Head of Steam

The Role of Geothermal Energy in a Changing World

Milo Guan
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Introduction

Geothermal energy, the product of geothermal heat, is an energy source which is of increasing importance to modern-day society. Geothermal heat is generated by the radioactive decay of minerals within the Earth's mantle, as well as residual heat from the Earth's formation. Contrary to popular belief, the immense pressure in the Earth's mantle does not play a significant role in generating heat. Geothermal heat manifests in a variety of ways that are highly visible to human society, such as geysers, volcanoes, and hot springs. It is not surprising that, consequentially, geothermal heat has been socially constructed in a variety of different ways. For example, volcanoes have been viewed by different cultures as dangerous hazards, symbols of nature, bringers of destruction and renewal, or even sites of religious import (López-Vázquez et al., 2024). However, the role of geothermal heat in human society is more than just symbolic. Geothermal heat can be extracted from a heat source, either by pumping water into a geothermal heat source to produce steam, or by extracting hot steam from underground reservoirs directly. This steam is used to rotate a turbine, which in turn produces electricity. Geothermal energy produces less CO2 emissions than burning fossil fuels for energy, making geothermal power plants a renewable alternative to oil and gas power plants.

Geothermal power plants have been built anywhere where the tectonic conditions allow heat to flow to the surface. Most geothermal power plants are located in the "Ring of Fire", a region surrounding the Pacific Ocean where geothermal heat is readily available. The Philippines, Indonesia, California and New Zealand are within the Ring, and make use of geothermal energy. But the country which relies the most on geothermal energy is Iceland. Despite being outside the Ring of Fire, Iceland is well-known for its extensive use of geothermal energy, 70% of Iceland's electricity used comes from geothermal energy, and over 90% of Iceland's homes are heated using geothermal heating (Buchsbaum, M. L., 2023).

Geothermal energy is a renewable energy source - unlike wind and solar, it is not dependent on a variable source. Geothermal power plants provide a reliable and consistent flow of electricity, and can serve as a base-load electricity source. As global temperatures rise, and political shifts cause wind and solar to go out of favor, geothermal energy may be the ideal way to meet the world's growing energy demands while preventing the climate crisis from worsening.

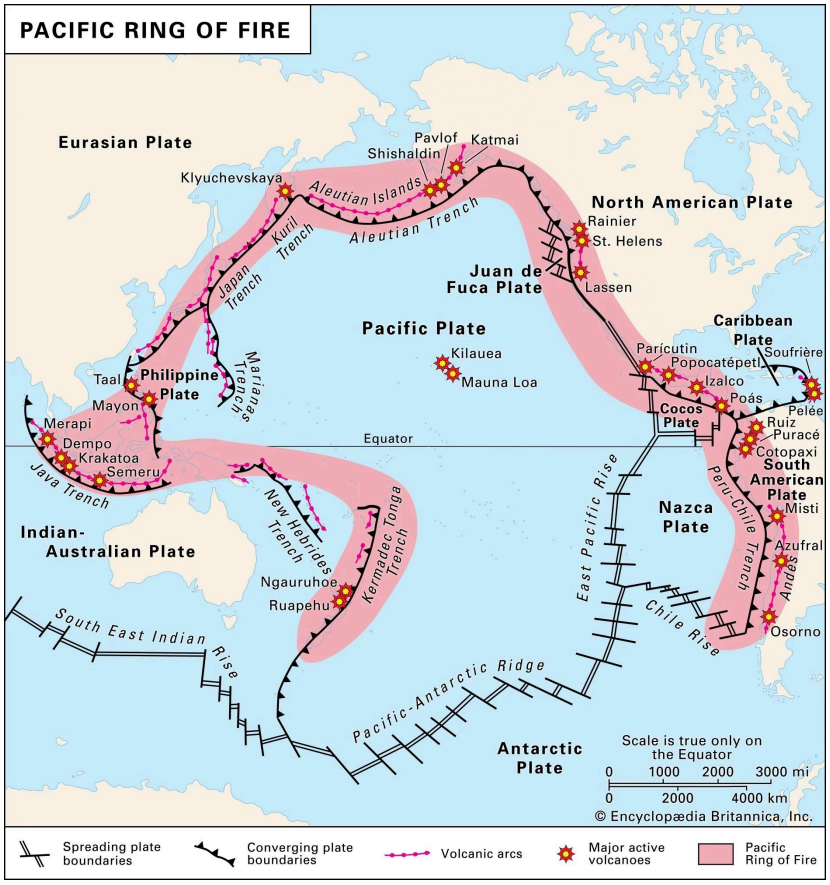

Figure 1: Map Of the Ring of Fire

Source: Encyclopedia Britannica, 2011

Economics and Politics of Geothermal Energy

The economic viability of geothermal energy is inhibited by the high startup costs involved. Expensive survey work is required to find an ideal location for geothermal power generation; seismic sensing, test well drilling, and confirmation testing, as well as further tests. The costs and logistical issues with drilling the geothermal well, as well as building the plant, are also substantial. For this reason, there is a large barrier to entry into the geothermal power market. Small firms and startups are unlikely to succeed in creating a geothermal power plant - only large pre-existing power companies, or organizations with government subsidies, are able to build geothermal power plants. Geothermal power extraction has significant technological overlap with fossil fuel extraction. The drilling and fluid injection equipment used to extract geothermal heat is nearly identical to that used in fracking. Some of the firms in the geothermal power

market, such as Chevron, are primarily fossil fuel companies, which have access to the funds and equipment needed to establish new geothermal power plants.

Figure 2: Darajat Geothermal Power Plant by Chevron, Indonesia

Source: Think Geo Energy, 2011

Geothermal energy is influenced by political shifts in addition to economic factors. Government support in the form of subsidies and supportive policies are necessary for further expansion of geothermal energy. Saul Elbein, a writer for the Hill, wrote that while Trump had not made any official statements directly addressing geothermal energy, the administration could potentially aid the development of geothermal energy. Jamie Beard of the geothermal advocacy group Project InnerSpace, stated that she was “cautiously optimistic” that “geothermal is going to shine under Trump” (Elbein 2025). And some advocates have interpreted Trump’s promises to “drill, baby drill” to be supportive of both the fossil fuel and the geothermal industry (Elbein 2025). Executive order 14260, the same order that aims to “Protect American energy from state overreach”, talks about the need to expand geothermal energy in addition to oil, gas, and coal. However, these indications of support for geothermal energy from the Trump administration are all tangential in nature, combining geothermal energy with the administration’s wider goals of expanding oil and gas mining.

The U.S. is the largest producer of geothermal energy out of any country on the planet, but the Trump administration's support of geothermal energy could have a negative impact on the perception of geothermal energy. Currently, geothermal energy has bipartisan support in the United States, due to its nature as both a renewable and a reliable energy source. However, the Trump administration could cause geothermal energy to be associated with the political right, which could discourage its adoption by future Democratic presidents and lead to a loss of subsidies that the industry relies on (Elbein 2025).

Risk Perception and Risk Actuality

A 2019 study in California, Oregon, and Washington found that 34% of respondents indicated they were "not familiar" with geothermal energy, while 38% were "somewhat familiar" (Karmazina & Steel, 2019). Geothermal energy as an energy sector was less familiar to the public than wind and solar. The risks and benefits of geothermal were an unknown unknown in the perception of the public of the U.S. West Coast. There is an existing risk perception bias due to unfamiliarity, and public awareness of geothermal energy can be increased to facilitate informed decision making (Karmazina & Steel, 2019). However, the 2017 Pohang earthquake in South Korea brought the risks of geothermal energy into the public consciousness.

Figure 3: Photo of Pohang After the 2017 Pohang Earthquake

Source: Changwoo Han, 2024

A Stanford study on the Pohang earthquake found evidence linking the earthquake to a nearby EGS, or enhanced geothermal system (Ellsworth et al., 2019). High-pressure water injection was

used to fracture the rocks, which activated a nearby, recently discovered fault line and triggered a 5.4 magnitude earthquake. William Ellsworth, one of the authors of the study, stated that future disasters could be mitigated through different approaches to risk assessment. “It’s important to consider [induced seismicity] through the lens of evolving risk rather than hazard,” said Ellsworth in an interview with the Stanford Report. Ellsworth stated that hazard is always a factor in an EGS, but that risk can be mitigated by moving the location away from heavily populated areas (Garthwaite, 2019).

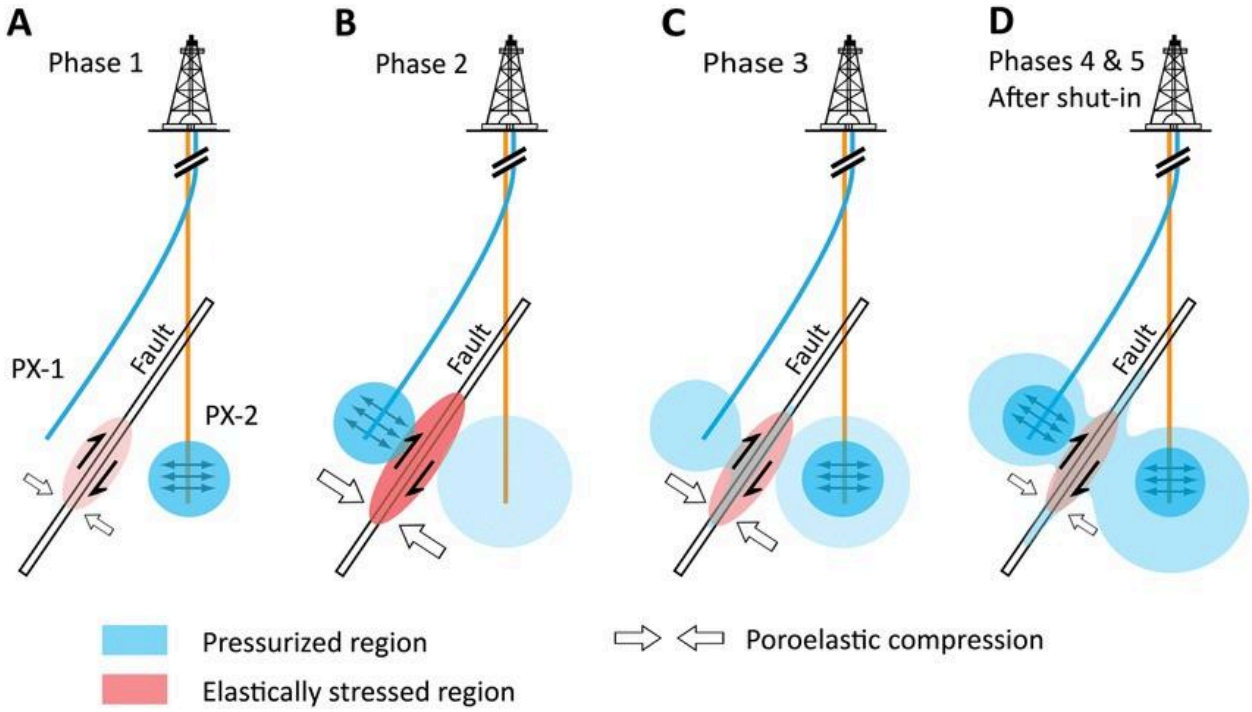

Figure 4: Diagram Showing how the Pohang EGS Fracking Activated the Fault Line
Source: Scientific Reports, 2020

Discourse, Power and Future Opportunities

The concerns of scientists have a real, tangible impact on where geothermal power plants are built, and the safety measures they incorporate. Scientists have raised concerns about the potential of geothermal power plants to release pollutant gasses like hydrogen sulfide, sulfur dioxide, and carbon dioxide that have been trapped in underground reservoirs. However, geothermal power plants emit 97% less sulfur compounds and about 99% less carbon dioxide than fossil fuel power plants of similar size (EIA, 2022). Another concern scientists have is that geothermal energy extraction can reduce or raise the ground temperature when there is an

imbalance of heat extracted and discharged into the ground. Because of the laws of thermodynamics, if too much heat is extracted from the ground, the lower temperature makes it much harder to extract geothermal energy from the same site in the future. Likewise, any heat that is injected back into the ground will remain there indefinitely, causing mechanical failure and changes to the environment in the ground due to increased temperatures (Kim & Lee 2020). To address both of these concerns, most geothermal power plants employ air scrubbers to remove carbon dioxide and sulphur from their emissions, and make sure to inject all of the fluid extracted from the wells back into the EGS to maintain temperature equality (EIA, 2022). Geothermal energy research also has the potential for future exploration and development. Iceland has continued to research new means of geothermal energy production, such as with the IDDP project. The IDDP project was a consortium of the National Energy Authority of Iceland and four leading geothermal energy companies in Iceland, and was tasked with exploring the economic viability of drilling geothermal wells deeper than conventional depths. In June 2009, the IDDP-1 test well drill encountered silica-rich magma, causing the drill to become stuck (IDDP, 2012). Rather than abandoning the project, the scientists and engineers chose to explore the viability of using the hot magma as a geothermal heat source. After inserting cold water into the well, which was in excess of 900 degrees Celcius, the IDDP successfully created the first operational Magma-EGS. The IDDP-1 well was the world's hottest production well, with the potential to produce 36 MWe of electricity (IDDP, 2016). In the case of the IDDP project, the power to produce new scientific knowledge and explore new technologies is held by an intersection of government, scientists, and the private sector.

Conclusion

Geothermal energy has the potential to serve as a base-line energy source that is both renewable and reliable. However, geothermal energy relies heavily on government subsidies due to high startup costs, meaning that its perception as political neutral is necessary for its continued development. Public risk perception of geothermal energy has been affected by a lack of awareness of geothermal energy, as well as the impacts of the 2017 Pohang earthquake. However, future decision-making can avoid similar disasters as long as people are informed of the risks. Furthermore, geothermal power plants have incorporated ways to mitigate the effects of ground temperature change and air pollution, and new research projects like the IDDP present new possibilities for the future adoption of geothermal energy.

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