Dynamic duo: Oil/gas and geothermal

Greater capital discipline and mitigated project risk have leaned up the current E&P sector. As economics begin to line up post pandemic, industry has set its sights on getting back to the business of pumping $70-a-barrel oil and building up returns to investors.

Business as usual, though, may have a few obstacles this time around. A push from investors is driving industry to realize that oilfield capital is contingent on demonstrable ESG (environmental, social and governance) programs and records.

Case in point is Exxon Mobil Corp. Activist hedge fund Engine No. 1 flexed its muscles this year after bulking up on institutional investment, including pension-fund backing. The "little engine that could" bought big chunks of Exxon equity and last May, voted in board members aligned with ESG.

Oil and gas companies now face the real prospect of change from the inside out. With little choice but to comply, industry has to take a serious look at renewable resources, including offshore wind energy and increasing stakes in solar energy.

The sun beneath our feet

Perhaps the most natural fit for energy diversification is the extraction of heat from hydrothermal reservoirs where water in the host rock is heated by a high geothermal gradient in the earth's crust. Tapping into the earth's natural heat to power residences and businesses is the essence of geothermal power.

Geothermal, considered a niche industry, is often overlooked. It only accounts for 0.4 percent of net electricity generation in the United States, which produces the most geothermal electricity in the world: more than 3.5 GW or enough to power about 3.5 million homes.

"How Geothermal Energy Works," published by Save on Energy LLC, outlines three main types of geothermal energy plants – dry steam, flash steam and binary cycle.

Expansion Pipework at the Nga Awa Purua geothermal power station in Taupo, New Zealand. Courtesy Creative Commons by Geothermal Resources Council; Licensed under CC BY-NC-ND 2.0

Binary ORC plants

Binary cycle plants circulate hot subsurface waters or steam in closed-loop systems (similar to a radiator). Water/steam is pumped to a heat exchanger where it heats a second liquid — an organic fluid, such as isobutene, which boils at a lower temperature than water. The Save on Energy primer summarizes open- and closed-loop systems.

Closed-loop systems with power generation based on Organic Rankine Cycle (ORC) are making it possible to produce electricity from low-temperature geothermal resources less than 100º C.

This opens up vast opportunities worldwide for geothermal energy. ORC has generated more than 2.7 GW of installed capacity for more than 700 power plants worldwide.

Focusing on ORC, **Mariia Shmeleva** wrote "Geothermal Energy Production from Oil and Gas Wells," an MS-degree thesis at the Gubkin Russian State University of Oil and Gas in 2018.

The thesis summarizes in more detail the ORC technology used to maximize thermal energy from oil and gas wells.

"ORC power generation using low-temperature geothermal resources is one of the most common geothermal power generation technologies," she writes. "The extracted water from a well is pumped to the evaporator where it transfers its heat to the organic working fluid. Shell and tube heat exchangers are widely used.

The heated organic fluid boils and high-pressure vapor drives the axial flow or radial inflow turbine, which is coupled to a generator. So, mechanical work is converted into electrical power. Then organic fluid is cooled and condensed. From the condenser, it is pumped back … (as) the cycle repeats again."

The Raft River geothermal plant, constructed in 1979, was the first binary-cycle commercial power plant in the U.S. Courtesy Creative Commons by Idaho National Laboratory; Licensed under CC BY 2.0

Crossover potential

For oil and gas drillers, geothermal developments have good crossover potential.

"No one is better at digging holes than the oil and gas sector. Over the last century, the industry has perfected the art of extracting fossil fuels many miles below the surface. Its future, however, may be in digging for heat," stated climate reporter **Michael J. Coren** in an article published by *Quartz Media Inc.* this year.

For oil and gas personnel in transition, geothermal makes use of many of the same skills.

"The transition from oil and gas to deep geothermal is a big opportunity for a highly skilled workforce that operates the drilling platforms," **Igor Kočiš**, CEO of Slovakia-based GA Drilling, told *Rigzone* recently. "On the side of upstream, the jobs are the same or similar – drilling, casing, cementing, drilling muds, logging, reservoir, production, etc."

Bottom line in kWh

In the renewables world, geothermal is a fledgling unable to compete with solar and wind, as measured by lobbying budgets and political pull. Solar and wind energy have historically raked in higher subsidies and incentives than geothermal companies.

Solar and wind also are reigning in costs more rapidly than geothermal.

The latest report from the International Renewable Energy Agency recently reported that solar and onshore wind remain as the cheapest new energy sources. Solar photovoltaics (PV) shows the sharpest cost decline over 2010-2019 at 82 percent, followed by concentrated solar power (CSP) at 47 percent, onshore wind at 40 percent and offshore wind at 29 percent.

Electricity costs from utility-scale solar photovoltaic cells fell 13 percent year-on-year, reaching nearly 7 cents per kWh in 2019. Onshore and offshore wind both fell about 9 percent

Please see Dynamic Duo: Oil/gas and Geothermal on page 4

Dynamic Duo: Oil/gas and Geothermal – Cont. from page 3

year-on-year, reaching 53 cents per kWh and more than 11 cents per kWh, respectively, for newly commissioned projects. Costs for CSP, still the least developed among solar and wind technologies, fell 1 percent to 18 cents per kWh.

Costs for utility-scale geothermal energy are as high as 17 cents per kWh for greenfield developments in remote areas. Where the costs begin to become more interesting to the oil and gas sector is second-stage development of existing fields for a rock-bottom 4 cents per kWh.

Wind and solar are developing and using battery back-ups, enabling those industries to provide more reliable power generation whether the wind blows or sun shines.

Nevertheless, geothermal is the most reliable source of renewable energy during various base- and peak-load cycles for electricity. Geothermal has a vital role in the energy mix that powers electrical generating plants during critical periods.

"Over the last few years, a number of start-ups in the geothermal space have gained traction, such as Eavor Technologies, Fervo Energy, Sage Geoystems, and GreenFire Energy," stated **Katie Brigham**, a *CNBC* producer, in May. A video accompanied the summary.

The new ventures are not big companies, but have the financial backing of several IOCs (international oil companies).

Petroleum-geothermal mix

The cost of drilling geothermal wells is 30 to 70 percent of the total investment to establish an industrial plant. That has given rise to a renewed interest in repurposing abandoned oil and gas wells for geothermal purposes.

"Practically, however, it's not that straightforward," according to an article by **Irina Slave** this year in *OilPrice.com* that answers the question, "Can Abandoned Oil Wells Be Used To Generate Geothermal Power?"

"For starters, flow rates from such wells are much lower than from newly drilled geothermal wells," **Jamie Beard** told *Oilprice*. She is executive director of the Geothermal Entrepreneurship Organization at the University of Texas at Austin.

"Then there is the issue of heat: most oil wells are simply not hot enough to make sense if we are talking about electricity generation, said Beard. "Existing wells often suffer from well integrity issues that will make them ill-suited for a 20- to 40-year lifespan as a producing geothermal asset."

Another article this year considered the repurposing of abandoned oil and gas wells. **Matthew Veazy** at *Rigzone* interviewed **Karl Farrow**, CEO of the geothermal project development firm CeraPhi Energy Ltd.

"So, we shouldn't expect that a repurposed oil well will replicate the results you would expect from a purposely drilled geothermal well in a geyser zone in California," said Farrow. "However, consider the repurposing of oil and gas wells effectively as having pilot test wells or the wildcat already-drilled well – following from which you then have the ability to prove up a new commercial case to help decarbonize a business model on that site and, if commercial, you have scalability and can drill new wells specifically for the production and configuration you require."

Derrick at St. Gallen geothermal project. Courtesy Creative Commons by Kecko; Licensed under CC BY 2.0. Geothermal drilling rigs are indistinguishable from oil and gas rigs. St. Gallen in Switzerland was temporarily sealed in 2013 after a gas kick and earthquake, and is now used for research.

The politics of oil well abandonment will also influence the future of retrofitting for geothermal, as lawmakers and regulators erect hurdles.

In an *OilPrice* article last May, "How Canada Could Repurpose Oil Wells for Its Renewable Revolution," **Felicity Bradstock**, a freelance writer, examines the tradeoffs.

In the article, **Regan Boychuk** at the Alberta Liabilities Disclosure Project said, "It's a transparent attempt to pass this liability to someone else."

Bradstock points out that repurposing the wells in Canada "would effectively shift the clean-up burden from the government to private companies, taking away the cost to the taxpayer," which is estimated at $166 billion.

Watered out, not down for the count

In some cases, operators of mature oil and gas fields with high water cut can use produced water as a carrier of heat.

Industry has established hydrothermal projects with low-temperature energy recovery in several regions of the world. Potential candidates for this conversion are mature oil and gas wells with adequate exit pressures, surface temperatures greater than 135º C, 10,000 B/D total fluid-flow rates and water cuts of more than 50 percent. Conversion of heat to electricity is used to power the field or nearby host communities.

"A high bottom-hole temperature, reliable wellbore integrity, and large production capacity make a well a viable candidate for geothermal energy extraction. Because geothermal energy has caught the attention of the oil and gas industry, there is interest in modifying existing wells. …Abandoned oil and gas wells can play a vital role in geothermal resource utilization," stated the authors of "Potential for heat production by retrofitting abandoned gas wells into geothermal wells," a paper published by Public Library of Science, 2019.

Outside ring of fire

California is the epicenter in the U.S. for shallow, hot reservoirs suitable for economic generation of thermal energy. Sliding through the state is the "ring of fire" created by the interaction of the Eurasian, Pacific and Indian-Australian tectonic plates.

The ring enables California to be the No. 1 source in the world for electricity from geothermal energy. The Geysers in northern California comprise the largest dry steam field in the world.

Not every geothermal energy producer can be located in the ring of fire. Oil and gas companies looking at opportunities have no further to go than their own backyards, in some cases.

For instance, the deepest, hottest reservoirs in the Permian Basin are in the Delaware sub-basin, and are the focus of a well repurposing study by TGS, an energy data and intelligence company headquartered in Oslo, Norway.

The company published a technical article this year on oil and gas well data for use in geothermal prospecting.

"There is a vast resource of data and analyses utilized by the oil and gas industry that may be effectively repurposed for other industries, such as developing geothermal resources," the report stated.

Useful information includes oil and gas well performance and production data, well completion data and basin temperature data and models.

"Combining end of life economic data with well depth, producing formations, completion intervals, and maximum production rates within a stratigraphic framework offers value to companies interested in assessing alternatives to abandoning their assets," the TGS article stated.

TGS plotted decline curves of Delaware Basin production wells for comparative analysis of potential fluid flow rates to evaluate repurposing. The firm also built a temperature model.

Artificial hydrothermal reservoirs

Industry and government have collaborated in developing engineered enhanced geothermal systems (EGSs) that, in some cases, make use of oil and gas wells and technology.

The EGS concept is to extract heat by creating a subsurface fracture system and adding water through injection wells. Creating an enhanced, or engineered, geothermal system requires improving the natural permeability of rock, which is dependent on fractures and pore spaces between mineral grains.

In a dual-well system, an injection well pumps water into a thermal reservoir of hot, dry rocks. That opens natural fractures and creates new fracture networks and flow paths that intersect the wellbore. The increased permeability maximizes heat exchange and output.

A two-way circulatory flow system includes bringing steam to the surface through a production well. After the heat energy feeds into a turbine for electrical power, the leftover condensed water is collected and reinjected downhole.

"The implementation of enhanced (or engineered) geothermal systems, following the original hot dry rocks (HDR) two-well or doublet model, has been met with technical and economic challenges, lower-than-expected performance and limited public acceptance, as they typically require the 'engineering' of the reservoir by artificial stimulation to create the necessary heat exchange in the subsurface," stated a U.S. Department of Energy paper, "Assessment of Deep Geothermal Energy Exploitation Methods: the Need for Novel Single-Well Solutions," Volume 160, October 2018.

However, the energy landscape and politics have changed dramatically in the three years since the DOE publication. Energy providers are seriously assessing the scalability and profit potential of EGS.

For one, it makes it possible to tap into deep high-temperature reservoirs that are much more abundant than shallow hydro-geothermal energy sources, such as hot springs, volcanoes, geysers and other tectonically active areas.

Secondly, drilling-and-completion technology developed for shale plays is successfully used in geothermal projects. Most production wells have been vertical, but horizontal wells hold more promise. Geothermal projects can make use of

Please see Dynamic Duo: Oil/gas and Geothermal on page 6

A section of the Hellisheidi geothermal power plant complex. Courtesy Creative Commons by Martin V. Morris; Licensed under CC BY-SA 2.0. Hellisheidi, the newest and largest geothermal project in Iceland, is a flash steam plant that can generate 300 MW of power and 400 MW thermal.

Dynamic Duo: Oil/gas and Geothermal – Cont. from page 5

hydraulic fracturing developed and refined over the past 15 years to tap into tight oil and gas plays.

Shale plays have become proving grounds for staging repeatable "manufacturing" processes. Geothermal is poised to be scaled that way.

Some indirect evidence in models predicts multi-stage horizontal wells will experience early thermal breakdown along higher-conductivity fractures, and as such, will need intervention.

EGS can produce from a greater "inventory" of dry thermal reservoirs with wider ranges of porosity, permeability, fracture distribution and connectivity than conventional hydrothermal accumulations. Lower reservoir-risk profiles also reduce exploration-and-development uncertainties.

High heat

Three "classes" of fluid temperatures at the wellhead are high (>180º C), intermediate (100 to 180º C) and low (30 to 100º C). High-temperature geothermal resources generate energy for industrial power plants, while low and medium temperatures typically are used for small-scale local power and heat pumps.

The offshore oil and gas industry has developed high-temperature, high-pressure (HTHP) drilling, completions and downhole tools, which are essential in geothermal energy extraction.

This year, an article published in the *Journal of Petroleum Technology*, introduced the growing concept of applied HTHP technology for geothermal projects.

Judy Feder wrote the January article, "Geothermal Well Construction: A Step Change in Oil and Gas Technologies."

She stated, "The cutting-edge technological developments in geothermal are devoted to drilling into deeper, hotter and harder rock. Oil and gas expertise and know-how holds the key to cost reduction."

The service companies are taking the lead on this technical front.

"Numerous oil and gas service companies are contributing to game-changing capability and cost improvements in deep (especially horizontal) well construction, logging, and materials that enable completions in ultrahigh-temperature regions; high-temperature cement and well casing that increases long-term well integrity; research ... on different working fluids, such as water and supercritical CO^2 (sCO^2)—that is, above the temperature at which it is neither gas nor liquid, but has properties of both," wrote Feder.

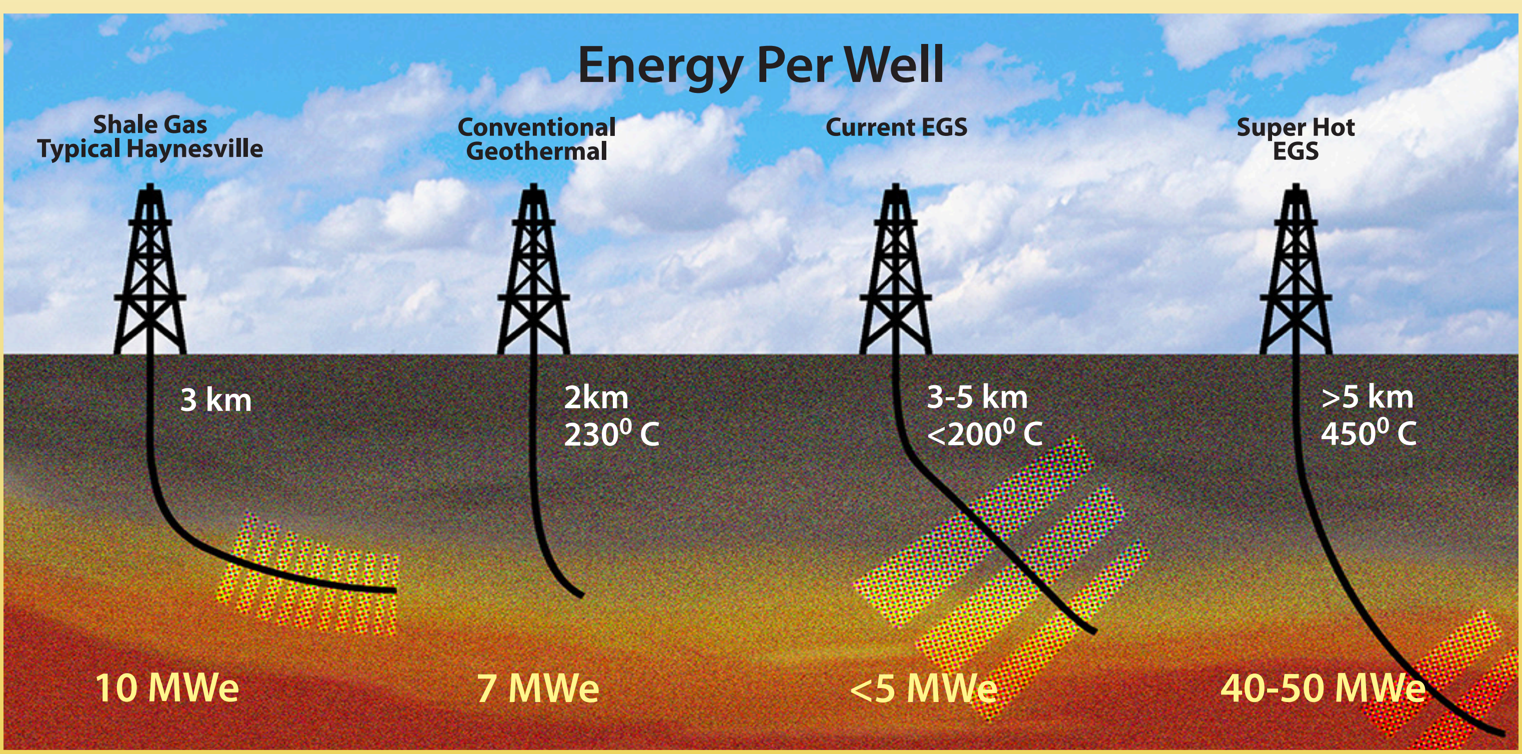
Hotter rock may be the future of EGS. Japan, Iceland, Mexico, Italy and New Zealand are investigating the development of very high temperature geothermal resources greater than 400º C using EGS methods.

A technical paper by **Susan Petty**, et al., "Technology Needs for Superhot EGS Development," explores the potential of harnessing the thermal energy of superheated rocks in brittle-ductile transition zones some of which are 5- to 6-km deep.

The paper, presented at the 45th Workshop on Geothermal Reservoir Engineering last year at Stanford University, delves into three areas of short- and long-term development needs: Wellfield development, reservoir characterization and creation, and long-term resource management.

The following chart from the paper shows relative megawatts (MW) of energy per well.

Please see Dynamic Duo: Oil/gas and Geothermal on page 9



Dynamic Duo: Oil/gas and Geothermal – Cont. from page 6

Petty, et al., state that water at 450^{o} C has four times the energy density of water at 200^{o} C while the energy conversion efficiency is 2.5 times that of ORC. Energy density is the amount of energy stored in a given system or region of space per unit volume. Energy conversion efficiency is the ratio between the useful output of an energy conversion machine and the input, in energy terms.

"While the U.S. DOE is focused on EGS at lower temperatures, the international geothermal community understands the economic value of producing supercritical fluid," stated Petty, et al.

No looking back

SPE is co-sponsoring the second part of a high-temperature well cementing workshop Oct. 7 to 9 in San Diego.

The event will be an opportunity for the petroleum and geothermal industries to share knowledge on the latest technical innovations, advancements, and best practices.

In addition to well completions events, SPE has presented the drilling side at the SPE/GRC (Geothermal Resources Council) Workshop, "High-Temperature and Corrosion in Drilling and Production - Exploring Geothermal and Oil and Gas Synergies," in March 2017.

The new name of the GRC professional association is Geothermal Rising.

If the pundits are right, the upstream industry will have to embrace change to survive long term. Undoubtedly, geothermal fills in all the blanks for the petroleum industry and its future. Crossover potential includes leveraging oil and gas technology developed over more than 75 years to scale up geothermal development.