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Drilling Down on Clean Energy: Geothermal Power Unlocked?

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Currently, geothermal energy meets less than 1% of global energy demand. Moreover, due to geographical limitations, only a handful of countries account for almost 90% of global power generation through geothermal sources. However, that landscape is poised to change as the potential for geothermal energy generation grows. According to a recent International Energy Agency (IEA) report, with continued technological advancements, geothermal energy could meet up to 15% of electricity demand growth by 2050, equivalent to around 800 GW of geothermal power capacity. In monetary terms, the IEA projects that total investment in geothermal energy could reach $1 trillion cumulatively by 2035 and $2.5 trillion by 2050, peaking at approximately $140 billion per year.

Geothermal energy uses heat trapped in the earth's subsurface to generate power or provide heating and cooling solutions. Geothermal power generation requires a combination of elements: heat, fluid, and rock permeability. The heat trapped underneath the earth's surface naturally warms the water stored in porous rock or in underground aquifers. Some of this hot water is naturally released to the surface through hot springs and geysers, while another portion remains trapped in pockets of high heat. The vapor naturally flowing to the surface can be captured to generate electricity. Additionally, subsurface pockets of high heat can be accessed through wells, allowing the heat to be drawn up to the surface to generate electricity. Until recently, power generation through geothermal energy was limited to locations with easily accessible underground hydrothermal reservoirs.

Technological advancements, particularly those developed for oil fracking, have made it possible to access heat trapped at greater depths in areas without preexisting hydrothermal reservoirs, thus overcoming geographical limitations. According to the IEA, geothermal energy potential increases as you access greater depths. For example, at a depth of 2000 meters, there is a limited number of countries with geothermal conditions favorable for power generation. At 4000 meters, opportunities for power generation expand greatly. However, at 7000 meters, almost every region of the world has the potential to tap into these underground sources of heat to generate geothermal power. Currently, geothermal power generation has been available only for countries with hydrothermal reservoirs located up to 2000 meters below the surface.

There are two main next-generation geothermal technologies that can overcome reservoir dependency: enhanced geothermal systems (EGS) and closed-loop geothermal systems (CLGS). An

EGS aims to expand an existing hydrothermal reservoir or create a new one using drilling, fracturing, and injection technologies developed for the oil and gas industry. In this approach, water is injected through an injection well to create or expand fractures in the rock. The water heated in the subsurface can then circulate through the rock and be recovered to the surface to drive turbines that generate power. In contrast, a CLGS involves drilling and sealing artificial closed-loop circuits to create an underground heat exchanger. A fluid that boils at a lower temperature than water is circulated through the system, and the resulting vapor can be used to generate power. In this closed-loop circuit, there is no chemical interaction between the fluid and the reservoir, as the fluid heats through conductive heat transfer alone.

Despite the potential of geothermal energy to contribute significantly to the energy transition, several challenges must be addressed and overcome. One major challenge lies in the regulatory frameworks governing geothermal projects. According to the IEA, in most jurisdictions, geothermal resources fall under the same regulatory frameworks as minerals or hydrocarbons, alongside additional regulations related to water management. This is the case notwithstanding the fact that geothermal projects may likely have a lesser footprint than mining or hydrocarbon projects in terms of water and land use and use of hazardous materials. For example, according to some estimates, geothermal projects in U.S. federal lands may currently trigger as many as six reviews under the National Environmental Policy Act. In some other jurisdictions, geothermal resources may also be treated as natural resources subject to an additional licensing regime. This lack of a specific legal and regulatory framework tailored to the particular characteristics of geothermal resources—as distinct from minerals and hydrocarbons—can make the approval process for geothermal projects both costly and lengthy.

The adoption of technologies originally developed for the oil and gas industry may revolutionize the geothermal energy sector by enabling previously inaccessible access to underground heat sources at greater depths. This breakthrough may help overcome the geographical limitations that have constrained geothermal power generation. As these technologies continue to advance and develop, the geothermal industry is poised for significant expansion as a key player in the transition to a more sustainable energy future.

However, several challenges must be addressed to facilitate this growth. Chief among these is the need to establish national legal and regulatory frameworks that account for the specific characteristics of the geothermal power generation industry, rather than applying existing frameworks designed for minerals or hydrocarbons.

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