Oil & Gas and Geothermal: like steam, the oil & gas industry could rise to the occasion

With a significant number of industry conferences targeting geothermal being held around the world this year, the oil & gas industry is starting to recognise the potential of geothermal as an energy source where the technical, commercial, financial and legal challenges are very similar to (and the associated experiences are readily transferrable from) oil & gas projects.

As has been seen with wind and solar (and now hydrogen and carbon capture), the decades of experience in engineering and project management of oil & gas companies is showing its worth in the transition to clean energy at scale, leveraging the global capabilities and financial strength of these companies.

Geothermal could have a key role to play in the shift to clean power and heat. Recent developments even see a role for geothermal as, in effect, underground storage for solar and wind energy. Geothermal could thereby assist in the provision of a clean peak load on electricity grids, as well as itself providing a baseload energy source.

In light of its potential, the geothermal market could well be on the verge of substantial growth precisely at a time when oil & gas companies are looking to further diversify their businesses.

In this article, we provide a summary of the geothermal sector and its recent developments before examining some of the similarities between geothermal and oil & gas projects, and the role which the oil & gas industry could play in developing geothermal as a part of the energy transition.

What is geothermal energy?

Geothermal energy can be extracted from just a few metres to multiple kilometres beneath the Earth’s surface.

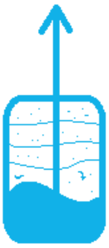
‘Ground-source energy’ or ‘shallow’ geothermal energy (from depths less than 200m below the Earth’s surface), is largely derived from solar radiation.

‘Deep’ geothermal energy (derived from depths of more than 500m below the Earth’s surface) is partly heat accumulated when the Earth was formed and partly heat from the decay of mildly radioactive elements. Heat from the Earth's core radiates outwards, warming rocks.

This heat warms up reservoirs of water, which can create hot water and, if hot enough, steam. While hot water can be used for heating, steam can be used to create electricity using turbines.

The process of accessing 'deep' geothermal is most readily comparable with oil & gas developments (and will be the focus of the below).

How is geothermal energy extracted?



To reach these underground heat and energy sources, wells can be drilled into rock, intersecting with hydrothermal reservoirs, tapping steam and very hot water which can then be brought to the surface and utilised for electricity generation or used directly for heating. This is much like the approach seen in the oil & gas sector.

As an industry still in its infancy, companies are working to develop ways to drill at much greater depths and through harder rock. For example, in the U.S. Quaise Energy is developing a technique which uses lasers to 'drill' through hard rock, deep underground (according to Quaise Energy these wells could reach 20km below ground at temperatures of 500°C).

Other drilling techniques, including some developed for natural gas fracking, are also helping to improve geothermal energy extraction.

Where is it extracted?

Geothermal energy can, in theory, be tapped anywhere. However, naturally accessible reservoirs of steam and hot water (particularly for electricity generation) are concentrated in certain regions – notably the United States, Mexico, Japan, New Zealand, Indonesia, the Philippines, Kenya, Turkey, Italy and Iceland.

On the other hand, the use of geothermal for heating purposes is much more readily available. It is found across Europe, for example in France (Paris) and in Germany (Munich is investing one billion euros ($1.1 billion) through to 2035 to develop geothermal energy and make the city's heating carbon neutral).

Despite being readily available, this clean energy source remains largely untapped in many places in the world. For example, according to UK Parliament research papers, geothermal technologies currently deliver less than 0.3% of the U.K.'s annual heat demand, using only a fraction of the estimated available geothermal heat resource.

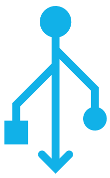
Even in the U.S., which is currently the biggest producer of geothermal energy, geothermal only makes up less than 1% of power generation. That said, with the new Inflation Reduction Act in place it is estimated that, with optimal use of the associated tax credits and an adequate level of investment, geothermal could provide approximately 8.5% of the U.S.' electricity generation by 2050. In order to reach this goal, much more drilling and project development will be required.

A leading example of where geothermal energy has been successfully commercialised in recent years is Iceland – one of the nations leading the charge on geothermal. Approximately 90% of Iceland's hot water for households and for heating now comes from geothermal energy. The country is also investing in geothermal energy projects such as the Iceland Deep Drilling Project (IDDP) – a project aimed at expanding electricity generation by drilling 4.5 km wells into volcanic fields to harness geothermal energy.

How is the energy and heat obtained and transported?

Geothermal plants can be split into two broad categories: (1) electricity generation; and (2) heat generation (as well as combinations of the two). The heats and depths involved in the sources for each can vary greatly (and will depend on the precise technology used) but examples are given below.

(1) – Electricity generation



Geothermal power plants work by circulating water through hot rock deep beneath the surface. In most plants it resurfaces at a production well head, as steam or, if not, water that's hot enough to convert other fluids (with lower boiling points) into vapor that moves a turbine, generating electricity.

— **Dry steam plants**

Dry steam plants are the oldest form of geothermal power plant and are currently used in northern California, the world's largest region for geothermal energy. Dry steam plants draw fluid (which is already largely steam), out of fractures in the ground to drive a generator – producing electricity. Temperatures in the reservoirs can exceed 260°C / 500°F.

— **Flash plants**

Flash plants are the most common form of geothermal power plant in operation. High-pressure and hot (greater than 182 °C / 360°F) fluids are drawn into a low-pressure tank underground. The change in pressure creates a vapour or "flash" (i.e. a rapid turning of water into steam) driving a turbine – producing electricity.

— **Binary plants**

Binary plants do not require quite so high temperature resources meaning they can be used in more locations. The lower temperature water (below 182 °C / 360°F) underground is passed by a secondary fluid with a lower boiling point. Again, a "flash" occurs, driving the turbine – producing electricity.

The electricity produced from the above plants can then be transferred to the domestic electricity grid.

(2) – Heat generation

Production wells extract warm geothermal water from around 2km to 3km underground. The heat in the water (typically in the 50°C to 100°C range) is distributed direct through a heating network (which serves, for example, residential areas and/or industrial hubs), with the water returning to an injection well to be returned to the reservoir.

The temperatures and depths involved mean that the use of geothermal as a source of heat (as opposed to electricity or power) could be much more common: in essence, just as wind and solar have made headway into the electricity market, geothermal heating could do the same in keeping homes and industrial sites warm.

Advantages and challenges

Geothermal has undoubted advantages, for example:

— Unlike wind and solar which rely on externalities such as weather, geothermal energy is readily available 365 days a year – at any time of day.

— The heat is naturally replenished continuously, meaning it is largely inexhaustible. It is also relatively inexpensive to produce, once the upfront exploration and development phase costs have been incurred. These factors make geothermal energy a baseload energy source.

However, it also has a number of challenges:

— Geothermal energy has been associated with the production of emissions such as sulphur dioxide and hydrogen sulphide. Also, geothermal plants can cause mini earth tremors, and geothermal fluids may contain low level toxic waste, requiring disposal in accordance with environmental regulations. These concerns are similar to those raised in relation to fracking for natural gas.

— In order to produce electricity, the temperature of the geothermal source needs to be very high, which is not the case everywhere.

— Although the Earth has virtually endless amounts of energy and heat beneath its surface, it is not possible to use it as energy unless the underground areas are “hydrothermal”: the underground areas must not only be hot, but also contain liquid and be permeable. Many areas do not have all three of these essential elements. However, in a sign of how quickly this industry could develop, enhanced geothermal systems (EGS) use drilling, fracturing, and injection to provide fluid and permeability in areas that have hot (albeit dry) underground rock.

— Most wells that extract heat will eventually cool if heat is extracted at a greater rate than it is given time to replenish (although water reinjection can mitigate this effect).

— Much like an oil & gas development, a key challenge for the geothermal energy sector is the large upfront capital costs required for the exploration phase.

— The current technological risks (and known unknowns) mean start-ups are struggling to find the investment they need to develop projects.

— Regulation, land rights and permitting are also barriers to entry in some cases.

The geothermal energy market

The current market

The industry could be said to still be in its early stages.

At present, deep geothermal currently makes a very minor contribution to the global energy system, with projects generally providing heat and electricity for small, local communities and/or industrial sites.

According to a February 2023 report by the International Renewable Energy Agency (IRENA), electricity generation from geothermal energy has grown at a modest rate of around 3.5% annually, reaching a total installed capacity of approximately 15.96 gigawatts electric (GWe) in 2021. Geothermal still amounts to a mere 0.5% of renewables-based installed capacity for electricity generation and heating, globally. However, geothermal deployment for heating grew at an average rate of around 9% annually between 2015 and 2020 to reach 107 gigawatts thermal (GWth) in 2020.

Historically, the complications, risks and expense of drilling deep underground and extracting heat have held the industry back, with little incentive to invest heavily when other, competitive sources of energy are plentiful.

Supply-chain gaps are a major factor hindering the advance of the geothermal industry. Operators have also been put off by high capital expenditure and a degree of uncertainty regarding the cost of drilling equipment and machinery for this (relatively) new industry.

U.K. Parliament research papers have identified a lack of information about the application of the technology in the U.K., which has meant that deep geothermal, in particular, has not historically factored into the U.K.'s carbon budget or government strategies.

However, the scales are moving because of the energy transition, with billions of dollars flowing into finding cleaner energy solutions and the price of carbon emissions going up in several jurisdictions.

Global concern over energy security after the war in Ukraine is also focusing minds on geothermal as a potential solution.

In practical terms, the geothermal industry will require significant investment and collaboration in technology, know-how and IP, drawing on expertise from energy companies, and in particular from the oil & gas sector.

Recent developments and trends

For some players, the involvement in geothermal is of long-standing. For example, the big wells contractors (e.g. Schlumberger, Halliburton and Baker Hughes) have been operating in the geothermal market for decades.

However, developments involving newer players are already afoot and there are (very) recent signs of industry collaboration – across the globe – for example:

- in Indonesia, Masdar (also known as the Abu Dhabi Future Energy Company) has made an investment in Pertamina Geothermal Energy, a state-owned geothermal developer;
- in Japan, Chevron has teamed up with Mitsui Oil Exploration to explore the feasibility of local advanced geothermal power generation;
- in Texas, the Texas Geothermal Energy Alliance has brought together a mix of oil giants, oil & gas service companies, utilities and start-up companies aimed at developing geothermal energy. Member companies include: Chevron, CenterPoint Energy, Baker Hughes, Halliburton, Repsol and Sage Geosystems;
- in Canada, BP and Chevron have both invested in geothermal start-up Eavor Technologies;
- in Wales, the Welsh Government has been exploring whether water in disused coal mines could be used to heat homes;
- in Cornwall, Geothermal Engineering (backed by asset manager Kerogen Capital) has been drilling near Redruth, reaching depths of three miles and accessing water at temperatures of 180°C. By 2024, it expects to be the first deep geothermal plant in the U.K. to generate electricity for the national grid and generate heat for nearby homes;
- Masdar and ADNOC recently joined forces to explore and develop geothermal projects. Under the Memorandum of Understanding, Masdar will deploy geothermal projects globally and ADNOC will provide drilling expertise;

- the Industrialization & Energy Services Company (TAQA), a Saudi Arabia-based company that develops technologies to the energy industry, and Reykjavik Geothermal, an Iceland-based global leader in the development of sustainable geothermal power, signed a joint venture agreement to establish TAQA Geothermal Energy LLC. TAQA Geothermal will explore and develop Geothermal resources in Saudi Arabia and the MENA region; and
- Baker Hughes (alongside Continental Resources, INPEX, and Chesapeake Energy) has formed a geothermal energy consortium "Wells2Watts", which seeks to transform non-productive oil and gas wells into geothermal wells capable of generating renewable power.

As such, there are already clear examples of companies using their existing technical expertise, developed over decades in the oil & gas industry, to play their part in the energy transition.

Nor is this diversification limited to the companies themselves. The experience of personnel from the oil & gas industry is already proving valuable. For example, Schlumberger personnel are now members of the senior management team at Quaise Energy. Denmark-based Innargi uses the knowledge of geologists, reservoir, facility and drilling engineers from the oil & gas industry.

Government interaction

A main risk for geothermal developers is associated with subsurface and geological uncertainties. A number of governments have increased activity in research and risk mitigation funding in recent years. Examples include:

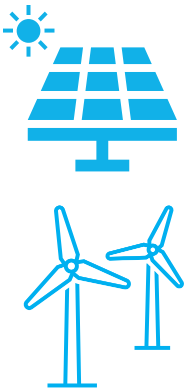
- in Switzerland, a geothermal guarantee scheme which provides financial contribution for up to 60% of the total sunk subsurface exploration (including deep drilling and subsurface exploration), and upstream investment and development costs required for direct use of geothermal energy to supply heat;
- in Hungary, an ongoing government geothermal de-risking scheme was launched in 2021. The total budget of approximately EUR 16 million is broadly intended to reimburse deep geothermal projects for eligible costs at a rate of 30% for successful projects, and 60% for unsuccessful projects;
- Germany has a long history of geothermal risk mitigation schemes which have had varying degrees of success. There has been recent suggestion by the European Commission that funding will be proposed for renewable heat networks, which would involve 40% subsidies;
- in Iceland, research is well funded (by Iceland's government and privately), with current projects including the IDDP funded by the International Continental Scientific Drilling Program, and the US National Science Foundation. Iceland's geothermal legal framework is amongst the most developed in the world, with the granting of licences for exploration and utilisation of Iceland's geothermal resources being governed by the National Energy Authority of Iceland (NEA). Geothermal-related support schemes have led to a situation in Iceland where geothermal energy accounts for approximately 25% of Iceland's total production. Accordingly, subsidy and risk mitigation schemes have been reduced. However incentives still exist, for example relating to: (i) initial foreign investment that relates to the production of electricity in Iceland from renewable energy sources (under Iceland's Act on Incentives); and (ii) more targeted support schemes, for example with a particular focus on geothermal heating;

— the EU-funded GEORISK programme was active until 2021, and conducted research into the risks and proposed mitigation methods associated with geothermal investment, with an emphasis on insurance;

— across Latin America, the Geothermal Development Facility (GDF) was launched in 2014 to provide both grant-based risk mitigation instruments (particularly with respect to drilling-related costs) and project financing; and

— for Eastern Africa, the Geothermal Risk Mitigation Facility (GRMF) offers co-financing to 12 African countries for drilling and subsurface study related projects.

Geothermal as solar and wind energy storage



Wind and solar are undoubtedly growing as a portion of the energy mix. For example, wind power contributed 26.8% and solar 4.4% of the U.K.'s electricity generation for 2022. As wind and solar energy grows, so does the need to find storage of energy from those sources (the sun does not always shine; the wind does not always blow).

Geothermal could provide a solution here as well. Very recent research has demonstrated that enhanced geothermal systems could be used as a form of energy storage – thereby assisting in the growth of all three forms of energy generation.

Researchers at Princeton University and Fervo Energy have demonstrated that these advanced reservoirs can store surplus power generated by wind or solar in the form of hot water or steam by powering water injection into artificial reservoirs to accumulate and generate pressure.

Production wells are then opened when energy is needed; the heated water and steam produced can then be used to turn electricity turbines (e.g. when renewable power isn't available).

With the ability to store energy over varying periods of time (a few hours to a number of days) and release it over similar periods – to 'ramp up' and to 'ramp down' – an EGS effectively acts as a giant underground battery (on a level of efficiency demonstrated as being on a par with lithium-ion batteries) – with the storage capacity being free, once the reservoir is commissioned.

A similar study into "reservoir thermal energy storage" and "solar-thermal hybridisation" is being undertaken at present by the Natural Renewable Energy Laboratory and Premier Resource Management, for the storing of excess solar energy as thermal energy in geothermal reservoirs – using old oil and gas reservoirs.

Interaction with the oil & gas sector

It may be apparent from the above that geothermal presents concepts, issues and challenges familiar to the oil & gas industry. There are a number of reasons the experience of the oil & gas sector could be a tremendous benefit to the development of geothermal:

— engineering and technical know-how ('old know-how, new tricks'): geothermal energy requires similar processes and technologies to find, quantify and exploit resources. Employment opportunities could be extended and diversified if those with significant oil & gas experience can transfer their knowledge and skills in, for example, subsurface engineering and drilling techniques and technology;

— identification of locations: seismic information held by oil & gas operators and regulators provide a ready mine of information to assist geothermal developers in deciding where to concentrate their efforts;

— quite literally using the same well or reservoir for both resources: this could be in the form of co-production (many petroleum wells encounter hot water) or, alternatively, it may be possible to repurpose an oil well at the end of its economic life; it could change what has traditionally been seen only as a liability into a clean, profitable asset; and

— legal, regulatory, financial, contractual and commercial similarities: the geothermal industry could benefit from the decades of learning in these areas undertaken by the oil & gas industry. Some of these issues are examined below.

Legal and regulatory framework

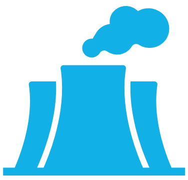
No real consensus yet

Broadly speaking, the legal regulation of geothermal is still in its infancy.

To the extent that it is regulated, there does not yet appear to be a clear consensus on how the resource is to be classified. Even in the U.S., there are varying means of classifying the resource: some States consider it part of the regime for minerals (e.g. California, Nebraska and Hawaii), others use the regime for water (e.g. Alaska and Utah), and yet more place geothermal in its own category (e.g. Washington and Idaho).

According to research at the University of Texas at Austin, no Texas Court ruling can be found determining the ownership of geothermal energy and associated resources – and whether it is to be classified as a surface or mineral resource under Texan law.

Using regulations for existing resources



In some jurisdictions, geothermal can be said to be regulated in large part by existing oil & gas regulations and/or by regulations in other related areas, such as water.

For example, geothermal energy is not recognised as a distinct natural resource under U.K. law, and there is currently no bespoke regulatory system for the licensing, ownership and management of geothermal resources. (Activities are instead controlled under existing regulations developed for oil & gas exploration or water resource use and protection.)

Additional regulations which may need to be tackled by geothermal energy investors include mining, planning and building consent, local / regional authority approvals and environmental regulations.

In addition to the requirement for a detailed understanding of these myriad regulations, sound project management and scheduling would also be required for the various approvals.

Potential development of bespoke geothermal regulatory regimes

The “existing regulations” approach has historically been regarded as being adequate for managing potential environmental and operational impacts, but a bespoke, streamlined regulatory process for geothermal could be of great benefit, especially if geothermal is to be increasingly used to generate electricity and/or heat homes and industrial sites.

Such a form of streamlining could include the creation of a geothermal regulator or an agency to coordinate the various approvals processes.

Indeed, some jurisdictions have already taken the bull by the horns. For example, Southern Australia passed the Petroleum and Geothermal Energy Act 2000 (updated by 2013 Regulations) – which establish a “co-regulatory” regime for the oil & gas and geothermal industries in order to streamline such matters as licence applications, third party access and environmental rules for both industries.

There are good reasons to expect that the development of geothermal regulatory regimes will create regimes very familiar to oil & gas operators (and also to mining operators). Both industries concern the extraction of a resource from the Earth. In consequence, both industries benefit from the regulation of the exploration, development, and production of that resource.

Land rights

As with most onshore oil & gas developments, the regulatory regime for geothermal would typically sit alongside land rights or real estate issues, most notably the requirement for consent of the land owner(s) for the development of the geothermal wells, plants and transport infrastructure.

Commercial / Contractual framework

Project contracts

A geothermal project would require many of the contractual arrangements common to oil & gas developments, including:

— the initial services agreements (such as seismic, drilling, wells goods & services);

— capital projects, construction and development agreements (such as FEED, Detailed Design and/or EPC for the well pad and site, the plant and/or the transportation infrastructure); and

— the operational contracts (including ongoing supply of equipment, wells and O&M services).

There may be debate around how physical risk (property, people, the environment) and financial risks (consequential loss / loss of profit) could be allocated in these contracts but there are good arguments in favour of using the knock-for-knock risk allocation regime adopted by the oil & gas industry.

Under that regime (also called “mutual hold harmless”), each party to the project will take responsibility for its own losses – regardless of cause, even if another party caused the loss. It allows risk to be allocated to the party best placed to deal with the risk; it also reduces insurance (and therefore overall project) costs by requiring the same risks only to be insured once (i.e. by the party sustaining the loss, rather than by all parties insuring their own risk as well as all other parties’ risks).

Sales contracts

The electricity / heat sales/supply agreements include power purchase agreements and/or heat off-take or heat supply agreements.

For heat sales, these contracts have seen a degree of development in the broader heat market (e.g. with waste-to-energy) and may include local and/or public authority purchasers. The sales agreements are typically split into ‘bulk sales’ or ‘network sales’, which regulate supplies between generators and network operators, whereas ‘customer sales’ arrangements regulate supplies to end users.

Where the buyer is a local or regional authority, this could also assist in local regulatory approvals and public relations for the project.

Financing

The sales contracts are also the key to securing financing for a development. Long-term supply contracts, as with gas and LNG arrangements, provide relative predictability for the rate of return and the assessment of risk. The viability of the project is most enhanced where buyers take the form of local or regional authorities, or large, industrial customers.

In some circumstances, this predictability can be enhanced further by local connection and use obligations (requiring consumers to connect to the relevant grid) – these are compulsory arrangements in some jurisdictions, e.g. parts of Germany.

In the context of financing, the experience of the oil & gas industry could again be of benefit, as banks and/or financial institutions look favourably upon the use of experienced “names”– this could be by inclusion in the development consortium, or appointment as the drilling, wells, EPC and/or O&M contractor.

This is particularly the case where, for example, drilling and well services companies are themselves willing to take on an element of project and/or funding risk in exchange for an exposure to the project’s production ‘upside’, something which has been under development (albeit in a limited way) in recent years in the oil & gas industry.

Conclusion

According to Advanced Research Projects Agency–Energy (a U.S. government agency), just 0.1% of Earth's total heat content could meet our energy needs for 2 million years. Even though only a small proportion of the energy pool resting at the earth's core is accessible from the surface of our planet, it does demonstrate the untapped potential of this clean energy source.

Geothermal energy has enormous potential and could make a significant impact on the energy transition and the role (and future) of oil & gas companies.

The geothermal and oil & gas industries both deploy similar exploration and exploitation methods and equipment. These similarities offer oil & gas companies and personnel the opportunity to transfer their expertise (of the seismic information, subsurface engineering, drilling techniques and technologies) and use them for geothermal development.

The expansion of oil & gas technologies into the geothermal sphere could enable a number of breakthroughs in geothermal development and indeed vice-versa.

By now, it is well recorded that traditional oil & gas companies are restructuring to become more clean energy focussed, which could have a direct effect on the geothermal industry through investment and development well into the future.

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