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Need for Internationally Recognized Guidelines for Assessing EGS Resources

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ABSTRACT

It is recognized by virtually every credible organization such the IEA, MIT, IGA etc that the EGS resource might be extensive in regions with appropriate igneous basement, yet it appears that in some instances the assessment of the potential of EGS is being manipulated and degraded to suit political agendas. The data used to quantify EGS potential are much the same regardless of who is making the assessment. Ideally, then, the estimated resource should in principle be relative constant across different assessments, with perhaps minor variation. Additionally, there appears to be misunderstanding between resource and reserve. To quantify the reserve in EGS is going to be difficult as there is no specific boundary similar to that in mineral or hydrocarbon reserve where the resource is locked up in a set boundary. For EGS, the igneous rock could be very extensive and a possible reserve would be the boundary of where the EGS reservoir could be economically created.

It is of great concern to see how estimates of EGS resource and reserve vary from one organization's assessment to another. Take an example of the various studies carried out in the UK.

- A study in 1976 estimated that EGS in southwest England could yield the equivalent energy to 8000 million tonnes of coal (ie about 60,000 TWh). Converted into electricity with an efficiency of l0%, this represented a resource of about 5000 TWh(e).
- A strategic review undertaken by ETSU in 1982 indicated that the EGS electricity resource might be between 2500 and 60,000 TWh(e) for depths down to 8 or 9 km in the UK.
- In 1984, ETSU estimated that the UK geothermal EGS resource could provide 20,000 to 130,000 TWh(e), with a 'technical potential' for electricity generation of up to 25 TWh/y (10% of the contemporary UK electricity demand) for about 800 years.
- In 1992, MacDonald assessed that with the low thermal gradients that exist in the UK, it was unlikely that EGS would provide an energy source with a wide application. Unless there was a significant technological break-through in an area that cannot currently be foreseen, the costs of generating electricity from EGS in the UK would likely remain uncompetitive with conventional methods by a large margin.
- In 2011, Ove Arup & Partners Ltd reviewed the potential for geothermal in the UK based on cost estimates and economic constraints. That review concluded that energy produced by deep geothermal methods is a viable energy source in Cornwall.
- Sinclair Knight Merz made a report for the REA in 2012 and concluded that, using today's technology alone, EGS could provide 9.5 GW of base load renewable electricity and 100 GW of heat for the UK. That equates to 20% of the UK annual average electricity generation capacity.
- Atkins wrote a report on geothermal for the DECC in 2013. The report stated that as geothermal power plants do not exist in the UK, no reserves could be defined by the Australian code. The report concluded that the potential for geothermal power was currently difficult to quantify, but tentatively 1 to 1.5 GWe might be argued in the longer term (2050) for the UK as a whole. This equates to 3-4% of current average UK electricity demand (or 1.0 – 1.7% of current UK generating capacity).

These wide variations in estimating the EGS resource should be a concern for the geothermal industry in general as potential investors and governments are disillusioned by the lack of sound quantification of the resource. A mechanism needs to be established whereby hydrothermal and EGS resources can be comparatively quantified based on a specific internationally recognized criteria.

1. INTRODUCTION

Many organizations have previously recognized that Engineered Geothermal Systems (EGS) could provide a large proportion of electricity generation in regions with appropriate igneous basement. These organizations have included International Energy Agency, Massachusetts Institute of Technology, the International Geothermal Association and others. Yet it appears that in some instances the assessment of the potential of EGS is being manipulated and degraded to suit political agendas. The data used to quantify EGS potential are much the same regardless of who is making the assessment. Such data include surface heat flow, estimates of rock volume, thermal conductivity estimates, rock specific heat capacity and density. Ideally, then, the estimated resource should in principle be relative constant across different assessments, with perhaps minor variation. However, this is not the case, largely because of wide degrees of variability in the estimates of how much thermal energy can be recovered from the subsurface.

Additionally, there appears to be a lack of common terminology and guidelines for distinguishing between 'resources' and 'reserves'. To quantify the recoverable energy for EGS is going to be difficult as there is often no specific boundary similar to that in mineral or hydrocarbon reserve within which the resource is locked up. For EGS, an igneous rock could be very extensive and a possible reserve would be the boundary of where the EGS reservoir could be economically created.

This paper looks at a range of EGS 'resource' and 'reserve' estimates for the UK over several decades, and illustrates how a lack of a consistent and accepted global assessment protocol for EGS can potentially be exploited for political means to "get the answer you want."

2. ESTIMATES OF EGS POTENTIAL IN THE UK

A number of studies of the potential for EGS to contribute a significant portion of the UK's electricity supply have been carried out since the mid-70's. It is interesting to note a possible correlation between the findings of the different reports and the political desire for renewable energy at the time.

2.1 1976–1982

A government study in 1976 (Department of Energy, 1976) estimated that EGS in southwest England could yield the equivalent energy to 8000 million tonnes of coal (ie about 60,000 TWh). Converted into electricity with an efficiency of l0%, this represented a resource of about 5000 TWh(e). A subsequent review undertaken by ETSU (1982) indicated that the EGS electricity resource might be between 2500 and 60,000 TWh(e) for depths down to 8 or 9 km in the UK.

2.2 Resource size estimates for geothermal hot dry rock technology in the UK, 1984

In 1984, the annual electricity generation for the UK was about 250 TWh(e). Against that benchmark, the Department of Energy commissioned a study to look at the potential electricity generation from geothermal energy in the UK (Newton, 1984). The report estimated that the UK geothermal EGS had 'technical potential' to provide 20,000 to 130,000 TWh(e), or electricity generation of up to 25 TWh/y (10% of the contemporary UK electricity supply) for about 800 years. That was an order of magnitude greater than ETSU's assessment just two years earlier.

2.3 MacDonald *et al.*, 1992

MacDonald et al. (1992) reported on the findings of the UK 'Hot Dry Rock' R&D program. They stated that electricity from EGS was unlikely to be competitive with conventional means of generation in the short to medium term, and that EGS was unlikely to attract private sector funding in the foreseeable future. In effect, that report concluded that the EGS 'resource' or 'reserve' in the UK was zero. The UK Department of Energy used these findings to justify closing the UK R&D facility and direct future UK research and development towards what became the Soultz Project in France.

2.4 Review of the generation costs and deployment potential of renewable electricity technologies in the UK, ARUP 2011

The Department of Energy and Climate Change (DECC) appointed ARUP to look at the deployment potential and generation costs of renewable electricity technologies in the UK up to 2030. ARUP submitted its study report in 2011. The report tried to estimate the likely development scenarios for different renewable energy technologies based on assumptions of cost and constraints. It forecast geothermal deployment in the UK up to 2030 as follows. The earliest geothermal deployment was assumed to begin in 2014. A 'low' scenario resulted in approximately 35 MWe online by 2020 and 175 MWe by 2030. A 'medium' scenario resulted in approximately 100 MWe by 2020 and 990 MWe by 2030. A high scenario resulted in 480 MWe by 2020 and 4,005 MWe by 2030.

2.5 Geothermal Energy Potential in Great Britain and Northern Ireland, SKM 2012

A self-funded report by SKM with the Renewable Energy Association in 2012 (Jackson, 2012) focused on 'deep geothermal' energy potential in the UK down to 5,000 m depth. It specifically looked at EGS prospects with potential for electricity generation in Cornwall, Weardale, the Lake District and the East Grampians in Scotland. The report adopted the terminology of the Australian Geothermal Reporting Code (AGEA and AGEG, 2010). It defines an 'Inferred Resource' as a part of a geothermal resource in which thermal energy is estimated with a low level of confidence, mainly from geological, geochemical and geophysical data without (or with very limited) information from drilling and well testing. SKM estimated the energy capacity of the granites based on an inferred uniform thickness throughout the resource areas, and the recoverable electrical energy in terms of MWe (gross) over a projected plant life of 25 years. Specifically, the recoverable thermal energy was based on the assumption of 2% recovery factor and that electrical generation reduced the brine temperature to 70°C.

The report concluded that, using today's technology alone, deep geothermal resources could provide 9500 MWe of baseload renewable electricity over 25 years. That equates to 20% of the UK's annual average electricity generation capacity. It was used as a basis for the REA to argue for increased government support for geothermal R&D and increased cash credits for power and heat generation from geothermal.

2.6 Deep Geothermal Review Study, Atkins 2013

The Department of Energy and Climate Change commissioned yet another study of the potential for EGS to contribute to power generation in the UK in 2013 (Atkins, 2013). That study found substantial uncertainty over whether or not EGS represents a viable resource in the UK. It suggested that the uncertainty would not be resolved until deep boreholes demonstrate both reserve extent and exploitability. In spite of this uncertainty, though, the report listed some areas of the UK with potential; the 'radiothermal' granites of Cornwall; and the 'radiothermal' granites of Weardale in the North East stretching across towards the Lake District. It determined that the current potential in South West England is up to approximately 100 MWe. In Weardale and the Lake District, the report suggested an upper limit potential in the order of 70 MWe.

2. CONCLUSIONS

The examples above demonstrate that in the absence of recognized and accepted international guidelines for assessing the potential for EGS power generation, it is possible to come up with almost any answer required. Estimates of EGS potential in the UK have varied from zero to almost 10,000 MWe. In many cases, it appears as though estimates have been deliberately manipulated to justify a political imperative at the time. Each estimate is justified for a given set of assumptions and constraints, but clearly the estimates are inconsistent and incompatible with each other. The lack of consistency not only perpetuates the uncertainty over the 'true' potential for EGS in the UK, but it is a cause for disillusionment of possible supporters and investors in the technology.

Beardsmore *et al.* (2010) suggested a standard 'protocol' for estimating EGS potential that has been endorsed by the International Geothermal Association, the International Energy Agency Geothermal Implementing Agreement, and the International Heat Flow Commissions. While that 'protocol' is itself based on a certain set of assumptions, it provides a common basis upon which estimates of EGS potential can be derived in all parts of the world; it removes a lot of the subjectivity in resource assessments; and carries the weight of endorsement from leading organizations.

The protocol starts with recommendations about best practice for estimating the temperature distribution within the earth's crust, and provides default values for density and specific heat capacity to convert the temperatures into estimates of stored thermal energy. It goes on to describe a standard process to estimate the 'theoretical potential' for power generation if all of the available heat could be extracted and converted to electricity over a 30-year time span. 'Available' heat is defined as the thermal energy above a cut-off temperature 80°C above average surface temperature. A default 'cycle thermal efficiency' for conversion of heat to electricity is given as a function of extraction temperature. The volume of rock is limited to crystalline basement lying between three and ten kilometers in depth.

The protocol then proposes a set of standard rules for estimating the 'technical potential', which is that portion of the 'theoretical potential' that can realistically be realized with available technology. 'Technology' has a broad meaning that encompasses land access, reservoir engineering and power conversion constraints, but not economic constraints. The constraints include excluding rocks beneath inaccessible land from the calculation, limiting the drillable depth, imposing a 'recoverability factor' on the proportion of heat that can be extracted, and limiting the temperature drawdown that can be managed by a typical power conversion plant.

The advantages of applying the protocol to estimates of EGS power include:

- Standard terminology to classify estimates of potential (e.g. Technical Potential);
- Cumulative MWe estimates, or MWe/km^2 power density maps;
- Transparent and consistent assumptions about the values of key parameters (e.g recoverability factor)
- Self-consistent, comparable outcomes from different studies;
- Simple to update if data or technology improves.

We argue that adoption and application of the same 'protocol' for an estimate of EGS potential in the UK would remove the potential for political manipulation of the outcomes, and improve investor confidence.

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