THE USA COUNTRY UPDATE

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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 about 2,002 MWe with 1,885 MWe net delivering power to the grid producing approximately 16,000 GWh per year for a 97% 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, due to recent declines in steam output, is injecting recycled wastewater from two communities into the reservoir, which presently has recovered 69 MWe of power generation. 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 about 4,350 MWt and the annual energy use is 22,250 TJ or 6,181 GWh. The largest applications is ground-source (geothermal) heat pumps (60% of the energy use), and the largest direct-use is in aquaculture pond and raceway water heating. Direct utilization is increasing at about six percent per year; whereas, electric power plant development is almost static. The energy savings from electric power generation, direct-uses and ground-source heat pumps amounts to 6.6 million tonnes of equivalent fuel oil per years and reduces air pollution by 5.8 million tonnes of carbon annually (compared to fuel oil).

Key Words: *The Geysers, Imperial Valley, electric power, direct-use, heat pumps.*

INTRODUCTION

The United States continues to lead the world in installed geothermal power capacity as well as in electrical generation producing about 16,000 GWh/yr from 2,002 MWe capacity (gross), and 1,885 net for a load factor of around 0.97. These are approximately 32% and 26% of the world output and capacity, respectively. However, this output only contributes about 0.25 of the total U.S. power capacity; however, in California, it contributes about six percent of the total output. These power plants are located in four states: California, Nevada, Utah and Hawaii with plants being considered for Idaho and New Mexico.

Geothermal energy is estimated to currently supply for direct heat uses and geothermal heat pumps approximately 22,250 TJ/yr or 6,181 GWh/yr of heat energy in the United States. The corresponding installed capacity is estimated at 4,350 MWt. Geothermal or ground-source heat pumps are the dominate direct heat use in the U.S. providing an estimate 60% of the energy use and 85% of the installed capacity. The two largest direct-uses in the U.S. are for bathing and swimming pools, and for aquaculture pond and raceway heating. Geothermal direct heat uses are found in 23 states, but is mainly concentrated in the western states.

ELECTRIC POWER GENERATION

Background

The two largest concentrations of geothermal power plants are at The Geysers in northern California and in the Imperial Valley of southern California. Two new plants have come online in the past eight years, two 50-MWe double flash and a 10-MWe triple flash plant constructed by CalEnergy Operating Corporation at the Salton Sea site in the Imperial Valley. Prior to this, the last power plant constructed in the U.S. was in 1989. In addition, several new plants are being proposed for Nevada and drilling is being undertaken for the 49-MWe plant at Glass Mountain in northern California.

The Geysers

In The Geysers, 10 units have been dismantled or retired for a total of 425 MWe, and the field has been

consolidated under one major operator, Calpine Corporation with 18 units and one minor operator, Northern California Power Agency (NCPA) with four units [14]. Owing to a shortfall in steam, the actual power capacity has been reduced from the rated capacity of the remaining plants by about 650 MWe. However, this shortfall is being reversed in several units by the Southeast Geysers effluent recycling system.

This project injects recycled wastewater into the reservoir to recovery more steam for power production. The Southeast Geysers Effluent Recycling Project (SEGEP) is the world's first wastewater-to-electricity system (www.geysers-pipeline.org). It transports treated wastewater effluent from the California communities of Clearlake, Lower Lake, Middletown to the Geysers geothermal steam field for injection and recovery by five power plants. The Phase 1 of that system, a 48-km pipeline transports 340 L/s of effluent to The Geysers. Power generation has increased an estimated 69 MWe since the start of the system in early 1997, due to the injection of almost 60 million tons of effluent to date (Figure 1). Plans are underway for Phase 2 to include other communities around Clear Lake.

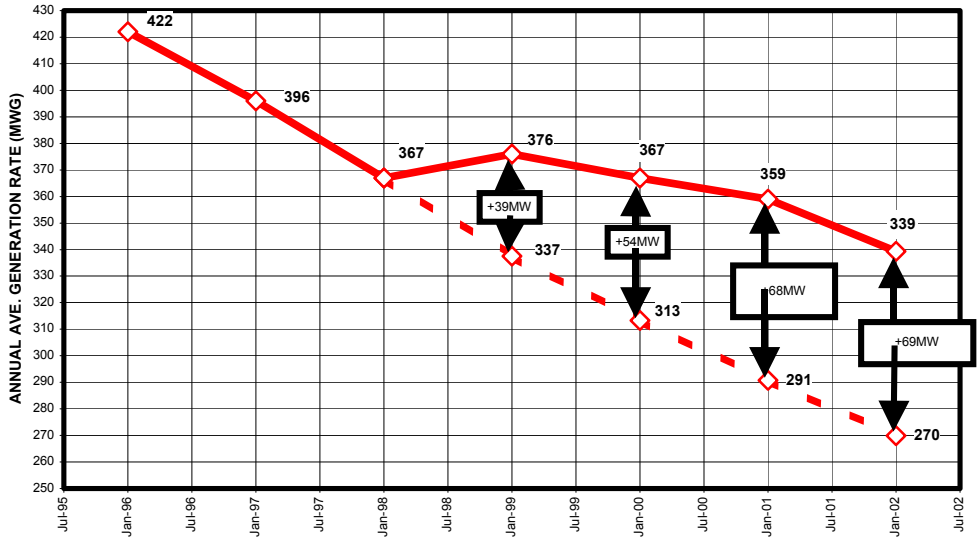


Figure 1. *Effect of SEGEP injection on SE Geysers generation. Calpine Power Plant Units 13, 16, 18 and NCPA Plants land 2 (courtesy of Calpine Corp.)*

In addition, the city of Santa Rosa plans to send its treated wastewater 66 km to The Geysers (http://ci.santa-rosa.ca.us/geysers/). The $237-million project is under construction and should go online in late-2003 and is estimated to add 85 MWe to The Geysers output. The 76 to 122 cm diameter pipeline will send over 40,000 m^3 of treated wastewater per day (482 L/s) to the field with an annual maintenance and operating cost of $2.8 million. Together, these two projects are expected to make The Geysers production sustainable and provide local cities with wastewater disposal solutions.

For 2002, the energy generated by the Calpine units was 6,142,000 MWh with a net installed operating capacity of 750 MWe giving an average capacity factor of 93.5%. Their gross installed operating capacity is 795 MWe [2]. The total capacity of The Geysers is 936 MWe (gross) and 883 MWe (net).

Other Locations

The Puna Geothermal Venture shut down their main production well, KS-11, in April of 2002 due to a casing failure from heat and corrosion. Halting production at that well dropped the output from the 10 combined cycle ORMAT Energy Converters (topping steam turbine and binary cycle units) from 30 to five MWe. After months of delay, a new well, KS-5, has been completed to 1,920 m with 315°F steam. The old well will be used as an injection well. The plant will be backup to the 30 MWe by April, 2003 [5][12].

Geothermal plants in Nevada, "the Saudi Arabia of geothermal," have been upgraded from a total gross output of 195 MWe as reported in WGC2000 to about 200 MWe. No changes are reported for Utah since 2000.

Plant Summary

There are a total of 66 geothermal power plants in operation in the U.S. consisting of 144 units. These single units range in size from 133 MWe to less than one MWe, and the individual units range in size from 0.35 to 133 MWe. About half of the plants, located in The Geysers use dry steam; whereas, the majority of the remaining plants are either double flash or binary. The average unit size ranges from the dry steam plants which are slightly less than 40 MWe to the binary units which are around 2 MWe. Table 1 is a summary of the plants and their location.

Table 1. Geothermal Power Plants in the United States

State	# of Plants	Gross Capacity MWe	Net Operating MWe
California	48	1741	1642
Nevada	13	200	189
Utah	4	31	27
Hawaii	1	30	27
TOTAL	66	2002	1,885

Planned Additions

New plants are proposed at Glass Mountain (Medicine Lake area) in northern California with a capacity of 49 MWe. A Denver company plans to build a 10-MWe plant in the Raft River area, site of a previous experimental plant. Contacts for four new power plants were recently signed by Sierra Pacific Resources of Nevada to supply to Sierra Pacific and Nevada Power companies: a 42-MWe Kalina cycle plant at Steamboat near Reno, a 25-MWe binary plant at Sulfur Hot Springs near Lovelock, and 10- and 20-MWe flash-binary ORMAT plants at Desert Peak [7]. CalEnergy has announced that they will build a 185-MWe unit at Salton Sea at a cost of $350 million. This will be the largest single unit in the U.S. These combined projects of 341 MWe will increase the U.S. capacity by almost 20% over the next five years. Additional increases may occur, if the federal production tax credit of about 1.7 cents/kWh is included in the national energy bill, along with renewable portfolio standards instituted by various states requiring that from 5 to 20% of new energy come from renewable sources such as wind, solar, biomass and geothermal.

GEOTHERMAL DIRECT UTILIZATION

Background

Geothermal energy is estimated to currently supply for direct heat uses and geothermal (ground-source) heat pumps approximately 22,250 TJ/yr (6,181GWh/yr) of heat energy in the United States. The corresponding installed capacity is estimated at 4,348 MWt. Of these values, direct-use is about 8,850 TJ/yr (2,460 GWh/yr) and 618 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. Aquaculture has the largest annual energy growth rate of the direct-use categories, increasing in annual use by 17% compounded over the past five years. From 1990, the growth rate for direct-use was 6.0% annually, and for geothermal heat pumps 8.4% annually for a combined total of 7.4% annually.

Resorts and spa use and development has actually remained fairly constant with only slight growth--most of the recent increase due to better reporting of the data. There has been a major decrease in use in the industrial section, as the gold and silver heap leaching projects in Nevada are not longer using geothermal energy. 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, there is no direct-heat cooling in the U.S. (except for geothermal heat pumps). Today, 35% of the annual geothermal direct-use energy is used for aquaculture pond and raceway heating, 28% for resort and spa pool heating, 18% for space heating (including district heating), 14% in greenhouse heating, 5% in industrial processing, including agriculture drying and snow melting. If geothermal heat pumps are included, they contribute about 60% to the annual energy use, with direct-use contributing 40%.

Figure 2 shows the direct-use development over the past 25 years, with the increase in geothermal heat pumps since about 1985 very evident. A summary of direct heat use by category is shown in Table 2.

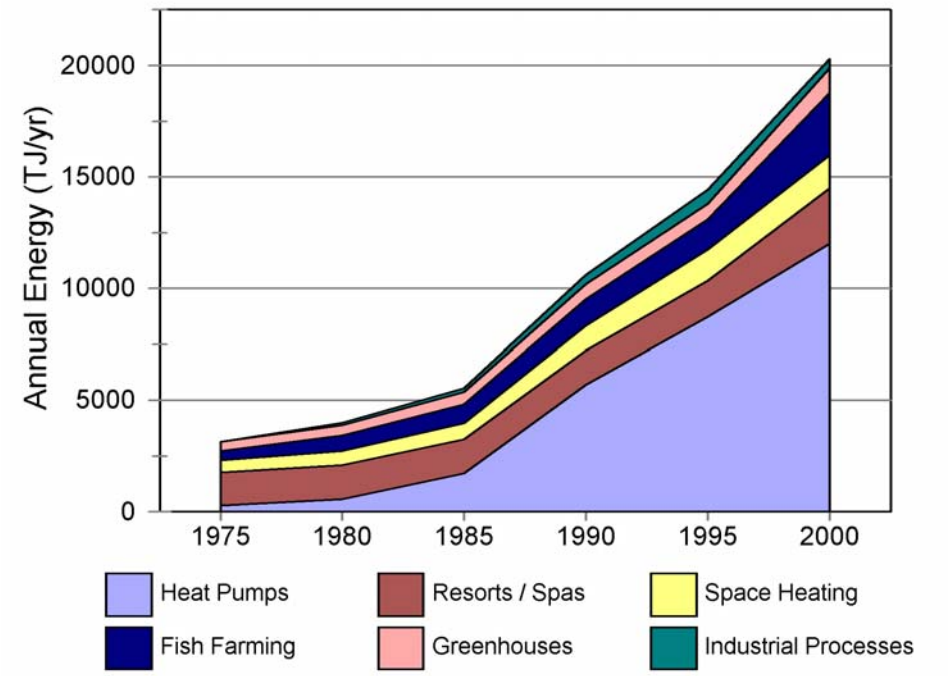


Figure 2. Direct-use growth in the United States.

Table 2. Summary of geothermal direct-use in the United States (2002)

Use	# of Installations	Installed Capacity (MWt)	Annual Energy Use (TJ/yr)	Capacity Factor
Space Heating	1,000	90	950	0.33
District Heating	18	105	665	0.20
Aquaculture	45	140	3,100	0.70
Greenhouses	40	140	1,230	0.30
Agriculture Drying	3	20	305	0.48
Industrial Processing	4	10	80	0.25
Resorts/Spas/Pools	220	110	2,500	0.72
Snow Melting	5	3	20	0.21
Subtotal	1,327	618	8,850	0.45
Geo. Heat Pumps	500,000	3,730	13,400	0.11
Total		4,348	22,250	0.16

Space Heating

Space heating of individual buildings in 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 100°C, use downhole heat exchangers. Thus, only heat is removed from the geothermal aquifer, conserving the water resource. A similar use of downhole heat exchangers is found in Reno, Nevada in the Moana area of town. The author's home in Klamath Falls is heated by such a system, and this use is described in a paper presented at this conference and included in the Proceedings [9][10].

District Heating

There are 18 geothermal district-heating systems in the United States [8]. These systems use geothermal fluids from 59° to 103°C, with peak flow rates from 5 to 250 L/s. Installed power varies from the small at 0.2 MWt (Midland, South Dakota) to the largest at 31 MWt (Boise, Idaho), and annual energy use from 0.6 to 22 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 no 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.

Aquaculture Pond and Raceway Heating

The largest increase in geothermal direct-use in the U.S. in the past five years was in aquaculture pond and raceway heating, with at least 45 sites in 11 states presently being reported [1]. 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 [13]. Most are shipped live to markets in Los Angels and San Francisco. A second area with a concentration of operations in 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 [4]. In conjunction with a Tilapia and catfish raising operation at Buhl, Idaho, where the fish are processed on the property–cleaned and filleted for market, over 90 tonnes of waste is produced 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.

Greenhouse Heating

There are about 40 greenhouse operations in nine states using geothermal energy [1]. These cover an area of about 50 ha, have an installed heat capacity of 140 MWt and an annual energy use of 1230 TJ (342 GWh). 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.

Industrial Applications and Agricultural Drying

There has been a major decrease in industrial applications in the U.S. in the past few years due to gold and silver ore heap leaching projects in Nevada no longer using geothermal energy, due in part to the low market price for the metals and to the cost of the U.S. Government energy royalties from 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 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 process 136 tonnes of raw product per day leading to 23 tonnes of dried product at 5% moisture [11]. A zinc-extraction plant has been completed in the Imperial Valley of California: it uses electricity from geothermal power plants for the recovery of metal from geothermal brines [3]. The $200-million zinc project by CalEnergy Company, Inc., brought online in 2002, will eventually extract 30,000 tonnes of zinc annually. The wastewater from eight power plants, having 600 ppm of zinc will be utilized.

Ground-Source (Geothermal) Heat Pumps

The number of ground-source (geothermal) heat pumps has steadily increased on the past 10 years with an estimated 50,000 units installed this past year, each of 12 kW equivalent size capacity. It is estimated that 500,000 equivalent units are presently installed in the U.S. Of these, 46% are vertical closed loop, 38 % horizontal closed-loop, and 15% open-loop systems. Recent studies by the U.S. Energy Information Agency [6] 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 1000 full load hours per year in the heating mode, the 500,000 equivalent 12-kW units removed approximately 13,400 TJ/yr (3,730 GWh/yr) from the ground. Since, most units in the U.S. are designed for the cooling mode, the heating mode is less efficient (assumed as 80% in the above calculations). 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. The majority of the geothermal heat pump installations in the U.S. are in the mid-west and southern states (from North Dakota to Florida).

Conclusions

The distribution of capacity and annual energy use for the various direct-utilization categories as shown in Table 2, are based on the best estimates made by the author. 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 and often isolated locations.

Direct-heat utilization has increased steadily at eight percent compounded annually over the past five years and was as high as 10% per year over the previous 10 years (1985-1995). Recent growth could have been higher, but competition from natural gas was a major factor. There are some positive signs on the horizon with growth in aquaculture and greenhouse projects, along with the start up of the zinc extraction plant in the Imperial Valley and the expansion of the onion dehydration plant at Empire, Nevada.

ENERGY SAVINGS

The total electricity produced from geothermal energy in the U.S. is equivalent to saving 27.2 million barrels (4.07 million tonnes) of fuel oil per year (generating electricity at 0.35 efficiency factor). This produces a saving of 3.58 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 10.5 million barrels (1.57 million tonnes) of fuel oil per years (by producing electricity at 0.35 efficiency). This produces a savings of 1.38 million tonnes of carbon pollution annually. If the replacement energy was provided by burning fuel directly, then about half this amount is used and saved (35% vs 70% efficiency). If the savings in the cooling mode of geothermal heat pumps is considered, then this is equivalent to an additional savings of 6.2 million barrels (0.94 million tonnes) of fuel oil and 0.83 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 43.9 million barrels (6.58 million tonnes) of equivalent fuel oil per year and reduces air pollution by 5.79 million tonnes of carbon annually.

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