Maturing Geothermal Energy for Saudi Arabia
Volker Vahrenkamp, Thomas Finkbeiner, Tadeusz Patzek, Hussein Hoteit
KAUST

The Arabian region has rapidly developing societies with some of the highest per capita energy consumption in the world and a projected strong growth in energy demand. At present, there is no noteworthy contribution to the energy mix from renewables. In Saudi Arabia, however, this will change as goals have been set by the government in its Vision 2030 to tap into the exceptional potential for renewables. Mega project developments such as NEOM and the Red Sea Project are to rely to 100% on renewable energy and be carbon neutral in their entirety requiring the development of renewable sources into the countries energy mix. In fact, under the renewable energy plan tens of billions of dollars are to be invested by 2025, so that 10-50 GW of its energy supply will come from renewable resources. This is an ambitious but also sensible goal since the Kingdom can harvest not only its plentiful supply of solar light and heat, and wind, but also has the potential for geothermal energy, which if exploited may offset variations in demand as well as fluctuations in supply. Geothermal may play a vital role if exploited in a technically sound and economic way as this may offset societal variations in demand as well as fluctuations in supply by intermittent renewable energy sources. However, critical details of geothermal energy sources are still unknown – in particular, of how large the potential really is. Further, geothermal energy thus far is mostly thought of as a high enthalpy source for electricity generation. Low-enthalpy sources, suitable for direct heat use for district cooling and desalination via thermal converters have not been properly assessed thus far. Because of these and other knowledge gaps, sources for geothermal energy supply in Saudi Arabia need to be properly mapped, categorized and evaluated in order to contribute to the country’s future energy mix.

Some of the important questions we need to ask are the following:

- Can geothermal energy be matured economically to provide a substantial contribution to the future energy supply?
- Can life-sustaining water [1] desalination and air-conditioning be run by geo-thermal energy?
- Is geothermal energy the sleeping giant in the renewable energy field?

Over one hundred top research, industry, and government representatives from around the world, came together at King Abdullah University of Science and Technology for a 3-day conference to address these and related questions and pave the way for geothermal energy towards practical solutions and applications. The event set the scene for this resource potential by discussing topics ranging from Arabian energy needs to geological potential, from subsurface fluid flow to drilling, from surface energy conversion systems to regulations and economics.

From an international and global perspective it is well understood that geothermal has become part of the solution for renewable mix in many countries. The top geothermal countries with more than 1 GW of power (i.e., USA, Indonesia, Turkey, Mexico, and Iceland) give testimony to this fact. These countries have shown that geothermal is competitive and reliable providing the low-cost energy for electricity production. In addition, geothermal has the exceptional potential in terms of heating and cooling (via advanced heat exchangers). With its major benefit for decarbonization, low enthalpy and direct use of geothermal energy are rapidly expanding their share in the market.
Furthermore, geothermal could offer many useful byproducts such as metals (lithium, zinc, and rare mineral, Salton Sea), food production (fisheries, algae, horticulture), hydrogen production (New Zealand and Iceland) and even health products such as therapeutic muds. These are new value propositions that greatly enhance the value of geothermal energy. Overall, geothermal can be considered a reliable base load energy provider, which guarantees prizes and revenue (this is particularly recognized in the USA).

Critical to any project in Saudi Arabia is to prepare and evaluate it sufficiently as a means for risk mitigation. Figure 1 divides Saudi Arabia largely into four major geologic provinces. Subsurface data to evaluate each of these and identify areas adequate for geothermal projects are sparse in the public domain making major data acquisition campaigns necessary. That said, we gained the following general understanding from conference contributions:

- geothermal gradients increase towards the East and South because the depth to the Moho decreases (i.e., the Moho with its temperature-based definition shallows increasing the thermal gradient to the surface)
- although the temperature gradient in the north-west is around 34°C/km the potential for geothermal energy (even low enthalpy) is low because a temperature of ~100°C occurs only within the dry basement; aquifers within shallower sediments are not sufficiently warm
- the area around Riyadh may offer higher potential for geothermal projects: temperature gradients are around 32°C/km with a temperature of ~100°C encountered at around 2,700m to 3,300m depth; this falls into the depth range of some prolific sandstone aquifers, which have a high yield and hydraulic conductivity averaging a flow rate exceeding 60 l/sec (derived from forty wells).

Figure 1. Schematic digital elevation map of the Arabian peninsula depicting its four main geologic provinces, major cities, two mega project developments along Saudi Arabia’s Red Sea coast – namely NEOM and the Red Sea project (blue stars) – as well as the location of King Abdullah University of Science and Technology (KAUST; red star).
There are many examples from around the world that provide learnings towards facilitating the maturation of geothermal energy as an accessible resource. Leading examples come from the University of Western Australia, the city of Munich in Germany, the Technical University of Delft in the Netherlands and more.

In view of Saudi Arabia’s large CO$_2$ point sources, one of the suitable and promising technologies, which has yet to be piloted, was presented by researchers associated with the ETH in Zurich, Switzerland [2-7]. It combines CO$_2$ capture with geothermal energy and storage (CCUS). Requirements for implementing this technology are a temperature of ~100°C in the reservoir and the existence of a caprock in order to develop a plume of injected CO$_2$, which can then re-produced once the reservoir’s pore volume is saturated with CO$_2$ to at least 40%. Because of the associated phase change from gaseous to supercritical liquid CO$_2$ this process would drive itself and achieve an efficiency and power output of double that compared to a water-driven geothermal system.

In terms of piloting and implementing geothermal energy for Saudi Arabia, the following way forward has been formulated:

- first focus on desalination and cooling using low enthalpy sources before moving into potentially more costly and risky EGS applications
- engage stakeholders; inform and sufficiently educate customers
- begin with a demonstration case (i.e., the “lowest hanging fruit”) to manage expectations and avoids failures:
  - a shallow test well that provides energy for cooling or/and small volume desalination;
  - test different designs of absorption AC which are powered by the well
  - test small scale CO$_2$ injection/production to investigate subsurface processes and efficiency of geothermal using CO$_2$ cycling
- provide a vision and road map to achieve a larger scale implementation of geothermal energy systems.

References


