PEP

POWER EFFICIENCY PROJECT

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How Geothermal Energy is Collected and Distributed

What is Geothermal Energy?

Earth is split into several layers: **crust**, **upper mantle**, **lower mantle**, and **core**. Natural **radioactive decay** of elements in the core generates heat. This heat spreads throughout the other layers towards the surface of Earth. The **mantle** consists of a layer of **magma** which forms when rock is heated at extremely high temperatures and becomes fluid or semifluid. In the mantle, magma flow is driven by the heat **convection** from the core: the magma rises to the surface as it is heated by the core and flows towards the core after it is cooled by the surface (**Figure 1**).[2] The magma movement in the upper mantle drives the movement

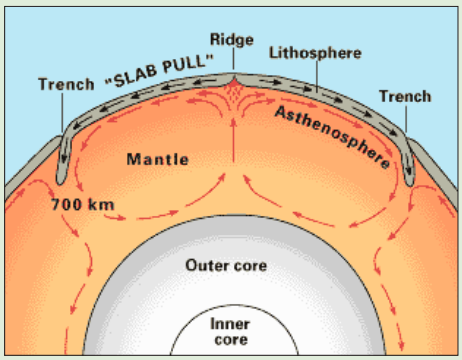

Figure 1:
Hydrothermal circulation in Earth's mantle.
Source: http://pubs.usgs.gov/gip/dynamic/unanswered.html

of the **tectonic plates**. Phenomena such as earthquakes and volcanoes occur at the **plate boundaries** and these "hot spots" are where magma movements break up the rock covering, allowing water to circulate and spurring development of natural **hot springs** and **geysers**. **Hot spots** are the most readily utilized sites for geothermal power plant technologies today. However, hot spots are not needed for smaller applications because usable energy is located just beneath the surface on a global-scale.[1] The amount of heat within the first 10,000 meters of Earth's surface contains 50,000 times more energy than oil and natural gas available in the world.[1]

Geothermal Energy for Heating and Cooling

The simplest way to utilize geothermal energy is through direct-use. People have been directly accessing geothermal energy for thousands of years by using hot springs for bathing and cooking.[2] A more complex form of direct-use is a **geothermal heat pump** (GHP). Geothermal heat pumps can be used to heat buildings and reduce electricity usage and costs by 30-60 percent.[2] The heat pump utilizes the constant temperature of the ground roughly ten feet to a few hundred feet below the surface which remains at approximately 50-60° **Fahrenheit** (depending on the region) year-round.[3] Since the temperature stays constant, the ground is warmer than the outside air during the winter and cooler during the summer. In a **heat pump system**, fluid is pumped underground, and then circulated into the building. In winter when heat is needed inside the building, the system pulls heat from underground and redistributes it into the building. In the summer when heat is not wanted inside, the process is reversed and heat is pulled from the building to redistribute underground. Four designs for geothermal heat pumps can be seen in **Figure 2**. Choice of design depends on geographic location, site criteria, and cost-effectiveness.

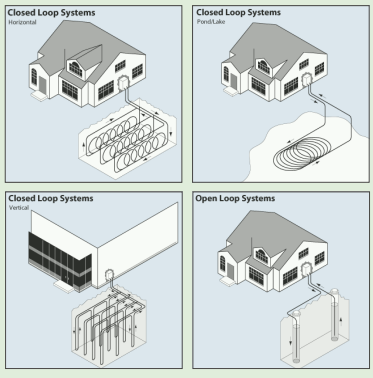

Figure 2:
Closed-and open-loop geothermal heat pump systems.
Source: http://energy.gov/energysaver/geothermal-heat p

Geothermal Energy Power Plants

Geothermal power plants use **hydrothermal** resources (both water and heat) that come from either dry steam or hot water. These hydrothermal resources are accessed by drilling wells into the earth and then pumping steam or hot water to the surface. The hot water or steam powers a turbine-generator that generates electricity. The three types of geothermal power plants are **dry steam**, **flash steam**, and **binary cycle** (**Figure 3**).[5] Choice of design is determined by the geothermal resource and load demands of the application. Using geothermal energy reduces global dependence on fossil fuels and provides continuous **baseload** electricity. Geothermal power plants have the potential to regulate electricity production throughout the day from 100 percent operational capacity to only 10 percent depending on the load demands which reduces production of unused energy.[1] In 2013, the global geothermal **capacity** was estimated at 11,700 MW.[1]

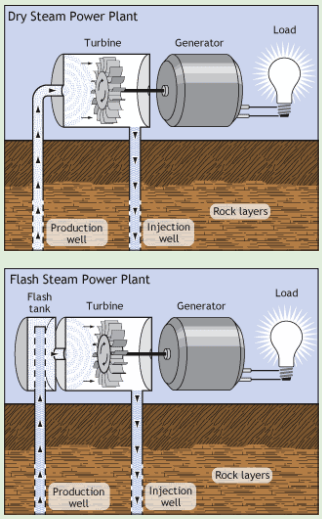

Figure 3:
Geothermal power plant designs.
Source: http://energy.gov/eere/geothermal/electricity-generation

Geothermal Energy and the Environment

While geothermal energy is an important renewable resource to continue utilizing in the future, it does have drawbacks. Despite the cost of electricity from geothermal power plants becoming increasingly competitive, up-front costs for these systems are high. Environmentally, open-heat-pump systems and electricity-generation systems emit some air pollutants. However, the U.S. Energy Information Association explains that "geothermal power plants emit 97% less acid rain-causing sulfur compounds and about 99% less **carbon dioxide** than fossil fuel power plants of similar size."[6] Another issue is the diminishment of geothermal steam and water from continued use of the geothermal system. However, one technological solution is to recharge the geothermal system by condensing the geothermal steam after it flows through the turbine-generator and pumping it back into the earth.

Geothermal Energy in Kansas

An article written by Catherine Evans of the Kansas Geological Survey assessed the geothermal capacity in Kansas. Evans explained that "Kansas has no direct-use systems and limited near-surface geothermal resources to run them."[7] However, geothermal heat pumps have been installed increasingly throughout the 2000s, either retrofitted in existing buildings or built during construction. In Lawrence, a retrofit of the historic Castle Tea Room included a geothermal heat pump installation that provides heating and cooling. In Greensburg, after the devastating tornado in 2007, renovations incorporated geothermal energy technologies, including several houses, the city hall, a K-12 school, an art center, and a business incubator.[7]

Curriculum & Activity Links

Primary

- Geothermal Factsheet, Grades K-2, http://www.need.org/files/curriculum/infobook/GeothermalP.pdf
- Geothermal Factsheet, Grades 3-5, http://www.need.org/files/curriculum/infobook/GeothermalE.pdf
- Geothermal Crossword Puzzle, Grade 4-7, https://www.eia.gov/kids/resources/teachers/pdfs/ElementaryActivityGeothermalPuzzle.pdf

Intermediate

- Geothermal Factsheet, Grades 6-8, http://www.need.org/files/curriculum/infobook/GeothermalI.pdf
- Geothermal Crossword Puzzle, Grade 4-7, https://www.eia.gov/kids/resources/teachers/pdfs/ElementaryActivityGeothermalPuzzle.pdf
- PBS Video, Grades 6-12, https://kpts.pbslearningmedia.org/resource/kqedcl11.sci.ess.geothermalenergy/geothermal-energy-harnessing-the-power-of-the-earth/#.WMbgvW_yu00
- Geothermal Activities, Grades 5-8, https://energy.gov/sites/prod/files/2014/06/f16/geothermal_energy.pdf
- Lesson Plans, Middle and High School, http://www.energytrends.org/show-your-students-the-basics-on-geothermal-energy/

Secondary

- Geothermal Factsheet, Grades 9-12, http://www.need.org/files/curriculum/infobook/GeothermalS.pdf
- Geothermal Energy Teacher Guide, Grades 9-12, https://energy.gov/eere/education/downloads/geothermal-energy-geothermal-teacher-guide-grades-9-12
- Lesson Plans, Middle and High School, http://www.energytrends.org/show-your-students-the-basics-on-geothermal-energy/
- Geothermal Energy PBS Video, Grades 6-12, https://kpts.pbslearningmedia.org/resource/kqedcl11.sci.ess.geothermalenergy/geothermal-energy-harnessing-the-power-of-the-earth/#.WMbgvW_yu00
- Geothermal Education Office Resources, http://geothermaleducation.org/

References

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2. "Geothermal Heat Pumps and Direct Heating Uses." Geo-Energy. Geothermal Energy Association, n.d. Web. 6 Oct. 2016. http://geo-energy.org/pdf/GeothermalHeatPumpsandDirectHeatingUses.pdf
3. "Geothermal Energy." Renewable Energy World. Web. 4 Oct. 2016. http://www.renewableenergyworld.com/geothermal-energy/tech.html
4. "Electricity Generation." Energy.gov. Department of Energy. Web. 4 Oct. 2016. http://energy.gov/eere/geothermal/electricity-generation
5. "Geothermal Energy and the Environment." Energy Explained. US Energy Information Administration, 7 Dec. 2015. Web. 14 Dec. 2016. http://www.eia.gov/Energyexplained/?page=geothermal_environment
6. Evans, Catherine S. "Geothermal Energy and Heat Pump Potential in Kansas." Public Information Circular (PIC) 31. Kansas Geological Survey, 21 Apr. 2011. Web. 04 Oct. 2016. http://www.kgs.ku.edu/Publications/PIC/pic31.html

For more information on geothermal energy is collected and distributed, contact Kansas State University Engineering Extension at 785-532-4998 or dcarter@ksu.edu.