GEOTHERMAL RESOURCES OF THE UK - COUNTRY UPDATE REPORT 1985-1990

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ABSTRACT

Geothermal energy applications and research are being actively pursued in the United Kingdom despite the relatively normal heat flow regime. The cumulative expenditure on geothermal activity from 1975 to 1989 has been approximately £46 million or 32% of the Renewable Energy Research Budget to date. The first practical application is a 2 MWt scheme at Southampton as part of a district heating scheme. Commercial operation started in February 1988 and further expansion is planned. The UK's enthusiasm for Hot Dry Rock has dimmed slightly as the entire programme is reappraised and the long heralded deep exploration hole has yet to materialise. Future activity looks likely to focus on geothermal opportunities that have multiple uses or applications for the fluids in small scale schemes and Hot Dry Rock research will probably be linked to a pan-European programme based in France.

INTRODUCTION

At the last Geothermal Resources Council International Meeting the geothermal resources of the UK were presented in detail by Garnish, 1985a, and the same author also described Hot Dry Rock (HDR) research activity in detail, 1985b. Very little further exploration and geological activity has taken place in the intervening five years although applications and feasibility investigations have been examined and reworked several times.

The first geothermal direct use district heating scheme has been a major success in the Wessex Basin, see Garnish 1985a for the geological details. It has become the first commercial geothermal development of any type in the UK other than the famous spa at Bath. An outline of the scheme in Southampton is presented in this paper.

The UK Department of Energy has continued to fund fundamental work in HDR development at the Camborne School of Mines research site at Rosemanowes. The three wells were interlinked by massive hydraulic fracturing in July 1985 and water has been circulated through the 'reservoir' continuously since 7 August 1985. HDR offers the only possible route for electricity generation from geothermal resources in the UK, albeit from wells 5500 m to 6000 m deep. Unfortunately, the uncertainty in the cost estimates of moving forward with HDR have grown over the last few years and there is a wide difference of opinion on the nature and key features that would be required in a successful reservoir. The state of the field work and the current philosophy of the UK Government have been presented in a Department of Energy document, 1989. Detailed results are available in the proceedings of a conference held in 1989, Camborne School of Mines, 1989.

THE ELECTRICITY MARKETS AND RENEWABLE ENERGY IN THE UK

Table 1 shows the most recently published UK power statistics with approximately 59 000 MWe on line. Currently, generation is controlled by three state owned generating authorities and twelve distributions boards. This is to change in April 1990 when the industry is split into approximately twenty companies ready for sale to the private sector in late 1990, early 1991. The nuclear plants will remain in state ownership.

This fundamental change with its consequent level of uncertainty has caused the industry to focus on the essential effort of starting up these new companies and, by necessity, concentrating on short to medium term requirements. It is anticipated that new generating capacity will be provided by combined cycle gas turbine systems in the 300 to 600 MWe station sizes while the industry settles down. The Government have introduced a compulsory 20% non-fossil purchase requirement on the new distribution boards which means that the 14% of nuclear capacity will be fully utilised. On the other hand, power sales contracts appear to be limited to eight years which has probably eliminated the capital intensive renewable element.

Table 1A shows the proposed expenditure for central government funded renewable energy research over the next four years together with the cumulative expenditure to date. The highly favoured position of geothermal research, £35.9 million HDR and £10.6 million for aquifers, is obvious and has accounted for 32% of all renewable energy expenditure. Several sources were used to compile this table and there are differing figures in various publications. The reasons for the discrepancies may be that contributions from the Commission of the European Communities and industry have been misallocated as government expenditure. The references to these sources are shown in a separate section at the end of the paper.

The aquifer programme was run down to virtually nothing in 1986/87 and the actual implementation of the Southampton scheme was undertaken outside the Government programme.

THE SOUTHAMPTON GEOTHERMAL DISTRICT HEATING SCHEME

The current status and future plans of the Southampton scheme are described in detail by the Southampton Geothermal District Heating Company, 1989. The details of the scheme are summarised below:

Southampton (Western Esplanade) well : Summary of basic data

Depth to top of aquifer	1725 m
Thickness of water-bearing sandstones	38 m
Pressure before start of test (12 Jan 83) measured at 657.7 m below ground level	6.478 MPa absolute
Pumping rate	19.8 l/s
Maximum drawdown during constant rate test (on 30 Jan 83)	3.03 MPa
Temperature over aquifer (to 1755 m below ground	76°C
Temperature gradient	37°C/km
Maximum temperature 48 m below pump intake (657.7 m below ground level	73.9°C
Maximum surface temperature (at degassing tank inlet)	74.9°C
Aquifer permeability	74-109 mD
Skin factor	-2.9

Results of computer modelling

Aquifer permeability	78-97 mD
Porosity	17.7-24.8%

Properties of the brine

Density at 20°C	1.086×10^3 kg/m^3
45°C	1.076×10^3 kg/m^3
76°C	1.059×10^3 kg/m^3
Dynamic viscosity at 76°C	4.84×10^{-4} Pa.s
Specific heat at 75°C	3.66 kJ/kg°C
Total dissolved solids in the brine	125 g/l

The project is the first commercial geothermal operation in the UK for district heating. The project has come to fruition through the determination of the City Council and the support and cooperation of Utilicom Ltd, a UK company with a French parent.

The production well was drilled to intersect Triassic sandstones at 1729 m to 1796 m with a temperature of 76°C. The original interpretation of the well test results has proved conservative and the resource has been shown to be capable of supporting much greater exploitation than 12 l/s for twenty years. It was this original interpretation of a limited reservoir that led the UK Department of Energy to reduce its support for the scheme but the City Council and Utilicom had the confidence to pursue the development with vigour and commitment.

A downhole hole turbine pump is used to deliver the brine; it is set at 652 m and has a design operating point of 12 l/s with a head of 500 m. The power is provided by a 250 kWe charge pump powered by a generator with full heat recovery.

At the surface, the brine is maintained under pressure to prevent gas breakout and it is filtered to 80 microns prior to circulation through the heat exchangers. During commissioning, there were significant filter clogging problems as the pipe dope was flushed from the joints with intervals between changes of less than twenty minutes at the start.

The brine passes to a 2000 kWt heat exchanger supplying heat to the district heating station equipped with the 250 kVA diesel generator with engine and exhaust gas heat recovery and a 2000 kWt gas fired watertube boiler.

The brine runs in 150 mm GRP piping to the exchanger and then to discharge in the estuary of the River Test at about 30°C. Future plans include an absorbtion heat pump to enhance the system performance.

Commercial operation started on 26 February 1988 and the system has been in full use ever since with minimal breakdown and stoppages. The current heat load is comprised of the City Council's own offices, a hypermarket, technical college and insurance office with plans to expand to two hotels, a clinic and a radio station.

Using the indices calculation standards of the Commission of the European Communities, the scheme shows a payback period of 7.3 years based on an avoided cost of Natural Gas.

OTHER DIRECT USE SCHEMES

The Gabbons Nursery scheme at Penryn, in Cornwall, exploits a small brine resource in fractured Palaeozoic rocks on the margin of a granite pluton. The hole was initially drilled as a heatflow hole by the Camborne School of Mines HDR project, see below, to verify the heatflow and gravity modelling of the granite. It intersected a fractured Greenstone at 256 m and produced up to

20 kg/s at 22°C. The chemical composition of the brine proved to contain trace minerals that matched the hydrophonic feed requirements of the adjacent glasshouse operation. Moreover, the irrigation costs for the hydrophonic operation were rising rapidly because of increased charges from the local water utility as it was prepared for privatization. Under UK regulations, water abstracted from a privately owned borehole for irrigation purposes does not attract a licence fee so the combination of reducing the feed costs, eliminating the irrigation charges and maintaining the root systems at 22°C proved to be a major benefit to the operator. This scheme started in 1988 and has had two full seasons of operation. The Department of Energy sponsored a study of the use of a heat pump to aid the actual greenhouse heating system but the results showed that the resource temperature was just too low for such an application.

Replication and further developments of this type of scheme have been sought aggressively by the author's company but the combination of an established operation with satisfactory geological conditions has proved elusive. All the studies show that either the well must be drilled with some form of grant and the reservoir characteristics proven to the point that the developer is not at risk, or the well must be drilled alongside an existing operation so the 'failure' of the well venture does not impact the original scheme. Even so, in the latter case, it is not clear that direct use can afford the exploration risk when the price of fossil fuel is $18-$20 bbl or equivalent.

A borehole drilled at Cleethorpes by the Department of Energy is just such an example of the first type of approach. Garnish, 1985a, describes the well in the East Yorkshire/ Lincolnshire Basin where it found its secondary target in the Triassic sands with transmissivities greater than 80 Dm with water at 49°C from a depth of 1100 m. This well remains unused today despite various feasibility studies for diverse applications.

Table 2B and Table 5 summarize the results of the direct use schemes.

HOT DRY ROCK

HDR research in the UK was initiated in November 1973 by the author and developed to a major research programme to investigate the stimulation of naturally fractured formations to provide the necessary heat exchange surfaces in the reservoir, Batchelor, 1989. The essential findings of the work to 1985 have been described at the previous meeting by Garnish, 1985b. The author and several colleagues left the programme in 1986 and the work has continued with long term circulation of the reservoir. The most recent results are given by Parker, 1989.

The main feature of the post 1986 work has been the development of a conceptual design for a commercial system in conjunction with industrial partners. This is due for completion in 1990.

Approximately £17 million has been spent in total by the HDR programme since 1986. This is very nearly double the expenditure from 1973 to 1986 and shows a strong commitment by the Government to maintain the programme.

Two essential factors remain unaddressed.

Firstly, it is clear from the results of all of the HDR research systems that they have hydraulic characteristics dominated by the natural fractures already present at reservoir depth. Flow channelling and wellbore connections to the fracture network are critically dependent upon the fracture geometry and connectivity. The underlying philosophy adopted in the UK programme from the start recognises the fact that it is the natural fracture patterns that will control HDR systems. However, the conclusion that massive hydraulic stimulation will not aid reservoir development away from the very near well region because the flowpaths are predetermined by the position of the wellbores themselves is recent and still hotly debated. The access to the reservoir is under the engineering control of the HDR engineer but the manipulation cannot be achieved with current technology. This forces a rethink of HDR philosophy towards considering basement formations with strongly developed fractures with long strike length and adds a geological constraint to the selection of sites that has not been considered previously. Multiple planar geometries and other concepts need to be put to one side for the moment.

The second factor stems from the argument that the geological constraint of needing large and more open fracture structures to build an HDR prototype system means that the system cannot be planned until exploration data is available from full depth. Only the USA, Los Alamos, and the Japanese HDR project have drilled holes that reach commercial temperatures and now have geophysical and geological data to enable a rational programme to be planned. The UK needs to drill a 5000 m to 6000 m hole into the granite before continuing to fund ongoing generic and shallow investigations if it is serious about the future. The marginal cost of completing the programme that has already spent £36 million is quite a small fraction of the total.

THE FUTURE

It is clear that there is an active community of professional people pursuing geothermal energy in all its forms with considerable involvement overseas as well as in the UK, Table 6.

Within the UK itself, it seems likely that the current introspective debate into the future of HDR will lead to the demise of the field programme and a much smaller participation in a European Project with the French and German groups at Soultz. In one way this is to be welcomed because of the need to focus resources but it is unfortunate that the conditions at full depth will not be known prior to stopping the UK work. This means that any experiment thought to be relevant to extrapolating to UK conditions will be based on speculation rather than fact.

Direct use operations will develop slowly as individual schemes are found to be viable and the developers will need to have the drive and determination of Southampton City Council and Utilicom. One new scheme may come to fruition in 1993 but it has to overcome the competition from natural gas first.

Institutional barriers such as tax breaks for the Oil and Gas developers that do not apply to geothermal schemes, eight year limits to power sales agreements and hidden subsidies to both the gas and electricity industries are being tackled but there are some strong vested interests to overcome!

The UK will still be active in promoting the use of geothermal energy in its widest possible sense and it is hoped to report more success stories of the Southampton type in the 1995 conference.

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TABLE 1 PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

Activity	Geothermal		Fossil Fuel		Hydroelectric		Nuclear	
	Capacity MWe	Utilization GWh/yr	Capacity MWe	Utilization GWh/yr	Capacity MWe	Utilization GWh/yr	Capacity MWe	Utilization GWh/yr
In operation	0	0	50 633	208 329	2320	5630	6519	42 672
Under construction	0	0	unknown	unknown	nil	nil	1175	nil
Funds committed	0	0	unknown	unknown	unknown	unknown	nil	
Total projected use by 1995	0	0	not published		not published		not published	

Great uncertainty now exists in the UK on the nature of the market for electricity. The industry has been split into approximately 20 companies ready for selling to the private sector in late 1990 and early 1991.

TABLE 1A RENEWABLE ENERGY R&D EXPENDITURE - ESTIMATE FOR 1989/1990, PROVISION FOR 1990/1991 AND REQUESTS FOR FUTURE YEARS

	£'000 1975 to 1989 Cumulative	£'000 1989/1990 Estimate	£'000 1990/1991 Provision	£'000 1991/1992 Request	£'000 1992/1993 Request	£'000 1993/1994 Request
Wind	29 500	5 000	7 000	8 000	9 500	10 138
Geothermal HDR	35 900	2 900	2 900	3 000	3 075	3 151
Solar	9 900	1 900	2 000	1 900	1 951	1 700
Biofuels	9 700	2 000	2 100	2 050	2 150	2 200
Wave	17 700	200	200	205	320	328
Aquifers - Geothermal	10 600	150	50	50	50	10
Tidal	5 800	1 000	1 200	1 225	2 000	2 050
Hydro electric	800	150	150	150	154	158
General studies	800	800	750	770	900	900
Technology transfer support	1 700	1 100	1 130	1 480	1 700	1 965
ETSU - Programme Management	24 000	2 700	2 850	3 000	3 200	3 400
TOTAL	**146 400**	**17 900**	**20 330**	**21 830**	**25 000**	**26 000**

TABLE 2 UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT - DECEMBER 1990

* Type of use:
I = Industrial process heat
C = Airconditioning
A = Agricultural drying
F = Fish and other animal farming
D = District heating
B = Bathing and swimming
G = Greenhouses
O = Other

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

Locality (Footnote for Comments)	Type*	Maximum Utilization						Average Annual Utilization				
		Flow Rate kg/s	Temperature °C		Enthalpy** kJ/kg		Flow Rate kg/s	Temperature °C		Enthalpy** kJ/kg	
			Inlet	Outlet	Inlet	Outlet		Inlet	Outlet	Inlet	Outlet
SOUTHAMPTON (Western Esplanade)	D	15	72	28	-	-	12.5	72	28	-	-
PENRYN (Gabbons Nursery)	G	5	22	10	-	-	5	22	10	-	-
BATH SPA (Avon)	B	13	46.5	-	-	-	Natural spring known from Roman times. In continuous use				

TABLE 5 WELLS DRILLED FOR DIRECT HEAT UTILIZATION OF GEOTHERMAL RESOURCES FROM 1 JANUARY 1985 TO 1 JANUARY 1990
(Does not include thermal gradient wells less than 100 m deep)

* Type or purpose of well and manner of production
(Uses one symbol from column (1) and one from column (2)

(1)
T = Thermal gradient or other scientific purpose
E = Exploration
P = Production
I = Injection
C = Combined electrical and direct use

(2)
A = Artesian
P = Pumped
F = Flashing

** For wellhead temperatures less than 100°C, temperatures in °C are multiplied by 4.1868 to obtain enthalpy

Locality (Footnote for comments)	Year Drilled	Well Number	Type of* Well (1)	(2)	Total Depth (m)	Maximum Temp °C	Flowing Enthalpy** kJ/kg	Flow Rate kg/s Max	Use
PENRYN (Gabbons Nursery)	1985	1	P	P	256	22	92.4	~15	5

TABLE 6 ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES
(Restricted to personnel with a university degree)

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

Year	(Professional Man Years of Effort)					
	(1)	(2)	(3)	(4)	(5)	(6)
1985	20	4	40	?	0	3
1986	15	4	27	1	0	3
1987	10	3	30	?	0	19
1988	8	3	40	?	0	23
1989	8	2	47	? 1	0	23