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Energy from the Earth

Ron DiPippo

Courtesy of Ron DiPippo

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- 15 Energy Transfer and Storage
- 16 Efficiency
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I'll never forget the day I learned about an energy source that would change the way I think about energy and power. I was in the library browsing through some magazines, when I happened to see an article about geothermal energy. "Free power with no pollution!" the article proclaimed. This was a radical idea. In a world where we pay a big price for power—in both outright costs and environmental degradation—could we really get electrical power for free? And without pollution? I couldn't imagine it.

My name is Ron DiPippo, and I recently retired as a professor of engineering at the University of Massachusetts at Dartmouth. It wasn't until I was well along in my teaching career—about twenty-five years ago—that I saw the article about geothermal energy. I was intrigued enough to do more research into geothermal energy.

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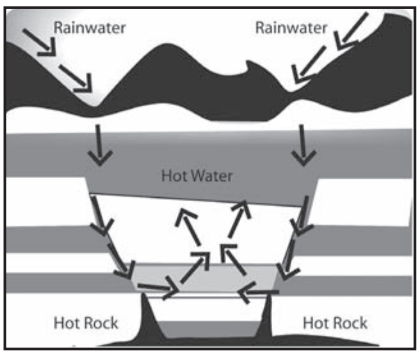
I learned that geothermal power plants could replace some conventional electrical power plants, which burn fossil fuels, in certain locations. I also learned that geothermal plants could generate electricity more cheaply while producing far less air pollution then conventional plants.

You can understand why finding cleaner and cheaper power options is so important if you consider just how many of our technologies require electricity to work. Think of all the electrical devices you encounter during a typical day: streetlights, computers, televisions, telephones, and cell phones, to name a few. Our designed world is full of them! There's no indication that Americans will be using less electrical power in the near future. Therefore, I think it's critical that we find cost-effective and environmentally friendly ways to produce electrical power. Geothermal power is both cleaner and cheaper. That's why I've spent the last two decades traveling the world to help engineers build geothermal power plants.

The Basics

Where does electricity come from? Right now, we generate most of our electricity by burning fossil fuels—natural gas, coal, or oil—to heat water. The water boils and turns into steam. This steam is then used to spin a steam turbine. The spinning of the turbine drives a generator, which creates electricity.



Burning fossil fuels to generate electricity leads to some serious environmental and health problems. Geothermal power plants eliminate the need for burning fossil fuels altogether. A geothermal power plant uses steam and hot water from geothermal wells. These geothermal wells form when pools of water under molten rocks deep below the Earth's surface are heated up. The water boils, creating steam. The large increase in volume increases the pressure in the well, and the pressure difference between the well and the atmosphere gets big enough that the hot steam and water erupt from the Earth's surface as a geyser. It's a ready-made energy source for a geothermal power plant!

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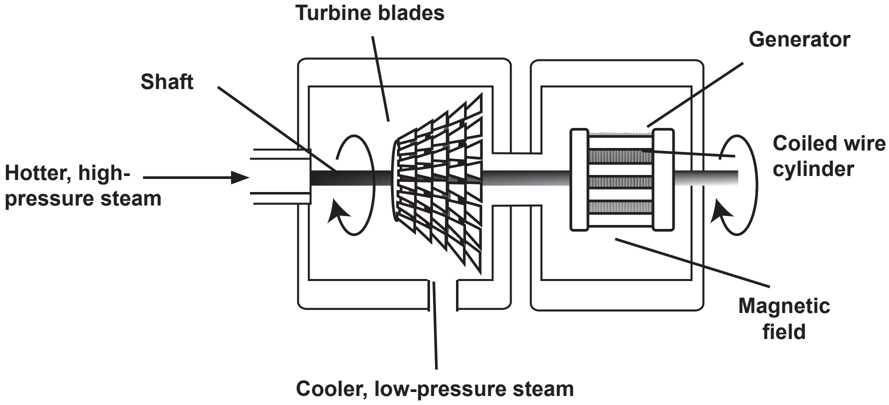
How does hot steam cause a turbine to spin? This subject is one I know and love. I've been a professor of thermodynamics, which is the study of heating and working. In a steam engine, water is heated into steam, the gas form of water. When water boils into steam, its volume increases by as much as 1,600 times.



The hot, high-pressure steam enters one end of a chamber, creating a difference in the chamber. Which way will the energy and matter tend to flow? That's right, from the area of higher concentration to the area of lower concentration. The steam expands and moves through the chamber to the exit. As the steam's volume increases, its temperature and pressure decrease, creating a temperature change, or gradient. When more hot steam enters the chamber, it will flow from the hotter side to the cooler side, creating convection current as it moves. ***Convection*** is energy transfer due to fluid motion.

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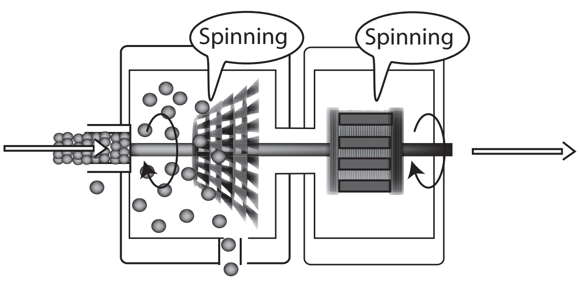
As it travels, the convection current hits the angled blades of a turbine. A turbine is like a huge fan with a long series of angled blades. When the moving fluid hits the turbine, the turbine spins much like a pinwheel spins when you blow on it. As the steam transfers its energy to the blades, causing the blades to turn, the steam loses energy, becoming cooler. The turning blades drive a generator that produces electricity. (You'll learn just how a generator produces electricity in Unit 4.) The energy flows through miles of electrical wiring to businesses and residences where you and I can use it simply by plugging in an appliance or flipping a light switch.



Steam transfers energy to blades, causing them to turn. Steam loses energy and becomes cooler. The turning blades cause the generator to produce electricity.

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The Benefits of Geothermal

Geothermal energy is what's called a renewable energy source. A ***renewable energy source*** is an energy source that is naturally replenished in a short time. As soon as water flows back over the molten rocks in the underground well, the cycle begins again. Some of the folks who first discovered this use for geothermal wells back in the 1960s worked for oil companies. These companies were drilling in the Imperial Valley in Southern California. Occasionally they would hit large underground reserves of water and steam instead of oil. One day, a few oil company executives had a thought: We burn oil or coal to make steam, and then use the steam to drive generators that make electricity. Why not make electricity with the steam directly from these wells and skip burning the oil or coal? It was a very good question, one that led to the development of geothermal technologies.

A ***renewable energy*** source is an energy source that is naturally replenished in a short amount of time.

No power plant can ever be 100 percent efficient. The useful energy outputs will never equal energy inputs because some energy is "lost" to the environment every time energy is transferred. In a typical power plant, the input is coal, oil, or natural gas, and the output is electricity. In a plant that is 100 percent efficient, the electricity leaving the plant should carry the same amount of energy as the coal that is burned. In reality, however, the coal-burning power plants are only about 35 percent efficient.

Where is all of the "lost" energy? Some energy is lost to the air when the coal is burned. A little more energy is lost in the second transfer when the convection currents turn the turbine—some of the energy of the hot steam never gets transferred to the turning blades and instead heats up the chamber.

More energy is lost in the third and final transfer, when the spinning turbine turns the generator. Other losses occur as well. Creating electricity from geothermal energy sources eliminates all the losses associated with the combustion processes. Geothermal power plants tend to be more efficient than typical fossil fuel power plants, having an average efficiency of about 40 to 45 percent.

A few logistical challenges arise when it's time to build the plant. Geothermal power plants need a very large and constant supply of steam so enough energy is available to operate the electricity and account for inefficiency. The large reserves of hot steam exist underground in many places on Earth, but they can be hard to access. Some countries are well-known for their many sources of geothermal energy. In fact, in some places, these geothermal sources are under so much pressure that the hot water and steam simply shoot above the ground.

One such place is located in El Salvador. It's called *Agua Shuca,* which means "dirty water" in Spanish. It was a small, quiet hot spring that people from nearby villages used for washing their clothes. On October 13, 1990, during the night while all the villagers were asleep, Agua Shuca erupted without warning,

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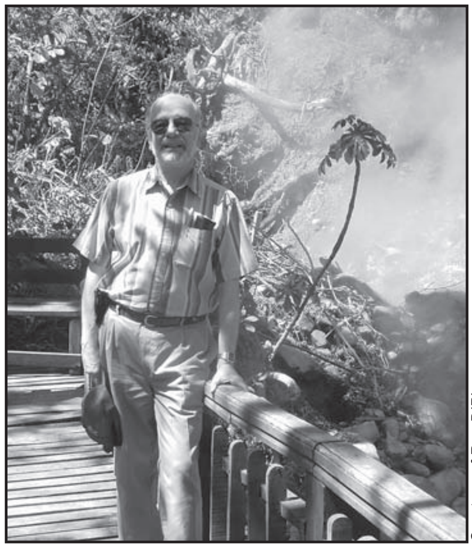
as geothermal sites are known to do. Hot water and mud, boulders, and steam rushed skyward with a tremendous blast. Some people were killed instantly and others were injured. What had been a 10-foot diameter pool of boiling water was turned into a 100-foot-wide by 50-foot-deep crater with vents of mud, hot water, and steam.

A few months after the eruption, I was asked to visit the area and make recommendations about building a geothermal power plant there. When I saw the village, only a few huts remained. Mud could be seen stuck high in the branches of the trees near the springs.


Courtesy of Ron DiPippo

Here I am consulting at a well site in Costa Rica.

The tremendous energy stored in geothermal wells is apparent in situations like this one. We can use that energy, but we also must take precautions. I always encourage geothermal engineers to design many safety features into their wells, piping, and power plants. You just never know when Mother Nature will lose her temper.

In Central America, large geothermal sites are commonplace. El Salvador produces almost 25 percent of its electricity with geothermal power plants. Guatemala, Nicaragua, and Costa Rica also draw a substantial portion of their power from geothermal plants.

I've helped engineers in Kenya, Costa Rica, El Salvador, Guatemala and other nations develop geothermal resources. Geothermal wells are expensive to build, costing as much as $1 million per well. You can never know for sure that you will find hot water until you drill a well. But because of the high cost of drilling, you should have a good idea that you will. I help engineers to decide where to drill wells based on proximity to other geothermal sites. After the well is drilled and the amount of hot water is determined, I make recommendations about how to build a power plant around it.

One type of plant I designed with some students actually uses both fossil fuel and geothermal energy to make electricity. In this type of plant, a combination of coal or natural gas and geothermal energy is used to heat water to create steam for the turbine. This system is necessary when the water from a geothermal source is not hot enough or runs in too short a supply to create enough electricity on its own. The system is more efficient than regular fossil fuel plants. So, while some pollution results from the burning of fossil fuels, the amount is greatly reduced because we burn less coal or gas to get the same amount of electricity that we would in a conventional power plant.

When I started working with engineers in Costa Rica in 1994, the country had only three geothermal wells. Now scores of wells and four geothermal power plants produce electricity in an environmentally clean manner. Overall, in 2001, about 10 percent of Central America's electrical power came from geothermal energy.

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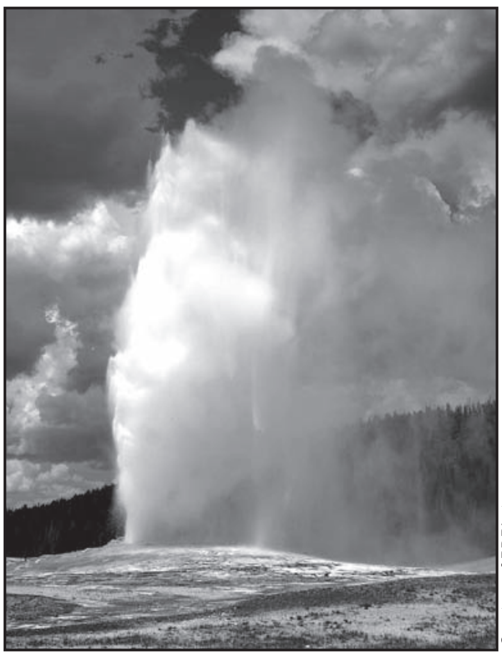
Geothermal in the United States

While we don't have many large geothermal sites in the United States, we do have a few. You probably know about Old Faithful in Yellowstone National Park. Every sixty to ninety minutes, Old Faithful erupts, shooting hot water and steam 100–200 feet into the air. But it does this for only several minutes. While it's a spectacular sight, it would be very impractical for geothermal power. Why? The geothermal energy would be available for only a few minutes every hour or so. We could never rely on a generator with such a sporadic schedule.

The first geothermal plants in the United States were almost a disaster. Engineers quickly discovered that the hot water and steam from deep in the Earth was full of contaminants. In some places, the hot water has ten times the level of salt that we find in seawater. Why? Because when you increase the temperature of water, you can dissolve more in it. Think of how instant hot chocolate powder dissolves faster in hot water than in cold water. The hot water below the surface—400 or 500 degrees Fahrenheit in some places—can dissolve all kinds of minerals, salts, and even metals. When this watery mixture reaches the surface, the pressure and temperature drop, and all of that dissolved stuff emerges as solids. In some places, early geothermal experiments were plagued by clogged pipes—they would plug with minerals within just a day or two.

Chemical and civil engineers who worked on waste treatment plants devised ways to filter out the contaminants so they wouldn't clog the power generators. And do you know what they found? Zinc, silver, even gold! The "junk" that was clogging the pipes was actually loaded with valuable minerals and metals. These geothermal wells delivered much more to the surface than hot water!

Another problem with geothermal energy is water availability. Remember that Old Faithful erupts only every ninety minutes or so because only a trickle of water seeps through the ground to refill it. When enough water has dribbled in, it boils. The pressure increase in the well causes water and steam to blast to the surface. As soon as it blasts into the air, the source is depleted until more water collects.



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Old Faithful Geyser

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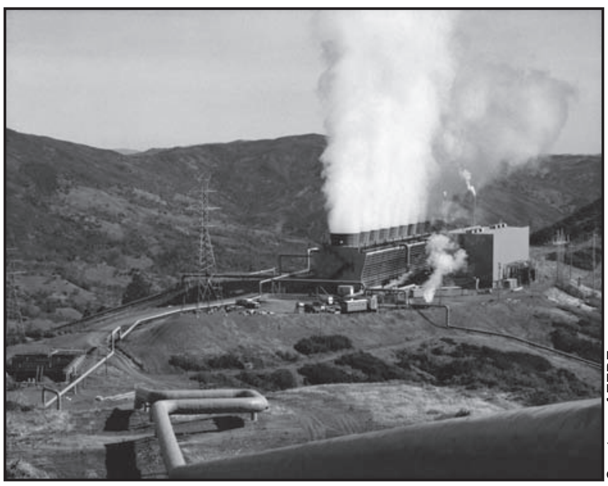
Engineers working with the first geothermal power plants noticed something similar. When they first started the power plants, plenty of hot water and steam was available to spin the turbines and generate electricity. But as the plants used the hot water and steam, the amount reaching the surface steadily decreased. Just like Old Faithful, the output of the geothermal well was limited by the recharge rate—or the rate at which fresh water would flow underground back over the hot rock. In these cases, engineers were taking the water out, but not putting any water back in. If too little water were flowing over the hot magma, then too little hot water would come up the wells. And the more water they took out, the less remained to come up. What to do?

Towns near some well fields in California had another problem: finding the best way to dispose of excess wastewater from their sewage treatment plants. While the water was partially cleaned, it was not suitable for domestic use. It also could not be discharged into rivers and lakes, so it had to be disposed of in other ways. The engineers devised a means to pump this unwanted "gray water" into the geothermal wells. Eureka! Two problems solved at once. The contaminated wastewater was sent down into the hot geothermal wells, where the very high-temperature rocks energized it. The pressurized steam came up through the geothermal well, bringing energy with it.

It just goes to show you that with some creativity, solutions are possible for even the most dumbfounding problems. I truly believe that solving the problems associated with fossil fuels will be an engineering task more challenging and complex than going to the moon was in the 1960s. But the energy we need is all around us. Sure, we must be extraordinarily clever to figure out how to harness the energy. But a little ingenuity goes a long way!

Northern California is well known for its geothermal resources.
Most of the United State's geothermal power plants are located there.



Courtesy of EERE

Navy 1 Geothermal Power Plants in Coso Junction, CA

Courtesy of EERE

The Leathers Geothermal Power Plant in Calipatria, CA

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What's the Story?

1. Why are there so few geothermal power plants in the United States?
2. According to Ron, what are some of the benefits of geothermal power plants?
3. What's the basic difference between fossil fuel–burning power plants and geothermal power plants?

Designing with Math and Science

4. What is convection?
5. Why is convection critical to the function of a steam turbine?
6. Why are geothermal power plants usually more efficient than fossil fuel–burning power plants?

Connecting the Dots

7. Ron mentions that geothermal energy is a renewable energy source. What other renewable energy sources have you learned about in this book?

What Do You Think?

8. Imagine that you have been asked to design your own power plant with an unlimited budget. Use your imagination to brainstorm some other ways you could make a turbine spin to generate electricity without burning a fossil fuel.

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