Proceedings World Geothermal Congress 2005
Antalya, Turkey, 24-29 April 2005

The United States of America Country Update

John W. Lund[1], R. Gordon Bloomquist[2], Tonya L. Boyd[1], Joel Renner[3]

[1]Geo-Heat Center, Oregon Institute of Technology, Klamath Falls, OR

[2]Washington State University Energy Program, Olympia, WA

[3]Idaho National Engineering and Environmental Laboratory, Idaho Falls, ID

lundj@oit.edu

Keywords: The Geysers, electric power, direct-use, heat pumps, energy savings, well drilled

ABSTRACT

Geothermal energy is used for electric power generation and direct utilization in the United States. The present installed capacity (gross) for electric power generation is 2,534 MWe with about 2,000 MWe net delivering power to the grid producing approximately 17,840 GWh per year for a 80.4% gross capacity factor. Geothermal electric power plants are located in California, Nevada, Utah and Hawaii. The two largest concentrations of plants are at The Geysers in northern California and the Imperial Valley in southern California. The latest development at The Geysers, starting in 1998, is injecting recycled wastewater from two communities into the reservoir, which presently has recovered about 100 MWe of power generation. The second pipeline from the Santa Rosa area has just come on line. The direct utilization of geothermal energy includes the heating of pools and spas, greenhouses and aquaculture facilities, space heating and district heating, snow melting, agricultural drying, industrial applications and ground-source heat pumps. The installed capacity is 7,817 MWt and the annual energy use is about 31,200 TJ or 8,680 GWh. The largest application is ground-source (geothermal) heat pumps (69% of the energy use), and the next largest direct-uses are in space heating and agricultural drying. Direct utilization (without heat pumps) is increasing at about 2.6% per year; whereas electric power plant development is almost static, with only about 70 MWe added since 2000 (there were errors in the WGC2000 tabulation). A new 185-MWe plant being proposed for the Imperial Valley and about 100 MWe for Glass Mountain in northern California could be online by 2007-2008. Several new plants are proposed for Nevada totaling about 100 MWe and projects have been proposed in Idaho, New Mexico, Oregon and Utah. The total planned in the next 10 years is 632 MWe. The energy savings from electric power generation, direct-uses and ground-source heat pumps amounts to almost nine million tonnes of equivalent fuel oil per years and reduces air pollution by almost eight million tonnes of carbon annually (compared to fuel oil).

1. INTRODUCTION

Geothermal resources capable of supporting electrical generation and/or direct use projects are found primarily in the Western United States (Figure 1). However, geothermal heat pumps extend the utilization to all 50 states. The total identified potential for electrical production, estimated by the United States Geological Survey, stands at 22,990 MWe (Muffler, 1979). A recent evaluation of potential in just California and Nevada by GeothermEx, Inc. (Lovekin, 2004) places the most likely combined total for those two states at 6,200 MWe. This would be nearly triple the existing capacity.

Achieving this electric capacity potential will be dependent upon a number of factors including competing prices for energy and incentive programs that encourage development of renewable energy resources. Recently passed Renewable Portfolio Standards in a number of western states should have a significant impact on renewable development in general and could well result in increased interest in geothermal exploration and development. A production tax credit recently passed by Congress and signed into law in October 2004 provides for a 1.8 cent per kilowatt hour credit, greatly improves geothermal's ability to compete with fossil fuel generation (Gawell, 2004).

In addition to these incentives programs, the United States Department of Energy (USDOE) continues to provide support for research and development of geothermal resources through cost sharing with industry and through research being conducted at a number of the national laboratories. Some ongoing efforts are directed at enhanced geothermal system, downhole diagnostics, enhanced evaporative cooling, mixed binary working fluids, corrosion resistant coatings and co-production of minerals. USDOE has recently cost shared the drilling of geothermal production wells through the Geothermal Resource Exploration and Definition (GRED) program. Three different solicitations have been offered to date. The USDOE is also funding a number of state programs aimed at removing barriers to geothermal development. Finally, USDOE continues to provide technical assistance to direct-use, and small-scale electrical project developers and users with their GeoPowering the West program (Hill, 2004) (www.eere.energy.gov/geothermal/deployment_gpw.html) through national laboratories and organizations such as the Geo-Heat Center at Oregon Institute of Technology (http://geoheat.oit.edu) and the Center for Distributed Generation and Thermal Distribution at Washington State University (www.energy.wsu.edu).

The United States continues to lead the world in installed geothermal power capacity as well as in electrical generation, and considering geothermal heat pumps, is one of the leaders in direct-use applications.

Geothermal energy remains, however, a small contributor to the electric power capacity and generation in the United States. In 2004, geothermal plants constituted about 0.27 percent of the total operable power capacity, and those plants contributed an estimated 0.48 percent of the total generation due to their high load factor.

On a state level, geothermal electric generation is a major player in California and Nevada. The generation in California provides about 6% of the state's energy consumption. It is a minor source of power in the states of Hawaii and Utah. However, it is significant on the Big Island of Hawaii where it now provides for approximately 25% of the power requirements. There has also been renewed interest and activity in Idaho, Utah, Oregon and New Mexico.

The most impressive geothermal growth in the United States occurred during the 1980s, with an average annual increase in capacity of about 11 percent. In contrast, from 1990-1998, it averaged only 0.14 percent due to a leveling off of new plant construction (Sifford and Bloomquist, 2000), and from 2000 to 2004 only approximately 70 MWe of new capacity was added. The period 2000-2004 also saw a reduction at The Geysers in California to an installed capacity of about 1,421 MWe, down from a total installed capacity of 1,875 MWe in 1990. However, only about 1,000 MWe are currently operating. Contributing to the capacity stagnation was the retirement and shut down of six units at The Geysers in California. These include the four original Pacific Gas and Electric (PG&E) units (78 MWe), both of the Central California Power Agency (CCPA) units (130 MWe), and the 55 MWe Bottle Rock plant. Some capacity at The Geysers has been restored due to the construction of two effluent pipelines that bring over 26 million tonnes of water per year to The Geysers for injection. The Lake County pipeline has allowed over 77 MW to be added (Dellinger, 2004) (GRC, 2003) and there are now plans to build as much as 100 MWe in new plants in what was previously abandoned areas of the Geysers. Capacity that will result from the completion of the Santa Rosa pipeline is yet to be determined as it was only completed in 2004, but estimates are that a total of about 100 MWe have already been added by the two lines.

Direct-use, other than geothermal heat pumps, has also remained fairly static with modest increases in space heating and agricultural drying. Even though the onion and garlic dehydration plant at Empire, Nevada (Empire Foods) has temporarily shut down due to competition from dried garlic imports from China, the plant at Brady's Hot Springs (ConAgra Food Ingredients) has added a second line (4 m by 60 m continuous drier) that together can handle over twelve tonnes of wet onions per hour. A small district heating system has come online, I'SOT at Canby in northern California; existing greenhouses have been expanded and a new facility of 1.6 hectares added to the district heating system in Klamath Falls, Oregon, along with additional sidewalk and pavement snow melting systems in the downtown area. Geothermal heat pumps have been the largest growth area, mainly with installation in the mid-western and eastern states. Precise numbers for these installations are hard to determine due to lack of any centralized data gathering; thus, estimates are conservative at 600,000 installed 12.0 kW equivalent units. Except for a few states, which have tax rebate programs for geothermal heat pumps, there is very little support for implementing direct-use projects. However, the USDOE geothermal program is attempting to revitalize direct-use and geothermal heat pump development in the United States.

Table 2 summarizes geothermal electric plant capacity and estimates for the future and Table 5 summarizes direct-use capacity and utilization.

2. PRODUCTION OF ELECTRICITY: ALL SOURCES

Table 1 presents operable electric production capacity and power generation in the United States from all sources for 1999-2003. For 2004, no data were available at the time of writing. All data in this table, except those footnoted, came from the USDOE Energy Information Administration (EIA) (website: www.eia.doe.gov).

Geothermal power production has stayed somewhat constant from 2000 to 2004, with steep declines in capacity slowed by reinjection activities at The Geysers and plant expansions elsewhere. This is discussed further below.

EIA data for geothermal energy are liberally estimated. We use our own estimates of operable geothermal capacity, and they are lower than EIA data. Discrepancies can be traced to plant status and load factors that vary each year. Capacity variations are due to both contractual issues and resource conditions.

3. GEOTHERMAL DEVELOPMENT BY STATE

3.1 California

California accounts for approximately 90 percent of the installed geothermal power capacity in the country. The major areas of development are The Geysers, Imperial Valley, Salton Sea, and Coso. Other areas with geothermal plants are Casa Diablo (Mono-Long Valley or Mammoth) and the Honey Lake Valley including Wendel and Amedee. Glass Mountain is scheduled for development but has been held up due to a number of lawsuits filed by opponents to the project. The locations of all of these areas are shown in Figure 2.

The Geysers

There have been no new plants installed since 1989 when the 2x10 MWe J.W. Aidlin plant came on-line. The four original PG&E units were officially retired in 1992; all surface equipment for Units 1 through 4 has been dismantled. Supply wells have been redirected to other units. Unit 1 was designated a National Landmark in 1985 by the American Society of Mechanical Engineers. Plants no longer in service include PG&E Unit 15 (59 MWe, retired in 1989), DWR Bottle Rock plant (55 MWe, closed in 1990), and the CCPA Units 1&2 (130 MWe, retired in 1996).

Table 2a gives data on the plants at The Geysers, including the rating and the actual output. Owing to a shortfall of steam, the difference between rated and actual power capacity is significant (1421 to 1020). However, this shortfall is being reversed in several units by the southeast Geysers effluent recycling system and the new Santa Rosa pipeline as discussed below.

What has changed in the last decade at The Geysers is ownership. Calpine Corporation now owns over 800 MWe of steam reserves and power plants in The Geysers. Calpine first expanded its ownership there in 1998 with the purchase of the 72 MWe SMUD No. 1 plant for $13 million (GRC, 1998a). Up to 50 MWe of off-peak power from the renamed Sonoma plant was initially sold to Sacramento Municipal Utility District (SMUD). In addition, SMUD has the option to purchase up to an additional 10 MWe of peak power production through 2005. Calpine Corp. markets the excess electricity into the California power market.

PG&E and Unocal Corp., for different reasons, put their respective assets at The Geysers up for sale. On May 10, 1999, Calpine Corp. acquired two PG&E plants in Lake County and 12 plants in Sonoma County for $212.8 million. The 14 geothermal facilities have a combined capacity of 699 MWe.

Calpine Corp. purchased the steam fields supplying the Sonoma County plants from Unocal Corp. on March 19, 1999, for $101 million. The company already owned the steam fields supplying the Lake County plants.

The latest development at The Geysers is injecting recycled wastewater into the reservoir. Both the Lake County and the Santa Rosa projects are now operational. The Southeast Geysers Effluent Recycling project (Lake County) was the world's first wastewater-to-electricity system (www.geyers-pipeline.org) (Dellinger, 2004a). It transports treated wastewater effluent from the California communities of Clearlake, Lower Lake, and Middletown to The Geysers geothermal steam field for injection and recovery as steam for power generation. In Phase 1 of that project, a 48-km pipeline provided 20,500 L/min of effluent to The Geysers. Power generation increased 39 MWe between January 1998 and January 1999, and now stands at nearly 80 MWe. The pipeline was extended and now stands at 80 km. Phase 2 of that system was completed in 2003 and a second pipeline from Santa Rosa to The Geysers was completed in 2004 (GRC, 1999; GRC 2004e).

The city of Santa Rosa pipeline sends its treated wastewater 66 km to The Geysers. The $200 million project went on-line in 2004 (http://ci.santa-rosa.ca.us/geysers/). Together, these two projects are expected to sustain and even increase The Geysers production and at the same time provide local cities with wastewater disposal solutions.

Imperial Valley

The Imperial Valley consists of facilities at the Salton Sea, Heber, and East Mesa geothermal fields in southern California (Figure 2a). Development of Imperial Valley geothermal resources slowed during 2000-2004. One plant, Unit 5, was added at Salton Sea in 2000. Plant data for these areas are given in Table 2b.

Salton Sea Unit 5 is a 50-MWe geothermal power plant located at CalEnergy's Imperial Valley operations. A modification of the current technology is used at Unit 5, as additional energy is extracted from brine already brought to the surface. Salton Sea Unit 5 provided the power needed to operate CalEnergy's Zinc Recovery Project (GRC, 1998b). The zinc recovery project was put online in 2002, but was shut down in 2004 due to technical problems. A 185-MWe facility is planned to be built by California Energy and could be on line as early as 2006.

Mammoth Lakes

There are four units operating at Mammoth Lakes with a total power plant capacity of 40 MWe (Table 2e). The facility was purchased by ORMAT from Covanta in 2004. Although no new capacity has been installed since 1990, a number of projects involving enhanced evaporative coolers have been tested beginning in 2001. The use of evaporative coolers has successfully increased production during the summer peaking season by an average of nearly 25 percent (GRC, 2002). ORMAT has plans to expand production and is scheduled to begin drilling in late 2004 or 2005.

Honey Lake Valley

There has been no new activity in this area since 1989 when the 35 MWe hybrid geothermal-wood products plant went into operation (DiPippo, 1995). Geothermal hot water is used for its direct heat value to augment the efficiency of the wood-waste-fueled unit and contributes about 1.5 MWe of the total plant output in the form of a preheat for the boiler condensate water. In addition to the hybrid plant, four small binary plants produce 2.35 MWe and have been on line since the late 1980s. See Figure 2 for location, and Table 2c for more details.

Coso

Power plants at Coso were sold by CalEnergy (operator and minority owner) to Caithness Energy LLC for $277 million in January 1999. See Figure 2 for location, and Table 2d for more details. The plants were rerated to higher capacity levels from operational efficiencies allowed due to regulatory changes. Output is now 274 MWe up from 240 MWe. Other changes at Coso include installation of H_2S abatement systems and central operation of the three separate facilities. Both the Navy and Caithness have continued to drill in the area. There are plans to develop an enhanced geothermal system to increase infield permeability.

Planned Additions

Two new plants are under development at Glass Mountain in northern California by Calpine Corporation. (www.calpine.com). Each of these plants is proposed for 49.9 MWe net capacity, 52 MWe gross capacity. These facilities have been plagued by legal challenges, the last having been filed in May 2004 (Gilles, 2004.). CalEnergy has plans to build a 185-MWe plant at the Salton Sea in the 2006-2007 time frame.

3.2 Hawaii

A 26-MWe hybrid, single-flash/binary plant was commissioned in 1993 at Puna in the Kilauea East Rift Zone on the Big Island of Hawaii (DiPippo, 1995). The plant is located at the easternmost point of the island, about 34 km south of Hilo, and 5.6 km southeast of the town of Pahoa (Figure 5). This plant is now producing approximately 30 MWe and was recently purchased by ORMAT (Table 2h). ORMAT is expected to increase the capacity of this facility in the near future to 60 MWe.

3.3 Nevada

As of 2004, there were 50 power plants operating at ten different sites in Nevada with a total power capacity of 239 MWe (Wells, 2004). The plants in Nevada include flash and binary energy conversion systems. Figure 3 shows plant locations and Table 2f have more details.

One change in the last five years in Nevada has also been ownership. ORMAT in May 2004 acquired Advanced Thermal Systems, formerly Steamboat Development Corp. of Reno, Nevada, which includes the 47.8-MWe Steamboat 2 and 3 geothermal power plants and rights to the 600 acres of underlying geothermal resource fields. The purchase also included the smaller Steamboat 1 and 1A power plants. ORMAT also purchased the 14.4 MWe Yankee-Caithness plant at Steamboat Hills in May 2004. Recent new power plant approvals include a 30 MWe project at Desert Peak, a 5 MWe expansion at Brady's, and a 1.5 MWe expansion at San Emidio. In addition, power plant projects are proposed at Salt Wells (10 MWe), Steamboat Hot Springs (20 MWe), Rye Patch (12 MWe), and Blue Mountain (≈30 MWe) (Wells, 2004).

3.4 Utah

Roosevelt

The site is near the location of a hot spring resort used by early miners in the area. The wells were drilled in the late 1970's and plant construction took place in the early

1980's. A 14.5 MWe Biphase wellhead power plant was tested at the site from 1982-84 (Studhalter, 1984), but was then abandoned. A 23 MWe (gross) single flash unit was installed in 1984, and then upgrade to 26 MWe in 2001 (Forman, 2004). The plant (Blundell) uses 170 ^{o}C fluid from a 343 ^{o}C resource producing 18% steam from four production wells and uses three injection wells.

Cove Fort/Surphurdale

In the 1990s, the Bud L. Bonnett power plant came on-line at the Cove Fort/Sulphurdale geothermal field (DiPippo, 1995). The unit was rated at 7 MWe, and was the latest addition to the power complex at that site. There was also a 2-MWe backpressure steam turbine and four binary units (with a total rating of 2 MWe) that were located downstream of the steam turbine. AMP/Recurrent Resources purchased this facility in 2003. The plant had been operated by the City of Provo, Utah (Blackett, 2004; Magleby, 2004.) At the present time the entire project is shut down, but the new owners have plans to reopen and to expand the facility from 30 to 40 MWe. Figure 4 shows the locations, and Table 2g give more details.

3.5 Other Plants Planned for the United States

Alaska

Chena Hot Spring, approximately 100 km northeast of Fairbanks, Alaska plan to installed a $1.7 million, 400-kWe binary power plant. The funding for the plant and associated research will come from Alaska Industrial Development and Export Authority and USDOE (GRC, 2004a).

Idaho

U.S. Geothermal, Inc. recently raised $3.4 million for a 10 to 15 MWe first phase power plant at Raft River. The project will use existing wells at the site after the 5-MWe binary plant was shut down in 1982 (GRC, 2004b). Idatherm Co., begin drilling on a geothermal prospect near Willow Creek in east Idaho for a proposed 10 MWe power plant. The firm is also proposing a second site at China Cap near Soda Springs that could provide up to 300 MWe of geothermal power capacity (GRC, 2004c).

Oregon

Plans to develop plants at Vale and Newberry Volcano were both cancelled during the 1990s due to unsuccessful reservoir confirmation projects. Attempts to revive the Newberry project have met with little success despite numerous attempts to win power purchase contracts during the period 2000-2004. ORMAT recently acquired a large leasehold including the area around Crump Geysers east of Lakeview, OR. They plan to begin exploration activities at this site in early 2005.

4. GEOTHERMAL WELL DRILLING

The drilling of wells to support geothermal power generation has tapered off since the 1980s and early 1990s. Only a limited number of make up wells have been drilled except in Nevada where a number of exploration projects are underway, including drilling both temperature gradient and deep exploration wells. A total of 54 wells have been drilled for a total depth of 44.2 km as shown in Table 6.

4.1 California

The vast majority of wells for geothermal power in the United States are in California. For the period 2000-2004 (for which data exists), the number of exploration, production, injection, and observation wells drilled fell from 26 in 1995 to only 20 new wells during the entire latter half of the 1990's, 13 production wells and 7 injection wells (Hodgson, 2000; Thomas, 1999; Johnson, 1999). From 2000-2004, 4 wells have been drilled at The Geysers, Coso, and three in the Salton Sea area of the Imperial Valley.

4.2 Nevada

Geothermal well drilling in Nevada peaked in 1992 when 31 wells of all types were completed. Over the period 2000-2004, a total of five production and injection wells were drilled along with five exploration wells. However a large number of temperature gradient wells and deep test wells have been completed during the same period.

4.3 Hawaii

The primary drilling activity in Hawaii occurred in the early-1990s in support of the 26-MWe Puna Geothermal Venture power plant (GRC, 1993). All drilling has been confined to the active Kilauea East Rift zone where very high temperatures have been encountered. Unfortunately, permeability in the high temperature part of the reservoir has been unpredictable and not always sufficient to yield commercial productivity. Only one well has been drilled in Hawaii since 2000.

4.4 Other States

There were few wells drilled in the other states that might have high-grade geothermal prospects.

Alaska

The only site under serious consideration is Unalaska Island in the Aleutians, but there was no drilling from 2000-2004. There were plans to drill five wells during the 1990's to support a proposed 15-MWe power plant−three for production and two for injection, but the project never materialized (Liss, 1994; Schochet, 1994).

There has been renewed interest in Chena Hot Spring and drilling for a small power plant could begin in 2005. Some exploratory drilling took place in 2004.

Idaho

The field at Raft River has been idle since the 5-MWe pilot binary plant was shut down in 1982 (Bliem and Walrath, 1983). No drilling took place from 2000-2004, however the site has been purchased by U. S. Geothermal, Inc., and testing of the existing wells took place in early 2004 and is expected to continue.

New Mexico

No drilling was done from 2000-2004 at either the Valles Caldera or the Fenton Hill sites. Both areas were actively developed starting in the mid 1970s; the former area was abandoned due to low well productivity (poor permeability) and the latter area was used as a test facility for Hot Dry Rock technology. Flow tests were carried out at the HDR site during the early 1990s (Brown, 1993). The project was terminated in 1997 (Duchane & Brown, 2002).

Oregon

No new deep wells were drilled during 2000-2004. Several wells that had been drilled in the early 1990s were plugged and abandoned during the period 1995-2000. ORMAT may begin to drill near Crump Geyser in 2005 or 2006, and drilling could resume at Newberry Volcano as soon as a new power purchase contract can be signed

Utah

The power plants at Cove Fort/Sulfurdale (Bonnett) were shutdown in 2003 and will be replaced by up to 40 MWe plants. One well was drilled during the period 2000-2004.

5. OUTLOOK AND CONCLUSIONS – ELECTRIC POWER GENERATION

If all the planned new capacity comes on-line during the next five years, the installed geothermal electric power capacity would increase by 632 MWe and total capacity could reach 3160 MWe. This would represent an average annual growth rate well above that of the past 5 years (18%). Most of the growth will likely be in the states of California, Nevada, Utah, and Idaho; however, continued and increasing interest in Oregon is encouraging. This is a realistic assessment, based on the current capacity and assuming that the planned additions appear over the next five to ten years.

How the industry fares in this coming period will to a large extent be dependent upon the success of renewable portfolio standards to encourage geothermal development and the impact of the production tax credit legislation passed and signed into law that provides for a 1.8¢ credit for every kWh produced. Passage of Renewable Portfolio Standards in Nevada and California should result in considerable growth in these states. Stranded cost legislation has allowed many plants in California to operate in the new economic environment. New plants are scheduled to sell power into the "green" market, thereby capturing some added price for power

When the present excess capacity in the western states begins to disappear, and as the price of fossil fuel -- particularly natural gas – continues to rise, geothermal energy can be expected to resume its once strong growth.

6. GEOTHERMAL DIRECT UTILIZATION

6.1 Background

Geothermal energy is estimated to currently supply for direct heat uses and geothermal (ground-source) heat pumps 31,238 TJ/yr (8,677 GWh/yr) of heat energy in the United States. The corresponding installed capacity is 7,817 MWt. Of these values, direct-use is 9,024 TJ/yr (2,507 GWh/yr) and 617 MWt, and geothermal heat pumps the remainder. It should be noted that values for the capacity and energy supplied by geothermal heat pumps are only approximate since it is difficult to determine the exact number of units installed, and since most are sized for the cooling load, they are oversized in terms of capacity for the heating load (except possibly in the northern U.S.).

Most of the applications have experienced continual increases over the years; however, the largest annual growth has been in geothermal heat pumps. Space heating and agricultural drying have the largest annual energy growth rate of the direct-use categories, increasing in annual use by 9.3% and 10.4%, respectively, compounded over the past five years. From 2000, the growth rate for direct-use was 2.6% annually, and for geothermal heat pumps 11.0% annually for a combined total of 8.0% annually (based on revised numbers for 2000).

Resort and spa use and development have actually remained fairly constant with only slight growth. There has been a major decrease in use in the industrial section, as the gold and silver heap leaching projects in Nevada are no longer using geothermal energy and one garlic dehydration plant has suspended operations. In addition, the lithium-bromide chiller used on the Oregon Institute of Technology campus has been replaced with an electric chiller (due to the low efficiency of the geothermal system); thus, except for geothermal heat pumps, there is only one direct-heat cooling site in the U.S. at a mushroom growing plant at Vale, Oregon (Culver, 2004). Greenhouse heating and district heating numbers are lower than reported in 2000 due to revision of the data; even though, there has been slight growth in these two areas. Today, 33% of the annual geothermal direct-use energy is used for aquaculture pond and raceway heating, 28% for resort and spa pool heating, 23.5% for space heating (including district heating), 8.5% in greenhouse heating, 6% in industrial processing, including agriculture drying and snow melting. If geothermal heat pumps are included, they contribute about 69% of the annual energy use, with direct-use contributing 31%.

Figure 6 shows the direct-use development over the past 30 years, without heat pumps. A summary of direct-heat use by category is shown in Table 5.

6.2 Space Heating

Space heating of individual buildings is mainly concentrated in Klamath Falls, Oregon where about 550 shallow wells have been drilled to heat homes, apartment houses and businesses. Most of these wells, ranging from 60 to 100EC, use downhole heat exchangers (Lund, 1999a). Thus, only heat is removed from the geothermal aquifer, conserving the water resource (Lund, 1999a). A similar use of downhole heat exchangers is found in the Moana area of Reno, Nevada (Flynn, 2001).

6.3 District Heating

There are 20 geothermal district-heating systems in the United States (Lund, 1999b). The newest being a small project in northern California (Merrick, 2002 and 2004). These systems use geothermal fluids from 59E to 100EC, with peak flow rates from 5 to 250 L/s. Installed power varies from the small at 0.1 MWt (Midland, South Dakota) to the largest at 31 MWt (Boise, Idaho), and annual energy use of 0.2 to 26 GWh. Both open- and closed-distribution systems are used –the latter type using a secondary fluid to supply the heat to the customers. Both volume and energy metering systems for customer billing are used. Several systems, including Klamath Falls and Boise, are expanding, but only one new system has been constructed in the United States for over 10 years. This is mainly due to the low cost of competing natural gas as the alternative fuel source, the high initial investment necessary for geothermal systems, and the low heat load density of many western U.S. communities.

6.4 Aquaculture pond and raceway heating.

There are 49 aquaculture sites in 11 states (Boyd and Lund, 2003). The largest concentration of geothermal aquaculture facilities is in the Imperial Valley of southern California where approximately 3.66 million kg of Tilapia, catfish and hybrid striped bass are raised in 12 facilities (Rafferty, 1999). Most are shipped live to markets in Los Angeles and San Francisco. A second area with a concentration of operations is along the Snake River Plain of southern Idaho. Over 10 operations produce one million kg of Tilapia and catfish annually. These installations use cascaded water in raceways for raising their fish, whereas, in the Imperial Valley, ponds and tanks are most common. Several unique aquaculture related projects are in operation in Idaho and Colorado – that of raising alligators (Clutter, 2001). Alligators are raised in conjunction with a Tilapia and catfish operation at Buhl, Idaho, where the fish are processed on the property–cleaned and filleted for market producing over 90 tonnes of waste annually. To eliminate the disposal problem, alligators were introduced in 1995 to consume the waste. The alligators, (around 2 m in length and weighing 200 kg) are then harvested for their meat and skin. Recent trends in the U.S. aquaculture industry have seen a decline in growth due to saturation of the market and imports of Tilapia.

6.5 Greenhouse Heating

There are 43 greenhouse operations in nine states using geothermal energy (Boyd and Lund, 2003). These cover an area of about 45 ha, have an installed heat capacity of 96 MWt and an annual energy use of 765 TJ (213 GWh)(revised from 2000). The main products raised are potted plants and cut flowers for the local markets. Some tree seedlings and vegetables are also grown; however, vegetable raising is normally not economically competitive with products from Mexico. Recent import of roses from South America has made this market extremely competitive. The IFA greenhouses in Klamath Falls (1.6 ha), raising tree seedlings, are the only new ones to come online during the past five years (Lund, 2002).

6.6 Industrial Applications and Agricultural Drying

There has been a major decrease in the number of industrial applications in the U.S. in the past few years. This is due to gold and silver ore heap leaching projects in Nevada that no longer use geothermal energy, due in part to the low market price for the metals and to the cost of royalties from geothermal wells on federal lands. The two largest sites had an installed capacity of 15 MWt and used 250 TJ (69 GWh) annually. They were able to increase the extraction of gold and silver by 17% and extend their operating season into the colder months. The two largest agricultural-drying operations are large onion and garlic dehydration plants, also in Nevada. They processed 136 tonnes of raw product per day leading to 23 tonnes of dried product at 5% moisture (Lund and Lienau, 1994). The plant near Empire, Nevada, has recently suspended operation due to competition with imported dried garlic from China (Bloomquist, 2004). However, the facility at Brady's Hot Springs, Nevada (ConAgra Food Ingredients), has added a second line (1999) and together now process 12.7 tonnes/hr producing 5,400 tonnes of dried onions annually.

In 2002, a zinc-extraction plant was completed in the Imperial Valley of California. It used electricity from geothermal power plants for the recovery of metal from geothermal brines (Clutter, 2000). The $400-million zinc project by MidAmerican Energy Holding Co. was supposed to extract 30,000 tonnes of zinc annually. The wastewater from eight power plants, having 600 ppm of zinc was utilized. Unfortunately, the plant, which ran until 2004, produced less than 50% of capacity and lost $69 million on the project (GRC, 2004d). It is now shut down and being dismantled due to poor economics and technical problems. MidAmerican is now looking at silica extraction.

6.7 Geothermal (Ground-Source) Heat Pumps

The number of geothermal (ground-source) heat pumps has steadily increased over the past 10 years with an estimated 60,000 units installed this past year, each of 12.0 kW (3.4 U.S. tons of cooling capacity) equivalent size capacity. Between 600,000 and 800,000 equivalent units are estimated to be presently installed in the U.S in all 50 states. The Geothermal Heat Pump Consortium in Washington, DC, (www.geoexchange.org) estimates 900,000 equivalent units installed in the U.S.; however, independent investigations by the Geo-Heat Center estimate a more conservative 600,000 units (Geyer, 2004 and Chiasson, 2004). Of these, we estimate 44% are vertical closed loop, 36% horizontal closed-loop, and 20% open-loop systems. Recent studies by the US Energy Information Agency (Holihan, 1997) indicate that the open-loop systems have increased to 25% of the annual production and shipment. Using a Coefficient of Performance (COP) of 3.5 and 1,200 full load hours per year in the heating mode, the 600,000 equivalent 12.0 kW units removed approximately 22,214 TJ/yr (6,170 GWh/yr) from the ground. Since, most units in the U.S. are designed for the cooling mode, the heating mode is less efficient (at 80% of cooling load). Also, the cooling mode energy is not considered, since this rejects heat to the ground; however, the cooling mode does replace other forms of energy, and is thus considered in the greenhouse-gases emission savings (estimated at 27,768 TJ/yr)(7,714 GWh). The majority of the geothermal heat pump installations in the U.S. are in the mid-west, mid-Atlantic, and southern states (from North Dakota to Florida). Schools, military and public buildings lead the growth.

6.8 Conclusions – Direct-Use

The distribution of capacity and annual energy use for the various direct-utilization categories as shown in Table 5, are based on the best estimates made by the authors. The Geo-Heat Center, where most of these data is gathered and analyzed, estimate that anywhere from 10 to 20% of additional geothermal direct energy use is unreported throughout the U.S., due to their small sizes, lack of data, and often isolated locations.

Direct-heat utilization (including heat pumps) has increased steadily at 8.0% compounded annually, over the past five years and was as high as 10% per year over the 10-year period (1985-1995). If heat pumps are excluded, the growth has been only 2.6% compounded annually during 2000-2004. This recent growth could have been higher, but competition from natural gas was a major factor in limiting investments. There are some positive signs on the horizon with growth in space heating and greenhouse projects, along with the increased nation-wide interest in geothermal heat pumps.

7. PROFESSIONAL GEOTHERMAL PERSONNEL

There are certainly many more individuals working on geothermal projects than those who belong to the Geothermal Resources Council (GRC), but we can use the GRC membership as a conservative measure of those engaged in geothermal work of all kinds. This would include scientists, engineers, technicians, drillers, managers, analysts, etc.

The GRC membership has decreased steadily from over 1000 in the early 1990's to 680 in 2001. The average U.S. membership for the period 2000-2004 is 558, the average non-U.S. membership is 197, and the average total is 755. This shows a considerable down-turn in GRC membership since the 1990's and reflects, to a large extent, the low level of activity in the industry as well as the numbers of active geothermists due to the large number of mergers that have significantly reduced the number of companies involved in geothermal and thus employment. The memberships has started to climb in 2002, which is encouraging. Using a multiplier of about 1.2 for private industry, the average over the past five years is 660 as shown in Table 7.

8. INVESTMENT IN GEOTHERMAL

It was impossible to estimate investments for the periods 1990-94 and 1995-99, as no data had been reported for electric power in the past, but the totals were probably higher than that reported for 2000-2004 as shown in Table 8, especially since the USDOE geothermal budget was two to three times higher. The figures for 2000-04 are based on U.S. Department of Energy Geothermal programs and private investment, including matching funds. Two new electric generation plants were built in the Imperial Valley, existing plants elsewhere expanded and improved, and limited exploration to expand existing fields and to define new resources were also undertaken. Direct-use investments were primarily done by the private sector, which included greenhouse construction and expansion of an onion dehydration facility. Public investment in direct-use involved expanding existing district heating projects, including adding pavement and sidewalk snow melting in Klamath Falls, along with federal and state funding support for a small district heating project in northern California. A number of individual space heating wells and systems were installed throughout the western states. Installation of geothermal heat pump systems were not included, as they are almost impossible to estimate, but could be $1.5 billion, mainly by the private sector, for 200,000 units installed during the five-year period.

9. ENERGY SAVINGS

The total electricity produced from geothermal energy in the U.S. is equivalent to saving 30.3 million barrels (4.53 million tonnes) of fuel oil per year (generating electricity at 0.35 efficiency factor). This produces a saving of 4.00 million tonnes of carbon pollution annually. The total direct utilization and geothermal heat pump energy use in the U.S. is equivalent to savings of 14.7 million barrels (2.20 million tonnes) of fuel oil per years (by producing electricity at 0.35 efficiency). This produces a savings of 1.94 million tonnes of carbon pollution annually. If the replacement energy was provided by burning fossil fuel directly, then about half this amount is used and saved (0.35 vs 0.70 efficiency). If the savings in the cooling mode of geothermal heat pumps is considered, then this is equivalent to an additional savings of 13.1 million barrels (1.96 million tonnes) of fuel oil and 1.73 million tonnes of carbon annually.

In total, the savings from present geothermal energy production in the U.S., both electricity and direct utilizations amounts to 58.1 million barrels (8.69 million tonnes) of fuel oil per years, and reduces air pollution by 7.67 million tonnes of carbon annually. CO_2 reduction is estimated at 21.7 million tonnes.

10. REFERENCES

Blackett, R.E., 2004. Geologist, State of Utah. Personal communication.

Bliem, C.J. and L. F. Walrath, 1983. "Raft River Binary-Cycle Geothermal Pilot Power Plant, Final Report." EG&G Idaho Rep. No. EGG-2208.

Bloomquist, R. G., 2004. "Empire Energy, LLC – A Case Study," Geo-Heat Center Quarterly *Bulletin*, Vol. 25 (3), pp. 11-13, Klamath Falls, OR.

Boyd, T. L. and J. W. Lund, 2003. "Geothermal Heating of Greenhouses and Aquaculture Facilities," *Proceedings*, International Geothermal Conference (IGA-2003), pp. 14-14 to 14-19, Reykjavik, Iceland

Brown, D.W., 1993. "Recent Flow Testing of the HDR Reservoir at Fenton Hill, New Mexico," Geothermal Resources Council *Bulletin*, Vol. 22(8), pp. 208-14, Davis, CA.

Chiasson, A., 2004. Engineer, Geo-Heat Center. Personal communication.

Clutter, T., 2000. "Mining Economic Benefits from Geothermal Brine," Geo-Heat Center Quarterly *Bulletin*, Vol. 21 (2), pp. 1-3, Klamath Falls, OR.

Clutter, T., 2001. "Gator in the Sage," Geothermal Resources Council *Bulletin*, Vol. 30 (6), pp. 246-9, Davis, CA.

Culver, G. G., 2004. "Oregon Trail Mushroom," Geo-Heat Center *Quarterly Bulletin*, Vol. 25 (1), pp. 12-14, Klamath Falls, OR.

DiPippo, R., 1995. "Geothermal Electric Power Production in the United States: A Survey and Update for 1990-1994." *Proceedings* of the World Geothermal Congress, IGA Vol. 1, pp. 353-362.

Dellinger, M. 2004a. "Lake County Success," Geothermal Resources Council *Bulletin*, Vol. 33 (3), pp. 115-119, Davis, CA

Dellinger, M., 2004b. Lake County, California. Personal communication.

Duchane, D. and D.Brown, 2002. "Hot Dry Rock (HDR) Geothermal Energy R&D, Fenton, Hill, NM," Geo-Heat Center *Quarterly Bulletin*, Vol. 23 (4), pp. 13-19, Klamath Falls, OR.

Flynn, T., 2001. "Moana Geothermal Area Reno, Nevada – 2001 Update," Geo-Heat Center *Quarterly Bulletin*, Vol. 22 (3), pp. 1-7, Klamath Falls, OR

Forman, L. K., 2004. Blundell Power Plant, Roosevelt Hot Springs, Utah, personal communication.

Gawell, C., 2004. Geothermal Energy Association, Washington, D. C. Personal communication.

Geyer, J., 2004. Consultant, Vancouver, Washington. Personal communication.

Gilles, Dennis, 2004. Calpine Corporation, Personal communications.

GRC, 2004a. "DOE and Alaska Fund Chena Hot Springs Project," Geothermal Resources Council *Bulletin*, Vol. 33 (5), p. 184, Davis, CA

GRC, 2004b. "U.S. Geothermal Raises $3.4 Million for Raft River Project," Geothermal Resources Council *Bulletin*, Vol. 33 (5), p. 183, Davis, CA.

GRC, 2004c. "Idahterm Begins Drilling in May," Geothermal Resources Council *Bulletin*, Vol. 33 (3), p. 90, Davis, CA

GRC, 2004d. "CalEnergy Cuts Zinc Production, Lays Off Quarter of Workforce," Geothermal Resources Council *Bulletin*, Vol. 33 (4), p. 136, Davis, CA

GRC 2004e. "Santa Rosa Geysers Pipeline Completed," Geothermal Resources Council *Bulletin*, Vol. 33 (5), p. 177, Davis, CA.

GRC, 2003. "Recharging The Geysers," Geothermal Resources Council *Bulletin*, Vol. 32 (6), p. 242, Davis, CA

GRC, 2002. "Exploring the Possibilities," Geothermal Resources Council Bulletin, Vol. 31 (4), pp. 149-151, Davis, CA.

GRC, 1999. "Santa Rosa/Geysers Pipeline Update." Geothermal Resources Council *Bulletin*, Vol. 28 (5), p. 145, Davis, CA.

GRC, 1998a. "Calpine Buys SMUD Geothermal Plant." Geothermal Resources Council *Bulletin*, Vol. 27 (10), p. 126, Davis, CA.

GRC, 1998b. "Stone & Webster to Build CalEnergy Geothermal Plant." Geothermal Resources Council *Bulletin*., Vol. 27 (8), p. 220, Davis, CA.

GRC, 1993. "PGV Power Plant Online." Geothermal Resources Council *Bulletin*, Vol. 22 (5), p. 136, Davis, CA.

Hill, R., 2004. "GeoPowering the West," Geothermal Resources Council *Bulletin*, Vol. 33 (2), pp. 63-66, Davis, CA

Hodgson, S.F., 2000. State of California. Personal communication.

Holihan, P., 1997. "Analysis of geothermal Heat Pumps Manufacturers Survey Data," U.S. Energy Information Agency, Washington, D.C., (available from: www.eia.doe.gov).

Johnson, L., 2000. California Division of Oil and Gas, Sacramento, CA. Personal communication.

Liss, S., 1994. State of Alaska. Personal communication.

Lovekin, J., 2004. "New Geothermal Site Identification and Qualification," *Consultant Report*, California Energy Commission (PIER), Sacramento, CA

Lund, J. W., 2002. "New Greenhouses in Klamath Falls," Geo-Heat Center *Quarterly Bulletin*, Vol. 23 (3), pp. 9-10, Klamath Falls, OR.

Lund, J. W., 1999a. "Examples of Individual Downhole Heat Exchanger Systems in Klamath Falls," Geo-Heat Center *Quarterly Bulletin*, Vol. 20 (3), pp. 20-24, Klamath Falls, OR

Lund, J. W., 1999b. "Examples of United States Geothermal District-Heat Systems," *Proceedings* of the European Geothermal Conference, Basel '99, Vol. 1, pp. 457-466, Bulletin d'Hydrogeologie, Universite de Neuchatel.

Lund, J. W., and P. J. Lienau, 1994. "Onion and Garlic Dehydration in the San Emido Desert, Nevada," Geo-Heat Center *Quarterly Bulletin*, Vol 1 (4), pp. 19-21, Klamath Falls, OR.

Magleby, E., 2004. AMP. Personal communication.

Merrick, D., 2004. "Adventures in the Life of a Small Geothermal District Heating Project, Part II," *Proceedings*, Vol. 28, Geothermal Resources Council, pp. 111-116, Davis, CA

Merrick, D., 2002. "Adventures in the Life of a Small Geothermal District Heating Project," Geo-Heat Center *Quarterly Bulletin*, Vol. 23 (3), pp. 1-5, Klamath Falls, OR

Muffler, L.J.P., (editor), 1979. "Assessment of Geothermal Resources of the United States – 1978." U.S. Geological Survey *Circular 790*, US Department of Interior, Arlington, VA.

Rafferty. K., 1999. "Aquaculture in the Imperial Valley - A Geothermal Success Story," Geo-Heat Center *Quarterly Bulletin*, Vol. 20 (1), pp. 1-4, Klamath Falls, OR.

Schochet, D, 1994. ORMAT. Personal communication.

Sifford, A. III and G. R. Bloomquist, 2000. "Geothermal Electric Power Production in the United States: A Survey and Update for 1995-`1999," *Proceedings* of the World Geothermal Congress 2000, Vol. 1, International Geothermal Association, Pisa, pp. 441-454, Pisa, Italy

Studhalter, W.R. 1984. "Biphase Geothermal Wellhead Plants," *Procceedings*, 6th New Zealand Geothermal Workshop, 1984, pp. 141-144, Auckland, New Zealand

Thomas, R.P., 1999. California Division of Oil, Gas and Geothermal Resources, Sacramento. Personal communication.

Wells, L., 2004. "Nevada Geothermal Update, September 2004," Division of Minerals, State of Nevada, Carson City

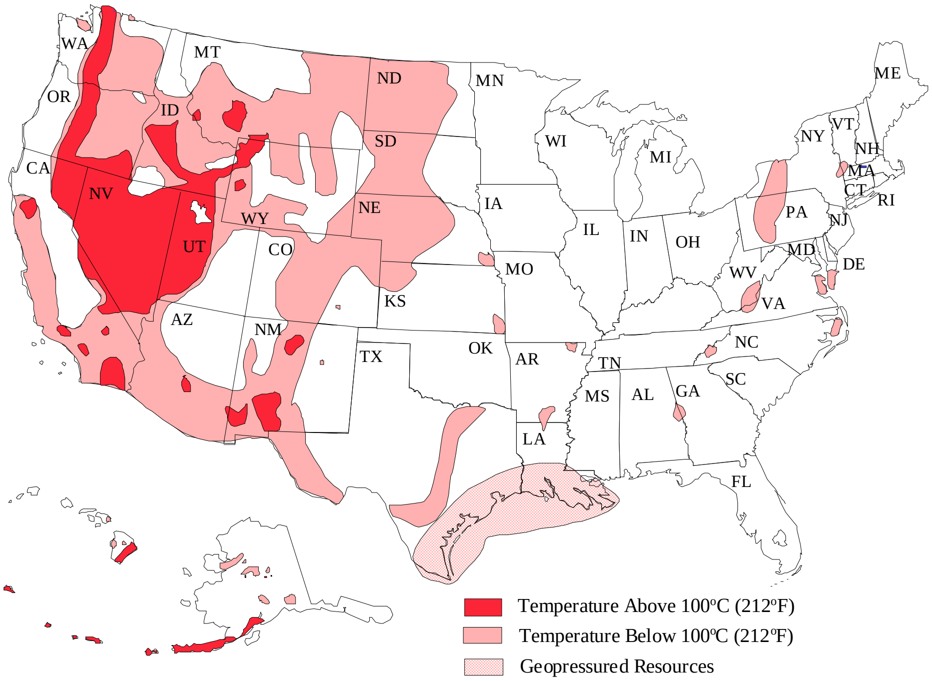

FIGURE 1. Geothermal Resource map of the United States

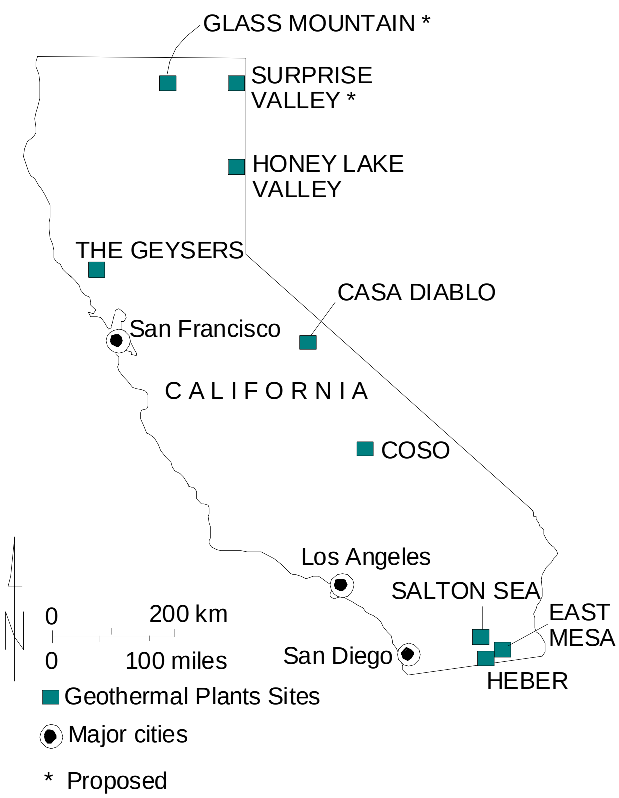

FIGURE 2. Geothermal Power Plant Areas in California.

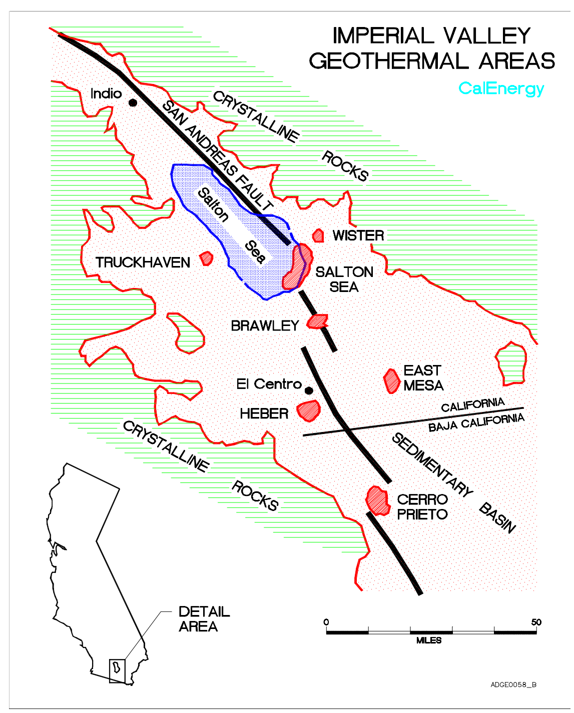

FIGURE 2A. Geothermal Power Plant Areas in the Salton Sea.

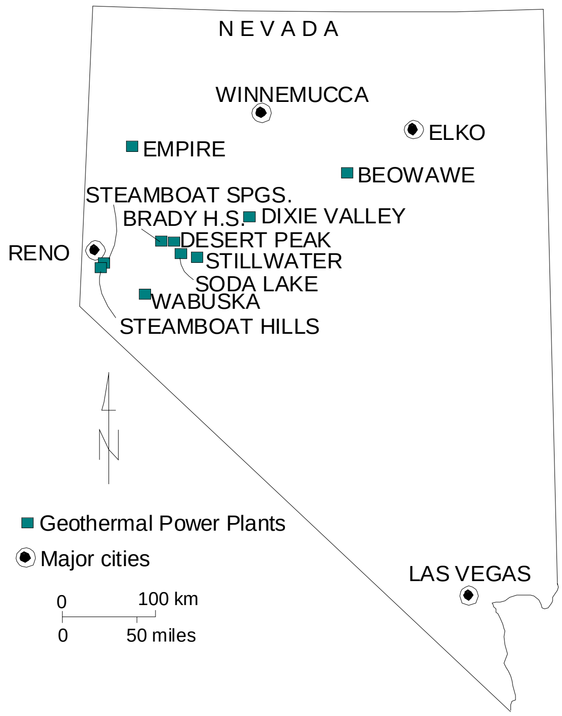

FIGURE 3. Geothermal Power Plant Areas in Nevada.

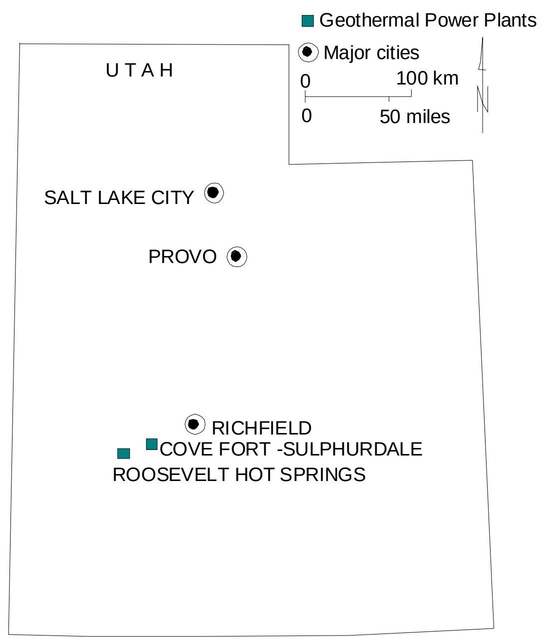

FIGURE 4. Geothermal Power Plant Areas in Utah.

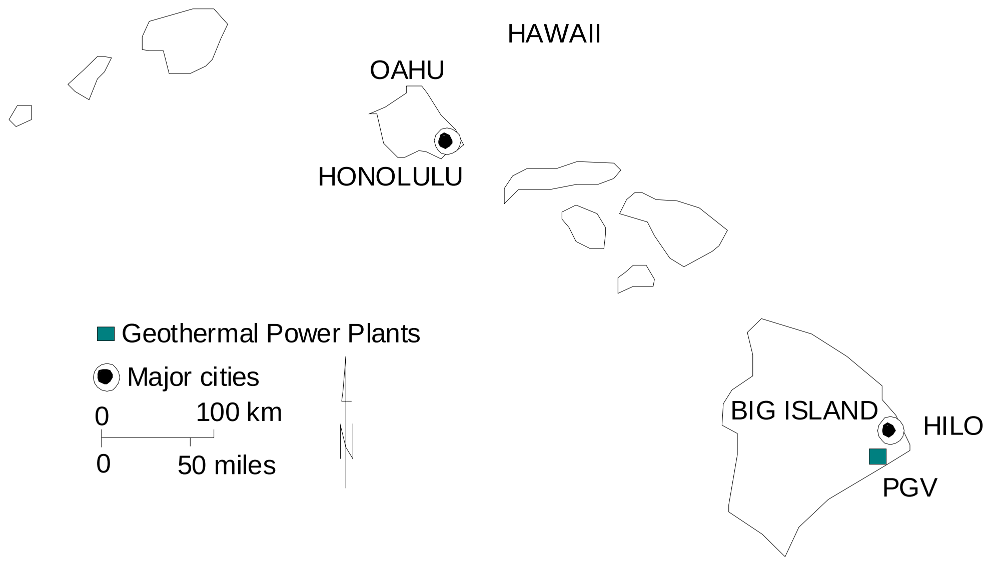

FIGURE 5. Geothermal Power Plant Areas in Hawaii.

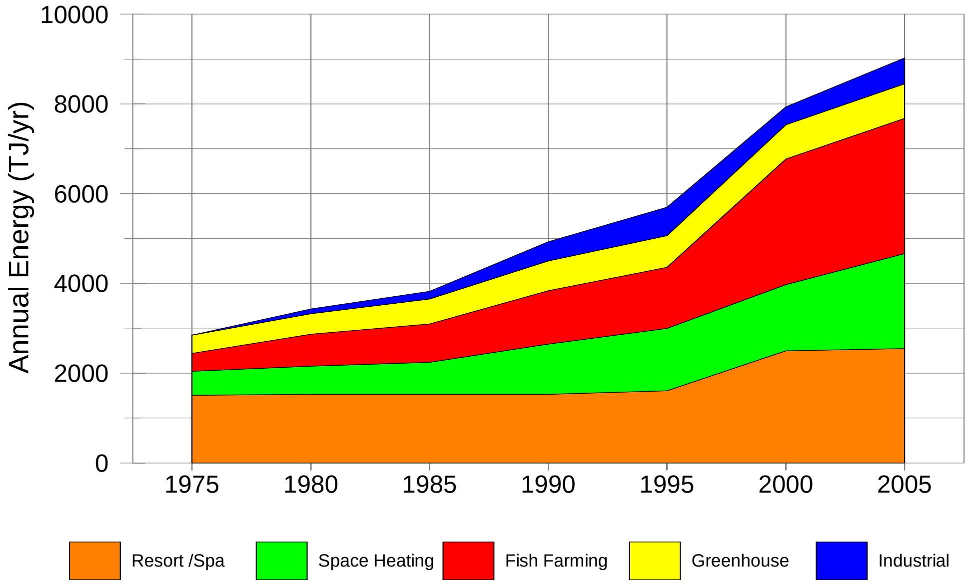

FIGURE 6. Direct-Use growth in the United States.

TABLE 2a. The Geysers Geothermal power Plants

1) N = Not operating (temporary), R = Retired. Otherwise leave blank if presently operating.
2) 1F = Single Flash B = Binary (Rankine Cycle)
2F = Double Flash H = Hybrid (explain)
3F = Triple Flash O = Other (please specify)
D = Dry Steam

Locality	Power Plant Name	Year Com-missioned	No. of Units	Status[1)]	Type of Unit[2)]	Installed Capacity MWe	Annual Energy GWh	Under Constr. or Planned MWe
1	Aidlin	1989	1		D	20	109	
2	Bear Canyon	1988	1		D	22	120	
3	Sonoma	1983	1		D	72	394	
4	West Ford Flat	1988	1		D	29	158	
5&6	McCabe	1971	2		D	106	580	
7&8	Ridge Line	1972	2		D	106	580	
9&10	Fumarole	1973	2	R	D	--	--	
11	Eagle Rock	1975	1		D	65	355	106 MW generator, new turbine installed
12	Cobb Creek	1979	1		D	106	580	
13	Big Geysers	1980	1		D	78	426	133W generator, new turbine installed
14	Sulfur Springs	1980	1		D	65	355	109MW generator, new turbine installed
16	Quicksilver	1985	1		D	113	619	
17	Lake View	1982	1		D	113	619	
18	Socrates	1983	1		D	113	619	
19	Callistoga	1984	1		D	80	437	
20	Grant	1985	1		D	113	619	
	NCPA 1-2	1983	2		D	110	607	
	NCPA 3-4	1985, 86	2		D	110	607	
TOTALS			**23**			**1421MW**	**7784 GWh**	

TABLE 2b – Imperial Valley Power Plants

Owner	Plant	Type[1]	Year	No. of Units[2]	Rating MW	Capacity Factor %	Annual Energy GWh
• EAST MESA							
ORMAT	GEM 1	B	1979	1	R		
	2	2F	1989	1	18.5	92.5	146
	3	2F	1989	1	18.5	92.5	146
ORMAT	ORMESA I	B	1987	26	20	90.0	158
	II	B	1988	20	20	90.0	158
	IE	B	1989	10	10	90.0	79
	IH	B	1989	12	12	90.0	95
			Sub-Totals:	71	79		782
• HEBER							
SDG&E (decommissioned)	Binary Demo.	B	1985	1	R		
ORMAT	Dual-Flash	2F	1985	1	52	90.0	410
ORMAT	Second Imperial Project	B	1993	12	33	80.0	231
			Sub-Totals	14	85		641
• SALTON SEA							
CALENERGY	S.S. 1	1F	1982	1	10	104.0	91
	S.S. 2	2F	1990	3	20	104.0	182
	S.S. 3	2F	1989	1	50	104.0	455
	Vulcan	2F	1985	2	38	104.0	346
	A.W. Hoch (Del Ranch)	2F	1989	1	42	104.0	383
	J.J. Elmore	2F	1989	1	38	104.0	346
	J.M. Leathers	2F	1989	1	38	104.0	346
	S.S. 4	2F	1996	1	40	104.0	403
	S.S. 5	2F	2000	1	50	104.0	503
	CE Turbo	1F	2000	1	10	104.0	91
			Sub-Totals	10	336		3146
			TOTALS	**97**	**500**		**4569**

[1] B Binary, 1F Single-Flash, 2F Double-Flash.
[2] A "Unit" has one turbine-generator set.

TABLE 2c – Honey Lake Valley Geothermal Power Plants

Owner	Plant	Type	Year	No. of Units	Rating MW	Capacity Factor %	Annual Energy GWh
Wineagle Development	Wineagle	B	1985	2	0.7	80.0	5
TG/USEC	Amedee	B	1988	2	1.6	80.0	11
HL Power Company	Honey Lake	H[1]	1989	1	1.5	80.0	10
			TOTALS	**5**	**3.8**		**26**

TABLE 2d: Coso Geothermal Power Plants

Owner	Plant	Type	Year	No. of Units	Rating MW	Capacity Factor %	Annual Energy GWh
Caithness	Navy 1 Unit 1	2F	1987	1	34	116	345
	2	2F	1988	1	30	116	305
	3	2F	1988	1	30	116	305
	Navy 2 Unit 4	2F	1989	1	30	116	305
	5	2F	1989		30	116	305
	6	2F	1989	1	30	116	305
	BLM 1 Unit 7	2F	1988	1	30	116	305
	8	2F	1988	1	30	116	305
	9	2F	1989	1	30	116	305
TOTALS				**9**	**274**		**2785**

TABLE 2e: Mammoth/Pacific Geothermal Power Plants

Owner	Plant	Type	Year	No. of Units	Rating MW	Capacity Factor %	Annual Energy GWh
ORMAT	Mammoth/ Pacific	B	1984	2	10	90.0	79
		B	1990	2	30	90.0	236
TOTALS				**4**	**40**		**315**

TABLE 2f: Geothermal Power Plants in Nevada

Owner	Plant	Type	Year	No. of Units	Rating MW	Capacity Factor %	Annual Energy GWh
Caithness	Beowawe	2F	1985	1	16.6	90.0	131
ORMAT	Brady Hot Springs	2F	1992	3	21.1	98.0	181
ORMAT	Desert Peak	2F	1985	2	12.5	98.0	107
Caithness	Dixie Valley	2F	1988	1	62	90.0	489
Empire Energy	Empire	B	1987	4	4.8	90.0	38
Constellation	Soda Lake 1	B	1987	3	26.1	90.0	206
	2	B	1991	6			
ORMAT	Steamboat I	B	1986	7	10.8	95.0	90
	IA	B	1988	2			
	2	B	1992	2	47.8	95.0	398
	3	B	1992	2			
Stillwater Holding	Stillwater I	B	1989	14	21	90.0	166
Home Stretch Geothermal	Wabuska I	B	1984	1	2.2	90.0	17
	II	B	1987	1			
ORMAT	SteamboatHills[3]	1F	1988	1	14.4	95.0	120
TOTALS				**50**	**239.3**		**1943**

TABLE 2g: Geothermal plants in Utah

Owner	Plant	Type	Year	No. of Units	Status	Rating MW	Capacity Factor %	Annual Energy GWh
Pacific Corporation	Blundell I (Roosevelt)	1F	1984	1		26	88	200
City of Provo	CF[1] No. 1	B	1985	4	R	2		
	CF Steam	DS[2]	1988	1	R	2		
	Bonnett	DS	1990	1	R	7		
TOTALS				**1**		**26**		**200**

[1] Cove Fort. [2] Dry steam.

TABLE 2h: Geothermal plants in Hawaii

Owner	Plant	Type	Year	No. of Units	Status	Rating MW	Capacity Factor %	Annual Energy GWh
ORMAT	Puna Geothermal Venture	1F	1984	10		20	83	145
		B		10		10	83	73
TOTALS				**20**		**30**		**218**

STANDARD TABLES

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY (Installed capacity)

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specify)[1]		Total	
	Capac-ity GWe	Gross Prod. TWh/yr	Capac-ity GWe	Gross Prod. TWh/yr	Capac-ity GWe	Gross Prod. TWh/yr	Capac-ity GWe	Gross Prod. TWh/yr	Capac-ity GWe	Gross Prod. TWh/yr	Capac-ity GWe	Gross Prod. TWh/yr
In operation in December 2003	2.5	17.8	730	2612	74	269	99.5	764	17.5	40	923.4	3702
Under construction in December 2004	0		51		0		0		2		53	
Funds committed, but not yet under construction in December 2004	0.6		3		0		0		0		3.6	
Total projected use by 2010	6.3	45	810	2900	74	269	100	768	28	64	1018	4046

[1] Biomass, wind and solar

TABLE 2. UTILIZATION OF GEOTHERMAL ENERGY FOR ELECTRIC POWER GENERATION AS OF 31 DECEMBER 2004

1) N = Not operating (temporary), R = Retired. Otherwise leave blank if presently operating.

2) 1F = Single Flash B = Binary (Rankine Cycle)
2F = Double Flash H = Hybrid (explain)
3F = Triple Flash O = Other (please specify)
D = Dry Steam

3) Data for 2004

Locality	Power Plant Name	Year Com-missioned	No. of Units	Status1)	Type of Unit2)	Total Installed Capacity MWe	Annual Energy Produced 2004 3) GWh/yr	Total under Constr. or Planned MWe
CALIFORNIA								
Geysers						1,421	7,784	155
Imperial Valley						500	4,569	185
Others						318	3,126	120
NEVADA						239	1,943	82
UTAH						26	200	60
HAWAII						30	218	30
Total						2,534	17,840	632

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2004 (other than heat pumps)

[1)]
I = Industrial process heat
C = Air conditioning (cooling)
A = Agricultural drying (grain, fruit, vegetables)
F = Fish farming
K = Animal farming
S = Snow melting
H = Individual space heating (other than heat pumps)
D = District heating (other than heat pumps)
B = Bathing and swimming (including balneology)
G = Greenhouse and soil heating
O = Other (please specify by footnote)

[2)] Enthalpy information is given only if there is steam or two-phase flow

[3)] Capacity (MWt) = Max. flow rate (kg/s)[inlet temp. (oC) - outlet temp. (oC)] x 0.004184 ($MW = 10^6$ W)
or = Max. flow rate (kg/s)[inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

[4)] Energy use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (oC) - outlet temp. (oC)] x 0.1319 ($TJ = 10^{12}$ J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.03154

[5)] Capacity factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171
Note: the capacity factor must be less than or equal to 1.00 and is usually less, since projects do not operate at 100% of capacity all year.

Note: please report all numbers to three significant figures.

Locality	Type[1)]	Maximum Utilization					Capacity[3)]	Annual Utilization		
		Flow Rate	Temperature (°C)		Enthalpy[2)] (kJ/kg)			Ave. Flow	Energy[4)]	Capacity Factor[5)]
		(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	
Alaska	H, G, B						6.27		106.35	0.54
Arkansas	H						0.35		7.27	0.66
Arizona	H, F, B						21.54		292.17	0.43
California	D, H, G, F, I, B						104.28		2132.6	0.65
Colorado	D, H, G, F, B						28.33		597.51	0.67
Georgia	H, B						0.62		10.96	0.56
Idaho	D, H, G, F, B						103.02		1387	0.43
Montana	H, G, F, B						15.76		297.78	0.60
New Mexico	D, H, G, F, B						41.37		373.6	0.29
Nevada	D, H, F, A, B						77.97		1202.5	0.49
New York	H, B						0.88		12.12	0.44
Oregon	D, H, G, F, I, A, S, B						61.73		625.76	0.32
South Dakota	D, H, F, B						66.28		577.59	0.28
Texas	H. B						4.04		27.4	0.22
Utah	H, G, F, B						54.64		621.51	0.36
Virginia	H						0.32		3.06	0.30
Washington	B						1.61		38.15	0.75
West Virginia	B						0.15		3.69	0.78
Wyoming	H, G, F, S, B						28.33		706.81	0.79
TOTAL							617.48		9023.9	0.46

TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF 31 DECEMBER 2004

This table should report thermal energy used (i.e. energy removed from the ground or water) and report separately heat rejected to the ground or water in the cooling mode. Cooling energy numbers will be used to calculate carbon offsets.

1) Report the average ground temperature for ground-coupled units or average well water or lake water temperature for water-source heat pumps

2) Report type of installation as follows: V = vertical ground coupled (TJ = 10^{12} J)
H = horizontal ground coupled
W = water source (well or lake water)
O = others (please describe)

3) Report the COP = (output thermal energy/input energy of compressor) for your climate

4) Report the equivalent full load operating hours per year, or = capacity factor x 8760
Thermal energy (TJ/yr) = flow rate in loop (kg/s) x [(inlet temp. (^{o}C) - outlet temp. (^{o}C)] x 0.1319
or = rated output energy (kJ/hr) x [(COP - 1)/COP] x equivalent full load hours/yr

Note: please report all numbers to three significant figures

Locality	Ground or water temp. (^{o}C)[1]	Typical Heat Pump Rating or Capacity (kW)	Number of Units	Type[2]	COP[3]	Heating Equivalent Full Load Hr/Year[4]	Thermal Energy Used (TJ/yr)	Cooling Energy (TJ/yr)
States: Northwest 13% Midwest 45% South 36% West 8%	5-25	12.0	600,000	V = 44% H = 36% W = 20%	3.5	1200	22,214	27,768
TOTAL			600,000				22,214	27,768

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2004

1) Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (^{o}C) - outlet temp. (^{o}C)] x 0.004184
or = Max. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

2) Annual Energy Use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (^{o}C) - outlet temp. (^{o}C)] x 0.1319 (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg) x 0.03154

3) Capacity Factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171 (MW = 10^6 W)
Note: the capacity factor must be less than or equal to 1.00 and is usually less,
since projects do not operate at 100% capacity all year

Note: please report all numbers to three significant figures.

Use	Installed Capacity[1] (MWt)	Annual Energy Use[2] (TJ/yr = 10^{12} J/yr)	Capacity Factor[3]
Individual Space Heating[4]	146	1335	0.29
District Heating [4]	84	788	0.30
Air Conditioning (Cooling)	<1	15	0.95
Greenhouse Heating	97	766	0.25
Fish Farming	138	3012	0.69
Animal Farming	0	0	0
Agricultural Drying[5]	36	500	0.44
Industrial Process Heat[6]	2	48	0.80
Snow Melting	2	18	0.30
Bathing and Swimming[7]	112	2543	0.72
Other Uses (specify)	0	0	0
Subtotal	617	9024	0.46
Geothermal Heat Pumps	7200	22,214	0.10
TOTAL	7817	31,238	0.13

4) Other than heat pumps
5) Includes drying or dehydration of grains, fruits and vegetables
6) Excludes agricultural drying and dehydration
7) Includes balneology

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2000 TO DECEMBER 31, 2004 (excluding heat pump wells)

[1)] Include thermal gradient wells, but not ones less than 100 m deep

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration[1)]	(all)	35	0			7,620
Production	>150° C	16	0			29,535
	150-100° C	0	7			1,907
	<100° C	0	0			0
Injection	(all)	3	1			5,139
Total		54	8			44,201

TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with University degrees)

(1) Government
(2) Public Utilities
(3) Universities
(4) Paid Foreign Consultants
(5) Contributed Through Foreign Aid Progra
(6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2000	100	30	50	0	0	675
2001	100	30	50			640
2002	100	30	50			560
2003	90	25	45			470
2004	80	20	40			585
Total	470	135	235	0	0	2930

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2004) US$

Period	Research & Development Incl. Surface Explor. & Exploration Drilling	Field Development Including Production Drilling & Surface Equipment	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1990-1994	N/A					
1995-1999	N/A					
2000-2004	250	200	100	200	80	20

Note: Excludes geothermal heat pumps, estimates at $1.5 billion for 2000 - 2004