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A REVIEW

Geo thermal energy - Clean, safe and renewable - A review study

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Abstract : The rising demand of energy and exhausting sources of fossil fuels has compelled people all over the world towards a renewable, clean energy source *i.e.* geothermal energy. Geothermal resources are reservoirs of hot water that exist or are human made at varying temperatures and depths below the Earth's surface. In side the great depths of the Earth, the temperature (1,250 °C) and pressure is sufficient to melt rock into magma which is termed as lava (750°C) once it comes out of the crust. This heat content is harnessed as geothermal energy and utilized for heat applications as well as generation of power. The majority of the world's geothermal resources are located in the tropical Pacific Rim (Ring of Fire). The types of geothermal resources are categorized as convective hydrothermal systems; EGSs; conductive sedimentary systems; coproduction, with water from oil and gas fields; geopressure systems; and magma energy. Mostly, geothermal fluid can be used directly or indirectly depending on the enthalpy. High-temperature geothermal resources are primarily used for energy production, whereas low to medium ones are particularly equipped for non-electric applications. The extraction of geothermal energy from the grounds leads to a release of greenhouse gases like hydrogen sulfide, carbon dioxide, methane and ammonia etc. However, the amount of gas released is significantly lower than in the case of fossil fuels. Moreover, geothermal energy has proven its capacity to be a reliable, clean, and uninterrupted sustainable renewable energy.

Key Words : Geothermal energy, Extraction methods, Enhanced systems, Direct heat applications, Power plant technologies, Hybridized systems

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INTRODUCTION

Geothermal energy is heat within the earth. The word geothermal comes from the Greek words *geo* (earth) and *therme* (heat). The slow decay of radioactive particles in the earth's core, a process that happens in all rocks, produces geothermal energy. Deep inside the Earth, at depths near 150 kilometers, the temperature and pressure is sufficient to melt rock into magma. As it becomes less dense, the magma begins to flow toward the surface. Once it breaks through the crust it is referred to as lava. Lava is extremely hot; up to 1,250 °C. Average lava temperatures are about 750°C. The heat flowing from Earth's interior is continually replenished by the decay of naturally occurring radioactive elements and will remain available for billions of years. Over a significant period of time, the earth's core has accumulated a lot of heat energy which created a

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substantial temperature difference between the earth's core and the surface. The temperature difference is termed as 'Geothermal Gradient' and this gradient is the source of energy (Gupta *at al.,* 2007). It is a mature renewable energy technology that has a potential to provide clean and reliable energy for power generation and direct heating or cooling. It can be utilized for both electric power production as well as direct heat applications including Ground Source Heat Pump (GSHP) for space or district heating, generating hot water for domestic/ industrial use, running cold storages and greenhouse, horticulture, etc. Our ancient ancestors knew about this free and reliable energy. They bathed and prepared food in hot springs and many cultures considered geysers and other surface geothermal features as sacred places. Today, due to the explorations and calculations of many scientists and engineers, we've realized that only 1% of the geothermal energy contained in the uppermost ten kilometers of the Earth's crust is 500 times that contained in all the oil and gas resources of the world. However, Geothermal Energy has experienced modest growth worldwide in recent times as compared to other renewable energy sources especially wind or solar due to its site specific nature, risk/uncertainty involved with resource exploration and high capital cost.

According to the last World Geothermal Congress 2020 (WGC 2020) held in Reykjavik, Iceland, the world total installed capacity of geothermal energy has been documented to be 10,897 MWe in 2010; 12,283 MWe in 2015 and 15,950 MWe in 2020 respectively. The world total installed capacity is forecasted to be 19,361 MWe in the year 2025 (Sharmin *et al.,* 2023).

Resources and their span :

The exploration for potential geothermal reservoirs is the prime requirement before going into the extraction procedures. There are different kinds of geothermal resources, but the optimum conventional geothermal system needs heat, permeability, and water. The worldwide distribution profile of geothermal resources is primarily focused in three areas: the first is the circum-Pacific belt's west coast, which includes Australia, West Indonesia, the Philippines, Japan, China, and Taiwan. The second zone is the Mid-Atlantic Ridge, which spans the northern end of Iceland and is mostly in the ocean; the third zone is the Mediterranean to the Himalayan region, which includes Italy and China's Tibet (Dincer *at al.,* 2021). The majority of the world's geothermal resources (Archer, 2020) are located in the tropical Pacific Rim (Ring of Fire), which also has the largest geothermal power plants in the world due to its region's high geothermal gradient and heat flux.

Categories of geothermal resources :

The types of geothermal resources are convective hydrothermal systems; EGSs; conductive sedimentary systems; coproduction, with water from oil and gas fields; geopressure systems; and magma energy. The convective hydrothermal system is a heat reservoir that has high enough permeability and porosity for the convection of water. The reservoir has a non permeable rock layer to retain the heat but enough fractures for recharge. Surface indications of such reservoirs are hot springs, geysers, and the like, and the reservoirs may or may not be associated with volcanoes.

Extraction of geothermal energy :

Geothermal resources are thermal energy reservoirs that could be harnessed in the future at comparable costs. Geothermal sources heat water in porous rocks by concentrating heat in the upper crust. The most energy-dense resources are usually located near plate boundaries, where the visible geothermal gradient is common (Muffler *at al.,*1978). A geothermal gradient is nearly always the first indicator that the underlying rocks in a certain area are hotter than the mean value. A magma intruding in the range of a few kilometers of the crust constituting a temperature reading of 600–1000^{o}C could be the localized heat source. The initial step of utilizing the geothermal heat for different applications should be selecting its extraction mechanism, both the conventional (drilling of wells, extraction of fluids) and advanced techniques (EGS). The fundamental steps for conventional extraction method involves drilling of high or low temperature wells, extraction of fluids, testing of well, reservoir modelling and distribution of fluids. The exploration for potential geothermal reservoirs is the prime requirement before going into the extraction procedures. There are different kinds of geothermal resources, but the optimum conventional geothermal system needs heat, permeability, and water. Some advanced methods are also used to harness geothermal energy. Enhanced Geothermal Systems (EGS) is one such method. An EGS plant consists of both aboveground and subsurface infrastructure. Developing an EGS reservoir involves injecting cold fracturing fluid deep underground to open up preexisting cracks or develop new ones (Feng *et al.,* 2022 and Sheng *at al.,* 2020). Then, the geothermal energy is extracted by rerouting a working fluid. By pumping it through the geothermal reservoir's fractured network, the fluid can be heated to a higher temperature before being withdrawn from yet another well (Zhou *et al.,* 2022).

Utilization of geothermal energy :

The heat from the molten core of the earth conducts to the nearby rocks and eventually proliferates by convection to underground water reservoirs. Multiple technologies can be used to tap into the steam or water heated by geothermal energy and channel it toward different uses. The thermodynamic properties and chemistry of geothermal fluid are highly significant for its utilization methods. Generally, geothermal fluid can be used directly or indirectly depending on the enthalpy. High-temperature geothermal resources are primarily used for energy production, whereas low to medium ones are particularly equipped for non-electric (direct) applications (Dincer *et al.,* 2018). Electricity generation is the most important form of utilization of high-temperature geothermal resources (> 150°C). The medium-to-low temperature resources (< 150°C) are suited to many different types of application. Fluids at temperatures below 20°C are rarely used and in very particular conditions or in heat pump applications.

Limitations/shortcomings :

The extraction of geothermal energy from the grounds leads to a release of greenhouse gases like hydrogen sulfide, carbon dioxide, methane and ammonia etc. However, the amount of gas released is significantly lower than in the case of fossil fuels. Furthermore, despite being considered a sustainable and renewable energy, the chances are that specific locations might cool down after time, making it impossible to harvest more geothermal energy in future. The only non-depletable option is sourcing geothermal energy right from magma but the technology for doing so is still in the process of development. The drilling fluid corrodes tubes and associated components in the wellbore at high temperatures. To sustain its qualities, drilling fluid must be kept at a consistent temperature. Drilling geothermal wells is difficult due to loss of circulation fluid, fracturing of abrasive rocks, and elevated temperatures that cause mechanical failures in drilling rigs (Sircaret *et al.*, 2021; System, 2006 and Vivas *et al.,* 2020). Another disadvantage is the high initial cost for individual households. When geothermal energy was contrasted against other renewable energies generating methods, this was discovered that greater capital investment expenditures, longer repayment times, difficulties accessing the source as well as issues regarding modularization stifle geothermal expansion (Kristj, 2005)

Conclusion :

Geothermal energy has proven its capacity to be a reliable, clean, and proven source of providing uninterrupted sustainable renewable energy to societies across different economic and political backgrounds. More than 78 countries are currently using geothermal directly or indirectly, either for electricity production, industrial, agricultural, or domestic applications. Since estimated total amount of geothermal energy that could be used is significantly bigger than the total quantity of energy resources based on oil, coal and natural gas all together, geothermal energy should be having more significant impact. Especially since it's cheap, renewable energy resource that is also ecologically acceptable. But since geothermal energy isn't easily available on all areas, at least areas where this energy is easy available should be exploited (edges of tectonic plates) because this could soften the pressure on fossil fuels helping Earth to recover from dangerous greenhouse gases.

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