GLOBAL DEPLOYMENT PROJECTIONS OF SUSTAINABLE & RENEWABLE GEOTHERMAL ENERGY - THE GOOD, THE BAD AND THE OUTRAGEOUS – FROM AN IEA-GIA PERSPECTIVE

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Keywords: *deployment projections, sustainable, renewable, IEA-GIA*

ABSTRACT

Geothermal energy may be ubiquitous, but being 'out-of-sight' (subsurface) can also mean 'out-of-mind' for many people. This paper explores the legacy of past deployment projections, and how to increase confidence in future projections and awareness of global geothermal resource potential, while remaining cognisant of its technical, economic and social deployment challenges, and the adaptive strategies necessary to sustain utilisation in the long term.

1. INTRODUCTION

In the future, geothermal could become the cheapest and safest source of non-polluting, base-load heat and power (without subsidies) for as much as 15% of the global population (those living near active volcanic zones), and could make a significant contribution (with subsidies) to the renewable energy mix for the rest. For example, geothermal could become a sizable base-load component of many isolated electricity grids on poorly-developed volcanic islands. But away from these tectonic areas, geothermal could also play a larger role through deployment of more-efficient ground-source heat-pumps and advanced technologies such as enhanced geothermal systems (EGS). Other development ideas might include tapping super-critical temperature reservoirs, hot brines in deep sedimentary basins, or even heat sources along oceanic spreading-ridges where near enough to the coast.

Truly innovative ideas are needed to popularize geothermal technology and to accelerate our existing, somewhat sluggish, global geothermal growth rate. More could be learnt from countries where recent geothermal growth rates have exceeded 20% per year. Knowledge and resources from the shale-gas drilling industry could be applied to EGS to reduce costs and accelerate deployment. More innovative ideas could surface in the area of geothermal direct use, for heating and cooling of building spaces, energy-intensive industrial processes, agricultural food processing, or better technologies for efficient bulk heat-transfer.

In preparing resource assessment protocols and undertaking deployment projections we should also be addressing the concepts of sustainable development and renewability in order to attain an optimum long-term geothermal utilisation rate. The focus should be on establishing what is technically feasible as well as realistic and good for the environment.

Also, the legacy of publishing unattainable deployment targets can end up as a source of public scepticism and a consequent reluctance to invest. So, in order to truly accelerate global geothermal growth to mitigate climate change effects, what are needed are more forward-thinking, perhaps even somewhat outrageous ideas. These should be more effective than relying on optimistic deployment projections to gain attention and stimulate enthusiasm.

Commentators such as Mearns (2015) have posed the question : why does 'geothermal energy', as a replacement for significant amounts of carbon-emitting, fossil-based energy sources, remain a 'minor player' in the global field of renewable energy politics, despite being a 'major player' in some economies such as New Zealand and Iceland ? One reason might be the economic disadvantages of long project lead times (delays between conceptualizing a good project and finally achieving it). Another reason might be risk-averseness, through lack of knowledge, by potential project investors. An investigation of such barriers could be fruitful.

Mearns (2015) succinctly summarised the virtues of geothermal electricity relative to alternative sources in a July 2015 article:

"Geothermal electricity is about as close to a perfect source of renewable energy as one can get. It's (almost) carbon-free, doesn't emit large quantities of noxious gases or generate radioactive waste, doesn't require the clear-cutting of virgin forests, doesn't take up lots of room, doesn't blight the skyline (at least, not by much), doesn't decapitate or incinerate birds, is replenished by the natural heat of the earth, delivers base-load power at capacity factors usually around 90%, and can even, if necessary, be cycled to follow load. It's also one of the lowest cost generation sources available. No other renewable energy source can match this impressive list of virtues or even come close to it."

Despite these 'virtues', the barrier that Mearns saw as the main reason for sluggish growth rate at present was that the location of favourable geothermal sites is often far from major centres of energy consumption. Large areas of the world, that are heavily populated, simply don't have direct access to the high temperature resources needed to produce electricity at economically favourable prices.

In a panel discussion on Climate Change and Society; The Age of Resilience, held in Auckland on 26th August 2015, participants saw the issue of socio-economic drivers for renewable energy differently. Their theme was a plea to 'think holistically' through innovation and was expressed as follows:

“Economic production systems and consumption patterns are both the problem and the solution to climate change. A resilient economy is not just about reducing our ecological footprint through producing and consuming less – economics can be used to drive change: aligning incentives, sparking innovation and encouraging transformation throughout the production/consumption chain. Humankind has irrevocably altered the planet’s natural systems – can we use that same human power to unleash true “Green Growth” and achieve a high and sustainable level of human well-being?”

This message was echoed at a recent world energy summit for students in Bali (Indonesia) http://www.ises2015.com/ where innovative ideas for helping replace fossil fuels with renewable energy sources were canvassed and some novel suggestions involving geothermal in hybrid combinations were discussed.

It is timely and appropriate, therefore, to review the history of geothermal deployment projections and perhaps to draw conclusions on strategies to improve awareness and to help advocate for sensible growth through innovation. In the following sections we explore this legacy and suggest better ways to increase awareness of global geothermal resource potential, whilst remaining cognisant of its technical, economic and social deployment challenges.

2. IPCC DEPLOYMENT PROJECTIONS

The energy capacity from the global geothermal resource (that portion of the earth’s crustal heat that is potentially accessible and extractable) is estimated to be about 5000 EJ/yr (Rybach, 2014). This is about three times that of solar and eight times that of wind. A smaller portion of this resource is considered to consist of ‘reserves’ that could be sustainably and economically developed. This has been estimated to be in the range of 300 to 500 EJ/yr (UNDP, 2000). Such a rate is similar to the continuous rate of heat-flux through the earth’s surface, and would therefore theoretically be indefinitely sustainable, while meeting the current total annual energy needs of all mankind.

Geothermal deployment projections out to 2100 were published by Goldstein et al., (2011a, 2011b) and Bromley et al. (2010) in conjunction with preparation and review of a geothermal chapter for the Intergovernmental Panel on Climate Change (IPCC), Special Report on Renewable Energy (SRREN).

Technically-recoverable and accessible global stored-heat reserves were assessed using a log-normal probability approach in Goldstein et al (2011a). A conservative estimate of 0.7 * 10^6 EJ (90% probability, and 1.34% heat recovery factor), applies to stored heat within 5 km depth beneath the continents. At an extraction rate of 567 EJ /yr (total world energy consumption in 2012), this would last about 1200 years, even without any consideration of continuous heat recharge from below 5 km depth (which would theoretically be at or greater than the rate of natural surface heat loss from the continents (12.5 TW or 400 EJ/yr). Therefore, the issue for geothermal in terms of future capacity is not so much the global resource size, but rather deployment constraints from economics and individual project feasibility.

Comparisons between deployment projections of installed capacity (GWe) for geothermal power from the IPCC report (Goldstein et al, 2011a and 2011b) and those from other studies (Fridleifsson, 2000, Zheng et al., 2015, Bertani, 2015, and GEA, 2015) are plotted in Figure 1. The legend gives the base year that the projections started from. They show a wide variation in trends. Relative to the realized installed capacities (for example, 12.63 GWe at the start of 2015, Bertani, 2015) the previous predictions of both Fridleifsson (2000) and Goldstein et al. (2011) have subsequently proven to be too optimistic. However, the prediction of Zheng et al. (2015), based on data up to 2012, proved to be too pessimistic.

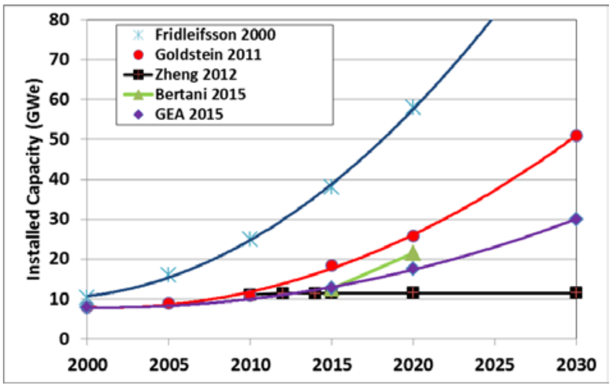

Figure 1: Predictions of global geothermal power capacity. Legend shows author and prediction date.

Figure 2 shows a similar plot for projected direct use installed capacity growth in GW(thermal). In this case, the earliest prediction (Fridleifsson, 2000) was relatively conservative and significantly under-estimated the actual realized values. In retrospect, the main difference can be attributed to the unexpectedly high growth rate in ground source heat pump (GSHP) installations that occurred in several countries over the past 15 years.

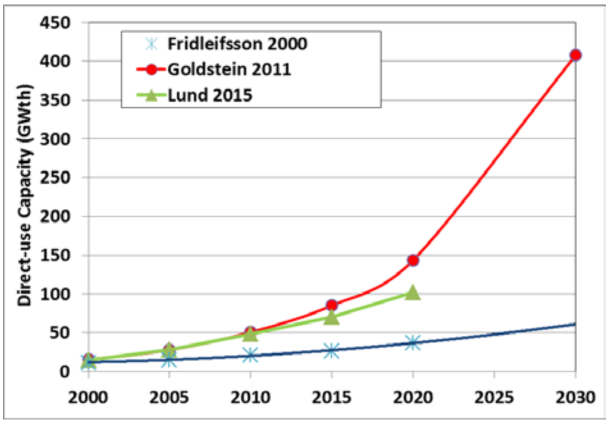

Figure 2: Predictions of global geothermal direct-use heat capacity. Legend shows author and prediction date.

3. IGA DEPLOYMENT PROJECTIONS

Bertani (2015) produced an update for the start of 2015 on global geothermal installed power capacity and annual generation for the World Geothermal Congress. These were summarized from country reports prepared by representative members of the International Geothermal Association (IGA). The average growth rate of installed electrical capacity over 2010-2015 was 3.2% per annum. His forecast growth for 2015-2020 is 12.6-21.4 GWe, or an average of 14% per annum growth rate, implying that a significant acceleration in deployment is anticipated. However, as noted by Bertani (2015), the 2020 forecast is at best 'hopeful'. It follows an exponential growth curve and assumes that all 8 GWe of projects that are 'on paper' transform into reality. This will be a challenge.

Bertani (2015) also provided a projected global target out to the year 2050 of 70 GWe from conventional hydrothermal resources plus 70 GWe from EGS and non-conventional geothermal resources. The combined target of 140 GWe is similar to the IPCC 2050 target value from Goldstein et al. (2011a) of 150 GWe. If achieved, this would provide up to 8.3% of total world electricity, serving 17% of the world population. A total of 40 countries could potentially be relying on geothermal for the bulk of their electricity needs. Such numbers should get the attention of renewable energy analysts and policy makers, but only if they are found to be believable.

Lund & Boyd (2015) updated global direct utilization data for the World Geothermal Congress. By the start of 2015 installed thermal power amounted to 71 GW(th) producing 165 GWh(th) per annum, and growing at about 7% compounded annually since 2010. Approximately 55% of this energy use was for heating and cooling using GSHP (the fastest growing category), 20% for bathing, 15% for space heating (including district heating), 4.5% for greenhouses, 2% for aquaculture and 1.8% for industrial process heat. If the growth rate continues at a similar pace then another 46% increase can be estimated for the next 5 years (to 2020).

Figure 3 illustrates a range of predictions of global geothermal power generation and direct heat utilization in terms of TWh/yr. Arguably this is a more reliable indicator of actual trends in deployment than the installed capacity figures because it takes into account changes in capacity factor or energy utilization factor. The values for each five yearly measurement refer to the accumulated generation or heat utilization over the previous year. (Heat value for Lund in 2020 uses a linear projection of the current growth rate.)

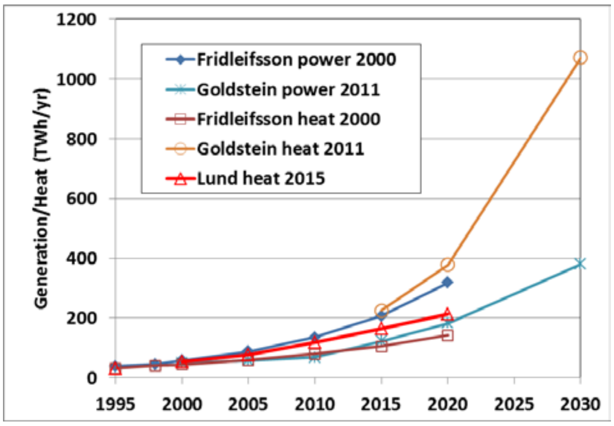

Figure 3: Predictions of global geothermal power and direct-use heat generation (TWh/yr). Legend shows author and prediction date.

In terms of power generation, both the Fridleifsson (2000) and Goldstein (2011) predictions were optimistic compared to the actual 2015 value (from Bertani, 2015) of 73.6 TWh/yr. In terms of heat utilization, the actual 2015 value (from Lund & Boyd, 2015) of 165 TWh/yr lies midway between the predictions of Fridleifsson and Goldstein.

4. IEA-GIA TREND REPORTS

Weber et al. (2015a) and Mongillo & Bromley (2015) describe the organisation and preparation of annual trend reports under a working annex (Annex X) of the IEA-Geothermal Implementing Agreement (IEA-GIA). The purpose of these is to analyse and disseminate annual data and commentary that indicate deployment trends in the geothermal industry, particularly within the 15 countries that are represented by the IEA-GIA through government – sanctioned membership or through industry associations. The intention is to provide a more regular update on such trends than is currently accomplished through the more-comprehensive 5 yearly updates undertaken by the IGA for World Geothermal Congresses. Over time it is planned to seamlessly merge the IEA-GIA and IGA efforts in this regard. So far two IEA-GIA trend reports have been published (see Weber et al., 2015b, and http://iea-gia.org/category/publications/ for the latest).

Figure 4 shows a trend plot in geothermal power generation since 1995 using data from Weber et al. (2015b), supplemented by data from Bertani (2015), other World Geothermal Congress summary papers, and the United States Energy Information Administration (EIA) online data depository. From this it can be seen that IEA-GIA membership currently represents approximately 55% of the global geothermal electricity generation, a decrease from 2000 when it was 67%. The USA (an IEA-GIA member) currently produces 23% of the total, but this is a decrease from 1995 when it was 37%. The trends in terms of growth rates tell a compelling story. A reasonable fit is achieved using a linear gradient to all three sets of data between 1995 and 2015. There is no evidence yet of a significant switch to exponential growth rates. Growth rates in USA geothermal generation have been relatively flat at 1% or 0.12 [TWh/yr] per annum, compared to the 2% or 0.67 [TWh/yr] per annum across all IEA-GIA member countries and 5% or 1.88 [TWh/yr] per annum across the world. Clearly deployment growth has been occurring at a faster pace within countries that are not yet represented within the membership of the IEA-GIA.

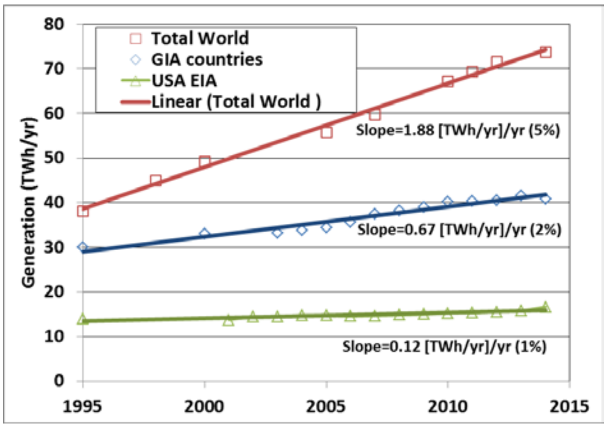

Figure 4: Trends since 1995 in geothermal power generation comparing global, IEA-GIA member countries (15) and USA (EIA) data (modified from Weber et al., 2015b and Bertani, 2015)

5. OTHER DEPLOYMENT PROJECTIONS

Based on observed growth rates of 9%/yr between 1975 and 1995, a World Energy Assessment by the UNDP (2000) predicted geothermal generation of 134 TWh(e) from 24

GWe installed by 2010 and 318 TWh(e) from 58 GWe by 2020. Direct use was predicted (on the basis of 6% observed annual growth rates) to increase to 81 TWh(th) from 22 GW(th) in 2010 and 146 TWh(th) from 40 GW(th) by 2020. In retrospect, the 2010 predictions for power have proven to be about twice what was actually achieved, while for direct use the 2010 predictions were about half what was actually achieved.

An observer of global geothermal deployment trends, Romitti (2015), prepared an updated summary of the international geothermal market for the US Geothermal Energy Association (GEA) in May 2015. This used an annual report (GEA, February 2015), and a list of international projects compiled by GEA. Global growth rates were assessed to have been about 5% per annum over the previous 3 years.

Rybach (2014) has also observed that global annual geothermal growth rates are currently about 5%. This is far less than those of other renewable energies such as wind and solar (25% to 30%). His observation was that the solution could eventually be in tapping into ubiquitous ‘petratherm’ (deep hot rock) resources. Faster (exponential) growth should then eventuate. Enhanced Geothermal Systems (EGS) technology for creating and maintaining deep heat exchangers must first mature.

In the past, observers of global geothermal deployment have sometimes relied on individual country projections for forecasts of global installed capacity. This can prove perilously inaccurate, especially if the projections are optimistic targets. With the benefits of hindsight, an example of this problem can be tracked from the published predictions of capacity growth over time from Indonesia (Radja, 1983 to 1997) and five-yearly World Geothermal Congress country update reports (2000-2015). For the period 1985 to 2015, the 5-yearly predictions turned out, on average, to be about twice what actually eventuated in terms of the installed capacity. Also, published estimates of potential resource capacity across Indonesia have tripled over this period (from 10 GWe to 28 GWe). Approximately 50% of these estimates were considered of sufficient certainty to be treated as “reserves”. The current prediction targets for the next five year period (to 2020) are again quite ambitious at about four times the 2015 installed capacity. Based on previous experience with such targets, some care is advisable in applying them to calculate realistic global projections of future deployed capacity.

At the other, more pessimistic end of the range of published global geothermal deployment predictions, Zheng et al. (2015) argued that geothermal power generation is a mature technology which reached a peak in terms of growth rate in 2008. Using a statistical approach on data from 2000 to 2012, they predicted that global installed capacity would ‘saturate’ and reach a maximum of only 11.5 GWe, with near-zero growth from 2015 onwards. Clearly, with observed growth rates of 5% per annum, reaching about 12.6 GWe in early 2015, this prediction has already proven to be inaccurate (Figure 1).

6. SUSTAINABILITY AND RENEWABILITY

Axelsson et al. (2015) and Bromley & Axelsson (2015), and references therein, provide succinct accounts of the concepts and complex issues surrounding sustainability and renewability of geothermal resources.

In summary, if properly managed, using flexible and adaptive injection and production strategies, supported by good-practice monitoring and reservoir model simulations of alternative scenarios, geothermal reservoir systems are sustainable for very long term operation (that is, for more than 100 years). This exceeds the foreseeable design-life of surface plant and well casings. Their replacement is likely to be needed long before the resource needs to be suspended because of declining temperature and pressure. Upon production suspension, the reservoir would be rested in order to allow for energy recovery through natural and induced fluid and heat recharge. A long-term ‘heat-grazing’ strategy could allow for sequential or rotational operation of several adjacent or underlying geothermal reservoirs. Through periodic cycles of discharge and recharge, this would provide for a continuous supply of renewable energy.

Consequently, such strategies need to be taken into account when undertaking projections of global geothermal deployment and net energy extraction over long periods of time.

7. CONCLUSIONS

Based on this brief review of past predictions of geothermal deployment growth relative to actual achievement, it seems that such projections have generally been too optimistic in terms of power generation, overestimating growth rates by, on average, a factor of two. Using this observation to modify the predictions of Bertani (2015), the installed global geothermal power capacity by 2020 is more likely to be about 17 GW(e) rather than 21 GW, representing more-conservative average growth rates of 7%/yr. This coincides with the GEA (2015) prediction based on the sum capacity of all announced projects. For direct-use the average of past predictions appears reasonable, but the big unknown is future uptake rates for GSHP technology.

To answer the question implied by the theme of this workshop “The Next 10,000 MW”, in a realistic manner, it is therefore likely to be 10 to 15 years before this global milestone can be achieved. The locations where greater than average growth rates are likely to occur will be in countries where the economics are more favourable, access is easiest, policies are favourable and grid connections to load centres are feasible. In the 0-5 year time-frame this probably includes East Africa, Turkey, Central America and South-East Asia, whereas Japan and North and South America may provide higher growth rates in the 5-15 year time-frame. Deployment growth rates in island nations such as Iceland, Hawaii and New Zealand may be constrained by demand growth but this could change dramatically if HVDC cable connections to United Kingdom, Oahu and Australia, respectively, are constructed.

Environmental and social issues will also play a part in project deployment decisions. Global warming and threats of climate change effects may be motivators at a personal level for involvement in geothermal projects, but they need to translate into real economic benefits (e.g. through carbon trading, feed-in tariffs, subsidies or tax benefits) before they will have a significant impact on private investment and deployment growth decisions.

In summary, optimistic geothermal resource potential assessments and deployment projections are still, in a manner of speaking, lurking somewhere beneath everyone's backyard. What is needed are more novel, even 'outrageous', ideas to help break down the barriers to future deployment growth, and bring the bigger picture global issues into a better perspective. Innovation, research collaboration, and information dissemination, seem to be the key elements. These already form the backbone of the objectives of the Annex working groups within the IEA-GIA (www.iea-gia.org).

Ideas that we consider most worthy of investigation include: a) facilitating widespread deployment of EGS through reductions in costs of deep drilling and fracture stimulation, b) utilisation of super-critical resources deep beneath hydrothermal systems, c) tapping into hot brines in deep sedimentary basins, and d) experimental development of off-shore geothermal resources.

ACKNOWLEDGEMENTS

The author gratefully acknowledges ideas and concepts from discussions with IEA-GIA colleagues, Mike Mongillo, Brian Carey, Gudni Axelsson, Ruggero Bertani and Barry Goldstein in particular, and research time provided under GNS Science's Geothermal Research programme (GRN) funded by the Government of New Zealand.

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