GEOTHERMAL ENERGY

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Abstract

This article analyzes the physical and mechanical nature of geothermal energy, its sources, and the technologies used to harness it. Geothermal energy exists in the form of heat stored in the deep layers of the Earth's crust and is released through natural steam, hot water, or heated rocks. This energy source is characterized by its renewable nature and environmental safety. The paper examines the various applications of geothermal energy, including electricity generation, heating systems, and greenhouse agriculture. In addition, the global development of geothermal energy, advanced technologies, and the experiences of leading countries such as Iceland, Italy, the United States, and the Philippines are discussed.

Keywords: Geothermal energy, renewable energy source, natural steam, hot water, geothermal power plant, environmentally clean energy, subsurface heat, low-temperature geothermal waters, energy conversion, geothermal resources of Uzbekistan, hot springs of the Fergana Valley, Qashqadaryo geothermal zone, sustainable development, energy independence, alternative energy.

Introduction

Geothermal energy is a power sector based on the utilization of the Earth's internal heat — either for electricity generation through geothermal power plants or for direct heating and hot water supply. Today, geothermal energy is regarded as one of the most efficient and sustainable energy types due to its clean, reliable, and renewable characteristics. It uses the heat stored beneath the Earth's surface for electricity generation and for heating and cooling homes and businesses [1-2].

Geothermal resources have been used in North America for over 10,000 years; Native American tribes historically utilized hot springs for heating, cooking, and bathing. Currently, the United States is the world's leading producer of geothermal electricity, although it still accounts for only a small share of the nation's total energy consumption. Since geothermal energy is most abundant near tectonic plate boundaries, most geothermal power plants in the U.S. are located in the western states. California has the highest geothermal power capacity, operating over 40 geothermal power plants [3-6].

Countries like Iceland, the Philippines, and El Salvador are also global leaders in geothermal energy, with over 25% of their total energy consumption supplied by geothermal sources.

Dry steam power plants utilize natural underground sources of steam. The steam rises to the surface through production wells, transferring its energy to a turbine, then condenses and is either reinjected into the ground or released into the atmosphere. Dry steam plants are the oldest and simplest type of geothermal power generation and are considered highly efficient. The first dry steam power plant was established in Larderello, Italy, in 1911, and it continues to supply electricity to more than one million people. Another significant example is The Geysers geothermal field located north of San Francisco, which has been generating electricity since the 1960s and currently provides around one-fifth of California's renewable [7-12].

Flash steam plants pump hot water under high pressure from deep within the Earth, where temperatures exceed 180°C. When the hot water reaches the surface, it is directed into a "flash tank" maintained at a lower pressure. The rapid pressure drop causes a portion of the water to instantly vaporize or "flash" into steam, which drives turbines. The remaining liquid can be passed through a secondary flash chamber to extract additional steam. Flash steam power plants are currently the most common type of geothermal energy system in use. For example, Iceland, a volcanic island nation, uses flash steam geothermal power plants to meet nearly all of its electricity needs. The largest flash steam plant in the world is located in the Philippines, along the Pacific Ring of Fire [13-15].

Binary cycle plants use a different approach to generating power. They operate at lower temperatures, typically between 107°C and 225°C, and use heat exchangers to transfer thermal energy from geothermal water to a secondary fluid with a lower boiling point. This secondary fluid vaporizes and drives the turbine. Because moderate-temperature geothermal water is more widely available, binary cycle plants are expected to become the most common type of geothermal power plant in the future [16-17].

The installation cost of geothermal heat pumps ranges between $3,500 and $7,500 for the base unit. High-end systems with additional features such as domestic hot water heating can cost significantly more. Drilling and installation expenses can raise the total cost to $12,000–$15,000 or more. However, some countries offer incentives, rebates, or tax credits to offset these costs. Over time, these systems offer high return on investment due to their energy efficiency. Homeowners who install geothermal heating and cooling systems can expect to save between 30% and 70% annually on energy bills [18-19].

Geothermal energy is based on the Earth's internal heat sources. Unlike solar or wind energy, it is a constantly available form of energy that does not depend on weather conditions. It allows for continuous and stable energy production.

Geothermal power plants emit little to no harmful gases into the atmosphere, making them an effective solution in combating climate change and reducing greenhouse gas emissions.

Although initial construction costs for geothermal power plants can be high, operational and maintenance costs are relatively low in the long term. This makes geothermal energy economically viable over time.

Geothermal energy can be used in various sectors, including:

• Electricity generation

• Residential and district heating

• Greenhouse agriculture

• Industrial processes requiring heat

Unlike wind or solar power plants, geothermal facilities require less surface area, making them suitable for urban outskirts or mountainous regions where space is limited.

Geothermal energy depends on domestic resources, reducing reliance on imported fuels and enhancing national energy independence.

Can only be used in certain areas: To effectively extract geothermal energy, geologically active areas are needed - volcanic zones, areas with tectonic activity. This is not possible in all countries. High initial investment: Identifying geothermal deposits, drilling and building stations requires a large investment. The drilling itself also carries a risk of failure. Negative impact on subsurface layers: In some cases, geothermal drilling can cause ground movements or minor seismic activity. Resource depletion over time: If a heat source is used more than its capacity, it can temporarily cool down or lose power. This requires long-term planning.

Conclusion

Geothermal energy is recognized as one of the most promising and environmentally safe directions in modern energy development. The ability to generate electricity or heat by utilizing the Earth's internal thermal resources positions geothermal energy as a leading source among renewable energy types. Since this energy does not release harmful emissions into the atmosphere, it significantly reduces the carbon footprint and plays an important role in mitigating global warming. Countries such as Iceland, the United States, the Philippines, and Italy are actively utilizing this resource, which demonstrates the economic efficiency and technological reliability of geothermal systems.

In Uzbekistan, geothermal resources—particularly underground hot water sources—are present in regions such as the Fergana Valley, Surkhandarya, and Kashkadarya. These resources hold great potential for application in greenhouse farming, heating systems, healthcare facilities, and industrial needs. However, geothermal energy also presents certain challenges, such as high initial investment costs, geographical limitations, and environmental risks related to the chemical composition of underground waters. Nonetheless, modern technologies are effectively reducing these limitations.

In summary, geothermal energy represents an alternative energy source of economic, environmental, and strategic importance. A phased implementation of geothermal technologies in Uzbekistan could enhance the country's energy security, increase the share of renewable energy use, and contribute to the fight against climate change. The development of this sector requires scientifically grounded, sustainable collaboration between public and private sectors.

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