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Perspective

Geothermal Energy and the Path Toward Carbon Neutrality

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DESCRIPTION

Energy is central to human progress and sustainable development. In the modern world, the need for clean, reliable and renewable energy sources has become increasingly urgent due to the growing effects of climate change and environmental degradation. Among various renewable options, geothermal energy stands out as a stable, efficient and sustainable resource. Derived from the natural heat of the Earth's interior, geothermal energy provides a continuous source of power and heat, unaffected by weather or seasonal changes. Unlike solar and wind energy, which are intermittent, geothermal energy offers consistent output throughout the year. This reliability, combined with its low emissions and small land footprint, makes it one of the most promising solutions in the transition toward a carbon-neutral future. This article explores geothermal energy from a global perspective, highlighting its origins, technologies, applications, advantages, challenges and future prospects.

This heat gradually moves toward the surface through conduction and convection, creating natural hot springs, geysers, and volcanic activity. Geothermal energy harnesses this natural heat by accessing underground reservoirs of steam or hot water, typically found in regions with high tectonic activity. The temperature and depth of these resources determine their usability for different applications ranging from direct heating to electricity generation. Low-temperature geothermal (below 90°C) Used for direct heating in homes, agriculture, and industry. Medium-temperature geothermal (90–150°C) Suitable for combined heat and power systems. High temperature geothermal (above 150°C) Typically used for electricity generation in power plants. The diversity of geothermal resources allows it to serve multiple purposes from heating buildings and greenhouses to producing large-scale electricity. These are the oldest and simplest geothermal systems. They directly use steam from underground reservoirs to drive turbines and generate electricity. Flash steam plants are the most common type today. They utilize high-pressure hot water from underground reservoirs. When the pressure is reduced, the water "flashes" into steam, which then drives a turbine connected to a generator. The condensed water is often re-injected into the ground, maintaining the sustainability of the reservoir. Binary cycle technology allows the use of lower temperature geothermal resources. The vaporized secondary fluid turns the turbine to produce electricity.

Since there is no direct contact between geothermal fluid and the turbine, binary systems have minimal environmental impact and can be used in a wider range of locations. Geothermal energy is one of the cleanest forms of renewable power. Its greenhouse gas emissions are extremely low compared to fossil fuels. Moreover, geothermal systems require minimal land area and water use compared to solar and hydroelectric power. Re-injecting spent geothermal fluids helps sustain the resource and prevent surface pollution. Additionally, geothermal heat pumps significantly reduce electricity consumption in heating and cooling, lowering overall carbon footprints. By providing a steady, weather independent source of clean power, geothermal energy strengthens grid stability and contributes to long-term sustainability goals.

Geothermal energy represents one of the most reliable and sustainable pillars of the renewable energy landscape. It taps into the Earth's internal heat an inexhaustible resource to generate clean electricity and heat with minimal environmental impact. From the icy landscapes of Iceland to the volcanic zones and geothermal energy is proving that the planet itself can power human progress. While challenges such as high exploration costs and limited accessibility remain, technological advancements and supportive policies are steadily overcoming these barriers. As the world seeks to reduce dependence on fossil fuels and mitigate climate change, geothermal energy offers a unique combination of stability, efficiency and sustainability.

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