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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 developed high temperature resources and limited development of low and medium enthalpy resources. However, in the reporting period 2015-2020, there has been a resurgence of interest in all aspects of geothermal energy in the UK.

The most significant development has been the completion of the drilling phase of the United Downs Deep Geothermal Project in Cornwall. The production Borehole UD-1 has recently been completed to a depth of 5.2 km MD, and injection borehole UD-2 to a depth of 2.5km.

Several deep aquifer projects, minewater projects, deep co-axial projects and another EGS/HDR project are at various preliminary stages.

In terms of real activity "in the ground" in this reporting period, other than United Downs, a new borehole research facility has been started, a minewater project has begun, and the Renewable Heat Incentive has finally led to a revival in growth of ground source heat pump installations. "Geothermal" seminars and conferences have been held.

With the growing interest in the need for large scale utilization of low carbon heat, a recent announcement by the UK Climate Change Committee should lead to significant expansion in the application of GSHPs and direct use geothermal heat.

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 and are now where the United Downs Deep Geothermal Project is currently underway.

The work at the Eastgate and Newcastle boreholes in northeast England also suggested 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, 2016 (Curtis et al 2013, 2016).

2. POLICY / INSTITUTIONAL

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. While the early targets were met, the UK is currently not on a trajectory to meet forthcoming targets. The Climate Change Committee is currently addressing this, and a revised CO_2 reduction plan is to be announced imminently. Part of this will see a requirement for all new build housing after 2025 to be fitted with low carbon heating systems. This is expected to become a significant driver for GSHPs.

In October 2017 the UK government released its Clean Growth Strategy, This sets out a comprehensive set of policies and proposals that aim to accelerate the pace of "clean growth".

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, the tariffs for biomass and borehole based GSHPs initially led to a disproportionate fraction of the non-domestic RHI being taken by biomass installations (>90%). This tariff imbalance has been reviewed and addressed by DECC / DBEIS resulting in a fall-off in the rate of biomass installs, and a significant increase in GSHP installs, particularly in larger installations in the non-domestic sector. It is hoped that this will continue until the end of the RHI scheme in March 2021.

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.

Because of the increasing interest in geothermal energy in the UK, The British Geological Survey published a Briefing Paper in November 2018 on the topic of geothermal heat ownership. (Abesser et al, 2018)

3. GEOTHERMAL UTILISATION

3.1 Medium / Low Enthalpy Aquifer Projects

The City of Southampton Energy Scheme (Smith 2000) remains the only significant 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°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. (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.

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/)

A recent development is that the cascaded flow from the hot springs, as supplied to the baths, is to be used to provide space heating for a new underfloor installation in the nearby Bath Abbey.

In 2018 work commenced on a geothermal borehole to supply the newly refurbished seawater lido pool at Penzance in Cornwall. The intention was that a 1700m deep borehole would supply direct use heat to a partitioned sub-section of the larger seawater pool. In the event, there were difficulties with the drilling. The first borehole on the esplanade was abandoned at circa 100m depth due to seawater ingress. A second hole was then attempted which reached a depth of ~400m before encountering difficult drilling conditions. However, significant water inflow was encountered at a temperature of ~25°C. The project has been modified to be an open loop water source heat pump system. The contract for this has been let at the time of writing, and the system is expected to be operational when the pool complex opens for the 2020 season.

Other preliminary work on aquifer based geothermal heat schemes and deep coaxial projects was reported in the Country Update paper for the period 2013-16. (Curtis et al 2016). At the time of writing there are no further updates to report on these.

3.2 Deep Coaxial Projects

Following the demonstration of a deep coaxial heat exchanger in borehole RH15 at Rosemanowes, Cornwall in 2014, (Law et al 2016) a number of proposals have been developed for similar projects in England and Scotland. Currently these projects are on hold for a variety of reasons.

A recent review of Deep Geothermal Energy in the UK, mainly related to the potential for heat production, was presented at EGC 2019. (Watson et al 2019)

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 were provided of the projects expected to bid for this funding. Two projects had already identified and secured potential sites in Cornwall. In this reporting period, it was announced that the project at United Downs, headed by Geothermal Engineering Ltd (GEL) had received approval to proceed. The delivery partners in this project are GEL, GeoScience Ltd, British Geological Survey (BGS) and Plymouth University. The drilling contract has been awarded to a joint venture formed between Marriott Drilling of the UK, and Angers-Soehne of Germany, who supplied the HAS Innova drilling rig (Figure 1). Site preparation began in early 2018, and the drilling of the first (production) borehole, UD-1 commenced in November following installation of the shallow conductor casing. TD was reached in April 2019 at a measured depth of 5275m, (5075m TVD) with a down-hole temperature of approximately 180 - 185°C (awaiting full recovery before final temperature is known). Following logging and preliminary hydro-testing, the rig was slid on the drill pad to drill the shallower injection well, UD-2 in early May. This was completed in July 2019 to 2,393m MD (2214 m TVD). A brief injection test was undertaken before the Innova rig was de-mobilised. At the time of writing a tender is out for the provision of a rig to support further hydrotesting of the wells which will begin in early 2020. More project information is available at https://uniteddownsgeothermal.co.uk. The project will be reported at WGC 2020 (Ledingham, Cotton, 2020), updated from the status at EGC 2019 (Law et al 2019)

In addition, funding has been secured for initial development of the other deep EGS project in Cornwall at the Eden Project. Final negotiations on the drilling of the first well are currently underway.

A new assessment of the resource base for EGS systems in the UK was published in 2017 (Busby, Terrington 2017). The potential for further suitable EGS sites in Cornwall is already underway. The GWatt project has been established to explore the potential for deep EGS systems based on fracture networks in the UK granites and will be reported at WGC2020 (Rochelle et al, 2020)

Figure 1: HAS Innova drilling rig on Borehole UD1 at United Downs Cornwall. February 2019

3.4 GSHP Activity

The background to GSHP activity in the UK up to 2013 and 2015 respectively is provided in 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 technical standards. In this reporting period a new standard for Thermal Pile installations has been published, and all of the UK GSHPA standards are now available via the CIBSE website. To promote awareness of the significant carbon reduction potential of GSHPs in the UK, due to the rapid reduction in the carbon intensity of the UK grid, the GSHPA released an online app that provides realtime, regionally based, CO_2 emissions for various heating systems:

https://planetcooler.pythonanywhere.com/static/CO2Reg0.html

During this reporting period, the Renewable Heat Incentive (RHI) for both domestic and non-domestic heating installations (solar, biomass and heat pumps) finally began to have significant (positive) impact on the rate of GSHP installations, following a decline since 2010. A review by DECC / DBEIS of the relative RHI tariffs for heat pumps compared to other technologies led to revised tariffs and a subsequent acceleration in GSHP installations since spring of 2017. The RHI scheme will continue up to March 2021.

In April 2019 the Climate Change Committee announced that they are recommending to UK Government that in 2025, all new housing will have to be fitted with low / zero carbon heating systems. At a local level, the Greater London Authority (GLA) has also recently announced revised carbon performance requirements for new and redeveloped buildings that fall within its region.

The challenge for the UK GSHP industry will be to manage the four year gap between the end of the RHI in 2021 and the requirement for low carbon heating systems in 2025.

A comprehensive review of the evolution of GSHPs in the UK domestic sector is summarized in a review paper by Rees / Curtis (2014), and the initial impact of the RHI scheme was reported at EGC 2016 (Curtis, Pine 2016).

The latest update (Dec 2018) from OFGEM on the RHI installation statistics for Domestic systems is published here:

https://www.ofgem.gov.uk/publications-and-updates/domestic-renewable-heat-incentive-quarterly-report-issue-18

and for Non-Domestic systems:

https://www.ofgem.gov.uk/publications-and-updates/non-domestic-renewable-heat-incentive-rhi-quarterly-report-october-december-2018

4. MINEWATER.

The EGC 2016 UK Country Update reported on a significant awakening of interest in the possible use of flooded abandoned coal and metal mines in different regions of the UK, viz Scotland, England, Wales and Cornwall. A number of potential schemes were described, and are not repeated here. In the interim there have been ongoing investigations. It is reported that the Coal Authority, who manage abandoned mines in the UK, are developing the heat resource from 16 existing minewater treatment schemes. In South Wales, following feasibility studies and reports, Bridgend Council have started drilling into old coal mines in the Llynfi Valley with the intention of heating 200+ homes.

The British Geological Survey are also developing a new geothermal research facility over former coal workings in Glasgow.

In June 2019 the D2GRIDS Project was launched as part of Interreg North West Europe. This will see five pilot minewater based sites initiated across Europe based on the successful minewater development at Heerlen in the Netherlands. The two sites in the UK will be in Glasgow and Nottingham.

There are few 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.

The principal UK geothermal energy conference was the 6th London Geothermal Symposium held on 16th October 2017 at the Geological Society. At the time of writing, the 7th Symposium will be held on 5th November 2019 at the Geological Society and has a full programme.

The UK GSHPA continues to hold its Annual AGM and Seminar/Exhibition and has also held two technical seminars in this reporting period, the last one in 2018 being hosted at the University of Leeds.

6. RESEARCH

UK geothermal research is largely concentrated on developing the potential of less conventional resources as deep hot sedimentary aquifers are only found in a few regions and often not in regions of high heat demand. Much research is undertaken within the Higher Education sector, usually as part of PhD programmes, as follows:

- Exploiting the permeability of deep fracture systems as viable geothermal resources (Glasgow University).
- Exploring the extent of palaeokarst within the buried Carboniferous Limestone and its geothermal potential (Durham University).
- Quantifying the potential of the thermal resource within disused mine systems in the UK (Newcastle University, Glasgow University, British Geological Survey).
- NERC funded GWatt project – Geothermal Power Generated from UK Granites – to increase knowledge of the geological conditions needed for deep fracture-controlled fluid flow within granitic rocks (University of Exeter, Camborne School of Mines) (https://gtr.ukri.org/projects?ref=NE%2FS003886%2F1)

7. 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. After a wait of over 30 years, real activity has restarted in Cornwall, with the United Downs Deep Geothermal Project now fully underway. The outcome of this significant project will be closely followed, with interest already developing in future systems in South West England.

GSHP activity is at last back on an upward curve after a decline triggered by a combination of factors in 2010. The requirement for low carbon domestic heating systems from 2025 should mean that there is a prospect of rapid growth in this sector.

The various deep geothermal heat projects that were reported in for EGC 2016 are still taking considerable time and effort to bring to fruition. Hopefully the Bridgend minewater project should be realised and encourage the utilisation of other UK minewater resources in Glasgow and Nottingham through the D2GRIDS project.

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TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specify)		Total	
	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr
In operation in December 2019	0	0	50,000	158,000	292	5,500	9,300	65,100	44,300	105,000	103,892	333,600
Under construction in December 2019	0	0	840	6,622	0	0	2,000	15,770	?	?	2,840	22,400
Funds committed, but not yet under construction in December 2019	3	21	0	0	0	0	0	0	?	?	3	21
Estimated total projected use by 2020	3	21	50,840	164,622	292	5,500	11,300	80,870	44,300	105,000	106,735	356,313

TABLE 2. **UTILIZATION OF GEOTHERMAL ENERGY FOR ELECTRIC POWER GENERATION AS OF 31 DECEMBER 2019**

1) N = Not operating (temporary), R = Retired. Otherwise leave blank if presently operating.

2) 1F = Single Flash B = Binary (Rankine Cycle)
2F = Double Flash H = Hybrid (explain)
3F = Triple Flash O = Other (please specify)
D = Dry Steam

3) Electrical installed capacity in 2019

4) Electrical capacity actually up and running in 2019

Locality	Power Plant Name	Year Com-missioned	No. of Units	Status 1)	Type of Unit 2)	Total Installed Capacity MWe 3)	Total Running Capacity MWe 4)	Annual Energy Produced 2019 GWh/yr	Total under Constr. or Planned MWe

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2019 (other than heat pumps)

1) I = Industrial process heat; H = Individual space heating (other than heat pumps)
C = Air conditioning (cooling); D = District heating (other than heat pumps)
A = Agricultural drying (grain, fruit, vegetables); B = Bathing and swimming (including balneology)
F = Fish farming; G = Greenhouse and soil heating
K = Animal farming; O = Other (please specify by footnote)
S = Snow melting

2) Enthalpy information is given only if there is steam or two-phase flow

3) Capacity (MWt) = Max. flow rate (kg/s)[inlet temp. (^{o}C) - outlet temp. (^{o}C)] x 0.004184 (MW = 10^6 W)
or = Max. flow rate (kg/s)[inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

4) Energy use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (^{o}C) - outlet temp. (^{o}C)] x 0.1319 (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.03154

5) Capacity factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171
Note: the capacity factor must be less than or equal to 1.00 and is usually less, since projects do not operate at 100% of capacity all year.

Note: please report all numbers to three significant figures.

Locality	Type[1)]	Maximum Utilization					Capacity[3)]	Annual Utilization		
		Flow Rate	Temperature (^{o}C)		Enthalpy[2)] (kJ/kg)			Ave. Flow	Energy[4)]	Capacity
		(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	Factor[5)]
Southampton	D		75				1.7		72.5	0.83
Bath	B						~1		~34	0.95
TOTAL							3.761		106.5	

TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF 31 DECEMBER 2019

This table should report thermal energy used (i.e. energy removed from the ground or water) and report separately heat rejected to the ground or water in the cooling rejected to the ground in the cooling mode as this reduces the effect of global warming.

1) Report the average ground temperature for ground-coupled units or average well water or lake water temperature for water-source heat pumps

2) Report type of installation as follows: V = vertical ground coupled (TJ = 10^{12} J)
H = horizontal ground coupled
W = water source (well or lake water)
O = others (please describe)

3) Report the COP = (output thermal energy/input energy of compressor) for your climate - typically 3 to 4

4) Report the equivalent full load operating hours per year, or = capacity factor x 8760

5) Thermal energy (TJ/yr) = flow rate in loop (kg/s) x [(inlet temp. (°C) - outlet temp. (°C)] x 0.1319
or = rated output energy (kJ/hr) x [(COP - 1)/COP] x equivalent full load hours/yr

6) Cooling energy = rated output energy (kJ/hr) x [(EER - 1)/EER] x equivalent full load hours/yr

Note: please report all numbers to three significant figures
Due to room limitation, locality can be by regions within the country.

Locality	Ground or Water Temp. (°C)[1]	Typical Heat Pump Rating or Capacity (kW)	Number of Units	Type[2]	COP[3]	Heating Equivalent Full Load Hr/Year[4]	Thermal Energy Used[5] (TJ/yr)	Cooling Energy[6] (TJ/yr)
all UK	10-14	18	29,000	V & H	3	2200	4,134	206
TOTAL			29,000				4,134	206

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2019

1) Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.004184
or = Max. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

2) Annual Energy Use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.1319 (T.
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg) x 0.03154

3) Capacity Factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171 (M
not operate at 100% capacity all year

4) Other than heat pumps

5) Includes drying or dehydration of grains, fruits and vegetables

6) Excludes agricultural drying and dehydration

7) Includes balneology

Use	Installed Capacity 1) (MWt)	Annual Energy Use 2) (TJ/yr = 10^{12} J/yr)	Capacity Factor 3)
Individual Space Heating 4)			
District Heating 4)	1.7	72.5	0.83
Air Conditioning (Cooling)			
Greenhouse Heating			
Fish Farming			
Animal Farming			
Agricultural Drying 5)			
Industrial Process Heat 6)			
Snow Melting			
Bathing and Swimming 7)	~1	~34	0.95
Other Uses (specify)			
Subtotal			
Geothermal Heat Pumps	522	4,134	0.25
TOTAL	525	4240	

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2015 TO DECEMBER 31, 2019 (excluding heat pump wells)

1) Include thermal gradient wells, but not ones less than 100 m deep

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration[1)]	(all)					
Production	>150° C	1				5
	150-100° C					
	<100° C					
Injection	(all)	1				3
Total		2				7.75

TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with University degrees)

(1) Government
(2) Public Utilities
(3) Universities
(4) Paid Foreign Consultants
(5) Contributed Through Foreign Aid Program:
(6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2015	5	0	15	0	0	8
2016	5	0	16	0	0	8
2017	5	0	18	0	0	8
2018	5	0	20	0	0	10
2019	5	0	25	0	0	10
Total						

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2019) US$

Period	Research & Development Incl.	Field Development Including Production	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1995-1999						
2000-2004						
2005-2009						
2010-2014						
2015-2019		18		6	25	75