4. Geothermal Energy Profile

The basics of geothermal energy resources, electricity generation technology, and the state of the geothermal industry were reported by the Energy Information Administration in 1991.[58] In 1995, the first issue of the *Renewable Energy Annual*[59] updated the status of various aspects of electricity generation from geothermal energy and reported preliminary data on direct consumption of geothermal energy.[60] Since 1991, six new geothermal power plants have been brought into operation in the United States. In Nevada, Soda Lake II, a 13-megawatt binary plant began operating in 1991; Steamboat 2 and 3, two 14-megawatt binary plants began operating in 1992; and Brady Hot Springs, a 21 megawatt double-flash plant also entered service in 1992. In California's Imperial Valley, the 33-megawatt Heber station began operating in 1993. And in Hawaii, Puna, a 25-megawatt hybrid single-flash plant, began producing electricity in 1993.[61]

In 1995, U.S. geothermal capacity totaled 2,968 megawatts nationwide (see Table 5 on page 13 of Chapter 1). This capacity produced 14,656,463 thousand kilowatthours of electricity (see Table 4 on page 12). This amount of generation is roughly equivalent to 24 million barrels of oil, 7.5 million tons of coal (and 8.6 billion pounds of carbon in the form of carbon dioxide), or 152 billion cubic feet of natural gas (and 4.8 billion pounds of carbon). An important side benefit from geothermal power sources is the reduction in amount of hydrocarbons that need to be consumed and the associated greenhouse gases.[62]

Activities in 1996

With the construction of new geothermal power facilities stalled, the most significant event in 1996 for the U.S. geothermal industry was the startup of a new 40-megawatt power plant in the Salton Sea known geothermal resource area (KGRA). Total geothermal electricity generation has continued to decrease, most notably as generation at The Geysers has declined. Most facilities, however, continue to produce steady quantities of electricity, including the Navy's Coso Hot Springs power plants (see Chapter 11 of this report, "Management of Known Geothermal Resource Areas").

Construction of new domestic electricity-producing geothermal facilities in the Western United States during 1996 was limited to one site, due to the availability of cheap, plentiful natural-gas-fired electricity in the West. With only one or two more geothermal sites continuing through the planning process, and with several other plans announced but showing little progress, the geothermal industry has searched abroad for new work.

Routine system maintenance and operation of virtually all geothermal facilities has led to a steady supply of electricity, with a high availability factor (often greater than 95 percent). Occasionally, the owners of a site consider an upgrade of steam supply system components, turbine, or generator. Currently, these decisions are made almost exclusively on economic grounds. Previously, such actions were often based on legislative or regulatory factors, which allowed avoided costs to be exceeded in utility contracts with independent power producers using renewable resources for fuel. Newer geothermal electricity contracts allow the purchasing utility to decline to buy a fixed number of hours of service without penalty, with take-or-pay options for the rest (see Appendix E, "Examples of Contract Arrangements at The Geysers"). The current market does not support the geothermal industry's efforts to maintain its share of the domestic electricity generation market.

Domestically, one unit was completed in 1996—Salton Sea Unit IV, a 40-megawatt project in the Imperial Valley. The area in the United States where a new geothermal power plant has the highest likelihood of being built (by the Calpine Corporation and Trans-Pacific Geothermal Corporation) in the next few years

The author of this chapter is Jim Disbrow, Operations Research Analyst, Energy Information Administration.

[58]Energy Information Administration, *Geothermal Energy in the Western United States and Hawaii*, DOE/EIA-0544 (Washington, DC, September 1991).

[59]Energy Information Administration, *Renewable Energy Annual 1995*, DOE/EIA-0603(95) (Washington, DC, December 1995).

[60]Direct uses of geothermal energy have been summarized by the Geoheat Center at the Oregon Institute of Technology and are available on-line at web site www.oit.osshe.edu. See Appendix C of this report for a brief discussion of geothermal energy and geysers.

[61]Geothermal Resources Council, "NGA Power Database," web site www.geothermal.org (October 15, 1996).

[62]Environmental aspects of geothermal electricity generation are discussed in Appendix D.

is in the Glass Mountain KGRA in northern California, located about 50 miles south of Klamath Falls, Oregon.[63] The Bonneville Power Administration (BPA) could purchase 20 megawatts from the 30-megawatt Glass Mountain power plant. Another candidate site was tested for sufficient resources in 1996. Preliminary well borings at the site, outside the Newberry National Volcanic Monument in Oregon's Deschutes National Forest, showed insufficient amounts of recoverable energy for power plant production.

With this modest level of activity, the U.S. geothermal energy industry has expanded its search abroad for new work and has been successful in signing contracts overseas, such as in the Philippines and Indonesia (see Chapter 12, "International Renewable Energy").

Corporate Changes

A major corporate merger occurred in 1994 when CalEnergy Company, Inc., acquired the Magma Power Corporation, including all of Magma Power's Salton Sea geothermal generating units. While the industry has been stable in recent years, the 15 years following deregulation of the electricity supply and distribution system should create an increased demand for the limited "green" electricity available from geothermal resources and for marketable renewable energy credits, if proposed legislation in Congress is enacted.[64] Changing laws, regulations, and rate structures will also create both incentives and disincentives for geothermal heat pumps and direct uses of geothermal energy.

Hot Dry Rock and Magma Resources

Producing electricity from hot dry rock requires fracturing hot rocks, pumping water into and out of the hot rock, and generating electricity. Federal funding for research into energy recovery from hot dry rock has decreased to $1.7 million in fiscal year 1997, and the Hot Dry Rock Program is being refocused to respond to industry needs.[65] While demonstration of the approach has been successful, the technology remains uneconomical. Funding of energy extraction research has ended, primarily because equipment used to penetrate the magma is not certain to prevent a blowout, and a way to engineer the containment of such a high-pressure, high-temperature blowout is unknown. Research continues in Japan and France, however.

Direct Geothermal Energy

Geothermal energy can be extracted directly for district heating and heat pumps (Table 14). District heating systems may deliver heat to the end user after passing the fluid through a central heat exchanger; thus, the geothermal fluid is not actually delivered to the end user. Such district heating systems exist in Boise, Idaho; San Bernardino, California; and Elko, Nevada; and a new one has been proposed in Reno, Nevada. District heating systems may also deliver the fluid itself to the end user. In both cases, the used geothermal fluid is either reinjected or disposed of on the surface.

Geothermal heat pumps (GHPs) always have heat exchangers. In a closed-loop GHP system, piping either in the ground or submerged in a pond contains a fluid that absorbs heat from its environment. An open-loop GHP system uses groundwater as a heat source and sink, transferring the groundwater to the heat pump unit.

District Heating Systems

Many communities around the world have engineered ways to tap into geothermal hot water aquifers and significantly reduce their fossil fuel consumption.[66] The Second Edition of the *Geothermal Direct Use Engineering and Design Guidebook* contains technical information on low- and moderate-temperature (100 to 300^{o}F) geothermal applications and equipment. The revised and updated version of the guidebook, prepared for the U.S. Department of Energy, represents a cooperative effort by the Oregon Institute of Technology, Idaho National Engineering Laboratory, University of Utah Research Institute, Battelle Pacific Northwest Laboratories, Radian Corporation, and the Washington State Energy Office.

[63]Personal communication with Dave Anderson, former Executive Director, Geothermal Resources Council (September 13, 1996).

[64]H.R. 3790, the "Electric Consumers' Power to Choose Act of 1996," would restructure the entire electricity generating, transmission, and distribution industry. It would also create a Federal market for renewable energy credits, which would be available from utilities contracting for electricity from geothermal facilities.

[65]U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Geothermal Division, *FY 1996 Program Summary*.

[66]P.J. Lienau et al., *Reference Book on Geothermal Direct Use* (Oregon Institute of Technology, Geoheat Center, August 1994). Prepared for the U.S. Department of Energy, Geothermal Division.

Table 14. Temperatures of Geothermal Fluids Required for Various Uses
(Degrees Centigrade)

Temperature	State	Uses
180	Saturated Steam	Conventional power production; evaporation of highly concentrated solutions; refrigeration by ammonia absorption; digestion in paper pulp, kraft
170	|	Conventional power production; heavy water via hydrogen sulfide process; drying of diatomaceous earth
160	|	Conventional power production; drying of fish meal; drying of timber
150	|	Conventional power production; alumina via Bayer's process
140	|	Conventional power production; drying of farm products at high rates; canning of food
130	|	Conventional power production; evaporation in sugar refining; extraction of salts by evaporation and crystallization
120	|	Fresh water by distillation; most multiple-effect evaporations; concentration of saline solutions
110	|	Drying and curing of light aggregate cement slabs
100	|	Drying of organic materials (seaweeds, grass, vegetables, etc.)
90	Water	Drying of stock fish; intense de-icing operations
80	|	Space heating; greenhouse space heating
70	|	Refrigeration (lower temperature limit)
60	|	Animal husbandry; greenhouse combined space and hotbed heating
50	|	Mushroom growing; balneological baths
40	|	Soil warming
30	|	Swimming pools; biodegradation; fermentations; warm water for year-round mining in cold climates; de-icing
20	|	Hatching of fish; fish farming

Source: J.S. Rinehart, *Geysers and Geothermal Energy* (New York, NY: Springer-Verlag, 1980), p. 176.

Klamath Falls, Oregon, has had several decades of reliable use from its geothermal district heating system. Iceland has had centuries of warmth in homes and businesses through district heating systems. In neither case is there a need for air conditioning. The City of San Bernardino, California, uses geothermal energy directly in a district heating program. The City of San Bernardino is located near several earthquake fault zones, including the San Jacinto, Loma Linda, and San Andreas faults. The consequence of being close to these faults is that, since the turn of the century, residents of San Bernardino have, on a very small scale, enjoyed natural heat in the form of steam baths and hot springs. Many wells in the valley exhibit temperatures between 120 and 140^{o}F. The heating district lies in the southwest portion of the city and currently serves more than 35 public and private buildings. Similarly, geothermal water warms greenhouses in Idaho, nurtures fish runs in Utah, and provides hot baths at resorts in Virginia.

Geothermal Heat Pumps

No active technology for home cooling is more efficient than the geothermal heat pump.[67] Ground-coupled heat pumps use moist earth-temperature soil[68] for heating during the winter, cooling during the summer, and supplying hot water year-round. Water-to-air heat pumps exchange heat with either groundwater, surface water, or water passed through cooling towers (for industrial or commercial use). A ground-coupled heat pump system begins with the installation of either coils of plastic piping buried 6 to 10 feet in the earth, long runs of tubing in trenches, or similar piping under the freeze level of a pond or lake. The goal is reached with a greatly reduced electricity bill of $1 per day for single-family dwellings; however, these systems may have a payback period in excess of 5 years. As electricity rates drop, this payback period will get longer and longer, unless equipment and installation costs drop dramatically.

[67]Energy Information Administration, *Annual Energy Outlook 1994*, DOE/EIA-0383(94) (Washington, DC, January 1994), Table 21.

[68]Groundwater temperatures hover around 50^{o}F most of the year in most parts of the lower 48 States. For space heating, geothermal heat pumps have the second best average equipment efficiency of the major equipment types.

In a 1988 survey of GHP buyers, 97 percent said that they were happy with their purchase and would buy again. Approximate estimates of the total number of geothermal ground-coupled heat pumps installed and in use range between 100,000 and 350,000 residences in the United States, out of a total of about 100,000,000 residences.[69] GHPs can be effectively used over the range of earth and air temperatures found in the United States, if designed and implemented properly. Economies of scale favor the conversion of large buildings with circulating water systems for heating and cooling.

The heat pump itself operates on the same principal as the home refrigerator, which is actually a one-way heat pump. The GHP, however, can move heat in either direction. In the winter, heat is removed from the fluid and delivered into the home or building (heating mode). In the summer, heat is removed from the home or building and delivered into the earth for storage, diluting and dispersing it (air-conditioning mode). On either cycle, household water can be heated and stored, efficiently replacing or reducing the requirement for a separate hot water heater. Since electricity is used only to transfer heat, not to produce it, the GHP will extract three to four times more energy than it consumes.

Heat flows naturally from a warm area to a cooler area. In its heating mode, a heat pump's outside ground-source fluid passes across a coil (called the evaporator) containing some refrigerant, a liquid which boils at a very low temperature (as low as 15°F.) When the refrigerant boils, it becomes a vapor, which is sucked into a compressor where it is pressurized. The vapor is then forced through a coil (called the condenser) within part of the heat pump located indoors. As cool indoor air passes over the coil, the vapor cools and turns back to a liquid, releasing heat that is blown through a duct system to heat the house.

The cycle begins again as the liquid refrigerant, cooled by releasing its heat into the house, is pumped back outside. On the way, it passes through an expansion valve, lowering the refrigerant's pressure and temperature again so that it can boil more easily in the coil. In its cooling mode, the heat pump works in reverse, extracting available heat from indoors and transferring it outside and into the ground.

The GHP unit sits inside the home or building, at the site of a normal gas furnace. In a typical closed loop installation, a loop of long plastic pipe (i.e., from one hundred to several hundred feet) is placed down a nearby hole—or horizontally 6 to 10 feet deep—and the hole is backfilled with clay. A water / antifreeze solution is circulated through the loop and through the heat pump to remove heat from or transferring it to the ground. No groundwater is used; no contact occurs between the solution in the plastic pipe and the earth. Installation easily conforms to local construction and well drilling regulations. Typical loop installations have 50-year warranties.

GHP installations are being actively promoted by a few investor-owned utilities and rural electrical cooperatives as a means of promoting energy efficiency and better managing demand. GHPs are estimated to cut 1 to 5 kilowatts of peak generating capacity requirement per residential installation. Since rural electric cooperatives often pay their electricity suppliers a rate based on the rate at the time peak load is experienced, shaving this peak reduces rates for all the members of the cooperatives.

[69]Energy Information Administration, *Annual Energy Outlook 1994*, DOE / EIA-0383(94) (Washington, DC, January 1994), Table 21.