Coal and Geothermal: A Path Forward, January 10, 2018
Participants' Comments and Discussion Points

A SEDHEAT TCU Sponsored Workshop

Executive Summary

While many U.S. power plants are combined-cycle natural gas plants, the largest capacity production is still generated by coal plants, many of which are considered near the end of their useful life because of maintenance and/or regulation updates. The coal plants can be shut-down within a short time-window, in Texas with a 30-day notice, thus impacting the area baseload capacity and employment. Studies over the past five years (Petty, EPRI) show at sites across the U.S., geothermal power can be transitioned into production using the coal plant footprint and infrastructure.

This Workshop discussed the geothermal capacity for converting coal plants to geothermal energy production. The workshop attendees examined the coal conversion capability of current geothermal power from both inside and outside the geothermal community. The attendees used their perspectives to come up with forward path suggestions to an emissions free, yet still baseload power source. The attendee backgrounds included: coal plant operators, experienced oil and gas subsurface and surface operations engineers, geothermal resource exploration and project development experts, technology companies, and outreach organizations focused on both clean energy and the oil and gas industry.

The rationale for examining geothermal energy development at coal plant sites derives from overlapping synergies. Both need similar physical footprints and permitting, market grid connectivity, water input/output, and skilled operating personnel. Through enhanced geothermal system projects, it is possible to develop geothermal power projects at 10*x* MW size with sites outside the conventional hydrothermal settings of western United States. This opens up today's ongoing hot oil & gas industry sedimentary basin operations, and opportunistically growing global geothermal energy production.

The main take-away for the Workshop coordinators is the lack of detailed knowledge about how to develop geothermal energy by the attendees. These are highly intelligent, energy aware individuals who started out asking basic questions from limited exposure to geothermal projects. Then while working in mixed teams with geothermal experts, these energy experts were able to understand the processes as discussed. Once they knew more about how geothermal energy is produced and the cross-overs between the coal and geothermal power projects, there was buy-in from Workshop attendees.

As part of this report, the types of questions/comments from the attendees are highlighted to guide future outreach efforts towards the energy industry and public. Similar to the need for reservoir resource evaluation of geothermal projects, there is also a critical need for an education program aimed at different educational backgrounds to reach people in government, finance, energy, and general public.

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Coal and Geothermal: A Path Forward

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January 10, 2018

Workshop Sponsor

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Workshop Focused Topics, Participant Questions and Answer

This SMU Geothermal Laboratory and SedHeat Workshop was a one-day event to examine ideas on how geothermal power can be used as a replacement energy source where a coal plant is currently located. The participants came together in the morning with overview presentations on the basics of geothermal power, drilling techniques, energy management, and resource availability. Then teams of 5 – 10 people focused on specific topics to delve deeper using their diverse backgrounds. The topics covered at the team level were: surface engineering, drilling – downhole engineering, reservoir development, community involvement, and economics. The group followed-up with panel discussions and a summary of ideas presented at the group level.

From these discussions there are key paths forward for the geothermal community to expand on as they research and develop projects in sedimentary basins and near coal plants. The topics of highest priority are:

Increasing general geothermal awareness and understanding;

Defining the mechanism for replacement and financing of a coal plant conversion to a geothermal power plant;

Expanding on techniques for Enhanced Geothermal Systems (EGS) to include supercritical geothermal opportunities and CO_2 – Carbon Sequestration.

The following synthesis summarizes the primary understanding and questions/suggestions from the day's activities.

General Geothermal Understanding

Geothermal power is baseload, renewable power (the only one besides hydro) that can be coupled with solar, wind, or energy storage to enhance power production flexibility and used as part of a power storage solution. It is a solution that uses and expands the knowledge of the oil and gas drilling into more difficult environments. In sedimentary formations, geothermal power production is technically possible through the use of fracture stimulation/creation and horizontal drilling. Hot rock resource extraction techniques (>300°F) are already being used in specialized shale plays, e.g., Haynesville Shale where temperatures are over 350°F.

Geothermal reservoirs normally last longer than the financed 30 years, but this length of timeline is not yet proven for sedimentary basin geothermal projects. Using the oil and gas industry experience, geothermal resources are expected to have a longer than 30 year lifespan. A geothermal field lifespan has been calculated to be over 100 years in geopressured and sedimentary formations in the research by the MIT researchers for the Future of Geothermal Energy (2006).

Questions

Are geothermal wells cased and screened similar to water wells? **Response –** in hydrothermal geothermal wells, most geothermal wells are completed with a slotted line across the productive zone. No cement is used in the productive interval. They are not completed like water wells. In sedimentary formations, a geothermal well is expected to be similar in casing and perforation (more of them or larger?) than the oil/gas industry standards.

Do production and injection amounts vary over time over the life of a project? **Response –** Yes, even on a daily basis they can change. Geothermal power plants fluctuate output, yet the changes in the thermal loads must be included in the design and long-term maintenance. The wells typically operate with pumps and VFDs such that the inlet flow rate into the plant can be reduced drastically without too much strain on the system. A power plant will spin rather than completely shut down and turn back on to maintain the rotating equipment.

What type of maintenance cycles are anticipated in long term systems, e.g., production chemicals, sealing failing? **Response –** the chemicals used will be determined by the chemistry of the produced fluids, therefore each location will have specific needs. Typically the maintenance of geothermal plants is between 4 – 10% of the operating time for the year.

What are the well intervention frequency for equipment, well repairs, logging for integrity and re-stimulation? **Response -** Every state in the US has different rules for injection wells. But, mechanical integrity testing and caliper logs are typically required in injection wells every 2-5 years to demonstrate that the groundwater is still protected. Production wells do not typically have any regulatory requirements as it pertains to long-term logging for integrity. The production wells either self-flow or are pumped with ESPs or line shaft pumps. Maintenance for pumped wells is more frequent due to equipment failure. As long as water chemistry is monitored and downhole treatment is applied as required to prevent corrosion or scaling, the wellbores last a long time and do not require intervention.

In a steam reservoir without sufficient recharge, the steam can become superheated and can be highly corrosive at this point. Sufficient recharge of injectate is necessary to maintain reservoir life and prevent corrosive fluids.

Suggestion

Review sites where crust may have flexed due to glaciation. (Bakken) Deadwood (4.5km)

Sedimentary EGS can use Landsat imagery to identify fractures penetrating to hotter formations.

Induced seismicity-lessons learned >100,000bbls/mo, avoid faults that reach basement

Passive, autonomous solutions for flow conformance is currently part of the High Temperature research of the C-FER Technologies SAG-D program.

Conversion Process from Coal to Geothermal – Steps to Take

University of Texas, Austin MBA student's determined a positive return on investments for their East Texas coal to geothermal project conversion using the public data in the area of East Texas Coal Plants This is an exciting first use of public data that the rest of the industry can use too. It is reasonable to expect that if we take an actual project with site and land owners' information we can determine if it is possible to develop geothermal at any site in the US. Blade Energy Partners and AltaRock Energy are two other groups working on the conversion of coal plants. As companies they have worked with coal plant owners to determine the actual sites a P10 to P90 analyses. These are necessary for actual site power potential (MWs) from nearby geothermal resources and the requirements for drilling, etc.

Questions

What is the step-by-step process of how to develop a geothermal site? **Response -** A feasibility study should be performed first. The study should include resource data gathering, initial resource assessment, and an initial economic evaluation of the EGS operation. If the economics are favorable, then the project would proceed forward with drilling a temperature gradient / core hole at the desired location to further understand the geothermal gradient and expected stress and lithologies at depth. If the initial results of temperature gradient holes are favorable, a plan to drill the wellfield is drafted with costs. With the drilling of an injection well, the targeted depth is stimulated and an installed microseismic array maps the "reservoir" being created from the stimulation. This microseismic cloud represents the drilling target for the production well. Once the production well is drilled, circulation testing and further stimulation of the well couplet commences. Information from the circulation test on geothermal brine chemistry, flow rates, producing temperatures, and connectivity of the wells determines the next step of designing the power plant. The power plant funding is finalized and built while additional well couplets (producer-injector wells) are drilled to reach the desired number for generation and ultimate mass flow rate. This process can take a year to multiple years depending on the site, permits, financing availability, etc.

What is the expected time frame to go from a coal plant with 0% geothermal to 100% geothermal? **Response** – depending on funding, from three to ten years.

Are reuses of equipment between coal and geothermal? **Response** – yes, many aspects of the coal footprint can be reused.

Is there a study of existing overlapping site needs/uses, permit changes to use the geothermal or coal heat during the conversion process? **Response** – There are a few studies completed for site specific coal plants.

Would the current cooling lake for a coal plant be enough? **Response –** This would be determined on a site-by-site basis during the feasibility study phase, yet this is expected to be generally yes unless there is a drought.

How much recharge/filling of the coal cooling pond takes place? **Response -** Only in a drought is there a need for make-up water currently. In geothermal power plants, make-up water supply wells and water rights are required for cooling tower chemistry and supply water to make-up for evaporative losses.

Are there other integration possibilities of CO_2/Natural Gas/Solar/Wind to assist in moving towards the desired final MWs? **Response** – Yes, with each plant site other integrated energy sources can be incorporated at the surface since the geothermal infrastructure is primarily below ground. If there are natural gas pipelines in the area, than extracting the gas from geothermally produced fluids can be incorporated as part of the energy stream.

Suggestions

Contact coal plants and industrial sites in communities currently interested in coal plant closure and discuss geothermal potential as a resource.

Talk one-on-one with municipalities who own a coal fired plant and determine what liabilities they are looking to remove by mothballing and/or repurposing coal plants and/or industrial sites.

Direct Use types of projects could be used as a lower risk, strong starting point for projects in new areas to prove resource and drilling.

Use waste water from coal plant as a process fluid for geothermal to reduce the number of permits necessary for a geothermal project. This helps the coal plant with the requirement for their water treatment methodologies to meet the Effluent Limitation Guidelines (ELG) compliance limits and Coal Combustion Residual (CCR) regulations when closing an ash pond.

Enhanced Geothermal Systems (EGS) and Supercritical Geothermal Opportunities

There are no insurmountable problems with Enhanced Geothermal Systems (EGS) or geothermal power production. We have not solved all the problems, yet this does not mean they are insurmountable – rather there has not been enough time or money. EGS is very much site specific - not necessarily replicable from site to site. Still, geothermal wells in the US go back to the 1960s. They are just as reliable as oil and gas wells and have expected lifespans between 20 and 30 years. There are wells in the Geysers field that are much older. Therefore we have sufficient data on the potential long term reliability and failure rates of the wells used for EGS projects.

Multiple countries and companies are already undertaking supercritical R&D for geothermal because the economics are so appealing (due to the high energy density of supercritical water). Iceland, Mexico, Italy, New Zealand and Japan are working on supercritical projects. In the U.S., AltaRock Energy is raising funds for a supercritical geothermal project at their leasehold in central Oregon.

Questions

Does EGS use more or less water than binary or hydrothermal geothermal projects?

If we develop supercritical conditions and drill deeper wells, does this make EGS more economical? **Response** - Yes, the energy density of supercritical steam is ~10 times that of regular steam, so supercritical is an advantageous resource to aim for if we are already drilling in areas that do not have conventional hydrothermal systems.

Suggestions

Stop the focus of low temperature EGS to reduce the 'distraction' and put more effort into developing tools and skills to reach supercritical EGS as it is a geothermal game-changer from an economics and global adoption standpoint.

CO_2 – Carbon Sequestration

There is a significant learning curve and cost to go from hydrothermal – geothermal plants in terms of well and equipment design/metallurgy to using CO_2 – Sequestration. There are ways to couple with coal plants and oil/gas for brown fields (SPE talk was given discussing idea, Robert Balch – NM Tech) to improve the learning curve. The oil and gas industry is already working with CO_2 with companies such as Denbury Resources, KinderMorgan and Occidental. It is expected that for carbon capture in a CO_2 cycle geothermal plant to be economically viable there needs to be broader application of a carbon tax or carbon limits regulation. As this process hasn't been attempted, the costs are not fully understood. The corrosion could be difficult to control, forcing the project to utilize expensive metallurgies like chrome to prevent premature equipment and well failure. There is a project in Texas discussing using the CO_2 as part of their solution for a geothermal plant collocated with an oil refinery.

Questions

Are the emissions from a coal-fired power plant sufficient to sustain a CO_2 system? What about the newer plants, can they also be used?

What are the parasitic loads of a supercritical CO_2 – geothermal generation plant?

- -pumps itself
- -no heat exchange necessary
- -cool CO_2 to inject it
- -reduce power to coal plant while increasing geothermal plant output.

Suggestion

Develop ways to use CO_2 in geothermal projects for both efficiency and carbon capture.

Big Picture Next Steps

The social and political aspects of our society directly impact our industry. From new technology adaptation to financing of projects, there are many reasons to focus on the related mechanisms of how geothermal projects can be improved with more societal awareness. A detailed discussion was included in the workshop and breakout sessions found the following questions and suggestions to move geothermal projects forward.

Suggestions

Geothermal energy is still considered a new energy source in sedimentary basins. Find a way to develop Community-geothermal power similar to solar.

Determine who to approach for greater community buy-in. Is it companies like Google, Microsoft, Amazon, Uber, etc - companies that use significant electricity AND are interested in a low-carbon mix as a way to find customers willing to pay a premium? Is it Public Utilities to help attract new customers/companies into their grid?

Follow the development occurring first in Europe/China to use their higher environmental standards and government financial incentives because of greater social-environmental-economic need.

Work with government/regulators to write bills to encourage geothermal, CO_2, coal combinations.

Highlight how spinning reserves in geothermal power can be useful for grid stability.

<u>Example: How to jump-start policy implementation for coal conversion</u>:

A team for education of decision makers includes: industry CEOs, academic leaders and respected engineers.

-Meet with the state senators in key states such as Texas, Alaska.

-Meet with Department of Energy leaders.

-Meet with utility executives-CEO: Duke Energy, Florida Power, CPS, AEP, etc.

-10 Meetings over one year time period; cost $25,000 to $40,000.

Keep Educating! Submit abstracts and presenting at other industry conferences (SPE, IADC, etc.). What is the cost of conversion of a coal-fired power plant to a *natural gas* fired power plant? How does this conversion compare in price and time from the expected geothermal conversion?

The "pieces" are there, but the industry needs to put them together with investment money and take advantage of opportunities to demonstrate the available technologies. The scale of coal conversion is huge (50,000 MW) in the near future. Develop one real example to prove to the public the capability and cost. Next, a key hurdle for the geothermal industry progress is creating scale pilots that encompass the impact of learning resource use efficiencies and efficiencies of scale.

Discussion of geothermal resources needs to be expanded from exclusively for its power generation to the many other benefits, e.g., district heating to carbon sequestration. Cheap power and tax imbalances present a large threat to EGS proliferation in the U.S. The European market is embracing EGS for deep heat direct use and power, this is a potential in-road for EGS to become a mainstream power source in the U.S.

Private investor money is available. For too long, geothermal has been reliant on government subsidies and hopes of tax credits. We need successes to point to for prominent angel investors and guardians of the public trusts to help us deliver the message of the promise geothermal holds. Think outside the box. Example: AltaRock Energy is looking into “stadium seat investing” where large players, like oil & gas multinational conglomerates, can buy access to the data and results that are generated from the supercritical R&D, but don’t have to necessarily invest at very high levels. IRR of a conversion project is sufficient for private investment but can it compete with other projects using mature technologies-coal and natural gas combined cycle?

For regulated investor owned power generation, we must provide an economical product that is capable of scrutiny by a utility commission.

Considerations for Coal Plants existing within a Community today

Social Risk

Don’t assume communities want to keep the coal power plant.

Ask communities what is important, e.g., jobs, environment, and safety.

Ask communities what are concerns, e.g., geothermal energy, drilling, and power production.

Are there opportunities to reduce power grid needs in broader distribution system?

Are there lower temperature, distributed, or cascading energy opportunities in area? To build confidence in geothermal are there small projects or deployment of projects to gain community acceptance?

Accommodate the message to reach the community based on education, culture, and relationship with coal plant. Who is the audience? Who is the messenger?

Discuss potential problems and develop risk levels and responsibilities. Develop community resiliency for project when “challenges/BAD” things occur.

- Plants are designed for 30 years because of bank loans/profit/loss.
- Wells/equipment may have corrosion issues that need workovers.
- Reserve wells are usually included in initial design for replacement over the life (and future life) of the field.

Are there existing models that incorporate social aspects in the conversion process? Once coal power plant is already in existence is it “easier” to convert to geothermal?

“Not in my backyard” –a problem if plant is designed for 30 years and project doesn’t realize the projected outcome. Can we keep finding more sites in 2050? How to make sure first few projects meet owner and community expectations?

What are the synergies between coal and geothermal power plants to provide cost savings for existing plants? How can geothermal work with our existing coal plant operators?

Political Risk

Who is the President impacts government decisions top – down.

Community (state/county/city) at each level grassroots efforts cause change.

Community outreach and education are key to getting geothermal established as a viable commercial energy option in a broader context. The geothermal industry is small and the participants are well informed and influential. Now the message needs to be pointed outward.

Induced seismicity is a concern within the oil and gas industry. Geothermal projects will also deal with this concern. Public notification and education is critical to the success of any project. Monitoring and open access to the seismicity data was shown to be helpful in public acceptance of the project at Newberry in central Oregon.

Determine the root cause analyses that are critical to the growth of the industry.

The geothermal community develops materials and communication with investors to understand it from capacity, then to assist in feeling comfortable with the risks.

As more individuals then communities buy-in to geothermal projects then increased financial risk is allowable for government officials and utilities.

Improve ability to find regulations on geothermal resources, they are buried within oil & gas regulations, particularly in Texas and other oil/gas states.

Climate Change is causing new energy awareness.

Summary Thoughts – Bob Pilko

Energy and electrical generation needed at large base load scale everywhere.

Geothermal provides continual baseload - resource base is global.

Economics only drives the depth at which the resource prize brings value.

Drilling & completion feasible (the technology exists today) to reach the geothermal resource prize anywhere.

Drilling & completion costs today are relatively low now - with the largest economic factor being the cost of tubulars (casing & tubing).

Proper geothermal well design integrating metallurgy & connection design in tubular selection can result in lower than expected tubular costs, and/or specialty tubulars & connections rolled by mills on special orders.

Land & facilities & electrical transmission costs low when existing power plants or industrial facilities re-purpose or multi-purpose to produce geothermal energy for internal site, regional use, and/or sale to grid.

Geothermal does not burn hydrocarbons that produce CO_2, though associated oil or gas or CO_2 or H_2S or other substances may be produced.

Geothermal injection can be used to consume waste water flows and/or be a carbon sequester.

Geothermal can and should stand on its own without Government subsidies or incentives to be sustainable over its 20-40 year wells life & investment plan.

Geothermal requires high initial wells Capex, yet low annual Opex over time - providing long-term cash flow and investment returns.