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ENERGY TRANSITION: WHAT ROLE CAN GEOTHERMAL POWER PLAY?

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Geothermal energy is among the oldest types of power harnessed by humans. It holds a unique place in the energy mix, thanks to being entirely independent of weather yet not relying on fossil fuels. Once operational, geothermal plants can produce a steady output all year round, day and night, often for at least 20-30 years. With the need to transition from fossil fuel power plants, countries around the world are looking for alternatives to stabilise electricity grids. Such alternatives are nowadays most often powered by renewable energy sources such as wind and solar power, many being intermittent in nature. Geothermal power, thanks to its baseload nature, could play a vital role in the energy transition.

However, to date, geothermal energy development has taken place in specific regions only, being those environments most conducive to geothermal power production. The most efficient geothermal power plants require both the hottest resources possible and satisfactory permeability of the hot rocks. For this reason, geothermal power plants have been developed primarily alongside major tectonic plate boundaries or in the vicinity of volcanic regions. Certain countries, among them notably Iceland, El Salvador, New Zealand, Kenya and The Philippines, already meet a significant share of their electricity demand through geothermal power plants, and these are the main geothermal hubs at present. Although these countries have demonstrated the significant benefits of this technology and continue to lead the way for other nations, the full potential of geothermal energy has not yet been realised on a global scale.

There has been a significant growth in investment in renewable energy in the past two decades, with a record high in 2022 of US$0.5 trillion. This investment has resulted in unprecedented growth in renewable energy, both in absolute terms as well as in its share of total energy output, with wind and solar power clearly standing out. However, although total renewables power output showed promising growth by more than doubling between 2012 and 2021, there is still a great discrepancy between the rate at which various types of renewable energy have been developing. In particular, the total installed capacity of geothermal energy in electricity generation is below 10% of its global potential, massively overtaken by output from wind and solar energy. This disparity is caused primarily by the fact that investments in geothermal energy have not kept pace with those in other renewables, which to date are favoured as they require far less upfront capital and are arguably less risky.

In this briefing, we explore recent trends in the development of geothermal power, including new technologies contributing to its expansion. We consider the recent trends in policies and subsidies relating to geothermal projects, with a particular focus on EU funding schemes, and look at what the future may hold for geothermal energy.

RECENT TRENDS

For a long time, exploration of locations for geothermal power plants was limited to regions with the highest reservoir temperatures (mostly above 180ºC) and wells between 1 and 2 kilometres deep. Only such conditions were thought to be suitable for investors, with acceptable levels for the risk of project failure and achieving the maximum efficiency of the future generation facility. However, these conditions are present primarily in regions around tectonic plate boundaries, are therefore limited and have already been explored to a great extent, presenting a problem for interested geothermal energy investors.

Finding "new" ground for geothermal development is challenging, and so is "proving" a resource, even in more traditional settings. To begin, identifying the location of a commercially viable geothermal reservoir has always been costly. Proving the suitability of a chosen site usually necessitates drilling and testing of deep wells, but these initial stages are the most risk-fraught and cost-intensive for investors. Geothermal investors have rightly been wary of all but the least risky locations, given that up to 90% of the total project costs can be consumed just in the drilling stage. Crossing the hurdle of proving viability is therefore of utmost importance in increasing total geothermal energy power output. There have been various attempts at minimising investor risk as well as maximising commercial viability of a wider range of geothermal wells. We set out four key ways in which this has been achieved so far.

Use of big data at exploration stage

Recent technological breakthroughs reduce the risk of drilling in an unsuitable location by ensuring a better survey of the identified location and more precise predictions of its parameters during exploration. Various machine learning algorithms have been identified as helpful tools in the search for the best locations for geothermal power plants. These tools enhance the visibility of geographical indicators, such as the contours of mountains, hot springs and rock composition, enabling more locations to be identified as viable options to develop new sources of geothermal energy. For example, the Dieng geothermal power plant located in Central Java, Indonesia, has benefited from this technology and is currently estimated to have a geothermal power potential of up to 440 MW.

Although the hype around the application of new technologies in the geothermal space has so far been confined to academic circles, we are now seeing private companies move into this space. One notable example is Zanskar – a company which uses big data to identify new viable sources of geothermal energy, attracting the attention of investors such as Munich Re Ventures. It has most recently signed an agreement with the US Department of Defense to deplay the technology at two installations, which will enable quicker and more accurate identification and de-risking of geothermal resources. Other players are also keen to explore the opportunities presented by big data themselves. Google has signed an agreement with Fervo – a clean energy start-up – in which it will help develop AI and machine learning technologies to boost overall productivity of geothermal power plants. At the end of November 2023, a new geothermal plant in Nevada became operational, and the electricity produced will serve Google's data centers and supply power to the local grid. This demonstrates that the Internet of Things and Artificial Intelligence technologies can go further than merely helping with resource detection. They have already been used on live geothermal energy projects for better responses to equipment failures and generally improving plant efficiency.

Both Google and Fervo are already looking at new projects. In September 2023, Google announced a partnership with Project Inner Space, a non-profit organization dedicated to rapid global development of geothermal energy. Meanwhile Fervo is constructing another next generation 400 MW geothermal power project in Utah, to be completed in 2028.

Improved drilling techniques

Advanced drilling techniques

Locating sources of geothermal energy as close to the surface as possible is far more cost effective than deep drilling. However, it is well-known that the temperature of rocks increases exponentially with the depth of the well – in other words, the best geothermal resources are normally found at significant depths. Reaching such resource is a costly and uncertain process. Being able to drill deeper at reduced cost would enable access to more resources for geothermal energy. Reducing the price of drilling wells could also allow for accessing more varied types of funding and thus improve the bankability of geothermal projects.

As with the use of big data, the ideas around advanced drilling techniques have been explored by researchers, with techniques such as horizontal drilling showing much promise. Even more encouraging is the fact that these and other ideas have already been tested and are attracting more and more attention.

- Quaise Energy is developing innovative technology to access resources located at greater depths in the Earth's mantle. The company is betting on vaporising rocks in order to access deeper reserves through a device called a gyrotron, which emits microwaves. Although the technology has not yet been implemented on live geothermal projects, Quaise is hoping to start harvesting energy from a pilot well by 2026.
- Slovakia's GA Drilling is relying on a combination of two technologies to access resources located as deep as ten kilometres below the Earth's surface – Anchorbit and Plasmabit. In the Anchorbit drilling system, the drill moves downwards in an earthworm-like fashion; another interesting feature of the technology is that it stabilises the surrounding rocks and prevents the kinds of vibrations likely to appear when operating drill equipment at the end of a cable several miles long. Plasmabit technology uses a pulse plasma drilling system, which will crack and weaken the rock using a no-contact drill bit, thereby eliminating the need to pull it up to the surface and have it replaced. GA Drilling has already conducted its first demonstrations in Houston and has committed to working towards using it in a geothermal energy setting.

Enhanced geothermal systems

The three key ingredients to a geothermal system are heat, fluid and permeability. Where heat is not sufficient, one of the solutions is to drill deeper in order to access hotter reservoirs. But what if the rock at a shallower depth is sufficiently hot but there is simply not enough permeability – or in other words, cracks – in it to allow for geothermal energy generation? Enhanced geothermal systems (EGS) may provide an answer. These are systems in which the rock permeability has been artificially improved, by fluid injection, or via chemical or thermal methods. Thus, by altering the rock structure, geothermal resources can be explored in regions with geology ordinarily deemed unsuitable.

The concept first originated in the 1970s, with the first EGS constructed in Los Alamos (New Mexico, USA) with a thermal capacity of around 10 MW. Since then, the technology has improved greatly, with the first private large-scale commercial EGS geothermal plant opening in 2013 in Habanero, Australia. Expertise gained through Geodynamics' Habanero Plant project is now being applied globally. Earlier this summer, Fervo Energy announced a 30-day well test in its full-scale EGS pilot project in Nevada, where the company applied existing drilling technology expertise from the oil and gas industry, including horizontal drilling.

Lower temperature geothermal power plants

Another important technical advancement is the ability to extract power from lower temperature geothermal resources, i.e., those below 150°C. These have traditionally been used in applications such as direct heating, rather than power generation, as the latter would not reach sufficient efficiency to render such projects viable. However, resources with temperatures as low as 70 - 80°C can, under the right conditions, now be used for electricity generation using improved binary cycle electricity generating technology.

Although low-temperature geothermal projects will usually be orders of magnitude smaller than typical wind or solar power plants, they have been proven to be technologically viable. One of the larger low-temperature geothermal power plants for commercial power production is located in Alaska at the Chena Hot Springs Resort, which generates around 400 kW of power using Organic Ranking Cycle units. Although such power output might seem insignificant, taken together, these low-temperature geothermal systems could contribute hugely to countries' energy portfolios. In that vein, the U.S. Geological Survey has identified more than 120,000 MW of unrealised low-temperature geothermal reserves in the country, showing that, in aggregate, these plants could have a big impact on energy make-up.

Use of existing oil and gas infrastructure

While more investments have been pouring into renewable energy sources, the existing oil and gas infrastructure has not disappeared. Once depleted, oil and gas wells cannot be simply abandoned. Unsealed oil wells have negative effects on the environment through both air and groundwater pollution due to methane, arsenic and other toxic substances leakages. It is therefore vital to seal them properly – both for the environment and society and, in addition, for the operators, because not doing so could carry significant liability. The costs of effectively sealing off depleted wells are significant. The well will not bring in any further income at this point, yet it can create significant costs and liabilities if sealing is not done properly.

What if dedicating some of these wells to geothermal development could give them a second life and so, not just postpone or save decommissioning costs, but also generate revenue? Most oil and gas wells are in regions not traditionally associated with geothermal energy power plants, as the temperatures at their depths do not usually exceed 150ºC. However, with improvements around the use of low-temperature resources for geothermal energy, it is possible that existing oil and gas wells could serve as a basis for geothermal exploration. Rather than spending money on ending the useful life of a non-income-producing asset, investors have been exploring ways in which existing wells could be used for geothermal energy.

This trend has already been picked up on by the U.S. Department of Energy. At the beginning of 2022, four new geothermal energy projects received grants of between US$1.7million and US$2.5 million to explore the possibilities of repurposing abandoned oil and gas wells. Each of these projects uses slightly different technology, including power generation from fluids produced at existing oil and gas facilities as well as innovative injection well patterns and data-driven technologies. The grants are admittedly small, and none of these are large-scale commercial solutions. However, they are important efforts aimed at proving the viability of generating a significant amount of energy from abandoned wells.

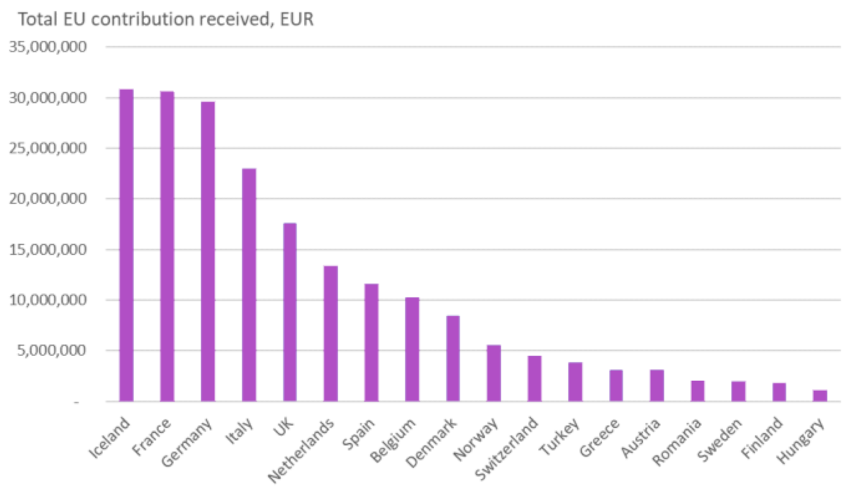
The Tu Deh-Kah geothermal project in British Columbia is an open-loop geothermal doublet, where one of the wells has been newly drilled while the other is an existing gas well which is being deepened for the purposes of the project. The current aim is to generate between 7 and 15 MW of electricity from geothermal waters of around 120º C, showing how advancements in both lower temperature power plants and the use of existing gas infrastructure can help to reap the benefits of existing geothermal resources. The project will be the first geothermal electricity facility in British Columbia.

GEOTHERMAL POWER AND THE EU

The importance of geothermal power for the energy mix and heating purposes, and the challenges facing the geothermal industry, have been increasingly recognised in Europe, especially at the EU level.

According to a study published by the European Commission (the Commission) in October 2022, under Horizon 2020 (2014-2020), the EU has supported 54 geothermal-related projects by awarding approximately EUR 208 million of grants. The graph below shows the total EU contribution per country, with Iceland, France and Germany as the largest beneficiaries.

Figure 4. H2020 funding for geothermal projects (countries receiving >EUR 1 million).



Source: JRC analysis of Cordis data

EU State aid rules

On 1 January 2022, the revised Guidelines of the European Commission on State aid for climate, environmental protection and energy (CEEAG) entered into force, extending the scope of the previous Guidelines to new areas in order to achieve the goal of reaching climate neutrality by 2050.

As explained in our recent briefing: New EU Guidelines on State Aid for climate, environmental protection and energy: which sectors could benefit, the revised guidelines set out the compatibility criteria for aid in several sectors that are expected to contribute to the 2030 and 2050 decarbonisation targets, including the production of geothermal energy. The Commission has decided to significantly widen the scope of the Guidelines, while it gives a particular weight to the assessment of the necessity and proportionality of the aid, rendering competitive bidding processes the default mechanism for awarding – and determining the level of – aid.

One of the most recent and significant aid schemes cleared by the Commission was notified by France (Case SA.101109). On 24 July 2023, the Commission, after assessing under the CEEAG, approved a guarantee fund supported by the French state that will operate for 10 years and provide guarantees for drilling operations for deep geothermal projects with a capacity of approximately 30 MW. For the establishment of the fund, the French State, through the Environment and Energy Management Agency (*Agence de l'Environnement et de la Maîtrise de l'Énergie* (ADEME)), will contribute EUR 140 million. At the same time, project promoters wishing to benefit from the guarantee will make contributions (in the form of subscriptions) of EUR 55.6 million. The maximum amount of compensation per project will be EUR 17 million, paid to project promoters in the event of failure to meet the quality or quantity required of the geothermal resource.

The scheme provides for two types of guarantees: (i) "short-term" and (ii) "long-term". The former will be financed mainly by the French state and will cover drilling operations of project promoters through a compensation mechanism if, at the end of the first or second well, they decide to discontinue the project in the absence of exploitable resources in terms of quantity or quality, while the latter will be financed by the project promoters themselves and will cover, in the event that the project is actually carried out, the geological risks incurred during the operational phase of the facilities.

EU funding tools

Geothermal projects are eligible for EU funding that is either directly managed by the Commission or is under shared management between the Commission and Member States. For instance, several Member States have developed geothermal projects using funding from the Cohesion Policy funds (e.g., Slovakia), the Just Transition Fund, Horizon Europe or the Innovation Fund (e.g., the EAVOR-LOOP project in Germany).

You can read more about the EU's funding tools and the applicable State aid rules in our recent briefing: Focus on hydrogen: EU funding programmes for energy projects.

GEOTHERMAL POWER AND THE US

Conventional geothermal projects are traditionally found in western US states (e.g., Nevada, Oregon, Alaska, Hawaii, etc.), where there are natural reservoirs of steam or hot water. The US continues to incentivise the development of all types of renewable energy projects, including geothermal projects, through a variety of incentives from the federal government, which can take the form of tax credits, grants or loans with favourable interest rates.

For example, the Inflation Reduction Act of 2022 (IRA) provided an extension to the Renewable Electricity Production Tax Credit under Section 45 of the US Tax Code. Under this tax credit, there is a possibility to add a 10% bonus for facilities that create renewable energy facilities on brownfield sites, or in fossil fuel communities to replace lost revenue and jobs in the coal, oil and gas sectors. The IRA also expanded Title XVII under the Energy Policy Act of 2005, which authorises the Department of Energy's (DOE) Loan Programs Office to provide financing for innovative energy technologies. Renewable projects such as geothermal energy have been a point of emphasis for the DOE, which can underwrite technology risk. The Bipartisan Infrastructure Law of 2021 (BIL) also allocated $84 million to the DOE's Geothermal Technologies Office to create four to seven enhanced geothermal system pilot demonstrations. Notably, one of these plants will be located in the east of the US, to showcase geothermal potential in that region.

There can also be various incentives offered at the state level, depending upon the state's commitment to alternative energy sources. For example, Colorado will provide a total of US$35 million in state investment tax credits for the production and generation of geothermal electricity. There is a limited, nationwide regulatory framework for geothermal development outside federal lands. The Safe Drinking Water Act provides some regulatory applications, but regulation is normally left to be decided by states and local municipalities.

PREDICTIONS FOR THE FUTURE

Synergies

The synergies between the oil & gas industry and geothermal energy are clear from the technological standpoint and have resulted in power plants which combine these ways of generating electricity and heat. One such example is a project in Colombia at the Las Maracas field. Although only a small-scale 100 kW geothermal power generation unit, it uses hot water extracted as a by-product in the oil production process. Projects like this one should be seen as initial steps toward opening avenues for the continued life of oil and gas wells, which, albeit starting from a fossil fuel past, have the potential to contribute to the energy transition and a green energy future.

Synergies for combined energy systems exist between geothermal energy projects and other renewables as well as green hydrogen:

- The Stillwater triple hybrid power plant in Nevada combines four power plants: a 33 MW geothermal; two photovoltaic solar (26 MWdc and 27 MWdc); and a 2 MW solar thermal. The geothermal power plant component uses a binary cycle to provide an increased continuous power output, with the solar components increasing peak capability. The power plant has been an award-winning project and a prime case study of the benefits of using multiple renewable energy resources.
- Halcyon Power marries geothermal energy with green hydrogen — a joint venture between Tauropaki Trust and Obayashi Corporation, it features a green hydrogen production facility of 1.25 MW capacity using electricity from the Mokai geothermal power plant, thereby being able to produce 180 tonnes of green hydrogen annually.

Financing options / structuring of projects

The continued progress in advanced geothermal energy technologies promises to minimise the risks involved at the early stages of geothermal projects, thereby also reducing the high upfront costs associated with the exploration and drilling stages. This trend should contribute to opening more liquidity for realising geothermal projects on the bank market, including from commercial debt. However, in the short term, we believe that investors will be forced to rely on more costly equity capital, especially in the early stages of a project, or, in the case of government offtakers, the public sector will take the initial development and reservoir risk.

International development banks, national development institutions and other donor agencies can continue to play a crucial role for catalysing investment in the geothermal sector, with a particular focus on developing countries. Their involvement in the past has encouraged commercial banks and private companies to participate in renewable energy projects, particularly in relation to financing the drilling stage as a risk-sharing option, and we expect that to continue, especially in a high-interest, high-inflation environment.

How can we help?

At Clifford Chance, we are well-placed to help our clients on innovative projects aiming to harness the power of geothermal energy. Our experience in geothermal energy projects spans all key jurisdictions, including projects in Indonesia, Turkey, alongside the East African Rift and in Australia, as well as in the USA, South America and Europe. Our breadth of experience across regions and sectors, including renewables, oil and gas infrastructure and battery storage, will be particularly important in the most innovative geothermal energy projects. At Clifford Chance, we understand the complexity of these market-leading ventures and can assemble a team that understands the complex regulatory landscape and can help optimise the financing model and structuring of a deal. Our full suite of advisory capabilities allows us to assist clients at every step of a project, from the bid, to project design and transaction structuring, through to construction and procurement, financing, development and operation.

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