Energy: it's the heat, stupid!

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On behalf of

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Heat and power from the Earth

Introduction

2009 was a turning point in our awareness of energy. In the UK, it was accompanied by a steady increase, from a low base, in oil prices, rising from a trough of about $40 to a peak of about $80. It brought aggressive state targets for cutting CO_2, and a growing awareness of the threat of power cuts in the next decade. These factors, coupled with engineering advances in renewable energy, have brought our Britain's consumption and production of energy into sharp focus.

In that context, we have produced this paper to shine a spotlight on heat, which now accounts for 60 per cent of a typical UK household's energy bills, 49 per cent of final energy demand and nearly half the country's emissions of CO_2. We look at what the UK's energy needs are and what its options in renewable energy may be, given that less than a mere one per cent of Britain's heat comes from renewable sources. We also discuss what is being done and what still needs to be done by government and industry to meet the UK's future energy and heat needs. In short, we have outlined why heat has become a key commodity.

1 Why heat is important

It's not just a spate of snowy winters that makes heat a live issue in Britain, nor fuel poverty, nor even the sad and needless deaths among pensioners that, each year, occur through hypothermia. With the Department of Energy and Climate Change's February 2010 Renewable Heat Incentive (RHI), heat, and particularly heat drawn from renewable sources of energy, has finally gained official recognition as a particular form of energy distinguished from electricity and transport fuels. In homes, commercial and public buildings and in industrial processes, heat is a basic commodity that cannot be done without. Like good health, we tend to take it for granted; but anyone who has ever encountered a breakdown in central heating knows how important a warm environment is to everyday living and working.

Administered by Ofgem, the RHI is set to begin offering cash for renewable heat from April 2011. As currently designed, it will provide consumers, communities and organisations with only a modest incentive to find sources of heat other than gas (69 per cent of heat generation), electricity (14 per cent) and oil (11 per cent). [1] But in beginning to give renewable heat the status it deserves, the RHI is a welcome gesture.

Heat will be more and more central to the UK view of energy. Homes don't use much for cooking (three per cent), but need a lot for hot water (27 per cent), and even more for warm air (69 per cent). Homes also now operate, on average, at 18°C – well up on the 12°C that was the average in the 1970s, when central heating was still not widespread. Although there have been increases in the energy efficiency of homes, the number of households in the UK has multiplied, so that

1 Department of Energy and Climate Change, *Renewable Heat Incentive Consultation on the proposed RHI financial support scheme*, February 2010, p7, on http://www.decc.gov.uk/Media/viewfile.ashx?FilePath=Consultations\RHI\1_20100204094844_e_@@_ConsultationonRenewableHeatIncentive.pdf&filetype=4

residential property now absorbs about 500 Terawatt hours of heat each year, compared with 400 TWh/yr 30 years ago. [2]

Overall demand for heat in Britain is more than 900 TWh/yr. [3] Although government forecasts predict a decline in this figure, Britain's quickly rising population is more likely to ensure that demand for heat remains buoyant. In addition, it is just possible that global warming will, in summers, bring about a more intensive use of baths and showers. Wouldn't the requirement for all new homes in the UK to be 'zero carbon' from 2016 onward lower the amount of residential heat required? Perhaps; but at current rates of housebuilding, these new homes will make little impact. At the same time, fully insulating all the country's existing homes and replacing all its old boilers with the condensing sort would take prodigious amounts of money and a long time; indeed in many cases it would be impractical or, because of the protections given to the country's heritage, illegal.

Finally, if Britain more than doubled its electricity generation, it could meet a total demand for heat which, the Government estimates, will amount to no fewer than 80GW in 2020. However, building that extra electricity capacity would be a massive task, and so would decarbonising it. Capacity would also have to handle demand spikes in winters, while lying rather idle in summers.

So it's time Britain got serious about generating heat, period. In Sweden, Denmark and Finland, fully a third of heat comes from renewable sources, from *combined heat and power* (CHP), in which both electricity and heat are simultaneously derived from the same fuel, and from *district heating*, in which central boilers heat blocks of flats, or heat is piped from a central facility to local organisations and homes. In Sweden and Finland, moreover, renewable heat is quite widespread in industry, while in Finland and the Netherlands district heating finds important industrial applications.

Still, Britain's RHI is the world's first scheme to offer cash in return for renewable heat, CHP, and district heating. Under it, an adequately insulated semi-detached house installing a ground source heat pump could receive £1000 a year; if the GSHP replaced oil-fired central heating, annual savings could amount to £200 a year. These figures are modest, and, sadly, at this stage, the scheme does not specifically cover some emerging technologies such as deep *geothermal energy* – which, with the right investment, will deliver not only extensive electricity, but also even larger amounts of pure heat to local areas. But if the RHI is properly built on, the chance is that, by 2020, no less than 12 per cent of Britain's heat will come from renewable sources.

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2 Department of Business, Enterprise and Regulatory Reform, *Heat call for evidence*, January 2008, pp12, 13, on http://www.berr.gov.uk/files/file43609.pdf. One Terawatt is equal to 1,000,000,000,000 watts. Of total demand for heat, 54 per cent is residential, 16 per cent comes 2 commercial and public buildings , and 34 per cent comes from industry. In commercial and public buildings, warm air takes 71 per cent of the heat used, hot water 13, and catering a sizable 15. In industry, processes such as drying require temperatures of less than 100°C, but the manufacture of glass and steel requires temperatures warmer than 400°C. The high temperatures required by industry mean that it must rely on fossil fuels more than homes do. As a result, it generates more than 40 per cent of the CO_2 that arises from the generation of heat.

3 Ibid, p12, citing BERR, *Energy Trends*, June 2007, on www.berr.gov.uk/files/file40156.pdf from

2 The energy options

Of course heat is not the only form of energy needed by the UK. In terms of demand, one way of breaking down the overall amount of energy consumed is as follows:

UK inland primary energy consumption, millions of tonnes of oil equivalent and percentages, 2008 [4]

	Mtoe	%
Renewables and waste	5.3	2.4
Primary electricity (mainly nuclear)	13.9	6.2
Coal	37.8	16.9
Gas	92.9	41.4
Oil	74.4	33.2
TOTAL	224.2	100

Right now, renewables account for an almost negligible portion of the UK's total energy demand; but the government hopes that they will meet 15 per cent of that demand in 10 years' time, and about 30 per cent of electricity demand.

By 2020, more energy will take the form of electricity, which is the most adaptable and, potentially at least, carbon-free form of energy. However, considerable doubt attends plans for building new nuclear power stations: they will not be operational before 2018, and that programme could easily slip. Also, the Conservatives have declared that 'Nuclear is not an alternative to developing and expanding renewable forms of energy', adding to the uncertainty surrounding nuclear. [5]

The other main imponderable is whether the government's ambitious plans for wind power can be achieved. It has been estimated that to install 7000 wind turbines in the North Sea by 2020, as is envisaged, would mean installing a colossal 10 a day from now on, given that conditions only allow an average of 60 working days a year. [6]

The RHI is welcome but in a certain sense overdue. Despite the advocacy of Prince Charles, few Britons have even heard of, still less installed, *ground source heat pumps* (GSHPs). Still fewer have heard of a related technology, *air* source heat pumps (ASHPs). People have an inkling that organic or '*bio'* materials can be used to raise heat, are aware of *solar water heating* (big in China), and often labour under the misapprehension that just one country – Iceland – draws tangible benefits from geothermal energy (in fact the US, Italy, China and Turkey all generate appreciable amounts of heat this way, from deep beneath the ground). But the scale of public ignorance of renewable heat in the UK only matches the miniscule amounts of renewable heat available.

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4 DECC, *UK energy in brief 2009*, 2009, p13, on http://www.decc.gov.uk/Media/viewfile.ashx?FilePath=statistics/publications/ukenergyinbrief/1_20090728165537_e_@@_energyinbrief2009.pdf&filetype=4

5 Conservatives, 'Where we stand: Climate Change and Energy', on http://www.conservatives.com/Policy/Where_we_stand/Energy.aspx

6 Professor Ian Fells and Candida Whitmill, *A Pragmatic Energy Policy for the UK*, Fells Associates, August 2008, p4, on http://fellsassociates.awardspace.com/site/LinkedDocuments/Pragmatic%20Energy%20Policy1.pdf

These things said, here's a rough assessment of the current and future UK potential of the major types of renewable energy:

	Period of take-off	Advantages	Disadvantages	Potential	UK rating now /10	UK rating for the future / 10
Hydroelectric	Already mature	Dual use for water management. Can deliver energy storage: Dinorwig pumped storage power station, Snowdonia, makes 1.7GW	Large-scale: limited by scarcity of suitable locations in the UK. Small scale generates only a few MW	Weak	2	2
Tidal	2025+	Geography of the UK makes it one of the world's best locations	The 250MW barrage on the River Rance, northern France, is the world's only example	Not yet clear. Severn Barrage could generate up to 8GW; barrages and the harnessing of tidal streams all around UK might deliver 25 per cent of UK electricity	2	7
Wind	2010-30	On-shore: relatively cheap. Already developing and can be rolled out quickly	Off-shore: dear. Need for energy storage to beat intermittency, a much stronger grid, and back-up with conventional electricity	In principle and at a large scale, strong. UK starts from a weak base	2	5
Photovoltaic solar	2020-40	Can be decentralised and expanded in modular units where appropriate	Need for energy storage to overcome intermittency. Sunlight on the UK underestimated, but no match for eg Middle East, Sahara	1G (today): crystalline silicon. 2G (coming on-stream): amorphous and polycrystalline silicon, thin film. 3G: dye sensitised cells, organic materials, quantum dots, multijunction cells	2	4
Geothermal	2020-50	Power available on demand	Technology still requires further development	Key to future takeoff will be Enhanced Geothermal Systems that fracture hot dry rocks, allowing fluid to flow through	1	6

For the Government, heat needs to come from renewable sources both to combat global warming, so as to meet the EU's target of a 20 per cent reduction in CO_2 emissions by 2020, and to protect UK energy security by diversifying supply (principally, away from imported gas). For energy users, renewable heat contains the medium-term promise of lower energy bills, as well as the immediate reality of local independence from shortages of gas, electricity or oil.

Heat can be piped, but not large distances in the manner of gas, electricity or oil. However, renewable heat can be generated in many places. Not subject to losses in transmission, from which electricity suffers, renewable heat is something that, in its production and consumption, lends itself to local control and local pricing.

3 Choice of technique in UK energy: the salience of heat

As our overview of UK energy has hinted, sources of renewable energy other than those associated with heat have significant limitations. What's more, Britain faces real problems simply meeting demand for electricity, and real problems, too, in lowering CO_2 emissions resulting from transport. Altogether, then, renewable heat is likely to make a major contribution to the Greening of Britain's energy supply.

Apart from improvements in energy efficiency, the main thrust of Government efforts to lower CO_2 emissions has been wind power, both on-shore and, increasingly, off-shore. Now, it is true that if *enough* wind turbines are built and made operational all around Britain, they could form a reliable source of electricity. However, the costs of such a gambit would be enormous – and in places such as Cornwall, local opposition, on the basis that wind turbines can be unsightly, would be very probable. On the other hand, anything less than a pervasive growth in wind power would make the *intermittency* of that power a very significant problem, and would certainly require a costly extension of other sources of electricity to provide back-up during times of low wind.

Mass installation of solar panels, as a means of displacing conventional sources of electricity, is a long way off, and again would face problems of intermittency. In addition, houses with north-facing roofs can make little use of the sun.

Tidal power, such as that which is available on the Severn, is intermittent but at least predictable. However, the scale of something like a barrage on the Severn has already prompted significant doubts, both economic and ecological.

What about decarbonising the UK's electricity supply? At the Copenhagen summit, the US, Australia and the EU committed a total of $4 billion to back 13 demonstration projects in Carbon Capture and Storage (CCS). [7] Yet although this money seems a lot, it is, for an international effort, too little and rather late, given the world's reliance on coal-fired power generation. In Britain, for example, the

7 Global CCS Institute, 'Governments commit USD$4bn to global Carbon Capture and Storage (CCS) projects', press release, 16 December 2009, on http://www.globalccsinstitute.com/downloads/media-releases/MR_Govts-commit-USD$4bn-to-global-CCS-projects.pdf

government has, since 2005, put just £6.4m into R&D in CCS. [8] The technology of CCS, though potentially of great importance, remains untested, and although Britain's experience in North Sea oil makes it well placed to be a site for storing much of Europe's CO_2, US energy secretary Stephen Chu is not alone in having expressed worries about the *safety* of CO_2 storage. [9]

Apart from meeting 2020 targets for CO_2 emissions, the UK faces the problem of avoiding power cuts. Because the UK now needs to retire old nuclear power plants and prematurely close coal-fired stations under the EU's Large Combustion Plant Directive, it faces losing 23GW, or a third of its generating capacity, by 2020. As Ofgem very recently put it: 'The unprecedented combination of the global financial crisis, tough environmental targets, increasing gas import dependency and the closure of ageing power stations has combined to cast reasonable doubt over whether the current energy arrangements will deliver secure and sustainable energy supplies'. [10]

There is no need to fret about the threat to Britain's power stations from Russia's manipulation of gas supplies: the Russia/Ukraine dispute over the winter of 2008/9 had little impact on the UK wholesale prices for gas, and in 2016/17, gas coming from continental Europe could represent just 14 per cent of peak supply capacity, with Russia merely one among a range of nations sitting behind these imports. [11] But given the centrality of gas to electricity and heat generation in the UK, there is certainly a need for Britain to improve its facilities for gas storage. In the round, then, electricity supply in the UK, like the supply of heat, cannot be taken for granted.

When we look at initiatives in the transport sector there are also problems. Transport minister Lord Adonis has admirably proposed a high-speed rail network connecting London with the North, and this, over the long term, might lower usage of cars and planes. For the rest, however, progress in lowering emissions from the internal combustion engine is woefully slow. The Government claims that its project for demonstrating new electric and lower carbon cars on the UK's roads is the largest in the world; but the sum total of vehicles on offer in this scheme is… 340. [12]

Altogether, even partly decarbonising UK electricity (mainly through wind) and UK transport over the next 10 years will be a very tough challenge. Just looking, though, at the Government's own chart for expected progress shows that, at more than four per cent in a total of 15 per cent, heat is already set to beat transport (about three per cent) in terms of the contribution it can make to sourcing UK energy from renewables:

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8 Tom Young, 'Exclusive: UK government invests just £6.4m in CCS since 2004', *BusinessGreen*, 11 March 2008, on http://www.businessgreen.com/business-green/news/2238238/government-invested-ccs-date

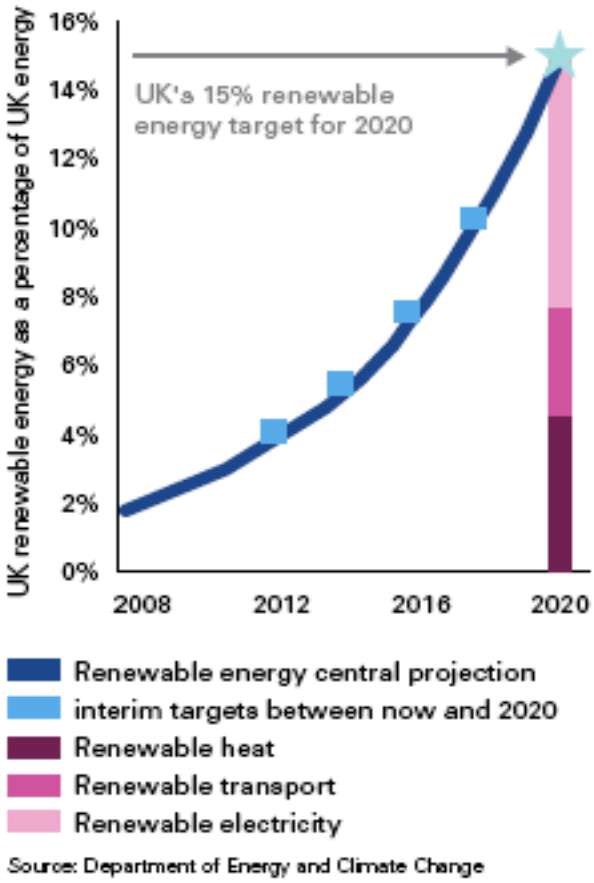
9 Steven Chu, 'The energy problem: what the Helios Project can do about it', YouTube, 31 minutes 17 seconds, 23 April 2007, on http://www.youtube.com/watch?gl=GB&hl=en-GB&v=pLr4YbStc0M

10 Ofgem, 'ACTION NEEDED TO ENSURE BRITAIN'S ENERGY SUPPLIES REMAIN SECURE', press release, 3 February 2010, on http://www.ofgem.gov.uk/Media/PressRel/Documents1/Ofgem%20-%20Discovery%20phase%20II%20Draft%20v15.pdf, and *Ofgem, Project Discovery: Options for delivering secure and sustainable energy supplies*, 3 February 2010, on http://www.ofgem.gov.uk/Markets/WhlMkts/Discovery/Documents1/Project_Discovery_FebConDoc_FINAL.pdf

11 Department of Energy and Climate Change, Business, Enterprise and Regulatory Reform, *Energy markets outlook*, December 2009, p68, on http://www.decc.gov.uk/Media/viewfile.ashx?FilePath=What%20we%20do\UK%20energy%20supply\Energy%20markets\outlook\1_20091216110910_e_@@_energyMarketsOutlook2009.pdf&filetype=4, and Department of Business, Enterprise and Regulatory Reform, *Energy markets outlook*, January 2008, p52, on http://www.berr.gov.uk/files/file41998.pdf.

12 Department for Transport, *Low Carbon Transport: A Greener Future – A Carbon Reduction Strategy for Transport*, July 2009, pp6, 41, on http://www.dft.gov.uk/pgr/sustainable/carbonreduction/low-carbon.pdf

Growth in the proportion of UK energy derived from renewable sources, 2008-20[13]



Source: Department of Energy and Climate Change

Even a magnanimous view on prospects for Green electricity in general and wind power in particular would take a fair slice away from the seven per cent contribution to '15 per cent renewable' that is officially hoped for by the year 2010. In sum, therefore, *renewable heat will jostle with renewable electricity for first place in leading the UK's transition to a low-carbon economy*. Why? In part, because, with the exception of solar water heating, *sources of renewable heat are not intermittent: heat can be derived from them continuously*.

4 Choice of technique in renewable heat

The intricacies, strengths and weaknesses of different methods of delivering renewable heat are many. Thankfully, however, the Government's January 2008 *Call for evidence* on heat provides a succinct, if not fully comprehensive, overview of these matters. We therefore reproduce it here:

13 Department of Energy and Climate Change, *The UK Low Carbon Transition plan: National strategy for climate and energy*, 15 July 2009, Chart 5, p45, on http://www.decc.gov.uk/en/content/cms/publications/lc_trans_plan/lc_trans_plan.aspx

Different measures for renewable heat, by capital cost and carbon saving [14]

Measure	Typical Capital Cost/ Household	Potential Carbon Saving[11]	Comments
High cost insulation e.g. Under-floor, solid wall	£20,000+[15]	Up to 68% where deliverable	Potentially disruptive. Cannot be employed in all homes because of technical and legal (e.g. heritage) constraints.
Ground source heat pump	£11,400[16]	14-40%	Greater carbon saving if combines with decarbonised electricity, or off gas grid. May require access to suitable land.
Biomass boiler	£7,200[16]	60%	Depends on access to land for storage, and on biomass supply chain. Greater saving if off gas grid e.g. replacing oil or electric heating.
Solar hot water	£35,00[16]	10%	Depends on solar aspect and building suitability, generally, only replaces hot water (not space heating) load.
CHP district heat	£1300-6000[17]	5-25%	Provides greater savings in electrically heated homes. Depends on collective action/coordination. As for all CHP, depends on relationship with electricity market. Lower savings as grid electricity market. Lower savings as grid electricity decarbonises.
Renewable district heat	£2000-10.000[17]	80%	Could be affected by air quality constraints. Depends on biomass supply chain and collective action/coordination.
District heat with remote heat supply	£500-4500[17] plus cost of heat and bulk transport	Up to 80%	Carbon savings depends on carbon intensity of primary heat source. Distance that heat is transported is a key determinant of cost, of which there are no reliable estimates for UK. Depends on collective action/coordination.

14 Department of Energy and Climate Change, *The UK Low Carbon Transition plan: National strategy for climate and energy*, 15 July 2009, Chart 5, p45, on htthttp://decc.gov.uk/Media/viewfile.ashx?FilePath=White%20Papers\UK%20Low%20Carbon%20Transition%20Plan%20WP09\1_20090715190000_e_@@_DECCWPUKLCTransitionPlan.pdf&filetype=4p://www.dft.gov.uk/pgr/sustainable/carbonreduction/low-carbon.pdf

15 John Willoughby J and Paul Ruyssevelt Low Carbon refurbishment: the case for 'example' refurbishment www.johnwilloughby.co.uk; confirmed by Defra figures

16 Renewable heat technology costs from Defra, Ernst and Young, 2007, Renewable heat initial business case.

17 District heat cost estimates from Carbon Trust, 2004, Community heating for planners and developers, adjusted where appropriate based on OCC stakeholder research.

Micro CHP	£4000[18] (if available)	5-10%	An unproven technology, cost may decline over time. Compatible with existing gas infrastructure. As for all CHP depends on relationship with electricity market, and savings reduce as grid electricity decarbonises.
De-carbonised electricity.	£3,000[19] plus grid costs	Up to close to 100%	Would require major increases in decarbonised electricity or CCS. Cost of upgrading grid is not known but could be very high as total annual electricity demand is gas heated homes would be quadrupled. Delivering any net carbon would require enough new capacity to halve the current carbon intensity of grid electricity.

As we have hinted, though, something is missing from the chart above.

Ground Source Heat Pumps, which are rewarded by the RHI, use pipes containing a liquid that, after being warmed by the earth, enters a heat exchanger and transfers heat from the ground to a second medium, usually water, which is then used to heat buildings. GSHPs use a compression cycle to increase the temperature of the fluid to that required to heat the building. They work from shallow depths, running pipes up to 200m beneath the surface, and rely on access to temperatures of about 12°C. For every unit of electricity powering the compressors, GSHPs typically deliver four units of heat. Thus if carbon-free electricity powers their pumps, they can make a real difference.

But the story does not end there. GSHPs are just the shallowest version of *geothermal energy*. Once systems are drilled to between one and two kilometres below the surface, the heat of the earth in the UK is between 40 and 80°C. In this case, direct heating is possible on a much larger scale than GSHPs. At these temperatures, there is often no need to use a GSHP, resulting in much greater cuts in CO_2 emissions.

Through this technique, and drawing also on CHP and a biomass (woodchip) boiler, the Southampton District Energy Scheme, established in 1986, annually sells £2m of heat, cooling and electricity to 40 organisations and hundreds of households. The impetus for the scheme was geothermal energy in the Southampton area.

Drill further, say four kilometres beneath the surface, and there are more energy riches to tap. At these depths, temperatures in the UK can mount to more than 160°C. As a result, heat can be produced on an industrial scale, 24/7, and, in the manner of CHP, electricity can also be generated at the same time. For example, Geothermal Engineering Ltd's first plant, in Cornwall, will be capable of providing more than 50MW of heat and 10MW of electricity. Indeed, if the plant proves to be successful, the company will generate 300MW of electricity and 1GW of heat in Devon and Cornwall alone.

18 Based on Carbon Trust estimate of £11,500 above considering boiler.
19 OCC estimate based on cost on new nuclear plant in Finland (€30bn, 1.6GW) and conservative peak heat load of 2.5 kW per household.

Could Britain ever apply geothermal energy on an Icelandic kind of scale? No. But though sources of geothermal energy must coincide with patterns of human settlement for them to be useful, more than 2.5billion tonnes of coal equivalent could be available from perhaps 50 potential geothermal schemes in the UK. [20] In Scotland, for example, using the hot water contained in flooded mines could generate at least 300MW of heat in areas with matching heat loads. [21]

As currently designed, the RHI takes little account of the potential for geothermal energy to generate large amounts of renewable electricity, as well as even larger amounts of renewable heat. With geothermal, initial investment costs are high; but, by contrast with wind or solar power, once the geothermal plant is built, running costs are very low and output is consistent.

Within a few years, therefore, the Renewable Heat Incentive will very probably have to face renewal itself. Renewable heat is too important to Britain's future for geothermal energy to be overlooked. Of little relative weight at the moment, geothermal energy is bubbling under. Once it is backed by the right kind of cash, and the right kind of public understanding, it faces a great future.

20 J A Barker and others, 'Hydrogeothermal studies in the United Kingdom', *Quarterly Journal of Engineering Geology and Hydrogeology*, Vol 33, Issue 1, 1 February 2000, p56.
21 Tony Batchelor and others, 'Country update for the United Kingdom', *Proceedings World Geothermal Congress 2005*, Antalya, Turkey, 24-29 April 2005, p1.