Scotland will have come to fruition.

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Tables A-G

Table A: Present and planned geothermal power plants, total numbers

	Geothermal Power Plants		Total Electric Power in the country		Share of geothermal in total	
	Capacity (MW_e)	Production (GWh_e/yr)	Capacity (MW_e)	Production (GWh_e/yr)	Capacity (%)	Production (%)
In operation end of 2015	0	0	80,000	360,000	0	0
Under construction end of 2018	0	0	3,000		0	0
Total expected by 2020	1-4 (estimate)	~16 (estimate)	75,000	~370,000 (estimate)	0.002	0.004

Table B: Existing geothermal power plants, individual sites

Locality	Plant Name	Year commiss.	No of units	Status	Type	Total inst. Capacity (MW_e)	Total running cap. (MW_e)	2012 product. (GWh_e/y)
N/A								
total								

Key for status:		Key for type:			
O	Operating	D	Dry Steam	B-ORC	Binary (ORC)
N	Not operating (temporarily)	1F	Single Flash	B-Kal	Binary (Kalina)
R	Retired	2F	Double Flash	O	Other

Table C: Present and planned geothermal district heating (DH) plants and other direct uses, total numbers

	Geothermal DH plants		Geothermal heat in agriculture and industry		Geothermal heat for individual buildings		Geothermal heat in balneology and other **	
	Capacity (MW_{th})	Production (GWh_{th}/yr)	Capacity (MW_{th})	Production (GWh_{th}/yr)	Capacity (MW_{th})	Production (GWh_{th}/yr)	Capacity (MW_{th})	Production (GWh_{th}/yr)
In operation end of 2015 *	2	14.0	0	0	0	0	0.55	~3.0
Under constru-ction end 2015	0	0	0	0	0	0	0	0
Total projected by 2018	0	0	0	0	0	0	1	0.2
Total expected by 2020	2	14.0	0	0	0	0	1.55	3.2

Table D1: Existing geothermal district heating (DH) plants, individual sites

Locality	Plant Name	Year commis-sioned	CHP **	Cooling ***	Geoth. capacity installed (MW_{th})	Total capacity installed (MW_{th})	2015 produc-tion * (GW_{th}/y)	Geoth. share in total prod. (%)
Southampton		1987	YES		~2.0	9.7	0.0	0.0
add	lines	as	required					
total					~2.0	9.7	0.0*	0.0*

*** downhole pump failure – currently being replaced.**

Table D2: Existing geothermal direct use other than DH, individual sites

Locality	Plant Name	Year commis-sioned	Cooling **	Geoth. capacity installed (MW_{th})	Total capacity installed (MW_{th})	2015 produc-tion * (GWh_{th}/y)	Geoth. share in total prod. (%)
add	lines	as					
total							

Table E: Shallow geothermal energy, ground source heat pumps (GSHP)

	Geothermal Heat Pumps (GSHP), total			New (additional) GSHP in 2015		
	Number	Capacity (MW_{th})	Production (GWh_{th}/yr)	Number	Capacity (MW_{th})	Share in new constr. (%)
In operation end of 2015	~19000	~370	~665	~1800	~20	<1
Projected by 2018	~25350	~500	~912			

Table F: Investment and Employment in geothermal energy

	in 2015		Expected in 2018	
	Investment (million €)	Personnel (number)	Investment (million €)	Personnel (number)
Geothermal electric power	~0.01M	4	~8M	20
Geothermal direct uses	~0.01M	8	~8M	15
Shallow geothermal	~2M	~125	~5M	~200
total	**~2.02M**	**~137**	**~21M**	**~235**

Table G: Incentives, Information, Education

	Geothermal el. power	Geothermal direct uses	Shallow geothermal
Financial Incentives – R&D	N/A	N/A	N/A
Financial Incentives – Investment	N/A	N/A	N/A
Financial Incentives – Operation/Production	ROCs*	RHI**	RHI**
Information activities – promotion for the public	Private company promotion	Private company promotion	Government agencies, Carbon Trust, EST
Information activities – geological information	N/A	British Geological Survey	British Geological Survey
Education/Training – Academic	as part of Renewable Energy MSc and BSc	as part of Renewable Energy BSc and MSc	as part of Renewable Energy BSc and MSc
Education/Training – Vocational	N/A	N/A	GSHP training, EU-HPCert, GEOTRAINET, MCS Installer training

Key for financial incentives:					
DIS	Direct investment support	RC	Risc coverage	FIP	Feed-in premium
LIL	Low-interest loans	FIT	Feed-in tariff	REQ	Renewable Energy Quota

* Renewable Obligation Certificates (Electricity) ** Renewable Heat Incentive (Heat)