National GEOTHERMAL Collaborative

Geothermal Energy: Technologies and Costs

Geothermal energy provides an affordable, clean method of generating electricity and providing thermal energy. Geothermal power plants tap certain high-temperature resources (above 190°F) to generate electricity with minimal or no air emissions. Heat pumps and 'direct-use' applications, which rely on more common low-temperature resources (typically from as low as 70°F up to 300°F) are used throughout the country as an energy and dollar saving alternative to traditional furnaces and boilers. Two challenges for geothermal energy are that resources are difficult to locate and tend to be found in rural areas. The fact that they are found in remote areas constrains generation and direct use development. It is difficult to transmit heat energy or electricity to the population centers where people will use it. *For further discussion, see "Guidelines for Siting Geothermal Power Plants & Electricity Transmission Lines" at www.geo-collaborative.org/publications.*

This brief focuses on:

- Technology and the different types of geothermal power plants;
- Using geothermal energy for agricultural purposes and for heating buildings; and
- The costs and challenges associated with each technology.

■ Current Technology

Geothermal Electricity Production

Geothermal power plants use the earth's heat— in the form of underground steam or hot water— to spin a turbine and generate electricity. Wells hundreds to thousands of feet deep are used to deliver the hot fluid to the power plant on the surface, where the heat is converted to electrical energy. Nearly all the water is returned to the reservoir through injection wells to be reheated. Currently, geothermal electricity production is limited to certain western states where the hottest resources are closer to the surface. Advances in drilling and energy conversion technologies could make it possible to expand the use of geothermal power plants to other states. The three types of commercial geothermal power plants are dry steam plants that use resources of pure steam, flash steam and binary cycle plants that tap reservoirs of hot water.

Dry Steam

When resources produce pure steam, the steam drives a turbine and generates power. However, these resources are rare; only five such fields have been discovered to date. The only commercially developed steam field in the United States is The Geysers, located in Northern California, which began the commercial production of electricity in 1960. Another dry steam geothermal field in Lardarello, Italy, began production in the early 20th century.

Flash Steam

Geothermal reservoirs that contain hot, pressurized water are much more common and provide energy for all domestic geothermal power production except The Geysers. Flash-steam power plants use resources that are typically hotter than 350ºF. Before fluids enter the plant, the pressure of the fluid is reduced until it begins to boil, or flash. This process produces both steam and water. The steam subsequently is used to drive the turbine; the water is injected back into the reservoir. These types of power plants operate in California, Hawaii, Nevada and Utah.

(Con't.) ▶

Geothermal Electricity Production *(Con't.)*

Binary Cycle

This rapidly expanding technology uses geothermal resources with temperatures as low as 190°F. Rather than flashing the geothermal fluid to produce steam, this type of power plant uses heat exchangers to transfer the heat of the water to another working fluid that vaporizes at lower temperatures. This vapor drives a turbine to generate power, after which it is condensed and circulated back to the heat exchangers. This type of geothermal plant has superior environmental characteristics compared to the others because the hot water (which tends to contain dissolved salts and minerals) is never exposed to the atmosphere before it is injected back into the reservoir. Binary power plants were introduced in the mid-1980s and are the fastest growing generating technology currently with more than 350 MW of binary generation capacity in California, Hawaii, Nevada and Utah.

Direct Use

Direct-use applications tap geothermal resources to provide thermal energy. These projects are feasible throughout a larger section of the country because they use more widespread, low-temperature resources (generally from 70°F to 300°F). Direct-use applications commonly support agricultural and industrial activities but are also an efficient means of heating and cooling buildings.

Agricultural Applications

Most western states—and even some in the Southeast—have direct-use projects to support rural businesses such as fish farming, commercial greenhouses, vegetable dehydration, and milk pasteurization. In New Mexico, four large geothermal-heated greenhouses currently employ nearly 200 people. In 2002, the company operating the greenhouses saved approximately $655,000 using geothermal heat instead of natural gas for their operations.

District Heating

District heating systems distribute geothermal heat to buildings and homes that are connected through a network of pipes. Boise, Idaho has a number of district heating systems to heat more than 350 buildings throughout the city, including the State Capitol. The first system has been in operation since 1892. In addition to heating buildings, Klamath Falls, Oregon, uses this technology for melting snow on some streets, bridges and sidewalks.

Geothermal Heat Pumps

Geothermal heat pumps provide an efficient means of heating and cooling buildings. Heat pumps use less energy than traditional heating and air conditioning systems because they use the earth as a heat source whose temperature is more constant than the outside air. For example, if the outside air temperature is 20°F a traditional air source heat pump requires electrical coils to boost that temperature to maintain a comfortable indoor climate of approximately 70°F. A heat pump, however, draws on the relatively constant temperature in the ground (usually between 50°F to 60°F) and thus does not require electrical booster coils to maintain that same comfortable indoor climate/air temperature. Heat pumps can reduce a building's energy consumption by 30 percent to 50 percent, compared to conventional electric heating and cooling systems. Although these systems are powered with electricity, the power is used to move, not generate, heat; consequently, a heat pump delivers three to four times more energy than it consumes. More than 1 million geothermal heat pumps (with a total capacity to generate approximately 8,600 MW of heat) operate across the country.

■ Advanced Technology

Geothermal power plants need reservoirs that contain heat, water, and permeable rocks located less than 15,000 feet below the surface to generate affordable electricity. Researchers and geothermal developers are searching for ways to enhance the productivity of geothermal reservoirs and to use more marginal areas, such as those that have ample heat but perhaps are only slightly permeable to water, or which are at greater depths. Advanced power generation techniques may make it possible to generate electricity using much lower temperature resources while advances in drilling may allow developers to tap valuable resources located deeper underground. If successful, these advances will enable developers to recover a much larger portion of the earth's thermal energy closer to areas where electricity customers are located or where there is a need for direct use applications.

Cost, Price and Challenges

Unlike traditional power plants that run on fuel that must be purchased over the life of the plant, geothermal power plants use a renewable resource that is not susceptible to price fluctuations.

New geothermal plants currently are generating electricity from $0.05 to $0.08 per kilowatt-hour (kWh). Once capital costs for the plant are recovered, the price of power can decrease to below $0.05 per kWh. The price of geothermal energy is within the range of other electricity choices available today when the costs over the lifetime of a plant are considered (see Table 1).

Most of the costs associated with geothermal power plants are related to resource exploration and plant construction. Like oil and gas exploration, it is expensive and risky to locate geothermal resources because only one in five wells yields a reservoir suitable for development. Geothermal developers must prove that they have a reliable resource before they can secure the millions of dollars required to develop geothermal resources.

Drilling

Although the cost of generating power from geothermal resources has decreased by 25 percent during the last two decades, exploration and drilling remain expensive and risky. Drilling costs alone can account for as much as one-third to one-half of the total cost of a geothermal project. Locating the best resources can be difficult; and developers may drill many dry wells before they discover a viable resource. Because rocks in geothermal areas are usually extremely hot and hard, developers must frequently replace drilling equipment. Individual, productive geothermal wells generally yield between 2 MW and 5 MW of electricity; each may cost from $1 million to $5 million to drill. A few highly productive wells are capable of producing 25 MW or more of electricity.

Transmission

Geothermal power plants must be located in specific areas near a reservoir because it is not practical to transport steam or hot water over distances greater than two miles. Since many of the best geothermal resources are located in rural areas, developers may be limited by their ability to supply electricity to the grid. New power lines are expensive to construct and may be difficult to site. Many existing transmission lines are operating near capacity and may not be able to transmit electricity without significant upgrades. Consequently, any significant increase in the number of geothermal power plants will be limited by those plants' ability to connect, upgrade or build new lines to access to the power grid and whether the grid is able to deliver the additional power to market.

Table 1. **Cost of New Electricity Production** (cents/kilowatt hour)

Technology	Geothermal Flash	Geothermal Binary	Wind	Hydropower	Natural Gas	Turbine
					Combined Cycle (Baseload)	*Simple Cycle (Peaking)*
Capital & Financing Cost	3.50	5.14	3.49	4.62	0.93	6.93
Fixed Operating Costs	1.43	3.08	1.79	1.12	0.19	2.43
Taxes *(credit)*	*-0.54*	*-0.91*	*-0.34*	*0.29*	*0.01*	*0.12*
Total Fixed Costs	**4.39**	**7.28**	**4.93**	**6.03**	**1.12**	**9.49**
Fuel Cost	0.12	0.08	0.00	0.00	3.83	5.11
Variable O&M Costs	0.01	0.00	0.00	0.00	0.24	1.09
Total Variable Costs	**0.13**	**0.08**	**0.00**	**0.00**	**4.06**	**6.20**
Total Levelized Costs	***4.52***	***7.37***	***4.93***	***6.03***	***5.18***	***15.69***

Table 1 Source: Badr, M & Benjamin R. "*Comparative Cost of California Central Station Electricity Generation Technologies*" California Energy Commission June 5, 2003

• These figures are for comparison only and represent the levelized costs as of June 2003 in California. Numbers will vary depending on the quality of the renewable resource and the price of natural gas. • Figures for wind do not include the federal production tax credit of 1.8 cents per kilowatt-hour. • "Taxes" refers to various state and federal tax provisions. • "Levelized costs" refers to the cost of electricity that a power plant will generate over its lifetime. • "Baseload" refers to plants that operate almost constantly while "peaking" refers to plants that operate only during certain hours when electricity demand is at its highest.