Enhanced Geothermal Systems (EGS) will Deliver Abundant, Affordable, Clean, Firm Power and Thousands of Jobs for Geologists, Geophysicists, and Petroleum Engineers

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Abstract

Hydraulically fractured horizontal wells are poised to revolutionize the production of electricity from geothermal resources much as they did for the production of oil and natural gas from unconventional reservoirs.

This should not be surprising since the key to unlocking both resources involves creating an extremely large amount of fracture surface area given that heat "flows" at a very slow rate via conduction through most naturally occurring lithologies and hydrocarbons move at a similar pace through nanodarcy permeability reservoirs.

That geothermal resources have been a largely overlooked solution for providing the affordable, clean, firm power needed for reducing greenhouse gas emissions is primarily due to two reasons:

1. The fact that hydrothermal systems (i.e., systems capable of flowing hot fluids to the surface without the need for hydraulic fracturing) are exceeding rare – so rare that exploring for them has resulted in exploration expenses far exceeding the value of the resources that one could reasonably expect to find, and

2. Previous attempts to create enhanced geothermal systems (EGS) almost exclusively relied on the use of vertical wells, which is a well geometry from which it is almost impossible to create sufficient fracture surface area via hydraulic fracturing, leading to either: i) rapid thermal breakthrough between injectors and producers (i.e., the rocks adjacent to fracture surfaces rapidly cool as water moves from a vertical injector to a vertical producer through fractures, resulting in inadequately heated water flowing out of the production well to generate electricity), or ii) the inability to connect injectors with producers, resulting in numerous development dry holes or marginal producers.

These two EGS failure mechanisms can however be relatively easily addressed by using hydraulically fractured horizontal wells since it is possible to create orders of magnitude more fracture surface area from horizontal wells than can be created from vertical wells, thereby making it much easier to connect EGS injectors with producers, avoid thermal breakthrough, and "harvest" resources (i.e., heat for EGS) much more quickly, with this last attribute being what allowed the United States to grow hydrocarbon production from 15 MMBOE per day in 2005 to over 35 MMBOE at year end 2023 using hydraulically fractured horizontal wells to develop unconventional reservoirs.

Importantly from the perspective of SEG, AAPG, and SPE members, EGS exploration and development activities will require an enormous amount of geoscience and petroleum engineering expertise to be deployed, with some of the more interesting applications including, but not being limited to:

1. Exploration for "prospects" with the right combination of lithologies, temperature gradients, and other factors in areas that do not contain large faults or pervasive fracturing (to minimize the risk of induced seismicity and the leak-off of injected fluids),

2. Developing comprehensive data acquisition programs, which will be far more important in EGS than has traditionally been the case for most unconventional reservoir targets since areas likely to be targeted for geothermal development generally contain far fewer well penetrations, seismic surveys, and other types of geophysical data sets than are available in petroleum basins,

3. Characterizing geothermal reservoirs during appraisal and development activities, including the use of fiber optic measurements, microseismic, conventional coring, well & mud logging, and VSPs.

4. Planning subsurface aspects of EGS developments and optimizing operations once fields have commenced production.

Like many other subsurface advancements, EGS using hydraulically fractured horizontal wells was born in the USA, with the U.S. Department of Energy funded Utah FORGE consortium and Fervo Energy's Blue Mountain EGS demonstration project having already established the enormous potential of hydraulically fractured horizontal wells and other O&G industry technologies for reducing the levelized cost of electricity (LCOE) from over $100 per MWh previously to around $60 today, with line of site on achieving an LCOE below $45 per MWh in the near future.

Given this LCOE trajectory, the use of hydraulically fractured horizontal wells to deliver abundant, affordable, clean, firm power from geothermal resources will almost certainly become a global phenomenon, with areas attractive as EGS targets being located throughout many parts of our world (e.g. Japan, Europe, east Africa).

EGS is therefore a topic AAPG, SEG, and SPE members will want to monitor closely and gain knowledge about.