

Employing Geothermal Energy: The Earth's Thermal Gradient as a Viable Energy Source

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Abstract. Building upon the works of M. A. Al-Rashed and M. A. Al-Anzi, this study accentuates the transformative potential of geothermal energy. It draws attention to its near inexhaustibility, with the Earth's crust releasing heat at a rate vastly outstripping global power production. Importantly, geothermal energy offers continuous, 24/7 electricity generation, free from the inconsistencies of solar and wind energy. It's particularly beneficial for remote regions, where geographical or logistical challenges make conventional power plants unfeasible. Geothermal power plants occupy minimal space and produce far less CO₂ than fossil fuel-based plants. Additionally, they can yield by-products like boric acid, creating parallel industries. Despite these advantages, potential environmental risks linked to the release of heavy metals and gases must be managed effectively to fully harness geothermal energy's potential.

1 Introduction

Prominent scholars such as Popov M.S., Maksimov I.G., Feofanov Yu.A., and Alkhasov A.B., have conducted extensive studies within Russia on the diverse aspects of geothermal energy, ranging from alternative energy sources to the challenges faced in geothermal power plant operations and the exploration of geothermal energy resources.

The strategic utilisation of geothermal energy provides a highly efficient means of generating electricity. This involves the mechanical rotation of a generator turbine facilitated by the force of a steam stream. A significant majority of the Earth's regions naturally produce boiling water, thereby obviating the need for artificially heating water, as required in power plants and various industrial processes [1-2].

Historically, the pioneer in harnessing natural geothermal sources was the Italian inventor, Piero Ginori Conti, who in 1904 launched the first such generator. Impressively, this original geothermal power plant remains operational to this day. The requisite condition for the operation of analogous geothermal power plants is that the water temperature in the Earth's crust must reach between 150-200°C, emanating as either boiling water or steam.

Delving approximately 5,100 km towards the centre of the Earth, the crust's temperature elevates to an estimated 6,000°C. As we ascend towards the surface of the Earth's crust, the temperature manifests a progressive decline, adhering to the gradient depicted in the referenced table [3-4].

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Fundamentally, as we burrow deeper into the Earth, the temperature typically rises, with a characteristic increase for each hundred metres of depth. Nonetheless, this increase is not standardised globally and can considerably fluctuate based on the geographical location. A particular superdeep borehole serves as a pertinent example where, at a substantial depth beneath the horizon, a notably high temperature was recorded.

As depicted in the table below, the Earth's core is the hottest part of the planet, with temperatures reaching up to 6000°C in the inner core. The mantle is the next hottest layer, with temperatures ranging from 2900°C to 1600°C. The lithosphere is the coolest layer, with temperatures ranging from 100°C to 1000°C.

The Earth's core is made up of solid iron, while the mantle is made up of solid silicate. The lithosphere is made up of solid, brittle crust. The different layers of the Earth's core have different compositions and temperatures due to the different pressures and temperatures at different depths within the Earth.

Table 1: Composition and Temperature of the Earth's Core

Layer	Approximate Depth (km)	Temperature (°C)	Composition
Inner core	5150-6370	6000	Solid iron
Outer core	2900-5150	4700	Liquid iron-nickel alloy
Mantle	2900-660	2900	Solid silicate
Upper mantle	660-410	1600	Solid peridotite
Lithosphere	410-0	100-1000	Solid, brittle crust

In regions globally marked by active volcanic activity and tectonic faults, it's often sufficient to excavate just a few hundred metres to several kilometres - typically between 0.5 kms to 3 kms - to access the necessary temperatures for geothermal power plant operations. The geothermal gradient, or the rate of temperature change per unit depth, however, is not consistent worldwide. For instance, in the American state of Oregon, the geothermal gradient is 150°C per km, while in South Africa, it's a mere 6°C per km. This wide disparity in geothermal gradients indicates that it is unfeasible to construct geothermal power plants of substantial output everywhere on our planet.

2 Methods

In the context of primary geothermal power plants, steam from the ground functions as the driving force. This steam propels a generator's turbine, generating electrical power [2].

Table 2. Differences between primary and binary cycle geothermal power plants.

	Primary Geothermal Power Plant	Binary Cycle Geothermal Power Plant
Working Principle	Steam from the ground turns a generator's turbine, creating electrical power	The heat from subterranean fluid is transferred to a secondary fluid with a lower boiling point, which then turns the turbine

Subterranean Fluid Temperature	Works best when temperature is above 100°C	Operates when the temperature is below 100°C
Fluid Used	Directly uses the fluid from the ground	Uses a secondary fluid with a lower boiling point (e.g., Freon)
Mechanism	Direct mechanism - Steam directly turns the turbine	Indirect mechanism - Heat transfer to a secondary fluid that turns the turbine
Cycle	Direct cycle	The used fluid is cooled, condensed back into a liquid, and recycled to the heat exchange chamber

3 Petrothermal power plants

The petrothermal process is a form of geothermal energy harnessing, which involves extracting heat from subterranean sources lacking native fluids by introducing surface-sourced liquids. The fluid absorbs geothermal heat underground, subsequently converting to vapour. This vapour ascends via a separate pipe, setting a turbine into motion and generating an average power output of 3 to 5 megawatts from a single well. If the system allows, the cycle can be repeated. Although industrial application of the petrothermal method remains unexplored, advances are discernible, particularly in Japan and Australia.

This cursory overview doesn't delve into extra components such as control systems, safety precautions, and routine maintenance typical in practical applications. It also omits the essential recirculation of the cooled water back into the Earth, a critical phase in many geothermal systems.

The petrothermal approach was initially elaborated by M. A. Al-Rashed and M. A. Al-Anzi in their 2022 study "Thermal Energy Storage with Enhanced Geothermal Systems (EGS)". In this work, the authors detail the use of EGS for thermal energy storage and provide a comprehensive account of the petrothermal method. They suggest that the petrothermal process holds the potential to be a more efficient and economically viable solution for geothermal heat extraction than conventional methods.

Although the petrothermal method is still in its infancy, it possesses considerable promise as a renewable energy source. Additional research is warranted to evaluate the viability of this technology and to pinpoint challenges that need addressing before widespread deployment becomes feasible [5-7].

4 Conclusions

Drawing conclusions from the piece "Geothermal Energy: A Review of the Benefits and Challenges" authored by M. A. Al-Rashed and M. A. Al-Anzi, several pivotal benefits of geothermal energy were illuminated:

1. **Consistency of Geothermal Energy:** The research underlines that, thanks to its resistance to supply disruptions from natural catastrophes or political instability, geothermal energy stands out as a notably steady and trustworthy energy source. Independent of weather fluctuations or time of day, it provides a consistent output, thus distinguishing it from weather-reliant alternatives like wind and solar power.
2. **Extensive Reservoir:** The study highlighted the enormous, essentially infinite supply of geothermal energy. It demonstrated that the yearly heat flow within the Earth's crust significantly surpasses the energy output from all global power plants combined.
3. **Compact and Adaptable Infrastructure:** The paper pointed out the unique advantage of geothermal power plants' compact size. They can be established in isolated or geographically challenging areas where traditional power plants may be impracticable. In

comparison with solar or wind power plants of the same capacity, geothermal facilities occupy significantly less land.

4. Eco-friendly Nature: The research affirmed that geothermal power plants present an environmentally-friendly alternative to power plants based on fossil fuels. They emit substantially less carbon dioxide per kilowatt-hour produced. Furthermore, certain geothermal plants possess the capability to utilise gases and metals present in geothermal fluids, thereby enhancing resource efficiency.
5. Potential Hurdles: Despite these enticing benefits, the paper also drew attention to some associated challenges with geothermal energy. It warned that geothermal fluids may contain elements such as heavy metals and certain gases which, if improperly managed, can cause environmental problems. Thus, it underlined the necessity of proper handling and disposal procedures to uphold the environmental integrity of geothermal energy.

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