LCEDN Rapid Response Reviews:[1]
What are the key issues regarding the role of geothermal energy in meeting energy needs in the global south?

CONTEXT

Globally, **the potential of geothermal far exceeds that of all other renewable sources together**, although investment in the other sources to date has far exceeded investment in geothermal. *World Energy Assessment* estimates in 2000 for the global potential of all renewables (EJ/yr) were Geothermal 5000, Solar 1575, Wind 640, Biomass 276, Hydro 50, giving a total of 7541 (UNDP, 2000). **When installed, geothermal plants have a far higher capacity factor than other sources** (solar depends on the level of direct insolation[2], wind power on wind, etc.); estimates (REN21, 2009) give wind-power 21%, solar PV 14% but geothermal is at least as high as 75% and often more than 95%, given that once a plant is established it operates continuously except for routine down-time for maintenance and rare break-downs.

Geothermal resources are not a homogenous whole, however, and **the nature of the resource is an important factor** (Goldstein et al, 2011). If the geothermal resource is in an area of high enthalpy, such as tectonic margins, it can be used to produce **super-heated steam for electricity generation**. Even in those cases where there is sufficient heat to be used for electricity generation, however, there is a choice of technology – although the most appropriate form of generation will generally be determined by the exact nature of the resource to be exploited: dry steam (for the relatively rare instances of dry stream fields), flash steam (for the highest temperature resources) and binary cycle (whether Organic Rankin or Kalina Cycle: for lower temperatures).

Geothermal plants are already playing a significant role in the electricity generation profile of countries in the global south – **"among the top fifteen countries in electricity production with geothermal, there are ten developing countries"** (Fridleifsson, 2007) - examples include the Philippines, Kenya, Indonesia, Mexico and several Central American states. **There remains considerable potential for further investment in countries with the appropriate geological profile.** As binary cycle technologies improve (with smart design, they can currently be operated economically with waters of temperatures as low as 95C) the potential for geothermal power generation can be expanded to countries outside of active tectonic/volcanic areas. An important principle (to date rather neglected in many developing country geothermal developments - cf Mburu and Kinyanjui. 2012), is the concept of cascading use, where the effluent hot water from electricity generation is next exploited for direct use purposes (Younger, 2012).

Direct use is not only feasible in high-enthalpy geothermal fields: in non-volcanic regions, **geothermal resources of low enthalpy** (such as within sedimentary basins) **can be used to provide heat directly for a range of purposes** such as space heating and cooling, swimming

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[1] This rapid response review was edited by Ed Brown and Jonathon Cloke on behalf of the LCEDN, it draws upon contributions from Richard Blanchard, Ed Brown, Jon Cloke, David Fisk, Jon Gluyas, Aled Jones. David Read and Paul Younger.

[2] Although new 'nano-antenna' technology permits solar panels to work without direct insolation; this technology and new grapheme-based panels stand to greatly increase the efficiency of solar panels.

pools and health spas and industrial uses such as drying, greenhouses and fish farming. A consideration of particular relevance to many low-latitude developing countries and one that greatly widens the range of possible uses is that **geothermal heat can also, paradoxically, be used to deliver valuable cooling,** by means for example of absorption chiller technology.

The global potential for expansion in the direct use of geothermal energy (which can be established across a range of geological situations) is thus far more extensive than for electricity production, especially with the advances made in **geothermal heat pump (GHP) technology** which can operate with shallow groundwater and/or heat stored in soil at only a few metres below ground at temperatures of only a few degrees celsius, thereby **opening up the potential for the development of direct-use geothermal energy projects right across the globe**. Whilst (with the exception of Mexico), there have been few direct-use geothermal projects thus far across the countries of the Global South, this is clearly an area of considerable interest as well as an anticipated area of exponential commercial growth in the near future.

Beyond direct use of heat, **desalinated water is also a common by-product of geothermal power generation, and this offers particular opportunities for addressing water scarcity in those countries with flash power generation**: condensate from geothermal power plants can be captured and re-mineralised inexpensively to deliver low-cost potable water (Younger, 2012). Only one documented case of this is known to date at Eburru in Kenya (still at rather small scale (Mburu and Kinyanjui 2012)), but this technique has enormous potential for wider applicability in those developing countries with high-enthalpy geothermal systems.

There is, finally, a need for more R&D concerning cheap deeper drilling, engineered geothermal systems (EGS) development and more efficient binary cycles which will help reduce costs and widen the potential of geothermal (Kaygusuz, 2012). The country with perhaps the largest potential is China, where it is already extensively in use and where geological conditions across the country for low-temperature use in particular are favourable.

Limitations for countries of the global south:

1. **Locationally specific (resource-centred) factors determine potential for electricity production** – For the purposes of electricity production, currently geo-thermal is limited in the main to active plate boundaries or volcanic areas. In this respect the East African Rift Valley, the whole of Central America, the Andean chain of South America and the island arc of South-East Asia have substantial potential, but there are many countries where this is simply not an option (despite the technological advancements referred to above).

2. **High risks of early drilling in undeveloped fields** – The industry rule of thumb is that the first few wells drilled in a new geothermal field are unlikely to meet with more than 60% success rate (defined as producing usable quantities of steam and/or hot water), whereas once fields are mature, success rates typically exceed 85%. Insurance mechanisms that incentivise early-state drilling in new fields could make a big difference to the development of geothermal power / heat delivery systems using private capital.

3. **High up-front costs** – The up-front costs for geothermal electricity-generation projects are relatively high (drilling accounts for about 1/3 of these) but overall costs have

dropped substantially since the 1970s and continue to drop (Kaygusuz, 2012). Recent decades have seen limited availability of large-scale investment for infrastructural projects in the Global South and this has been a major impediment to the expansion of geothermal generation projects. This will remain an issue given the political uncertainties facing long-term planning for renewables/ alternatives more generally in the global south.

4. **Potential Conflicts of Interest -** It has been suggested that there are broader environmental and scoial implications for geothermal projects in relation to drying up of water resources, soil erosion, land subsidence and even increased seismic activity (Arnórsson, 2004) – although the potential scale and impact of all of these are subject to some discussion in the literature. There is therefore a need to understand and balance the requirements of and for geothermal projects with those of other users (e.g. local communities, tourists) in highly-sensitive environments (see Mariita (2002) on this in relation to Kenya).

5. **Possibility of Contamination -** There can be sensitive issues regarding (for instance) GHPs in dense urban areas which have the potential to affect other users of ground water via the creation of local temperature anomalies and/or chemical pollution, occasioning legal discussions over groundwater temperature limits (for heating and cooling) and distance requirements between geothermal systems (Haehnlein et al, 2010; Younger, 2008). In terms of electricity production, some research (e.g. from Germany) on scales from pipe-work indicates that there are potential problems with the amount of radioactive waste they produce.

Advantages for countries of the global south:

1. **Potential to displace wood-burning stoves in domestic use** –The use of geothermal power (for electric cooking/heating) and/or geothermal heat-pump technology (for direct heat and domestic hot water provision) has the potential to combat deforestation and the respiratory health problems involved in domestic firewood use - although historical experience with cookstove projects demonstrates the detailed social research that would need to accompany any such project development.

2. **Deployable for cooling as well as heating** – There is also significant untapped potential in the role of geothermal energy in cooling across the Global South. The subsurface is typically around 12-15C at about 2m depth which will be cooler than the air temperature in many countries, so cooling can be provided through GHPs, which can be used across a wide variety of regions – examples are currently being developed in Baghdad. There is also the potential of the absorption chiller technology mentioned above.

3. **Wide range of uses** – Because GHPs can be used for both cooling and heating, they can be used for space/area heating or cooling in buildings and a wide, multi-scalar range of agricultural and industrial uses (as discussed above). There is considerable experience in projects of this nature within specific Northern (and some Southern) countries which could provide important potential for technology adaptation, exchange of experiences etc.

4. **Low running-costs and high reliability** – In terms of electricity production, the technology is proven and reliable and once established provides very low-cost power. There are no fuel costs, an indigenous renewable resource is being used that improves

energy security and at the same time reduces the need for expensive energy imports. It is also unaffected by changing climatic conditions, in contrast, for example, to HEP schemes.

5. **Economic potential as power source** – some countries/regions (Central America is a good example of this) have an abundance of geothermal resources as well as a relatively small population and a relatively low level of industrial development producing internal demand. This mix of geological, geographical and demographic features is favourable for the development of geothermal power as an economic resource.

6. **Relatively benign environmental profile** – The size of production plants is very small once constructed. Despite the issues mentioned in the preceding section, the consensus appears to be that the technology has much more limited and localized environmental impacts than technologies with the same electricity generation potential.

7. **High profile of geothermal in countries in development** - In terms of geothermal electricity-generation, existing experience makes for potential collaboration and knowledge transfer amongst low-/medium-income countries as well as a greater equality of partnership with northern countries using geothermal.

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