Geothermal Power

By Chris Eboch

WE ALL WANT TO LIVE, GO TO SCHOOL, AND WORK IN BUILDINGS THAT ARE warm or cool enough. We want lighting in our homes and electricity for computers and other electronics. The energy needed to do these things comes mostly from fossil fuels—coal, oil, and natural gas—which are extracted from the Earth. Burning these fuels releases carbon dioxide and other greenhouse gases into the atmosphere. The buildup of greenhouse gases, which trap heat and increase the Earth's temperature, can significantly alter the Earth's climate.

But there are also efficient sources of energy that are not expensive and do not pollute the environment. Solar and wind power are increasingly being used, and they are environmentally friendly. The main downside is that they require plenty of sun or wind. But another source of energy, which is clean, efficient, and available 24 hours per day, all-year-round, may be an even better alternative in some areas. This energy comes from inside the Earth. So why isn't it more widely used?

Tapping the Earth's energy

The Earth's internal energy is contained in rocks and fluids beneath the Earth's crust. As long as the Earth's core stays hot—which is expected for the next 5 billion years—this source of energy, called geothermal energy, will not run out, unlike coal and oil. So, power plants that extract and distribute geothermal energy can work all day and night, every day, regardless of the weather.

Also, geothermal energy is better for the environment than fossil fuels, which release greenhouses gases, such as carbon dioxide. In contrast, the geothermal power plants that are currently in operation produce less than 1% of the amount of carbon dioxide released by fossil-fuel power plants and little to none of the other polluting gases.

Another advantage of geothermal energy is that it can be cheaper than energy generated from fossil fuels; it can also be tapped locally, reducing dependence on foreign oil.

Traditional geothermal power plants

The first U.S. commercial geothermal power plant opened at The Geysers in California in 1960. Since then, more geothermal power plants have been built there, making The Geysers the largest geothermal development in the world.

Three items are required for a geothermal system: a heat source, permeability, and water. The heat is supplied by the Earth's interior. Most of this energy remains below the Earth's crust, heating nearby rock and water—sometimes to levels as hot as 700 °F.

When water is heated by the Earth's energy, it can be trapped in permeable and porous rocks under a layer of impermeable rock, forming a geothermal reservoir. This hot geothermal water can erupt on the surface as hot springs or geysers, but most of the time, it stays underground.

In the case of hot springs or geysers, the hot water is relatively easy to extract. But when it is trapped deep underground, the hot water needs to be found first, and then a well is dug, often at a depth of up to one mile.

Steam from this hot water is then used to produce electricity. The steam is fed to a turbine, where it passes through multiple rows of blades (Fig. 1). As the steam impacts the blades, it imparts some of its kinetic energy to the blades. The steam turbine drives a generator, which uses electromagnets to convert the kinetic energy into electrical energy.

After the steam is used, it condenses into liquid water. This used water can be recycled

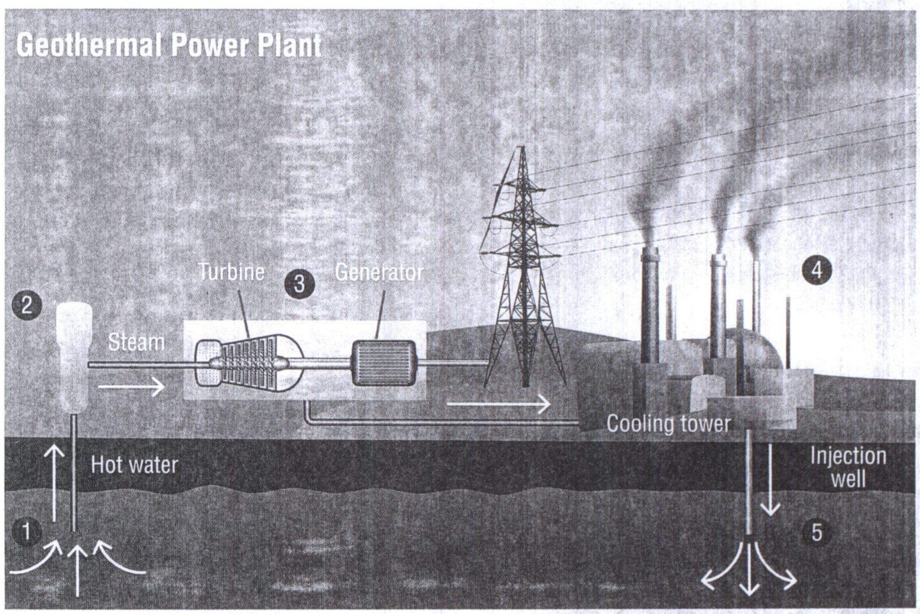

Figure 1. How a geothermal power plant works: (1) Hot water is pumped from deep underground through a well under high pressure; (2) When the water reaches the surface, the pressure drops, which causes the water to turn into steam; (3) The steam spins a turbine, which is connected to a generator that produces electricity; (4) The steam cools off in a cooling tower and condenses back to water; and (5) The cooled water is pumped back into the Earth.

RS GRAPHX, INC.; SOURCE: HTTP://WWW.EPA.GOV/CLIMATESTUDENTS/SOLUTIONS/TECHNOLOGIES/GEOTHERMAL.HTML to produce electricity, over and over again, by injecting it into the ground to refill the reservoir. When the water reaches the reservoir, it is reheated, re-extracted, and its steam is again used to spin the blades of the turbine, starting the cycle all over again.

The main difference between a fossil-fuel power plant and a geothermal power plant is that the former needs to burn fossil fuels to boil water (see "Energy Conversion," p. 12) while the latter extracts the boiling water from the ground. **Because a geothermal plant does not need to burn fossil fuels, it does not generate greenhouse gases, as fossil-fuel plants do.**

Hot Stuff

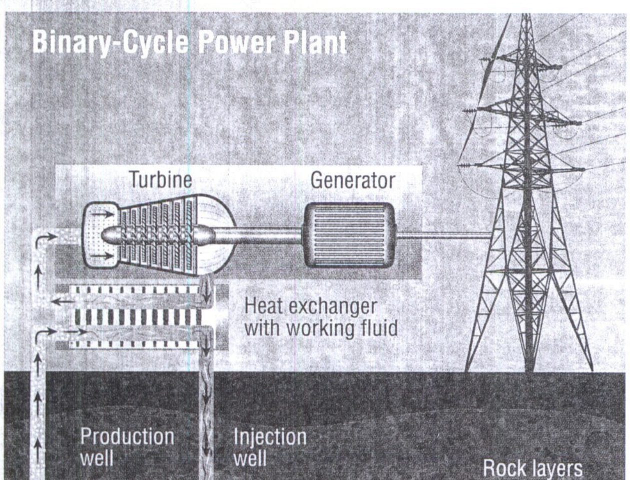

Figure 2. A binary-cycle power plant uses a heat exchanger, in which heat from geothermal water is transferred to another fluid which boils at a lower temperature than water. The heat causes the binary fluid to boil into steam, and the steam turns the turbines that power a generator, which creates electricity.

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Binary-cycle power plants

In the United States, most of the geothermal power plants are concentrated in the western states. The reason is that in many other areas, the underground water is not hot enough to be used in traditional geothermal power plants. In those regions, another type of power plant, called a binary-cycle system, may be used. The main idea is to use a fluid, called a binary working fluid, that boils at a lower temperature than water. This fluid is usually an organic compound such as isobutene or pentafluoropropane.

Instead of using steam from geothermal water, a binary-cycle system uses vapor from the binary working fluid. In this system, the hot geothermal water is pumped through pipes in a heat exchanger, which is a device that allows the transfer of heat between two fluids without their mixing or coming into direct contact (Fig. 2). The binary fluid goes to the heat exchanger, too, and picks up heat from the hot water. The heat causes the binary fluid to boil and turn into steam. This steam then impacts on the blades of a turbine, causing them to move and to drive an electric generator. Then, the extracted geothermal water is injected back into the reservoir, and the cycle starts anew.

Binary-cycle systems are expected to be the primary geothermal systems of the future because they can be used in more places.

Geothermal heat pumps

Heat pumps are another way to produce geothermal energy. These devices, which can be installed in individual homes and businesses, can either heat or cool a building. **In the winter, a heat pump absorbs heat from underground and transfers it to a building. In the summer, the process is reversed, and heat from a building is transferred underground.**

Ten feet below the ground, the Earth stays at a fairly constant temperature, between 50 °F and 60 °F. Usually, such temperatures are warmer than the air temperature in winter and cooler than the air temperature in the summer. A geothermal heat pump takes advantage of this temperature difference.

A heat pump is connected to a set of buried underground pipes in which an energy-absorbing liquid circulates. In the winter, this liquid from the pump is colder than surrounding rocks, so it gains heat from them; in the summer, the liquid from the pump is warmer than the surrounding rocks, so it dissipates its heat and becomes cooler.

Inside the heat pump are two heat exchangers, called an evaporator and a condenser (Fig. 3). They are connected to each other through a reversing valve and an expansion valve (top and bottom of Fig. 3, respectively). In these heat exchangers, a liquid, called a refrigerant, circulates. In the evaporator, the refrigerant exchanges heat with the liquid that circulates in the underground pipes. In the condenser, the refrigerant exchanges heat with the building's air ventilation system.

In the winter, the liquid from the underground pipes transfers heat to the refrigerant in the evaporator, which boils and turns into a gas. The gas then goes through the reversing valve and to the compressor, which increases the pressure of the gas and causes its temperature to rise. The hot gas then goes to the condenser, where it transfers heat to a liquid in a radiator or to incoming cold air, which becomes warm in an air ventilation system. Having cooled, the refrigerant goes from gas to liquid (it condenses), and the liquid goes to the evaporator, and the cycle starts again.

In the summer, the system runs in reverse. Imagine the reversing valve (Fig. 3) turned 90 degrees, so that compressed gas goes to the evaporator. The cycle starts as follows: Hot air inside a building heats the refrigerant inside the condenser. As a result, the air cools down and is blown through an air-conditioning system. The warmer refrigerant evaporates in the condenser, and the gas goes through the compressor, where its pressure is increased, which raises its temperature even more. The hot gas goes through the evaporator, which transfers heat to the fluid that goes through the underground pipes, and this heat is then released underground. Having cooled, the refrigerant goes from gas to liquid, and the liquid goes to the condenser, where the cycle starts anew.

Many families in the United States use geothermal heat pumps in their homes. According to the U.S. Environmental Protection Agency, geothermal heat pumps are the most energy-efficient, cost-effective, and environmentally clean systems. People in nearly every state use geothermal heat pumps.

Energy Conversion

Energy cannot be created or destroyed. However, it can be transferred from one place or substance to another, it can be converted from one form to another, and it can be "stored" in the molecules of substances we call "fuels." Coal, oil, and natural gas are types of fuel that store this **chemical energy.** When these fuels burn, reacting with oxygen, chemical energy is released because the products of the chemical reaction, carbon dioxide and water, are more stable, that is, they have lower energy, than the reactants—the fuel and oxygen.

In a traditional power plant, coal, oil, or natural gas is burned, and the generated heat is used to boil water into steam. The **chemical energy** that was present in the molecules that make up coal, oil, or gas is converted to **kinetic energy** of the steam molecules. The gaseous water molecules in steam are very hot and have lots of kinetic energy, so they are moving rapidly.

The fast-moving molecules of steam collide with a large fan, called a turbine. The collisions transfer energy from the molecules to the fan, which is set in motion, converting the steam molecules' **kinetic energy** to **mechanical energy.** The turbine turns an axle connected to an electric generator. The axle is part of the rotor, a moving part in the generator. The rotor turns a loop of wire in a strong magnetic field, which generates an electric current. So the **mechanical energy** in the rotor is converted into **electrical energy.** The electric current then goes through an electric grid, which delivers electricity to homes and commercial buildings.

Geothermal power plants work in the same way, except that the energy required to boil the water comes from the interior of the Earth instead of a burning fuel.

—Chris Eboch

Geothermal Heat Pump

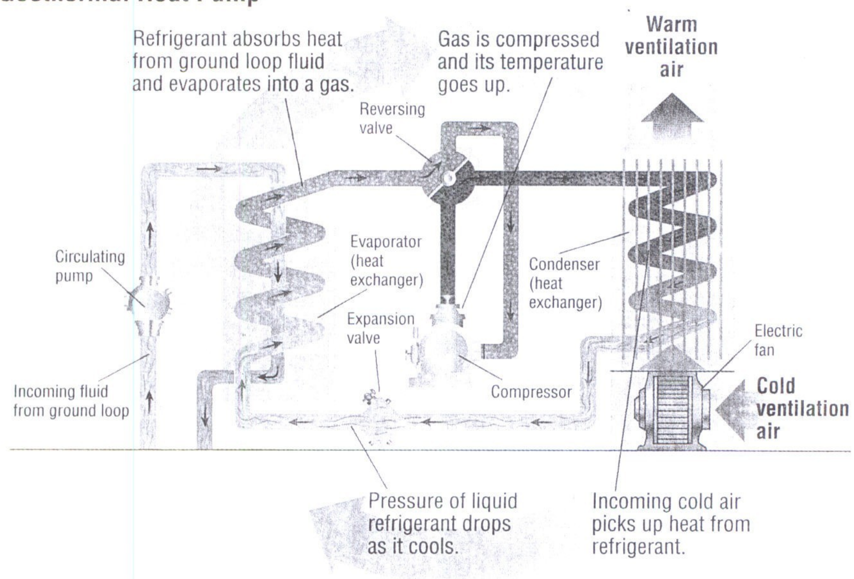

Figure 3. How a geothermal heat pump works. A fluid moves through a network of pipes that are buried underground. In the winter, the energy absorbed from the ground is transferred to a refrigerant in a heat exchanger, called an evaporator. In it, the refrigerant boils and turns into gas. Then, the gas goes through a compressor, where its pressure is increased, which raises its temperature. The hot gas goes through the second heat exchanger, or condenser, where the heat is transferred to the building's distribution system (radiator or blown air). On a hot day, the system runs in reverse. Hot air inside a building transfers its heat to the refrigerant in the condenser, producing cooled air that is recirculated through the building. The warmer refrigerant evaporates in the condenser, and the gas goes through the compressor, where its pressure is increased. Then, the hot gas goes through the evaporator, which transfers the heat to a fluid that goes through the underground pipes.

Growing potential

While geothermal power has room to grow, it does not work everywhere. The United States has only a few basins with the three factors needed to tap geothermal energy: high temperatures, enough water underground, and the ability of water to easily pass through rocks. These limitations mean that while geothermal power may work in some locations, in other areas, wind or solar energy might be better forms of alternative sources of energy.

Currently, geothermal power produces less than 1% of the electricity in the United States. Still, the U.S. government estimates that conventional geothermal energy could provide 10 times as much power as it currently does. Also, binary-cycle systems and geothermal heat pumps allow more access to the Earth's energy. With these advances, geothermal power has the potential to be an even more important energy source, in the United States and abroad. Also, such advances allow us to take advantage of a cost-effective, environmentally friendly, and renewable resource provided directly by the Earth. *CM*

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