ENERGY

GEOTHERMAL ENERGY UK POTENTIAL

Institution of MECHANICAL ENGINEERS

While geothermal energy has been used to produce electricity for more than a century, recent interest in geothermal has grown largely due to its potential to provide reliable baseload low-carbon electricity generation at commercial prices. The UK has a number of geothermal energy resources with the potential for exploitation, and although most are suited to industrial heat use and district heating, there are a number that have potential for electricity generation. In addition, there is an opportunity to access geothermal-based generation in Iceland.

Despite the fact that both national and international geothermal energy sources could make a useful contribution to the UK's climate change mitigation objectives, the exploration risks and current electricity market regime mean that they are not presently an attractive proposition for commercial investigation. In order to fully exploit the potential benefits of geothermal energy for the UK, the Institution of Mechanical Engineers therefore urges Government to adopt the following recommendations:

1. Make UK deep geological data available more widely and easily accessible to non-geologists, by producing and making freely available heat potential maps similar to those for heat demand already produced by the Department of Energy & Climate Change (DECC) for Combined Heat & Power.
2. Introduce licensing for geothermal heat resources and exploration risk mitigation for geothermal heat wells.
3. Secure an international treaty and structure a financially viable power purchase agreement, so that 1GW geothermal generation from Iceland can be delivered by High Voltage Direct Current (HVDC) interconnector.

GEOTHERMAL ENERGY UK POTENTIAL

Within Europe, geothermal springs have been used as a source of heating for thermal spas since Roman times, as famously illustrated in Bath. Geothermal energy was first used to produce electricity in 1904 in Larderello, Italy. However the main period of capacity growth occurred after World War II, when geothermal technology spread around the world to New Zealand in 1958, Mexico in 1959, the USA in 1960, Japan in 1966 and Iceland in 1969[1].

The current installed global capacity is over 11GW, with the largest capacity in the USA, Philippines, Indonesia, Mexico and Italy. The International Energy Agency (IEA) technology roadmap for geothermal[2] suggests that geothermal generation could grow to 200GW by 2050. There is now a growing interest worldwide in geothermal electricity production, because it provides a source of reliable baseload power generation with a low-carbon footprint at commercial prices.

The energy exploitable within a deep geothermal resource is stored as heat within rock or an underground aquifer. The heat source can be magma near the surface, radiogenic rocks or the earth's natural heat flux. These variations lead to three main internationally recognised resource classifications:

- Conventional Magmatic Resources (CMR) – these are usually associated with volcanic heat sources located close to the surface. The convective circulation of aquifer water associated with such systems results in reservoirs with relatively high temperatures (250–350°C).
- Hot Sedimentary Aquifer (HSA) systems – the heat energy is contained in a large, deep and well-insulated natural aquifer. These tend to be deeper and cooler (120–200°C) than CMR. Although the hot reservoir water represents a substantial energy resource, most of the heat still resides in the rock.
- Engineered Geothermal Systems (EGS) – the heat energy in this case is contained in the rock and a reservoir has to be engineered. This includes a spectrum of resources that are lacking in permeability and/or availability of water, including Hot Fractured Rock (HFR) and Hot Dry Rock (HDR).

UK GEOTHERMAL RESOURCES

Deep geothermal resources occur 1,000m to 5,000m below ground level where there is sufficient heat available and drilling costs are economically viable. There are two classifications of geothermal system present in the UK and these are shown **in Figure 1**:

- HSA – there are medium-temperature (90–160°C) resources in Cheshire and Wessex and low-temperature (below 90°C) resources in East Yorkshire and Lincolnshire, Worcester and Northern Ireland.
- EGS – there is EGS potential in Cornwall, Weardale and the Lake District.

In addition, there may be EGS potential in the East Grampians in Scotland, however the effects of the paleoclimate on the surface temperatures mean that there is great uncertainty. Similarly, additional HSA resources may exist in the carboniferous chalk that underlies the sedimentary sandstone in several areas of the UK.

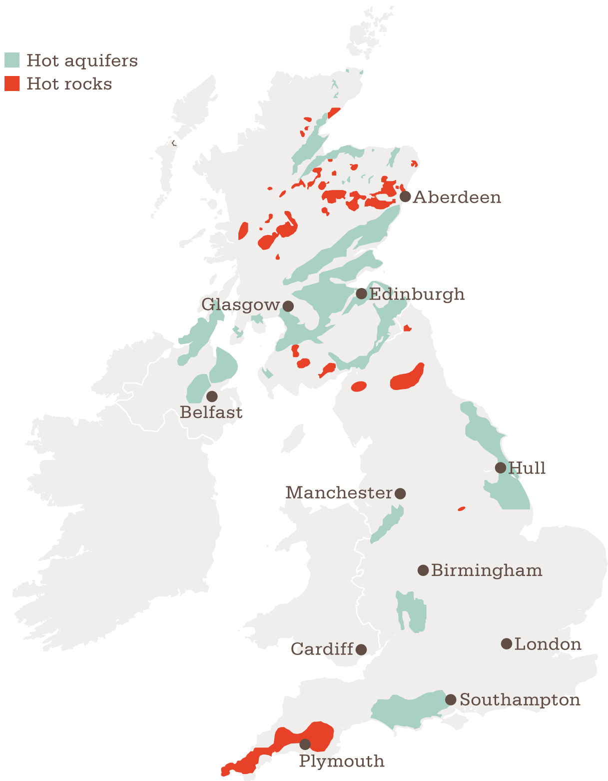

Figure 1: Indicative map of UK geothermal resources[3]

The UK also has a wealth of geoscience and drilling experience in consultancies and project developers, as well as at research organisations such as the Universities of Durham, Exeter (Camborne School of Mines), Glasgow and Aberdeen and the British Geological Survey.

Table 1 provides a summary of the most-promising resources and their potential for power generation and direct-heat utilisation[4]. Temperatures greater than 100°C are likely to be required for electricity generation and greater than 60°C for direct heat use.

Table 1: Summary of the main geothermal resources

Type	Location	Area (km^2)	Average Reservoir Temp (°C)	Stored Heat (PJ_{th})[1]	Gross Generation Capacity from Recoverable Electricity Energy (MW_e)[2]	Heat Use Capacity from Recoverable Thermal Energy (MW_{th})
HSA – Medium	Wessex	3,000	80	70,000	Direct heat	33,000
HSA – Medium	Cheshire	680	75	22,000	Direct heat	14,000
HSA – Low	East England	850	50	19,400	Heat pump	12,000
HSA – Low	Worcester	200	45	11,000	Heat pump	6,700
HSA – Low	Larne Basin	23	85	1,800	Direct heat	900
EGS	South West Cornubian Batholith	2,500	150	1,100,000	4,000	13,000
EGS	Weardale Granite	1,500	155	780,000	3,000	9,000
EGS	Lake District Granite	1,500	145	640,00	2,300	8,000
HSA – Medium	Wessex	33	115	1,400	80	500
HSA – Medium	Cheshire	3.5	110	140	10	80

1 The stored heat has been estimated or 'inferred' based on an internationally recognised code. As with oil and gas reserves, estimates are subject to the uncertainties and to the development of technologies that enable additional commercial exploitation. New research may well reveal greater resources.

2 Recoverable electrical energy in the study is reported in terms of the gross megawatt installed capacity (excluding site-specific parasitic pumping loads) that could be supported over a projected plant life of 25 years.

HEAT

Heating accounts for 48% of total UK final energy consumption and more than three quarters of energy use across all non-transport sectors. Maps of customer heat demand, existing district heating schemes and the geothermal resources in the UK, suggest that many current and proposed district heating schemes have the potential to use heat from geothermal resources. In addition, there are many other uses for geothermal heat that have been demonstrated, including fish farming, soil heating, bathing, greenhouses, drying and evaporating.

District heating has been deployed in the UK since 1950, yet it currently meets only 2% of UK space and water heating demand. This is partly because, in response to the 1970s' oil price shocks, the UK concentrated on cheap North Sea gas while many European countries increased energy efficiency measures such as district heating. As the technology for district heating is well established and the Government is providing impetus with the Renewable Heat Incentive (RHI) and other policy measures, it is anticipated that district heating in the UK can account for up to 20% of the total heat demand by 2020[5]. It has been estimated that nearly 10%, or over 2GW, of district heating could be provided by geothermal resources. However, in order to achieve this potential, the risks associated with geothermal district heating must be similar to those associated with a conventional natural gas boiler system, where fuel delivery is assured. This requires exploration risk support and a geothermal licensing regime to protect the heat resource.

Paris provides a good example of what can be achieved, as the geothermal resource is similar to that of the UK. In the late 1960s and 1970s more than 55 pairs of wells were drilled to provide heat to district heating systems. Of these wells 34 are still in operation, providing 230MW of heat.

ELECTRICITY

Table 2 shows how the two main electricity generation technologies available for geothermal power production are applied to geothermal resources. The more-established steam flash technique takes high temperature geothermal brine from conventional magmatic sources and flashes it to a lower-pressure to produce steam. The steam is then used to drive a modified steam turbine. For lower temperature geothermal brines, such as those located in the UK, binary-power generation technology is used, of which the most common form is the organic Rankine cycle. These plants use a refrigerant or hydrocarbon gas as the working fluid in a Rankine cycle, with the brine evaporating the fluid in a heat exchanger and an air-cooled fin fan cooler for condensing the fluid. A specialist turbine is used to generate electricity from the expanding gas.

Table 2: Three main classifications of geothermal resources and associated power generation method

Resource Type	Generation Technology	Commercial Status	Examples
CMR	Steam flash and condensing	Commercial (>90% of installed capacity)	USA, NZ, Indonesia, Philippines, Mexico, Iceland, Italy, Kenya, Japan
HSA	Binary, organic Rankine cycle	Commercial with subsidy (<10% of installed capacity)	Germany, USA
EGS	Binary, organic Rankine cycle	Demonstration	France, Australia

The inferred resources in **Table 1** have the theoretical potential for a gross power generation capacity of about 9,500MW_e (20% of UK electricity consumption) and direct heat use capacity of approximately 100,000MW_{th}[4].

FINANCIAL INCENTIVES

A financial analysis has previously been carried out on a suite of UK case studies[4]:

- Four cases using HSA resources for electricity generation
- Three cases using EGS resources for electricity generation
- The above seven cases were also evaluated for combined heat and power
- Three low-temperature direct heat cases
- One heat pump application

In the UK, power generation from geothermal resources is currently supported through Renewable Obligation Certificates (ROCs) and receives 2 ROCs per MWh (net). Together with embedded generation benefits and the wholesale price for electricity, this provides a revenue stream in the order of £130–160/MWh. The financial analysis indicated that the revenue stream would need to be higher, approximately £300/MWh (equivalent to 5 ROC/MWh).

For geothermal heat, the Renewable Heat Incentive (RHI) offers a tariff of £35/MWh (July 2013) indexed to inflation, which the analysis indicated was sufficient if the drilling risk was ignored.

Despite the significant potential for geothermal in the UK, the UK support regime is uncompetitive with other European countries. The industry has only about half the levels of support seen in Germany and Switzerland. As a result of support in Germany, the deep geothermal industry now employs 6,000 people and has attracted €4 billion of investment. Additionally Government support for geothermal in the UK contrasts with that provided, through various international climate funds, for its development in East Africa and its direct overseas funding of approximately £8.5 million for the Montserrat geothermal energy project in the Caribbean.

ICELAND INTERCONNECTOR

In 2010 DECC commissioned a high-level review of the costs and benefits, from a UK perspective, of developing renewable joint projects with other countries with direct interconnection to the UK, to meet European 2020 targets for renewable energy. These offer a range of potential benefits, including:

- Additional renewable generation
- Potential carbon savings
- Balancing cost reductions
- Security of supply implications
- Wholesale price impacts

The operational safety of the grid will ultimately limit the capacity of the interconnector and this constraint currently corresponds to a maximum of about 1.8GW.

Options including a 500MW geothermal plant in Iceland with a 1,200km direct interconnection to Northern Scotland were investigated[6]. The analysis suggested that, combining the interconnection costs with the generation costs, Icelandic geothermal directly connected to the UK could be delivered at lower cost per MWh than offshore wind. However, the project risks are significant when combining geothermal development with a 1,200km sub-sea cable. As a result, a higher return for the project may be required by a private developer. Alternatively, the Government could decide that it is better to socialise or take on some of the risks. In addition, the Government would also need to negotiate an international treaty and establish a financially viable structure for the power purchase agreement.

Factors that may hamper development are the relatively weak onshore transmission system in Iceland and the current in country installed geothermal capacity, which is about 500MW. Doubling the capacity by 2020 represents a challenge, but is achievable. For example since 2010 in Kenya: 280MW of geothermal is under construction for operation in 2014; 646MW is being procured for 2016; and an additional 495MW is in development for commercial operation in 2018. Similarly in the last seven years, seven projects have been developed in New Zealand with a total installed capacity of 550MW.

CONCLUSION

The main potential for geothermal resources in the UK is for district heating and industrial uses. Longer term there are opportunities for geothermal electricity generation to be exploited by the UK, but in the short term it is more cost-effective to import geothermal-produced power from Iceland.

The provision of a comprehensive scheme to manage exploration risk is the most critical issue to allow widespread cost-effective utilisation of the geothermal resources in the UK. The provision of grants and risk insurance is economically more effective than rewarding the production of power and heat. Furthermore, heat resource licensing and providing easily accessible information on resource potential offer low-cost options for reducing the exploration risk. These measures are particularly important to stimulate the early development of direct heat use, as this offers the most significant potential contribution to meeting the UK commitment to the EU's Renewable Energy Directive.

The Institution of Mechanical Engineers therefore urges Government to adopt the following recommendations:

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DESPITE THE SIGNIFICANT POTENTIAL FOR GEOTHERMAL IN THE UK, THE UK SUPPORT REGIME IS UNCOMPETITIVE WITH OTHER EUROPEAN COUNTRIES.