EXECUTIVE INSIGHTS

Geothermal: Is This the Right Time To Win?

As the global energy system continues its expansion of renewable resources, a new long-term and potentially sizable opportunity in energy is beginning to come into focus: geothermal.

Geothermal energy represents a relatively small share of U.S. renewable energy consumption (current capacity is a mere 1,351 megawatts (MW) out of the total installed power generation infrastructure of approximately 258 gigawatts as of September 2023)[1] and is forecast to experience modest growth of some 1% per year through 2035, in the most conservative scenario. But it's gaining momentum as a result of underlying growth in renewable energy, a market with enormous potential for further expansion.

Indeed, the limited long-term feasibility of fossil-based resources, ongoing improvements in the economics of renewable technologies versus traditional oil and gas (O&G), and an increase in awareness around sustainability that has consumers looking for more environmentally friendly energy resources make geothermal an increasingly attractive area in which to invest. Other factors include technological advances, government regulations and policies that support renewable energy projects broadly and geothermal work specifically, and increased activity from geothermal-focused startup/tech companies. While geothermal energy development projects have historically been both lengthy and costly, technological advances, government regulations and increased interest from geothermal-focused startups have restored interest in the space.

Moreover, geothermal is an area in which traditional energy companies have transferable proficiencies. O&G market participants, namely oil-field services and equipment (OFSE) providers, have expertise below ground (e.g., exploration, well construction, reservoir management) and related offerings that they can redirect to geothermal energy with minimal effort. Those focused on utilities, meanwhile, such as engineering and design firms; engineering, procurement and construction (EPC) companies; and equipment manufacturers can apply their aboveground skill sets and technologies to geothermal power plants. A shift to geothermal would be a natural — and lucrative — evolution of their skills and experience (and those of their investors).

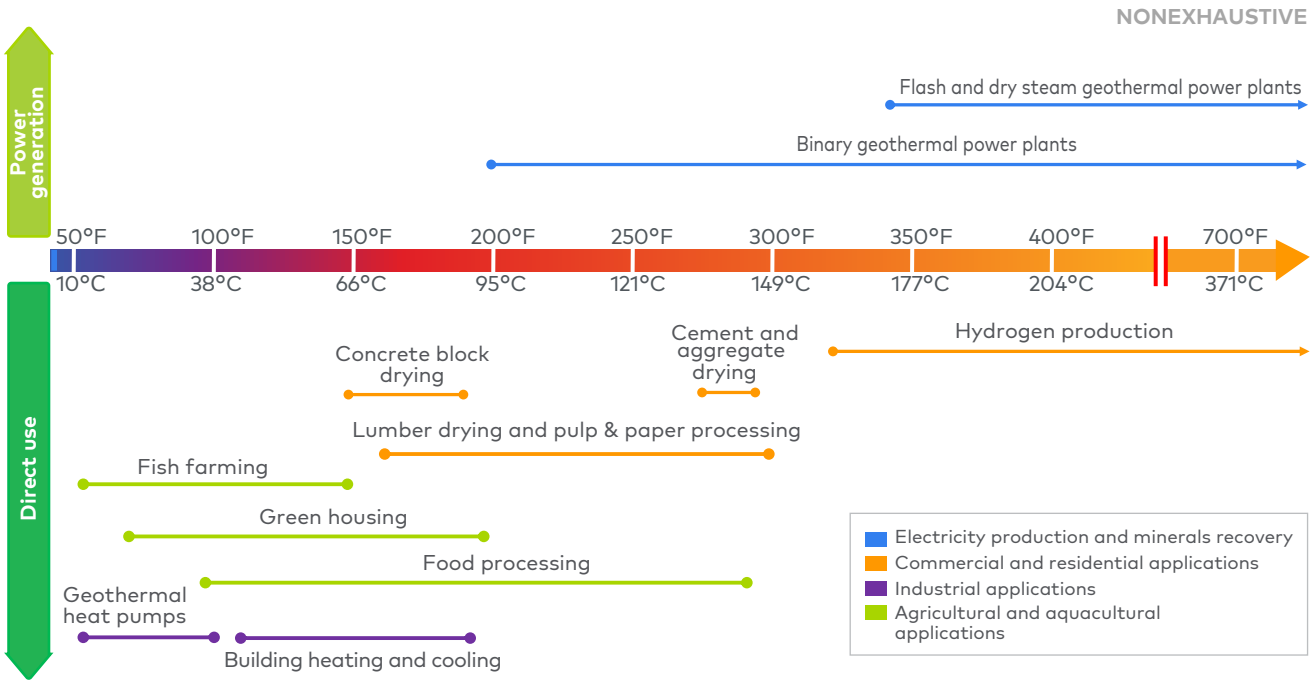
How geothermal is used

Unlike biomass, wind, hydroelectric and solar, geothermal accounts for only 2% of U.S. renewable energy consumption. Geothermal power plants capture heat to generate steam and convert it to electricity, its primary use case, and geothermal energy can also be used to generate heat. Each use case has different infrastructure requirements. Geothermal power plants harvest energy 10,000 feet-30,000 feet below the Earth's surface and force hot steam from the Earth's interior through a turbine. Geothermal heat pumps, on the other hand, harvest energy from, at most, a few hundred feet below the Earth's surface. Fluid is circulated through underground pipes that absorb heat, which is then extracted, compressed and circulated through buildings.

Specific applications/uses for a geothermal resource depend on the resource temperature. At the high end, roughly 320 degrees to more than 700 degrees Fahrenheit (roughly 160 degrees to more than 370 degrees Celsius), it can be used to produce hydrogen, for example. Indeed, renewable resources including geothermal are increasingly being promoted as ways to reduce the carbon footprint of hydrogen generation.

Meanwhile, at the low end, 50 degrees-200 degrees Fahrenheit (10 degrees-95 degrees Celsius), geothermal can be used for heat pumps and for heating and cooling both residential and commercial buildings, among other applications (see Figure 1).

Figure 1
Continuum of geothermal energy technology applications



Source: GeoVision; L.E.K. research and analysis

In geothermal district-heating applications, water from the geothermal resource is piped through heat exchangers or directly into commercial or residential buildings to meet the heating and hot water needs of entire districts.

The market for geothermal

Currently, the U.S. is the leader when it comes to installed geothermal power plant capacity, with approximately 25%. And while more than 90% of the country's geothermal electricity production capacity is located in California and Nevada, there is potential for geothermal applications throughout all regions of the U.S. for both power generation and direct use (i.e., heating and cooling).

Indeed, while U.S. geothermal installed capacity is expected to grow modestly, given the right conditions, significant upside potential remains. Streamlined regulations and permitting requirements can be achieved through a variety of mechanisms to shorten development timelines, which in turn can reduce financing costs during construction projects. Meanwhile, improving the technologies and methodologies used to explore, discover, access and manage

geothermal resources would reduce the costs and risks associated with their development on one hand while increasing geothermal capacity and power generation on the other.

Through technology improvements, geothermal electricity generation capacity has the potential to increase to 60,000 MW by 2050, according to analysis conducted by GeoVision, at which point it would account for 8.5% of all U.S. electricity generation. Elsewhere in the world, other notable geothermal players include Indonesia (where the geothermal market is expected to grow the fastest, driven primarily by strong government incentives), Turkey and Kenya.

To be sure, there are challenges associated with geothermal. Geothermal energy development projects tend to be both lengthy and costly, as it requires capital to identify and validate a geothermal resource and build out the necessary belowground (e.g., drilling) and aboveground (e.g., power transformers) technologies. And while the successful development of new technologies such as enhanced/engineered geothermal systems (EGS) will improve geothermal economics and could support industry growth above historical rates, geothermal energy currently costs more per megawatt hour (MWh) than utility-scale solar and wind energy.

But going forward, the ability of traditional energy companies — in particular, OFSE providers — to access their established assets, diversify their existing energy portfolios, accelerate their market entry and enhance their operational efficiency makes geothermal a logical, and potentially extremely lucrative, avenue of growth for such companies and their investors.

The geothermal opportunity for oil-field services providers

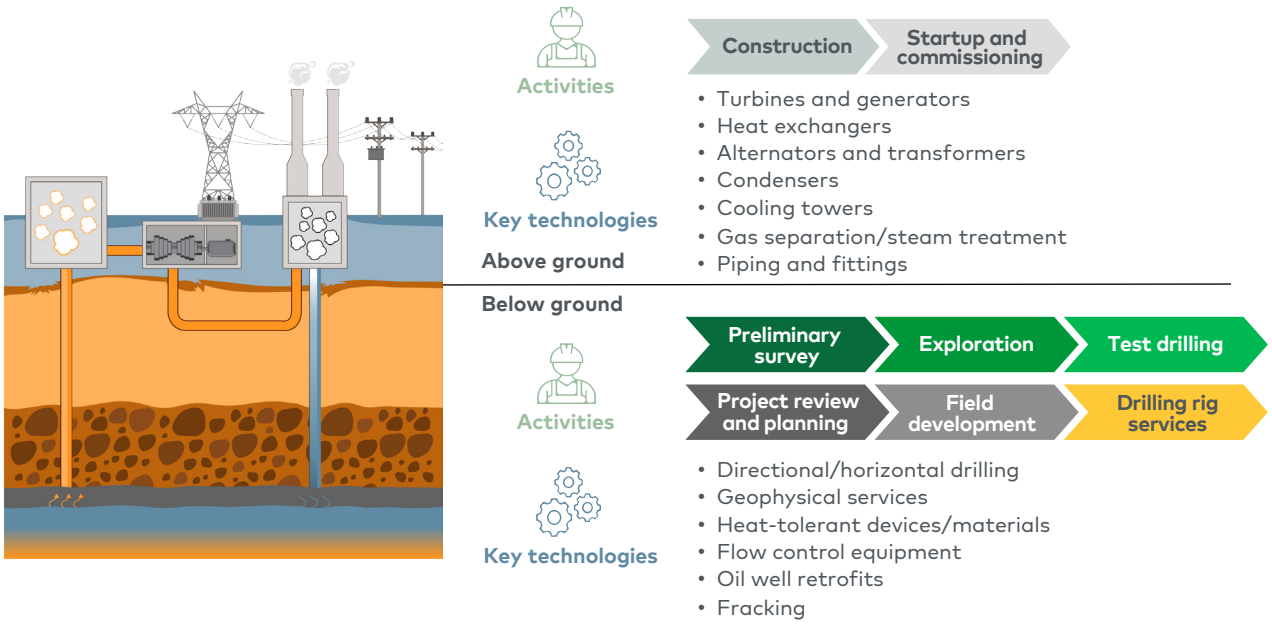
Oil-field services providers are well positioned to leverage the geothermal opportunity.

The development of a geothermal energy plant requires multiple steps and stakeholders. After starting with a preliminary survey — an initial reconnaissance of a geothermal area based on a study — surface-level surveys are needed to confirm a preliminary resource assessment. Such an assessment is followed by test drilling and then a review of the project so far, along with additional planning. The next step is field development, which includes drilling production and reinjection well development and partial construction of the pipelines needed to connect wells to the plant, followed by construction (i.e., installation of the steam-gathering system, separator and power plant components) and, finally, startup and commissioning.

There are numerous similarities between under- and aboveground activities across the geothermal value chain. In the market composed of energy companies; exploration, drilling and project development companies; and startups, traditional energy companies are

increasingly investing in geothermal energy, as equipment and design services applicable to traditional utility plants can be adjusted for use in geothermal plants. Notably, however, there has historically been less investment in aboveground technologies (e.g., cooling towers, condensers, turbines and generators) than in belowground technologies (e.g., flow control equipment, heat-tolerant devices/materials, geophysical services) (see Figure 2).

Figure 2
Geothermal activities and technologies: above ground vs below ground



Source: World Bank; NREL; L.E.K. research and analysis

Opportunities for oil-field services companies include tackling the underground market (e.g., exploration, reservoir characterization, drilling, well conversion) and working with utility EPC providers on surface-related infrastructure (e.g., plant design and engineering, construction, equipment, technology).

When it comes to exploration and site identification, the oil well drilling success rate has improved dramatically over the past decade thanks to developments in subsurface modeling; similar improvements in geothermal site location would significantly benefit the geothermal industry. O&G wells can also be converted or leveraged to create geothermal energy.

Market participants have also identified a need for innovation in well construction, including drilling innovations specific to the geothermal industry. The extreme temperatures in geothermal wells, for example, create challenges that will require R&D investment to solve in

the form of drilling devices and techniques specific to the needs of the geothermal industry. And while the construction of O&G wells is transferable to geothermal due to the similarities in well structure, geothermal temperatures and flow rate pose certain challenges (see Figure 3).

Figure 3
Leveraging O&G technology for deployment into the geothermal industry

Petroleum 		Geothermal 
125-350°F	**Temperature**	300-800°F
1,000-12,000 BOE/D (30-360 gal/min)	**Flow rate***	50,000 bpd is average (1,500 gal/min)
Up to 30,000 ft.	**Well depth**	Up to 30,000 ft.
Vertical and long-reach horizontal 5"-7" diameter production interval	**Drilling diameter**	Vertical/deviated 8"-12" diameter bottom hole
High initial flow (months) with a declining rate over years	**Production time frames**	Constant production for 20-30+ years
Sedimentary	**Lithology**	Volcanic/intrusive/metamorphic
Stratigraphic/structural	**Facies**	Complex fault-dominated

"... Many existing tools and technologies from the oil and gas industry could be leveraged for deployment in the geothermal industry, resulting in significant improvements in exploration and drilling success rates — and, in turn, reducing development costs. Modifications using existing technologies can help accommodate the higher temperatures and often corrosive environments found in geothermal drilling. Logging and measurement while drilling are also common technologies in the oil and gas industry that can reduce drilling costs by providing real-time information to optimize a drilling operation ..." (GeoVision, 2019)

*Flow rate describes water flow in flash steam and binary systems and steam flow in dry steam systems
Note: O&G=oil and gas; BOE/D=barrels of oil equivalent per day; bpd=barrels per day
Source: Thinkgeoenergy.com; Lowry et al. (2017); Aera Energy; GeoVision; L.E.K. research and analysis

But cost efficiencies have historically been realized in the O&G industry, and similar gains are possible when it comes to completing geothermal wells. Indeed, the feasibility of converting uneconomic oil wells into geothermal wells, which is currently being researched, could present a significant opportunity for O&G majors. Oil wells can be repurposed exclusively for geothermal production; alternatively, the wells can simultaneously produce hydrocarbons and heat.

Companies are already moving in this direction. Key stakeholders in aboveground activity and related technologies include geothermal energy companies; geothermal power plant engineering and design firms; generalist utility EPC companies with geothermal capabilities; and equipment manufacturers. In belowground activity, large OFSE providers; companies focused on exploration, drilling and project development; and geothermal technology startups are the key stakeholders.

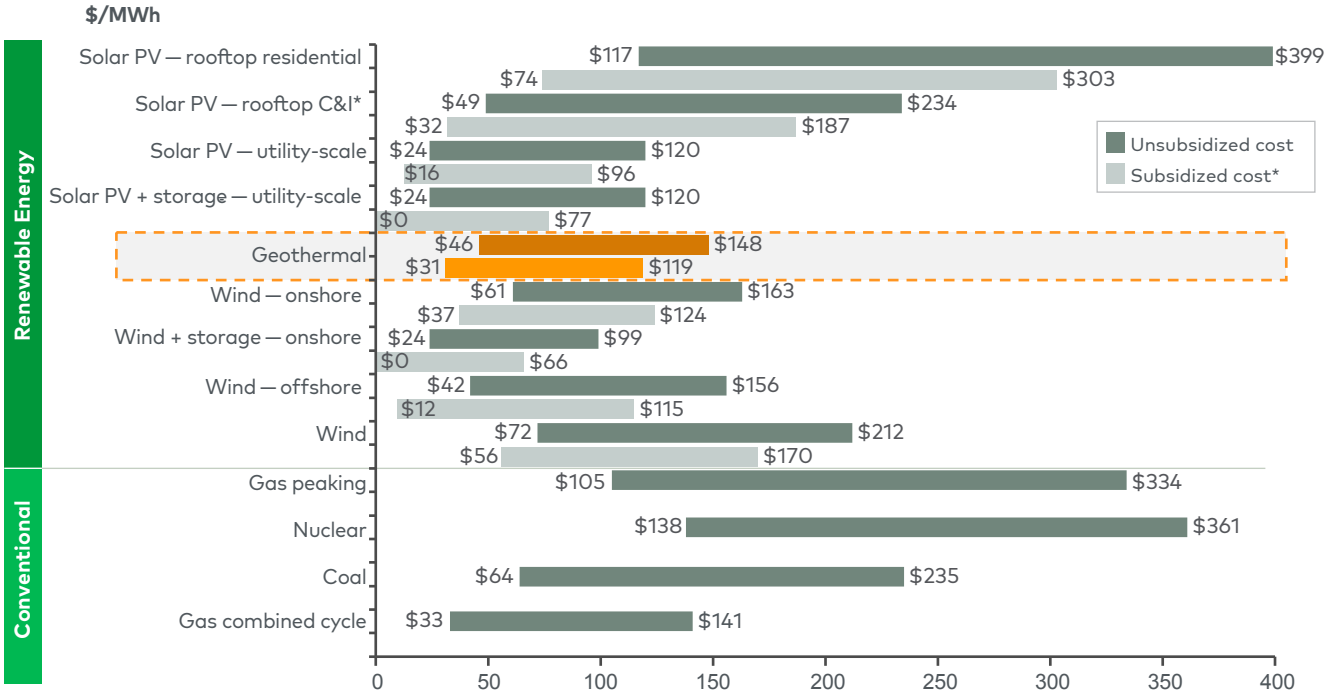
Policies, costs and challenges

In the U.S., incentives at both the federal and state levels can be used to offset the cost of investing in geothermal development. Federal incentives (e.g., the Inflation Reduction Act (IRA)) can collectively lower upfront deployment costs by up to 55% for large geothermal energy projects. Although geothermal heat pumps are typically more expensive for homeowners and building owners to install, the IRA has created tax credits, grants and rebates that will significantly help drive down upfront costs.

Meanwhile, financial incentives and green energy and carbon emissions targets that benefit geothermal energy can be leveraged at the state level. The four states that together produce more than 95% of geothermal energy in the U.S. — California, Nevada, Oregon and Utah — have each established clean energy goals and offer incentives for renewables (e.g., the Renewable Portfolio Standards).

And although geothermal energy costs more per MWh than utility-scale solar and wind energy, it is relatively cost competitive compared with other resources such as nuclear and single-cycle gas-fired plants (see Figure 4).

Figure 4
Levelized cost-of-energy comparison (2023)



*Subsidized cost estimates assume the projects qualify for the full ITC/PTC and have a capital structure that includes sponsor equity, tax equity and debt
Note: PV=photovoltaic; C&I=commercial and industrial; ITC/PTC=investment tax credits/production tax credits
Source: Lazard: L.E.K. research and analysis

Multiple novel technologies are being developed that could improve geothermal economics and result in industry growth above historical rates. The biggest opportunity for cost savings is via technology improvements (e.g., EGS, hybrid geothermal systems, closed-loop systems) in well development and completion. There are also opportunities for cost savings in aboveground activities, which are expected to become more cost-effective as geothermal development accelerates and the accumulation of experience yields efficiency gains. Indeed, significant opportunities exist for the next-generation geothermal industry to cut costs through a combination of technological innovation and flattened learning curves.

That said, current technology capabilities, as well as the environmental conditions under which plants operate, can be a barrier to geothermal development. The unique technical requirements of geothermal wells — and key differences relative to gas wells — present technical challenges to future development and may limit the involvement of traditional energy companies.

Another challenge to the growth of geothermal energy is the availability of funding for the exploration of geothermal reserves and test drilling operations. Administrative, political and social barriers can present challenges to geothermal project development as well.

So, before investing in geothermal energy, O&G companies, power utilities and their investors should consider the following key issues:

- **The long project development timeline** — Currently running at approximately seven years, it may take additional years for their investment to pay off
- **The regulatory environment** — Future investment in geothermal will depend on the U.S. continuing to push for/mandate carbon energy reductions, with the financial support of tax credits and other incentives
- **The alternative technologies landscape** — Investors should remain up to speed on alternative renewable energy technologies (e.g., wind, solar) as renewable resources that have gained market share, with support from regulatory policies, and have in turn benefited other renewable technologies
- **Unique customer dynamics** — Unlike O&G, which are traded on global markets, geothermal energy operates locally, so operators have to pay greater attention to the needs of their local customers
- **Geothermal applications** — Use cases for geothermal energy go far beyond utility-scale electricity generation and, thus, may present niche opportunities for investors

A long-term opportunity

As consumers clamor for more sustainable energy options, the long-term availability of fossil-based resources remains limited and natural gas prices continue to be volatile, the renewable energy sector continues to gain traction. It's why traditional energy players — O&G as well as power utility operators — should look into applying their capabilities and expertise to geothermal.

They would face, to varying degrees, challenges associated with financing, regulations, technology and related acquisitions. But such challenges would be heavily outweighed by the advantages of using their established assets, diversifying their energy portfolios, accelerating their market entry and enhancing their operational efficiency in what could prove to be not just a significant shift in the sector but a massive opportunity.

For more information, please contact industrials@lekinsights.com.

Endnotes

[1] EIA.gov, "Electric Power Monthly: Table ES1.A. Total Electric Power Industry Summary Statistics, 2023 and 2022." https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=table_es1a

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