Low-temperature geothermal energy

Modelling the potential resource in the UK

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Between 1979 and 1987, the BGS was involved in two large integrated programmes, funded by the Department of Trade and Industry and the European Commission, to assess the potential for geothermal energy in the UK. The second geothermal programme, which ran between 1984 and 1987, identified four Mesozoic basins which contained significant low-temperature geothermal resources above 40°C in Permian and Triassic sandstones: Eastern England, Cheshire, Worcester and Wessex. New geological, porosity and temperature data were used to reassess the low-enthalpy resources as part of a JOULE-2 project in 1994.

In general, temperature increases with depth. In the UK the mean geothermal gradient is close to 25°C per kilometre. Geophysical logs, providing the maximum recorded bottom-hole temperatures (BHT) observed by logging tools, are the main source (60 per cent) of deep sub-surface temperature information. The UK Geothermal Catalogue (UKGC) contains subsurface temperature data for about 1200 sites. These data indicate a mean temperature at 500 metres below sea level of 27.4 °C (±5.7°C), and at 1000 metres below sea level a mean of 42.5 °C (±8.4 °C). Temperatures above 40°C in permeable formations can provide a low-enthalpy geothermal resource, so that much of the resource evaluation involved assessment of formation porosity and permeability and deep temperature modelling.

Boreholes in each basin were selected for porosity log analysis. For the majority of wells, where only gamma ray and sonic measurements were

Basin	**Aquifer**	**Area** km^2	**GR (1988)** 10^{18} J	**GR (1994)** 10^{18} J	**IR** 10^{18} J	**T** °C	**TS** GJ/m^2
Eastern England	SSG Triassic	4827	99	122	24.6	65	60
Wessex	SSG Triassic	4188	23	27	6.5	95	18
Worcester	SSG Triassic	500	12	8	1.5	55	35
Worcester	BS Permian	1173	-	60	11.8	65	110
Cheshire	SSG Triassic	677	17	36	7.6	80	75
Cheshire	CS Permian	1266	28	38	9.1	100	60
Northern Ireland*	SSG Triassic	1618	35	35	4.7	60	25
Total			**214**	**326**	**65.8**		

GR Geothermal Resources >40° C

IR Identified Resources: resource available for development at a reject temperature of 25° C and a recovery factor of 0.33

T Maximum temperature

TS Maximum thermal store

* Northern Ireland resources not revised, (IR for reject temperature of 30° C and recovery factor 0.25)

SSG Sherwood Sandstone Group; BS Bridgnorth Sandstone; CS Collyhurst Sandstone.

Summary of the UK's low-enthalpy geothermal resources above 40 °C.

Energy resources

available, the sonic log was converted to a sandstone porosity, and the gamma ray log was used to identify clean, shale-free intervals. Where neutron and density logs were available, they were first normalised to a sandstone matrix. For individual sandstone sections the mean, standard deviation, and minimum and maximum porosities were then extracted by statistical analysis. The aim was to determine the proportion of the geothermal aquifers in the UK having a porosity of between 15 and 20 per cent, at selected boreholes.

Geothermal resources above 40°C for the UK have been estimated using a simple volume model of heat in place. Identified resource (IR) is that part of the geothermal resource which might be available for development and is dependent on the hydraulic properties of the reservoir, the method of abstraction, and the reject temperature of the disposal fluid.

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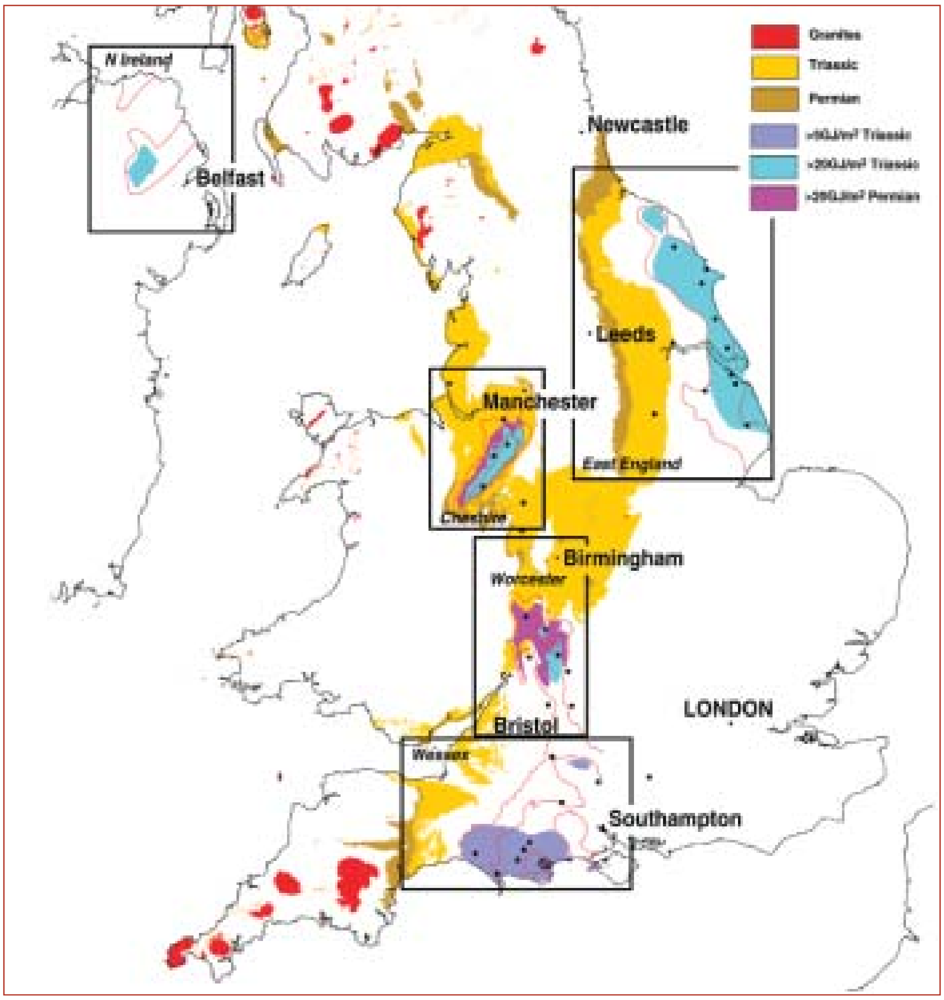
Areas considered as having the potential for geothermal energy abstraction were previously defined by a limit for reservoir transmissivity. This limit has been variously considered as ten darcy-metres or five darcy-metres as an absolute minimum. Under these criteria, the only active geothermal installation in the UK, at Southampton, would be at the minimum level of transmissivity. Subsequently, porosity and permeability were assessed in terms of what levels are required to define the reservoir and what proportion of the aquifer is likely to provide a reservoir.

The specific heat of the fluid component is approximately five times that of the reservoir matrix whereas the matrix density is about two and a half times the fluid density, so that a typical sandstone reservoir with 25 per cent porosity has about 45 per cent of the heat store in the fluid component.



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Distribution of low-enthalpy geothermal energy resources in the UK. The four basins identified in the second geothermal programme (Eastern England, Cheshire, Worcester and Wessex) plus the Northern Ireland field are shown.

Temperature modelling using steady state one-dimensional conductive transfer with heat production was used for reservoir temperature models in all basins except Eastern England where observed data were interpolated on to the reservoir structure contour map. The temperature models for Wessex show good comparison with about 40 observed data points at the base of the Sherwood Sandstone Group and suggests that large scale fluid flow and heat transport is not significant. This in turn might be related to the high salinity of the basin brines.

The estimate of total low-enthalpy geothermal resources above 40°C in the UK has increased by about 50 per cent from about 214×10^{18} joules in 1988 to 326×10^{18} joules in 1994. In several reservoirs thermal stores exceeded 50 gigajoules per square metre. The largest revisions are in the Worcester and Cheshire basins *(see table, opposite, and map, above)* with increases by factors of 5.6 and 1.6 respectively.

The new geological and temperature models are supported by observational data so that the main area of uncertainty lies in the estimation of reservoir fraction and permeability. Deep porosity and permeability data for the Cheshire basin, where temperatures might reach 100°C, are probably the greatest parameters of uncertainty. The salinity patterns and levels in the main reservoirs vary widely but there is little evidence of highly saline brines in either the Cheshire or Worcester basins. Nevertheless, abstraction of these thermal fluids would generally require reinjection or marine disposal.