Proceedings World Geothermal Congress 2010
Bali, Indonesia, 25-29 April 2010

Engineered Geothermal Program in the UK

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Keywords: Keywords: Engineered Geothermal System (EGS), Geothermal Energy and UK EGS resource.

ABSTRACT

Recent uncertainty in the supply of energy and the effect of global warming raised a call for a review of the potential of geothermal energy in the US. A study was commissioned by the US DoE via Massachusetts Institute of Technology. The study concluded that if Enhanced Geothermal System technology was pursued seriously then it was anticipated that something like ***11,000GWe*** could be generated by 2050.

Similarly, in 1986 an assessment was carried out by the Camborne School of Mines which indicated that a mature Engineered Geothermal System (EGS) technology could supply around *10% of the electricity demand in the UK for around 200 years.* Both of these assessments show that there is a vast energy resource which can supply base load 24 hours a day continuously with virtually no effect on the environment.

The concept of EGS itself is very simple but the development of the associated technology has taken longer than anticipated. Following the technological success at the European project in Soultz, France, and a commercially funded EGS plant in Landau, Germany, it was just a matter of time before the UK participated in the exploitation of this technology.

In the 80's the UK helped to pioneer the development of this technology by establishing ground rules for the migration of fluid in specific stress conditions, which are fundamental to the development of this technology. An International Conference on EGS (Hot Dry Rock) was organized in 1989 and the proceedings were published to highlight the resource available in the UK and the progress made to date on this technology, Baria, R. (1990).

In view of the large resource in the UK and the current state of the technology, a company has been established to exploit the EGS potential in the South West of England. The first phase is a background study to identity a favorable resource area and to develop a work plan to exploit it. The company, EGS Energy Ltd, includes BESTEC GmbH and altcom Limited as partners, thus reinforcing the technological and management potential of the company.

1. INTRODUCTION

At the 2005 Annual Geothermal Resource Council's meeting in Reno, the title for the book of Abstracts was "***Geothermal Energy - The World's Buried Treasure***" and how true this is. The general public at large is not aware of the potential of Geothermal Energy in being able to supply a major portion of our primary energy needs.

Geothermal energy is generally categorised as a "new renewable energy" but that is not the case in the short to medium term. Depending on the type of geothermal resource, it may take anything up to 20,000 years to recover naturally the energy extracted from an exhausted Engineered Geothermal System.

Geothermal energy has been used by people since the dawn of civilisation in many parts of the world for bathing and washing clothes from hot springs, an expression of geothermal energy on the surface, Cataldi, et al., (1999). Similarly, when geothermal energy is mentioned, the general public perception is that it is found in places such as New Zealand, Iceland, etc. on the crustal boundaries where the crust is thin, i.e. from hydrothermal fields. Nothing can be further from the truth, as we all know that the temperature normally increases as one goes deeper into the earth's crust. This means that to access the right temperature to exploit geothermal energy one would have to go deeper in some parts of the world and shallower in others. To extract the geothermal energy economically, it makes sense to extract it from shallower depth first and deeper at a later date to take advantage of the improvement in the deep drilling technology and increasing price of energy.

Although the initial idea of exploiting the heat resource at depth was developed at Los Alamos and named "Hot Dry Rocks", the technology to exploit it has gone through a number of innovations. Associated titles such as "Hot Wet Rock", "Hot Fractured Rock", "Enhanced Geothermal System", etc. have been given to try to fit it to a specific *in situ* geological condition. Although Los Alamos was the front runner during the 1970's, the concept appealed to Japan and Western Europe and the centre of gravity of this technology moved to Western Europe between the late 1980's and the present day.

As the technology continued to develop to address new challenges, it became evident that solutions were required to be engineered to fit with the local conditions at depth. This lead to acceptance of the title "Engineered Geothermal Systems" (EGS) as there is likely to be some variation in the *in situ* condition and an engineering solution will be required to address it. The advantage of this approach reduces the risk of classifying it into specific concepts and termination of the project if it does not fit into the preconceived idea. Considering this as an EGS reduces this type of risk and premature termination of projects, as from past experience one can find a solution to meet the new challenge.

2. EGS DEVELOPMENT IN THE UK

The United Kingdom, like many parts of the world, is not fortunate enough to be on the crustal margins and therefore does not have the advantage of high temperature at shallow depth and the likely presence of exploitable quantities of fluid at these depths for hydrothermal operations. The UK's research on the EGS project at the Rosemanowes site between 1976 and 1993 made a significant contribution to the understanding of the physical process involved in the creation of an EGS reservoir: diagnostic methods to determine its physical parameters, developing techniques to interpret the data and the potential EGS resource in the UK. The EGS programme at Rosemanowes was specifically tailored to keep it under 100°C so that the technology from the oil and gas industry could be used to understand the physical processes involved in the development of an EGS technology.

During the latter part of the project, development of reservoir creation modelling (FRIP); high temperature instrumentation (220°C); diagnostic techniques such as microseismic monitoring, engineering assessment for a deep system, the UK potential EGS resource, etc. were prepared to lead the existing programme to the next phase of the development of going down to 6000m depth to exploit the EGS resource at 200+°C. A review was carried out by the Department of Trade and Industry (DTI) at the time and based on the limited data, it was concluded that the technology was not economically attractive, even though the resource assessment showed that the accessible EGS resource was vast and had the potential of supplying around 10% the UK's electricity requirement for 200 years.

3. CONSOLIDATION OF EGS RESEARCH IN W. EUROPE

During this period, it became apparent that a demonstration EGS project at greater depth was needed to address commercial parameters and technology. It was also recognised that significant funding from the European Commission (EC) would be required. Realignment took place and a European EGS project was established at Soultz, France, in 1988 with funding support from the EC, Germany, France, and - in the early stages - from the UK.

The research on EGS carried out at Soultz lead to a number of conclusions - some of them are listed below:

a. Tensional regimes such as grabens are relatively easier to manipulate then compressive stress regimes.
b. Open systems and closed systems required a different approach for designing a circulation system.
c. Fluid is likely to flow proximately in maximum principle stress direction and is controlled by the *in situ* stress and joint network.
d. It is possible to engineer a large EGS reservoir with separation in excess of 650m and with acceptable reservoir impedance.
e. Uniformity of stress regime is advantageous and to avoid complex stress regimes such as centres of caldera or a complex and heterogeneous stress regime.
f. Avoid area with significant natural seismicity.
g. Take advantage of natural conditions such as fluid flow in deep structures.

4. EGS RESOURCE OF SW ENGLAND

The near surface geology of SW England is dominated by late Variscan granite batholith intruded at high crustal levels into folded and thrust thickened sequence of Devonian and Carboniferous basinal sediments, which probably developed on thin continental crust, Willis-Richards, et al. (1986). The partly exposed granite batholith extends for 200km along the spine of SW England, and probably extends further to the west across the continental shelf.

Exposed granite copulas are characterised by heat flows of between 110 and 135mW/m^2 compared to regional values of 60-5mW/m^2, Tammemagi and Wheildon (1974), Francis (1981), see Figure 1.

The radiogenic internal heat production of granite samples averages about 5.0μW/m^3, compared country rock values close to 2.0μW/m^3. No significant variation in heat production is observed down the 2.6km vertical section of the deepest wells at the Rosemanowes site. This lack of vertical fraction of the radiogenic heat producing elements is likely to be a general property of peraluminous S-type granites such as that found under SW England, Webb, et al. (1985), Sawka (1986). If the heat producing contrast between the granite and the country rock measured near the surface is maintained over the entire 10 to 15km thickness of the granite batholiths, Tomb (1977), Al-Rawi (1980), then the heat flow anomaly can be attributed entirely to the high heat productivity of the granite batholiths, without any contribution from entire lower crust or mantle.

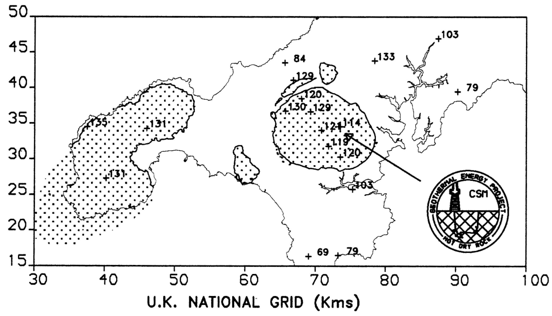

Figure 1: Heat Flow Measurements in the Carmenellis Area with Figures Large Enough to Read

Modelling of the EGS resource was established taking into consideration the shape of the granite (gravity survey, density measurements, seismic survey, outcrop and information from deep wells etc) 3D thermal modelling (heat flow, heat production, regional heat flow, thermal conductivity, etc.) thermal resource (temperature with depth from deep wells, abandonment temperature of reservoir, etc.) and defining the electrical resource (plant engineering, stimulation design, reservoir spacing, water availability, drill rig availability, reservoir characteristics, etc.).

The shape of the granite determined from the above data is shown in Figure 2. The shape of the granite model is verified against the observed gravity field, the outcrop of the granite, borehole intersections with upper surface of the granite and the mapped extent of the metamorphic aureole.

Temperature prediction at 6000m depth in the Carnmenellis region was independently estimated by the Imperial College (London) and by the Camborne School of Mines. There was a good agreement between the two predictions. Figure 3 shows the temperature extended at the same depth to cover the whole of SW England.

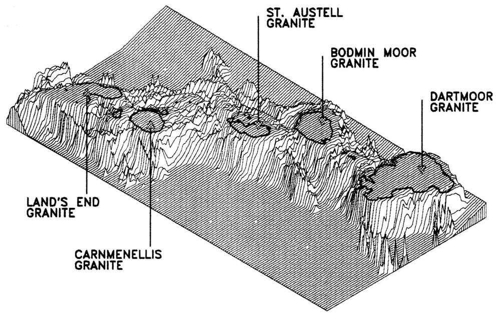

Figure 2: Isometric View of Granite Batholith Model

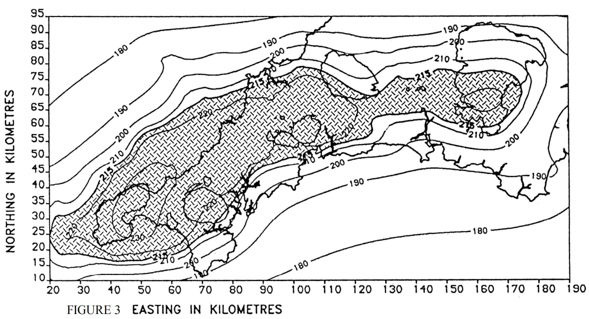

Figure 3: Temperature at 6000m, whole of SW England

The thermal resource can be expressed most usefully in the geothermal equivalent of a ‘grade-tonnage’ chart. This expresses the amount of useful heat that is contained in the rocks above a given bottom hole depth, counting only those areas where the bottom hole temperature is above a given value considered ‘economic’.

Under the land area of SW England, the resource that could be potentially available for electricity generation from geothermal energy exceeds 5 x 10^{20} joules for the most conservative criteria, and may be as much as 2 x 10^{21} joules if EGS reservoirs are developed as deep as 7 km below the surface. Advantage can be taken of deviated drilling under the coasted margin and can add further to the total EGS resource.

Using estimates of these non-geological constraints on the efficiency and taking a maximum exploitation depth of up to 7m, the thermal resource which can be possibly turned in to electricity varies from 0.2 to 1.0 %. By taking the worst case and low value for the thermal resource, an electrical resource of about 260TWHr is estimated, Willis-Richards, et al. (1986).

In 1985, Newton estimated, Newton, K., (1985) that the UK geothermal HDR resource could provide 20,000 to 130,000TWh, with a ‘credible contribution’ to electricity generation of up to 25TWh/y (~10% of the present UK electricity demand) for about 800 years. Drilling to a depth of 9km was then envisaged.

The last estimate in 1992, of accessible resource (i.e. the resource located within the practical limit of borehole drilling - currently set at 6km) was prepared for the 1990 HDR programme review. The accessible resource was shown as a cumulative function of cost. The data were calculated from temperature distributions provided by the Camborne School of Mines and the British Geological Survey and based on extraction using the Sunderland cost model with an 8% discount rate. From this evidence, the geothermal HDR accessible resource in the UK ranges from 900TWh (for Cornwall alone) to 1880TWh, for the whole of the UK, MacDonald, et al. (1992).

5. EGS DEVELOPMENT IN THE UK

Following the lessons learned from Rosemanowes and Soultz, the successful commercial EGS project by BESTEC GmbH at Landau, Germany, the increasing price for the energy worldwide and the concern for the emission of CO_2 in the environment, in 2008 the company EGS Energy Ltd was formed in partnership with BESTEC GmbH and altcom Ltd, to exploit the commercially EGS potential in the UK.

The EGS resource map of the UK was re-examined, refined and potential advantageous areas from the lessons learned above were identified near St Austell, in Cornwall, UK. The philosophy of EGS Energy was to find a long term consumer to take the heat and power generated prior to the construction of an EGS project in St Austell. Large heat load consumer The Eden Project in St Austell was identified as a potential client and negotiations took place for The Eden Project to become a partner. The Eden Project has an excellent environmental record and as such was the right partner for the EGS Energy Ltd.

The first commercial EGS project in St Austell will be the demonstration project for EGS Energy Ltd. It is based on the experience gained to date and will be similar in nature to the existing one in Landau. It is expected that there may be some variation due to the local conditions but the principle philosophy will be same. It is planned to exploit the available resource to a depth of around 4km and a moderate temperature of around 145°C. Any deviation from the main theme will be corrected by implementing techniques developed from the past experience. Innovation is also essential, but the primary drive will be the implementation of knowhow from past experience.

The present project is called EGS Power and the initial preparation such as planning permission and geophysical investigation, etc. has already started in conjunction with The Eden Project. The main thrust of development (drilling the first well) is anticipated to start around the middle of 2010.

Other such projects will be implemented in St Austell, in parallel but lagging behind the demonstration project. Some of these EGS projects potentially will be used to help process economic material, to support a proposed Eco-town, and to create recreation centres and hotels. The philosophy is to supply both heat and power to maximise the economic returns and to establish a healthy and environmentally friendly technology in Cornwall.

6 FUTURE EGS PROSPECT IN THE UK.

Projects at St Austell is the starting point, study will also commence to go deeper (~6000m and at higher temperature ~220°C) to design and develop a higher enthalpy initial EGS heat exchanger module which will, when clustered, provide an appreciable power plant in the range of 25-50MWe. The future of EGS lies in not just being able to supply heat and power for local consumption but also to become a base load and strategic power supplier for the nation. To develop this strategy will need a complete change in the normal way of developing and operating a system and will be more keen to mass production technology.

It has been suggested that something like 70% of the land mass has igneous rock at some depth. Once the deep drilling and the development of an EGS reservoir have been mastered, the growth of EGS as one of the suppliers of primary energy in the world becomes feasible by the middle of this century. After all, it is a type of mining operation and human beings have been mining for over 3,000 years.

ACKNOWLEDGEMENT

The authors would like to thank: Jonathan Willis-Richards for discussions on the resource assessment for the UK;, the European Commission (DG Research) for supporting the development of EGS research at Soultz; and J. Garnish for initiating the European EGS program and the tremendous support for Soultz. We would like to give special thanks to Tim Smit and all the staff at The Eden Project who have been exceedingly helpful and enthusiastic. We are also grateful to Lord Teverson, ORMAT Technologies, Inc. and Schlumberger Geothermal Services for their support.

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