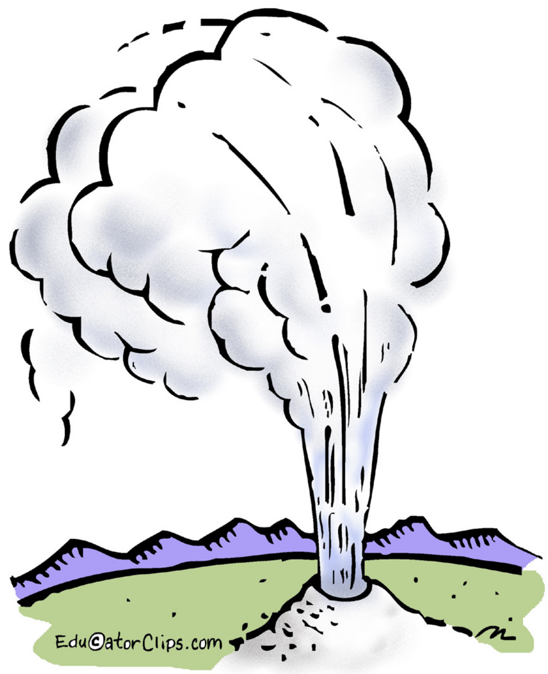
Facts about Geothermal Energy

Introduction



Like the sun, Earth's inner core provides energy in the form of heat to the surface above. This form of heat energy is called geothermal energy. Geothermal energy can be used for heat or power, depending on the location, with minimal impact to the environment. Geothermal resources range from shallow ground sources (low temperature) to hot water, steam, and rock miles below Earth's surface (high temperature).

Geothermal heat originates from Earth's fiery consolidation of dust and gas created over 4 billion years ago, called primordial heat. In addition to the primordial heat, the planet's internal heat source is mainly provided by the radioactive decay of long-lived unstable isotopes such as 238U, 235U, 232Th, and 40K and by latent heat. At Earth's core—4,000 miles deep—temperatures may reach over 9,000 degrees F. Energy from Earth's core continuously flows outward, heating a surrounding layer of rock called the mantle. As heat energy flows outward from the core, the mantle convects (hotter mantle rises to the surface, as it cools, it falls back down lower where it is heated again by the core). When temperatures and pressures become high enough, some of the upper mantle and crust rocks melt, becoming magma. Sometimes the hot magma reaches all the way to the surface, where it is called lava; however, most often the magma remains below Earth's crust. Mantle convection heats nearby rock and water, sometimes to temperatures above 700 degrees F. Heat also comes from the radioactive decay of isotopes found in the crust and mantle from earth's formation billions of years ago.

There are some places in the world known for their highly active geothermal sites, such as Yellowstone National Park. Throughout the globe, Earth's crust receives heat generated from its core and convected by the mantle. In Wisconsin, the temperature of the ground six-eight feet below Earth's surface is relatively stable, about 45-58 degrees F, throughout the year. So, in the summer, the ground temperature is generally lower (cooler) than the air temperature, and in the winter the ground temperature is generally higher (warmer) than the air temperature. Burrowing animals take advantage of the stable ambient ground temperatures, as it is cooler underground in the summer and warmer underground in the winter.

Geothermal Heating and Cooling

There are locations in Wisconsin and other parts of the world where people take advantage of the relatively stable ambient temperatures just below (six to eight feet) Earth's surface to keep indoor temperatures comfortable by using geothermal heat pumps to both heat and cool buildings. This is called low-temperature geothermal energy. Geothermal heat pumps circulate water or other liquids through pipes buried in a continuous loop (either horizontally or vertically) next to a building. Depending on the weather, the system is used for heating or cooling. For example, in cold weather, geothermal energy can be used to heat a home as the circulating liquids in the underground pipes transfer (via conduction) the heat from the ground (between 45-58 degrees F) to the building. In this case, a supplementary heat source like a natural gas furnace or electric heater is often needed to increase the temperature in the building from ground temperature to a

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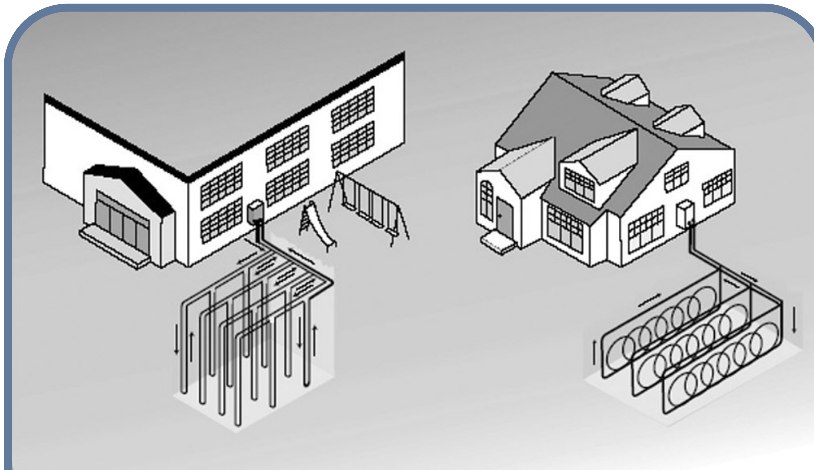
slightly warmer temperature. During hot weather, the continually circulating fluid in the pipes transfers heat from the building to the ground, thus cooling the building. The U.S. Department of Energy recommends indoor temperatures of 68 degrees F in winter and 78 degrees F in summer. Using geothermal energy conserves the amount of energy used by supplementary heating and cooling systems by getting the air temperature much closer to the recommended indoor temperatures than the actual outside air temperature.

Most heat pumps use a closed loop system where fluid circulates through loops installed in the ground horizontally or vertically. In other situations, the loops are submerged in a pond or lake. Open-loop systems, while the cheapest to install, have environmental regulations that limit their use. In open-loop systems, ground water is piped from and back into a well; during the process it passes through a building where its heat is transferred to the heat pump. Geothermal heat pumps are more efficient in the cooling cycle. A typical air conditioner takes the hot air from outside and cools it. With a geothermal system, the source of cooling is from underground and does not require as much energy making the geothermal system more efficient and cost effective. Since the systems are more efficient for cooling, if extensive cooling is not required a geothermal system may not be the best option.

In the U.S., thousands of geothermal systems are helping to make homes, schools, and offices more comfortable. Many schools like this technology because it allows each teacher to control his or her own system for improved comfort in the classroom. Temperature control can be applied to heat or cool whole buildings for events in just one area. In Wisconsin, Fond du Lac High School (closed-loop pond system) and Evansville High School (vertical ground closed-loop system) are among some of the structures acclimated by geothermal heat pumps. Geothermal heat pumps use very little electricity. The U.S. Environmental Protection Agency has rated geothermal heat pumps as among the most efficient of heating and cooling technologies, with a 300-600 percent efficiency in the winter. Many homebuilders consider geothermal heat pumps as a means to reduce their home energy costs and impact on the environment, although geothermal manufacturing and shipping activities decreased in 2009. Wisconsin consumed about 600 Btu of energy from geothermal sources in 2013, compared to 39.5 trillion Btu in the United States.



Source: Focus on Energy. Geothermal heat pumps for Wisconsin homes, businesses and schools. Fact Sheet. Publication REN2004-0602. ©2002 Wisconsin Focus on Energy

Electricity Production

High temperature geothermal resources are underground reservoirs of hot water or steam that can be tapped for electrical power production. Presence of volcanic activity is a good sign that there is high temperature geothermal power ready to be tapped. Developers drill wells into the geothermal reservoirs to bring the hot water to the surface. Geologists, geochemists, drillers and engineers do a lot of exploring and testing to locate underground areas that contain this geothermal water, so that they will know where to drill geothermal production wells. Once the hot water and/or steam travels up the wells to the surface, they can be used to generate electricity in geothermal power plants.

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In geothermal power plants, steam, heat, or hot water from geothermal reservoirs provides the force that spins the turbine generators and produces electricity. The used geothermal water is then returned down an injection well into the reservoir to be reheated, to maintain pressure, and to sustain the reservoir.

There are three kinds of geothermal power plants:

A “dry’” steam reservoir produces steam but very little water. The steam is piped directly into a “dry” steam power plant to provide the force to spin the turbine generator. The largest dry steam field in the world is The Geysers, about 90 miles north of San Francisco. Production of electricity started at The Geysers in 1960, at what has become one of the most successful alternative energy projects in history.

A geothermal reservoir that produces mostly hot water is called a “hot water reservoir” and is used in a “flash” power plant. Water ranging in temperature from 300–700 degrees F is brought up to the surface through the production well where, upon being released from the pressure of the deep reservoir, some of the water flashes into steam in a separator. The steam then powers the turbines.

A reservoir with temperatures between 250–360 degrees F is not hot enough to flash enough steam but can still be used to produce electricity in a “binary” power plant. In a binary system the geothermal water is passed through a heat exchanger, where its heat is transferred into a second (binary, or “working”) liquid, such as isopentane, that boils at a lower temperature than water. When heated, the binary liquid flashes to vapor, which, like steam, expands across and spins the turbine blades. The vapor is then recondensed to a liquid and is reused repeatedly. In this closed loop cycle, there are no emissions.

Since the world’s first production of geothermal electricity in Larderello, Italy in 1904, the use of geothermal electricity has continued to grow. The United States leads the world in the amount of electricity generated with geothermal energy. In 2015, U.S. geothermal power plants in seven states produced about 16.8 billion kWh, or 0.4 percent of total U.S. electricity generation. In 2013, twenty countries, including the United States, generated a total of about 70 billion kWh of electricity from geothermal energy.

Other Uses

Geothermal water is used around the world, even when it is not hot enough to generate electricity. Any time geothermal water or heat are used directly, less electricity is used. Using geothermal water directly conserves energy and reduces the use of polluting energy resources with clean ones. The main non-electric ways geothermal energy is used are direct uses and geothermal heat pumps.

Direct uses of geothermal waters ranging from 50 degrees F to over 300 degrees F include health spas, greenhouses, aquaculture, and milk pasteurization. These waters can also be used in the space heating of individual buildings and of entire districts. Geothermal district heating systems pump geothermal water through a heat exchanger, where it transfers its heat to clean city water that is piped to buildings in the district. There, a second heat exchanger transfers the heat to the building’s heating system. The geothermal water is injected down a well back into the reservoir to be heated and used again. The first modern district heating system was developed in Boise, Idaho. Modern district heating systems also serve homes in Russia, China, France, Sweden, Hungary, Romania, and Japan. The world’s largest district heating system is in Reykjavik, Iceland. Since it started using geothermal energy as its main source of heat, Reykjavik, once very polluted, has become one of the cleanest cities in the world.

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Effects

The environmental impacts of direct uses of geothermal energy and geothermal heat pumps are minimal. The average home built in Wisconsin has sufficient yard space to accommodate the area needed for a geothermal system. However, geothermal energy for heating, cooling, or to produce electricity is not available and/or feasible in all areas. As mentioned previously, Wisconsin is using the Earth's ambient temperature for heating/cooling, or low temperature geothermal. With open loop systems there is a chance that geothermal systems could pollute groundwater resources. Finally, low temperature geothermal systems are more efficient in the cooling cycle.

Some locations use high temperature geothermal energy to produce electricity. Using geothermal energy to generate electricity has more negative environmental effects. Heat and fluid extraction from geothermal reservoirs can deplete sources of geysers and surface hot springs, damaging ecosystems that depend on the unique characteristics of these for survival. Subterraneous extraction of heat and fluid can also cause land subsidence, much like the extraction of groundwater. Certain natural substances, such as arsenic, boron, and mercury, are sometimes present in the water released from geothermal cooling towers. Additionally, carbon dioxide, a greenhouse gas, is released from geothermal cooling towers. However, this release of carbon dioxide is less than one-tenth the amount that would be released from a fossil fuel electrical generation facility of similar capacity.

Outlook

Low-temperature geothermal heating and cooling systems are becoming increasingly popular in new construction for the long-term energy savings associated with these systems. Even though the installation price of a geothermal heat pump system can be several times that of an air-source system of the same heating and cooling capacity, the additional costs are returned to you in energy savings in five to 10 years. System life is estimated at 25 years for the inside components and 50+ years for the ground loop. There are approximately 50,000 geothermal heat pumps installed in the United States each year.

The United States has hundreds of locations in at least 15 states that have been identified as having potential to support high temperature geothermal electric power production. Thousands more megawatts of power could be developed from already-identified geothermal resources. As of February 2015, there was 3,522 MW of geothermal resources developed in the U.S. with an additional 1,275 MW planned. With improvements in technology, much more power will become available. The outlook for geothermal energy use depends on several factors including: the demand for energy in general; the inventory of available geothermal resources; and the competitive position of geothermal among other energy sources. The inventory of accessible high temperature geothermal energy is sizable. Using current technology, geothermal energy from already-identified reservoirs can contribute as much as 10 percent of the United States' energy supply, or about 39,000 MW of geothermal energy. With more exploration, the inventory can become larger.

Enhanced Geothermal Systems, or EGS, could be used to reach geothermal energy that is not easily accessed by other forms of engineering. An EGS is a man-made reservoir created where there is hot rock but insufficient permeability or fluid saturation. A fluid is injected into the subsurface to cause pre-existing fractures to re-open, creating permeability and allowing fluid to circulate throughout the rock, transporting heat to the surface. While this technology could lead to more geothermal electricity production, many risks are associated with it including increased seismic activities, especially dangerous in urban areas where it would be ideal to place. The geothermal resource base becomes more available as methods and technologies for accessing it are improved through research and experience.

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The Wisconsin K-12 Energy Education Program is supported through funding from

Wisconsin K-12 Energy Education Program (KEEP)
College of Natural Resources
University of Wisconsin-Stevens Point

Alliant Energy · WPPI energy · We · WPS · Xcel Energy · MGE

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