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Geothermal Resources

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ABSTRACT

The United States uses geothermal energy for electrical power generation and for a variety of direct use applications. The most notable developments are The Geysers in northern California, with approximately 900 MWe, and the Imperial Valley of southern California, with 14 MWe being generated, and at Klamath Falls, Oregon and Boise, Idaho, where major district heating projects are under construction. Geothermal development is promoted and undertaken by private companies, public utilities, the federal government, and by state and local governments.

Geothermal drilling activity showed an increase in exploratory and development work over the five previous years, from an average of 61 wells per year to 96 wells for 1980. These 96 wells accounted for 605,175 ft of hole. The completed wells included 18 geothermal wildcat 'discoveries,' 15 wildcat failures, and 5 geopressured geothermal failures, a total of 38 exploratory attempts. The successful wildcats accounted for 96,924 ft of hole at an average total depth of 5,385 ft per well; representing a success ratio of 47.4%. California, which had the highest total of completed geothermal wells at 83, also had 43 successful geothermal development wells; most of these were in The Geysers. Of the total of 58 geothermal development wells attempted, 55 were considered capable of production amounting to a success ratio of 94.8%. A total of 329,854 ft of hole was cut for the 55 potential producers, with an average total depth of 5,997 ft per well.

During 1980, two new power plants were put on line at The Geysers, increasing by 37% the total net generating capacity to over 900 MWe. PG & E's unit 13 went on line in April using steam provided by Aminoil USA to operate a 135 MWe plant. PG & E's new 110-MWe unit 14, supplied by steam produced by Union Oil Company, went on line in September.

Two power plants commenced production in the Imperial Valley in 1980. Southern California Edison started up a 10-MWe flash steam unit at the Brawley geothermal field in June. Steam is supplied by the Union Oil Company. After an intermittent beginning, Imperial Magma's pilot binary cycle, 11-MWe unit went on line on a continuous basis, producing 7 MWe of power. Hot water is supplied to the plant by Imperial Magma's wells.

INTRODUCTION

This is the first report devoted specifically to geothermal resources exploration and development activity in the United States. During the past few years, geothermal activity has been included in a terse form with the annual report of the developments in West Coast area, developments in the Four Corners-Intermountain area, and developments in the Upper Gulf Coast of Texas. The basic purpose of this paper is to present data on the drilling for and development of geothermal resources in the United States.

Geothermal utilization in the United States started with early efforts being concentrated around hot springs and geothermal surface deposits. Bathing, health spas, cooking and some mineral extraction were included in these uses. These developments primarily occurred in the western states due to the association of hot springs with recent tectonic activity. However, some development did exist in the older geologic provinces of the eastern part of the United States. Even though direct heat applications of geothermal energy occurred first, their present-day uses are limited in comparison to development in other countries. Today, the United States is noted mainly for its geothermal electrical power generation.

Most of the early geothermal development in the United States was undertaken by private industry and individuals such as B. C. McCabe (Magma Power Company) and Dan A. McMillan (Thermal Power Company). In recent years the federal government, through the Geological Survey (USGS), the National Science Foundation (NSF), the Energy Research and Development Administration (ERDA), and the Department of Energy (DOE) has initiated geothermal programs in order to stimulate development. State governments have formed energy departments, and some local governments have instituted land use planning and adopted ordinances related to geothermal development.

DIRECT USE DEVELOPMENT

Therapeutic and bathing uses have received great attention over the past century, at locations such as Steamboat Springs, Nevada; Hot Springs, Virginia; Lava Hot Springs, Idaho; Steamboat Springs and Glenwood Springs, Colorado; Thermopolis, Wyoming; and Calistoga, California. Today, national parks protect many of these geothermal uses and phenomena: Hot Springs, Arkansas, National Park (bathing), Lassen Volcanic National Park (sulfur mining), and Yellowstone National Park (tourism).

Space heating with geothermal energy has a recorded history of nearly a century in this country. However, this use has not received the publicity afforded the spas. Klamath Falls, Oregon, and Boise, Idaho, have the greatest energy consumption for space heating, with minor amounts used in Reno, Nevada; Lakeview, Oregon; Vale, Oregon; Susanville, California; Calistoga, California; and other locations. In Klamath Falls, over 400 wells are used for space heating, using waters from 104°F to 230°F. The principal heat extraction system is a closed-loop downhole heat exchanger using city water in the loop. Larger examples of space heating in Klamath Falls include the Oregon Institute of Technology campus, where three wells up to 2,000 ft deep produce up to 440 g/min of 192°F water and heat approximately 500,000 ft² of floor space. The well water is pumped from the well by using deep well centrifugal pumps, and in most cases, it is used directly in the heating system for each building. The annual operating cost when using geothermal energy in the campus system is approximately $30,000. This is a savings of almost $250,000/yr when compared with the cost of

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heating with conventional fuel. Other notable uses in the community include Presbyterian Intercommunity Hospital, where the present worth of a 20-yr savings due to a geothermal retrofitted heating system is over $1 million, and Maywood Industries, where 113°F water is used for heating a large manufacturing building. Development in Boise, Idaho, started in 1890 when two hot water wells were drilled northeast of town, producing 180°F water. A natatorium was built to be a community recreational center and health spa. By 1930, two hot water wells heated 400 homes and businesses. By the early 1970s, the Boise Warm Springs water district was formed. Today, the City of Boise and the water district have a legal working relationship through the Boise Geothermal Office to implement a geothermal program for the metropolitan area. Both Klamath Falls and Boise have received DOE funds for demonstration district heating projects.

Numerous greenhouse and aquaculture projects have been developed in this country over the past few years. The most interesting aspect of these geothermal developments is the location of many of these projects are in colder areas, where heating by conventional means is not economically feasible. Tree seedlings, tomatoes, cut flowers, and potted plants are the most profitable greenhouse products. Catfish, trout, and giant freshwater prawns are the most profitable aquaculture undertakings. Specific projects are located at Wendel, California (greenhouse), Klamath Falls, and Lakeview, Oregon (greenhouse and acquaculture), and numerous locations in Idaho (aquaculture).

There are two industrial processing uses of geothermal energy of note: Medo-Bel Creamery in Klamath Falls, where low-temperature fluid is used for pasteurizing milk, and Geothermal Food Processors at Brady Hot Springs, Nevada, where high-temperature fluid is used for dehydrating onions and other vegetables.

The fastest growing application of geothermal energy is as the direct source of heat for a variety of purposes. Individually, projects utilizing direct geothermal heat use a small amount of energy in comparison with electric plants. However, together these projects displace a significant amount of energy from conventional sources.

Current direct heat application comprise 183 activities in 15 states. Eight of these projects became operational during 1979 and 1980, providing 219 × 10^9 Btu per year. By the end of 1980, an additional 16 projects will be in service, supplying another 185 × 10^9 Btu of energy. The United States Department of Energy is supporting space-heating installations in the THS Memorial Hospital, Marlin, Texas, and ten other space-heating projects that include three more hospitals and two schools. The Holly Sugar plant at Brawley, California, with DOE support, is converting to geothermal water their boilers and dryers for refining beet sugar. The first geothermal ethanol production facility is in operation in La Grande, Oregon, and Bechtel has completed the conceptual design of a large ethanol plant for Raft River, Idaho. Other ethanol plants are at various stages of development in Nevada, Utah, New Mexico, California, and Oregon. A summary of direct use applications in each state is presented in Figure 3, while the locations of the major direct use projects are shown in Figure 4. There are a total of 129 planned projects. Tabulations of balenology applications (hot water spas and pools) are maintained separately, since the energy benefit from these projects is ambiguous. A summary of direct use applications is presented in Table 1.

ELECTRICAL POWER GENERATION DEVELOPMENT

The first commercial geothermal electric power complex in the United States is at The Geysers, about 80 mi north of San Francisco, California. The field, one of three sites in the world commercially producing dry steam, is located in the rugged Mayacmus Mountains of northeastern Sonoma County and western Lake County. Surface geothermal activity in the area, despite its name, is limited to numerous fumaroles and several hot springs, rather than true geysers, which are characterized by intermittent eruptions of hot water and steam.

When first viewed in 1847, the white plumes and hot springs in the area were described as 'The Gates of Hell' by their discoverer. In the 1860s, a hotel and bathhouse were built near the hot springs, but it was not until the early 1920s that an attempt was made to develop the area's power potential. Although the steam source was successfully tapped by drilling, its development was neither technologically nor economically feasible. The production equipment of that period could not tolerate the corrosive and abrasive effects of natural steam and its impurities, and hydroelectric sites were more economical to develop.

In 1956, a joint venture by Magma Power Company and Thermal Power Company again tapped the area's resources with the drilling of six successful steam wells. Pacific Gas and Electric Company (PG & E) tested the wells, which had a combined production rate of 299,200 lb of steam per hour, and determined that small steam turbines could produce power economically. Under a 1958 contract, PG & E designed and constructed a small 11-MWe turbine generator unit, while Magma and Thermal developed the steam wells and gathering system. The first power plant, costing $4 million, began to operate in 1960 and opened a new era in the use of geothermal steam for the commercial production of electricity.

Seven years later, Magma and Thermal merged their holdings with Union Oil Company of California. Union was then designated as operator of the steam field. From 1967, development of The Geysers accelerated, and in 1973, it became the world's largest geothermal electrical power installation, surpassing Italy and New Zealand. Fifteen units are now in operation, producing approximately 900 MWe.

In the United States, the growth surge at The Geysers in the early 1970's was followed by a delay coincidental with the promulgation of environmental guidelines and the proliferation of legislative, regulatory, and jurisdictional activities that followed actions by the United States Congress to promote geothermal development. However, growth at The Geysers has resumed, and about seven additional 100-MWe plants will come on line by 1986.

For many years, the Imperial Valley of southern California has been seen as another significant growth area for geothermal power. In the vanguard of development, there is the unique 11-MWe Magma binary cycle plant operating at East Mesa using the Magmamax process, followed closely by Union Oil-Southern California Edison's 10-MWe flash steam plant, which is on line at Brawley. Other plants have been announced by industry at Heber, Brawley, East Mesa, and Niland. The cost-shared efforts by DOE and San Diego Gas and Electric to solve the problems of highly saline brines at Niland have done much to accelerate the exploration of the Imperial Valley resources, where additional power from liquid-dominated resources could be on line by 1985.

A 50-MWe flash steam plant at the Valles Caldera, New Mexico, is being constructed under a cost-shared agreement between DOE, Union and Public Service Company of New Mexico. This plant will provide technical and economic data for the development of high-temperature, liquid-dominated, hydrothermal resources in the United States.

Other electrical generation development includes the 100-KW direct contact pilot plant at El Dorado, Arkansas, using a 210°F resource. Isopentane is used as the working fluid in this binary cycle system, which is mounted on the beds of two truck trailers. One of the hottest geothermal reservoirs in the world is at Puna, Hawaii, where a 676°F resource will be used to generate 3 MWe. The wellhead generator is designed to be easily transportable so that it can be moved to another site if threatened by lava flows. Developments are also taking place at Roosevelt Hot Springs in Utah, where 20 MWe will be on line in 1983, and in northern Nevada, where a consortium of electrical utilities are attempting to develop a site, initially using a single wellhead semiportable generator.

Application of geothermal energy to the drying of wood chips and forest slash to raise the combustion temperature, and thus the thermal efficiency of a wood-fired power plant, is the unique approach being used by GeoProducts Corporation at Honey Lake, by DOE, the U.S. Forest Service, and the California Department of Water Resources. Geothermal energy is used to preheat the feed water for the boiler. It is expected to be on line in 1984 and may be followed by similar plants in California and Oregon.

Currently, nearly all commercial electric power on line in the United States from geothermal sources is from The Geysers field in northern California, which has been developed solely by the private sector. The only geothermal electrical power being produced in the United States outside The Geysers is at the Magma Power-San Diego Gas and Electric 11-MWe East Mesa plant and at the Union Oil-Southern California Edison 10-MWe Brawley plant, both of which are in Imperial Valley, California. However, niether of these two plants has achieved full operational status. A 5-MWe research binary power plant located at Raft River, Idaho, will be operational this year.

Currently operating and planned geothermal electric power plants are listed in Tables 2 and 3, respectively: Estimates of the reservoir capacity and proposed power output for the more significant areas in the United States are presented in Table 4.

DRILLING ACTIVITY

The total number of geothermal wells drilled in the United States up to the end of 1974 amounted to 598 wells of which 562 were located in California. Yearly geothermal drilling summaries first published in 1975 by scientists at Republic Geothermal, Inc., have provided data through 1979. Between 1975 and 1979, a total of 305 wells were completed. Of these, 214 were in California, continuing the historical trend that was noted above, that is, most of the geothermal drilling activity has been concentrated at The Geysers in northern California and in the Imperial Valley of southern California. In Figure 5, completed geothermal wells for the 1975–1979 period are plotted as a function of the state in which they were drilled. In the same figure, the total number of wells per year are presented as an inset. Through the end of 1979, a cumulative total of 903 exploratory and development geothermal wells have been completed in the United States.

DRILLING ACTIVITY DURING 1980

Geothermal drilling activity, as compiled by Petroleum Information Corporation (Figure 5; Tables 5 and 6), showed an increase in exploratory and development work over the five previous years, from an average of 61 wells per year to 96 wells for 1980. These 96 wells accounted for 605,175 ft of hole.

The completed wells included 18 geothermal wildcat discoveries, that is, potential geothermal production wells drilled in unproven areas, 15 wildcat failures and 5 geopressured geothermal failures, for a total of 38 exploratory attempts. The successful wildcats accounted for 96,924 ft of hole at an average total depth of 5,385 ft per well. These successful wells included wells capable of producing dry and wet steam, as well as ones intended for direct use applications. These wildcats represented a success ratio of 47.4%.

Eight of the discoveries in California were either drilled as step-outs from The Geysers or tapped the liquid-dominated resources in the Imperial Valley in previously undrilled areas. Direct use projects accounted for three of the California geothermal producers. In fact, California, which had the highest total of completed geothermal wells at 83, also had 43 successful geothermal developments wells. Again, most of these were in The Geysers.

Of 58 geothermal development wells attempted, 55 were considered capable of production, which amounts to a success ratio of 94%. A total of 329,854 ft of hole was cut for the 55 potential producers, with an average total depth of 5,997 ft per well.

Outside of California, three geothermal discoveries were completed in Nevada in the Beowave KGRA by Chevron USA and in the Dixie Valley area by Sunoco Energy Development Corporation. Three discoveries in South Dakota and two completed in Texas at Navarro College for the community hospital in Marlin are intended for direct use geothermal projects.

Eight of the successful development wells were reported from New Mexico and Utah. Three were completed by Union for its Baca geothermal demonstration project in the Valles Caldera. The fourth New Mexico producer was completed for direct use application at the Jemez Indian Pueblo in Sandoval County. Two Utah development wells were completed at the Crystal Hot Springs to supply a space-heating project at the Utah State Prison. Two others were completed and tested for use in greenhouse operations by Utah Roses near the towns of Sandy and Bluffdale.

THE GEYSERS ACTIVITY

During 1980, two new power plants were put on line, increasing by 37% the total net generating capacity to over 900 MWe. PG & E's unit 13 went on line in April, using steam provided by Aminoil USA to operate a 135-MWe plant. PG & E's new 110-MWe unit 14, supplied by steam produced by Union Oil Company, went on line in September.

Union drilled 20 wells in The Geysers in 1980: 19 development wells (producers), and a step-out well Frandsen Federal 5232, was suspended due to drilling difficulties. Union plans to increase their steam production to a level adequate to support generation of an additional 440 MWe for four new power plants by 1985.

Aminoil USA drilled five wells, all producers, in The Geysers in 1980. The wells will supply steam to PG & E's unit 13. Aminoil plans to provide steam for an additional 220 MWe of installed generating capacity by drilling several additional wells on its leases.

Shell Oil Company spudded five wells during the year. Drilling difficulties forced the abandonment of one; however, the remaining four were successful producers.

MCR Geothermal Corporation (formerly McCulloch Geothermal) drilled one development well, Francisco 3-5, in the northern portion of The Geysers, bringing the total number of wells drilled within its lease to four. MCR will deliver its steam to a 55-MWe plant to be constructed by the California Department of Water Resources (DWR) in time for power generation by 1985. Six more wells are scheduled by MCR in order to meet its commitment to this power plant.

Thermogenics completed two new wells on its Rorabaugh lease in 1980. The steam from these wells will be used in PG & E's unit 15 to augment production due to flow rate declines, commonly observed during the initial production of steam wells.

Occidental Geothermal Corporation drilled two wells in The Geysers, both of which are producers. Occidental intends to build two 40-MWe power plants and sell the electricity to PG & E. Occidental plans to begin power generation by June 1984.

GRI Operator Corporation (a wholly owned subsidiary of Geothermal Resources International, Inc.) drilled a step-out well, Prati 1, in the northwest portion of The Geysers. This well is within 1.5 mi of proven production and is being evaluated.

GEYSERS VICINITY ACTIVITY

Sunedco drilled one wildcat well northeast of The Geysers near Wilbur Hot Springs. This well, which was drilled to a total depth of 9,104 ft, was suspended.

In late 1980, Phillips Petroleum Company drilled a wildcat well more than 12 mi to the northeast of the main Geysers development. The well Audrey A 1 is relatively close to several old steam wells drilled in the late 1960's at Sulphur Bank mine. This well was drilled to a total depth of 10,042 ft and is currently being tested to determine its potential.

IMPERIAL VALLEY ACTIVITY

Two power plants commenced production in the Imperial Valley in 1980. Southern California Edison started up a 10-MWe flash steam unit at the Brawley geothermal field in June. Steam is supplied by the Union Oil Company. After an intermittent beginning, the Magma pilot binary cycle 11-MWe unit went on line on a continuous basis, producing 7 MWe of power. Hot water is supplied to the plant by Magma wells, and the power is being purchased by the Imperial Irrigation District.

During 1980, a total of four wells were drilled in the East Brawley area by three companies. Phillips Petroleum Company drilled a wildcat well, which is a potential producer, and one confirmation well, which, due to mechanical problems, was completed as an injection well. Occidental Geothermal Corporation drilled and completed a potential producer in the same area and made plans to drill a second well in early 1981. Finally, Union Oil Company drilled and completed a well north of the Phillips and Occidental wells. This well was being evaluated at the end of 1980. All the East Brawley wells are deeper than 12,000 ft.

In 1980, two wells were drilled in the South Brawley area. TRW drilled an intended producer, and MCR Geothermal drilled an injector. Preliminary tests of the TRW well, which was to be used by the Holly Sugar plant, were not encouraging. MCR also re-drilled a former injector and completed it as a producer.

In the northern portion of the Imperial Valley near Niland, Republic Geothermal Inc. drilled Britz 3, a step-out confirmation well on its Niland prospect, which may be a northeast extension of the Salton Sea field. Both the Britz 3 and the Fee 1 wells (drilled in 1979) are considered to be geothermal producers.

East Mesa 87-6 was drilled to a total depth of 6,290 ft at East Mesa by Republic Geothermal Inc. and completed as a producer. This well, located at the DOE test facility, was funded by the DOE and intended for use to test a 'downhole pump' and 'gravity head binary heat exchanger' developed by Sperry Research.

Finally, in 1980, Mapco drilled a step-out confirmation well, Currier 2, at its Westmorland prospect. This well was drilled to a total depth of 10,456 ft, where commercial temperatures were encountered.

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Table 1. Summary of Direct Heat Use

Area of Use	Number of Users: xxx	Number of Users: Federal	Funding: State	Funding: Local	Funding: Private	BTU/Yr (10^9)
Current uses on line	187	3,848	49	64	1,481	1,487.1
Enhanced oil recovery	1	—	—	—	*	10,000.0
Baths and pools	90	—	2	9	73	51.8
Total	278	3,848	51	73	1,554	11,538.9

*Unknown.

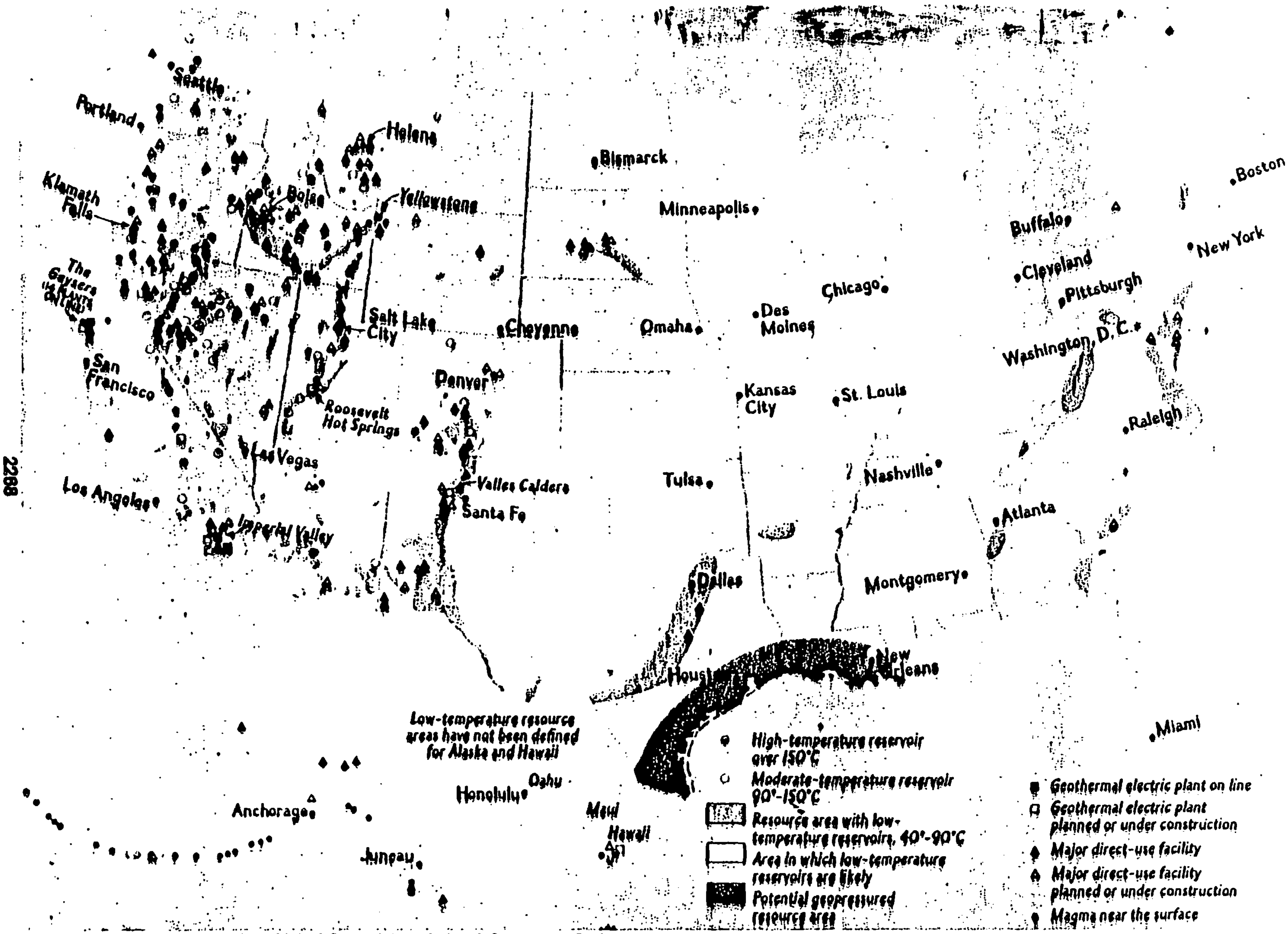

Figure 1. Geothermal map of the United States (after National Geographic Society, 1981).

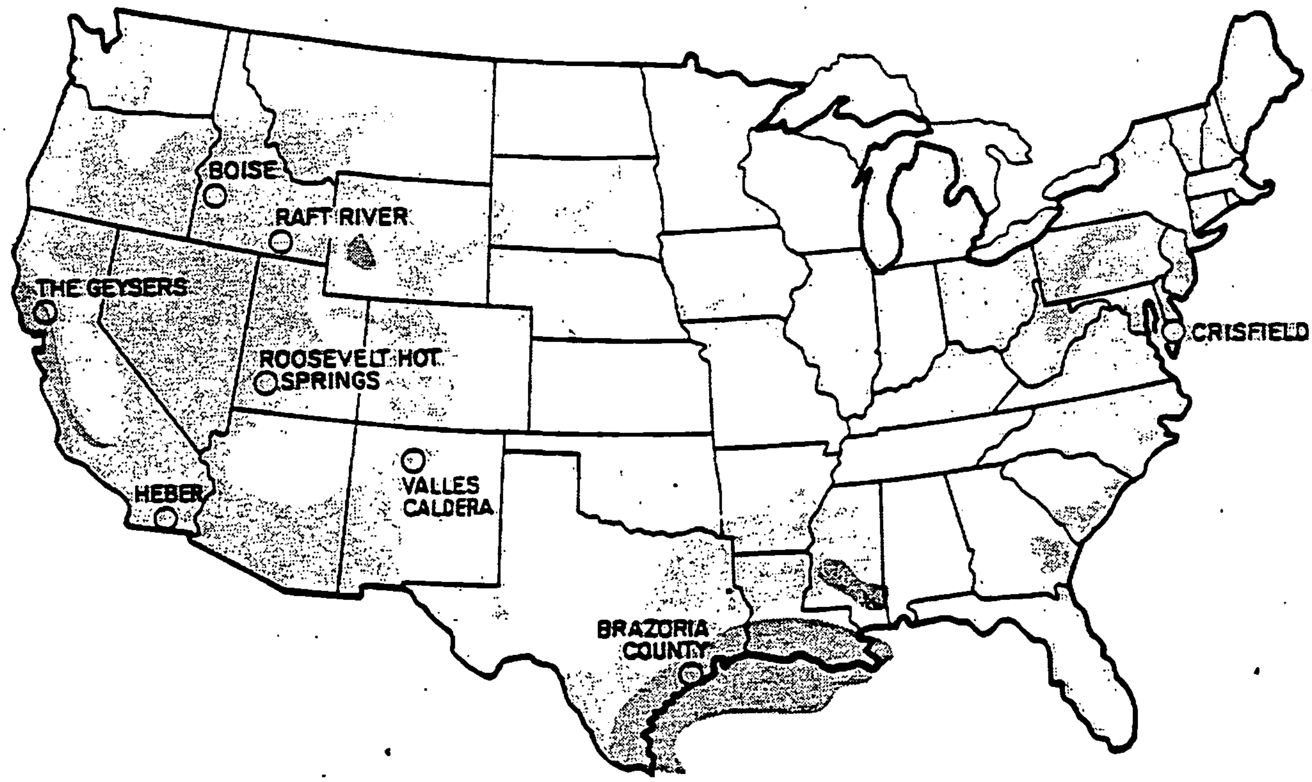

Figure 2. Map of representative geothermal projects in the United States, showing known and inferred hydrothermal areas (light shading) and known and inferred geothermal zones (courtesy of EPRI).

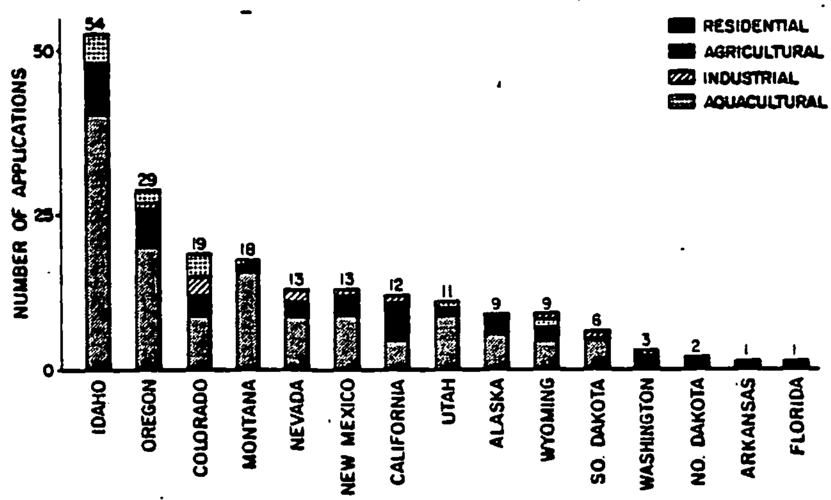

Figure 3. Current direct heat use. Cascaded applications are included, therefore, one site may provide energy for multiple uses.

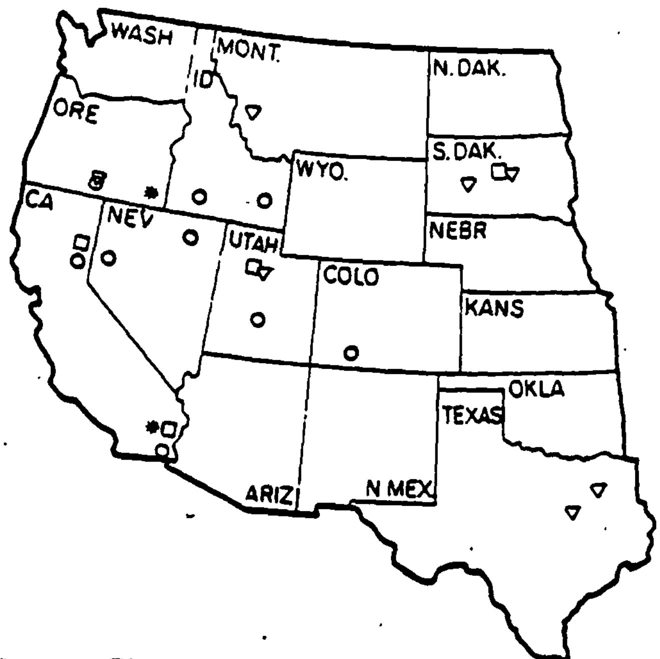

Figure 4. Direct use projects.

Industrial Process Sites
*Ore-Ida — Ontario, Oregon
*Holly Sugar — Brawley, California
Agribusiness
☐Utah Roses, Sandy, Utah
☐Diamond Ring Ranch, South Dakota
☐Aquafarms International, Mecca, California
☐Kelly Hot Springs, California
District Heating Systems
○Monroe City, Utah
○Klamath Falls, Oregon
○Boise, Idaho
○Elko, Nevada
○Madison County, Idaho
○Reno, Nevada
○Pagosa Springs, Colorado
○Susanville, California
○El Centro, California
Institutional Heating Systems
▽Navarro College and Hosp. Corsicana, California
▽Warm Springs Hospital, Montana
▽Utah State Prison, Utah
▽THS Hospital, Marlin, Texas
▽St. Mary's Hospital, Pierre, South Dakota
▽Philip School, South Dakota
▽Klamath Falls YMCA, Oregon

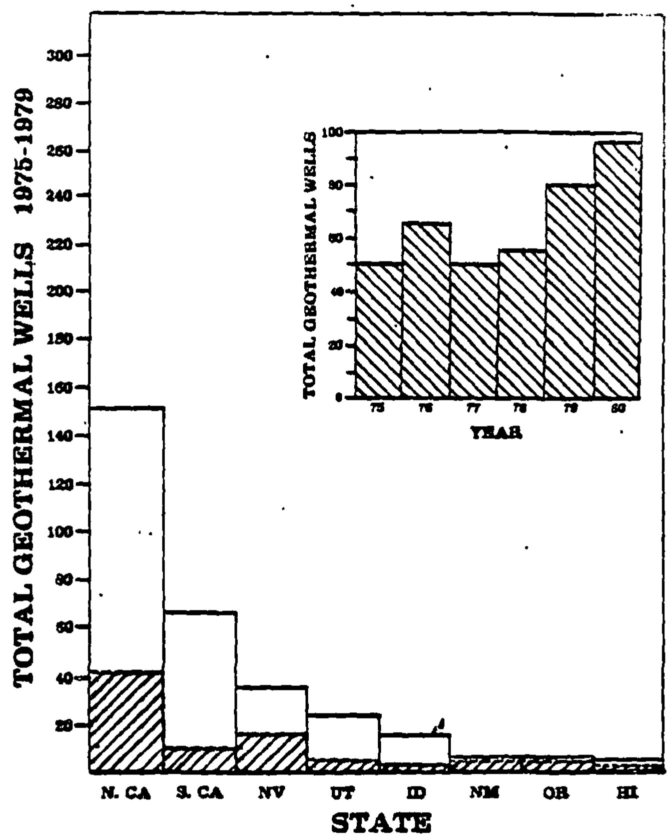

Figure 5. Geothermal well completions since 1975. Shaded area shows wells drilled during 1980.

Table 2. Geothermal Electric Plants on Line in California

Area, Developer	Utility	Plant	Plant Type	Net Output, MWe	Year on Line	Plant Cost, dollars	Notes*
Brawley							
Union Oil	SCE	SCE Pilot	Flash	10	1980	10,040	1
East Mesa							
Magma Power	SDG&E	—	Binary	10	1980	16,093	2, 3
Geysers							
Union-Magma-Thermal	PG&E	Unit 1	Steam	11	1960	2,005	4
Union-Magma-Thermal	PG&E	Unit 2	Steam	13	1963	2,005	4
Union-Magma-Thermal	PG&E	Unit 3	Steam	27	1967	3,805	4
Union-Magma-Thermal	PG&E	Unit 4	Steam	27	1968	3,805	4
Union-Magma-Thermal	PG&E	Unit 5	Steam	53	1971	6,378	4
Union-Magma-Thermal	PG&E	Unit 6	Steam	53	1971	6,378	4
Union-Magma-Thermal	PG&E	Unit 7	Steam	53	1972	5,760	4
Union-Magma-Thermal	PG&E	Unit 8	Steam	53	1972	5,760	4
Union-Magma-Thermal	PG&E	Unit 9	Steam	53	1973	6,760	4
Union-Magma-Thermal	PG&E	Unit 10	Steam	53	1973	6,760	4
Union-Magma-Thermal	PG&E	Unit 11	Steam	106	1975	19,668	4
Union-Magma-Thermal	PG&E	Unit 12	Steam	106	1979	27,580	4
Thermogenics	PG&E	Unit 15	Steam	55	1979	25,530	4
Aminoil USA	PG&E	Unit 13	Steam	129	1980	52,800	4, 5
Status total	—	—	—	812	—	201,125	—

*1, August 1, 1980, Southern California Edison. 2, August 17, 1980, Magma Power Inc. 3, August 7, 1980, San Diego Gas and Electric. 4, August 6, 1980, Pacific Gas and Electric. 5, August 15, 1980, Aminoil USA.

Table 3. Proposed Geothermal Electric Plants

State, Area	Developer	Utility	Plant	Plant Type	Net Output, MWe	Year on Line	Plant Cost, dollars	Notes
California								
Brawley	CU-I Venture	CDWR	—	Flash	45	1984	—	6
Brawley	Union Oil	SCE	SCE	—	—	—	—	1, 7
Coso	California Energy	US NAVY	Coso 1	Flash	20	1984	—	8, 9
Coso	California Energy	US NAVY	Coso 2	Flash	55	1989	—	8, 9
East Mesa	Republic Geothermal	SDG&E	—	Flash	50	1982	80,000	3, 10
Geysers	MCR Geothermal	CDWR	Bottle Rock	Steam	55	1984	—	6, 11
Geysers	Geothermal Kinetics	CDWR	So. Geysers	Steam	55	1985	—	6, 12
Geysers	—	CDWR	Binkley	Steam	55	1986	—	6
Geysers	Resources Funding	NCPA	NCPA 1	Steam	66	—	—	13, 14
Geysers	Shell Oil	NCPA	NCPA 2	Steam	110	1982	28,000	14
Geysers	Union-Magma-Thermal	PG&E	Unit 14	Steam	110	1980	27,966	4
Geysers	Union-Magma-Thermal	PG&E	Unit 17	Steam	110	1982	41,592	4
Geysers	Union-Magma-Thermal	PG&E	Unit 18	Steam	110	1982	48,882	4
Geysers	Aminoil USA	PG&E	Unit 16	Steam	110	1983	42,700	4, 5
Geysers	Union-Magma-Thermal	PG&E	Unit 20	Steam	110	1984	—	4
Geysers	Aminoil USA	PG&E	Unit 19	Steam	55	1986	—	4, 5
Geysers	Union-Magma-Thermal	PG&E	Unit 21	Steam	110	1986	—	4
Geysers	—	PG&E	Unit 22	Steam	110	1987	—	4
Geysers	—	PG&E	Unit 23	Steam	110	1988	—	4
Geysers	—	PG&E	Unit 24	Steam	110	1988	—	4
Geysers	Aminoil USA	SMUD	SMUD 1	Steam	55	1984	—	5, 15
Geysers	—	SMUD	SMUD 2	Steam	55	1985	—	15
Geysers	—	SMUD	SMUD 3	Steam	55	1986	—	15
Heber	Chevron	SCE	SCE 1	Flash	50	1982	—	1
Heber	Chevron	SCE	SCE 2	Flash	100	1986	110,000	1
Heber	Chevron	SDG&E	—	Binary	45	1984	128,400	3
Mono-Long Valley	Magma Power	SCE	—	Cogen	20	1985	—	1, 2
Niland	Union Oil	SCE	SCE	—	—	—	—	1, 7
Niland	Union Oil	SCE	SCE PILOT	—	10	1982	—	1
Niland	Magma Power	SDG&E	SDG&E 1	Flash	24	1983	30,000	2, 3
Niland	Magma Power	SDG&E	SDG&E 2	Flash	49	1985	50,000	2, 3
Wendel-Amadee	Geoproducts	CDWR	—	Cogen	50	1984	60,000	6, 16
Westmorland	Republic Geothermal	—	—	Flash	48	1985	—	10, 17, 18
Hawaii								
Puna	State of Hawaii	HELCO	HGP-A	Flash	3	1981	7,000	19
Idaho								
Raft River	INEL/EG&G	—	—	Binary	5	1980	24,000	20
New Mexico								
Valles Caldera	Union Oil	PNM	BACA 1	Flash	45	1983	—	21
Nevada								
Desert Peak	Phillips Petroleum	SPPC	—	Flash	10	1982	—	22, 23
Desert Peak	Phillips Petroleum	SPPC	—	Flash	50	1984	—	22, 23
Utah								
Roosevelt H. S.	Phillips Petroleum	UP&L	UP&L	Flash	—	—	—	24, 25
Roosevelt H. S.	Phillips Petroleum	UP&L	UP&L 1	Flash	20	1983	20.000	25
Status Total	—	—	—	—	2,250	—	698,540	—

*See Table 2 for notes 1-5. 6. July 31, 1980, California Dep. of Water Resourc. 7. SCE has contract with Union Oil for 450-MWe steam supply. 8. August 6, 1980, California Energy Co. 9. August 6, 1980, US Navy. 10. August 15, 1980, Republic Geothermal Inc. 11. July 21, 1980, MCR Geothermal Inc. 12. August 5, 1980, Geothermal Kinetics Inc. 13. developer in receivership. 14. August 7, 1980, No. Calif. Power Authority. 15. August 19, 1980, Sacramento Municipal Utility Dist. 16. August 7, 1980, Geoproducts Inc. 17. August 14, 1980, Dep. of Energy, San Francisco. 18. August 18, 1980, Mapco Inc. 19. August 11, 1980, Hawaii Dep. of Planning and Economic Develop. 20. August 12, 1980, Idaho Nat. Engin. Lab. 21. August 8, 1980, Dep. of Energy/BACA. 22. August 14, 1980, Sierra Pacific Power Co. 23. Desert Peak is tentative area. 24. UP&L negotiating with Phillips for 200-300-MWe steam supply. 25. August 11, 1980, Utah Power & Light.

Table 4. Estimated Reservoir Capacity and Proposed Power Output for Fourteen Hydrothermal Electric Areas

State, Area	Reservoir Capacity* MWe-30 Yr	Net Power Output MWe: Operating as of July 1980	Planned by 1990	Total by 1990
California				
Brawley	640	10	495	505
Coso Hot Springs	650	—	75	75
East Mesa	360	10	50	60
Geysers	1,610	792	1,551	2,343
Heber	650	—	195	195
Mono Long Valley	2,100	—	20	20
Niland (Salton Sea)	3,400	—	533	533
Wendel-Amedee (Lassen)	75	—	50	50
Westmorland	1,710	—	48	48
Hawaii				
Puna	40	—	3	3
Idaho				
Raft River	150	—	5	5
New Mexico				
Valles Caldera	2,700	—	45	45
Nevada				
Desert Peak	750	—	60	60
Utah				
Roosevelt H. S.	970	—	220	220
Total	15,805	812	3,350	4,182

Table 5. United States Geothermal Cumulative Well Completions During 1980

Type of Well*	Total	Feet	Percentage of Total Completions	Percentage of Total Footage	Average Depth, ft	Success Ratio, Percent
Exploratory						
GWD	18	96,924	47.37	37.39	5,385	47.37
GW	15	86,935	39.47	33.54	5,796	—
PW	5	75,338	13.16	29.07	15,066	—
Total	38	259,197	100.00	100.00	6,821	—
Development						
GDS	55	329,854	94.83	95.34	5,997	94.83
GD	3	16,124	5.17	4.66	5,375	—
Total	58	345,978	100.00	100.00	5,965	—
Miscellaneous						
IW	3	19,533	2.70	8.11	6,511	—
TO-TG	96	114,231	86.49	47.43	1,190	—
SUS	12	107,067	10.81	44.46	8,922	—
Total	111	240,831	100.00	100.00	2,170	—
All Wells						
Exploratory	38	259,197	18.36	30.64	6,821	—
Development	58	345,978	28.02	40.89	5,965	—
Miscellaneous	111	240,831	53.62	28.47	2,170	—
Total	207	846,006	100.00	100.00	4,087	—

*Key to geothermal well classifications: GWD, producing-potential geothermal wildcat discovery; GW, unsuccessful geothermal wildcat; PW, unsuccessful geopressured wildcat; GDS, producing-potential geothermal development; GD, unsuccessful geothermal development; IW, injection well; TO-TG, temperature-observation temperature-gradient stratigraphic well; SUS, suspended well.

Table 6. *United States Geothermal Well Completions During 1980 by State*

State	Exploratory Wells*					Development Wells*				Miscellaneous Wells*					Total Wells	Total Footage
	GWD	GW	PW	Total	Total Footage	GDS	GD	Total	Total Footage	IW	TO-TG	SUS	Total	Total Footage		
Alabama	1	0	0	1	150	1	0	1	150	0	0	0	0	0	2	300
Arizona	0	0	0	0	0	0	0	0	0	0	12	0	12	28,729	12	28,729
California	8	1	0	9	67,610	43	2	45	302,730	2	20	7	29	89,482	83	459,822
Colorado	0	0	0	0	0	1	1	2	599	0	4	0	4	1,980	6	2,579
Hawaii	0	2	0	2	12,095	0	0	0	0	0	0	0	0	0	2	12,095
Idaho	0	2	0	2	18,337	0	0	0	0	0	1	0	1	4,000	3	22,337
Louisiana	0	0	3	3	48,198	0	0	0	0	0	0	1	1	16,348	4	64,546
Maryland	0	1	0	1	5,562	0	0	0	0	0	0	0	0	0	1	5,562
Nevada	3	6	0	9	51,705	2	0	2	18,448	0	8	3	11	47,426	22	117,579
New Mexico	0	0	0	0	0	4	0	4	16,683	0	4	0	4	2,000	8	18,683
Oregon	0	2	0	2	8,847	0	0	0	0	0	44	1	45	37,195	47	46,042
South Dakota	3	0	0	3	10,564	0	0	0	0	0	0	0	0	0	3	10,564
Texas	2	0	2	4	33,653	0	0	0	0	1	0	0	1	4,760	5	38,413
Utah	1	1	0	2	2,476	4	0	4	7,368	0	1	0	1	8,021	7	17,865
Washington	0	0	0	0	0	0	0	0	0	0	2	0	2	890	2	890
Total	18	15	5	38	259,197	55	3	58	345,978	3	96	12	111	240,831	207	846,006

*See Table 5 for key to geothermal well classification.

Table 7. Representative Geothermal Projects in the United States

Location	Purpose	Technology	Capacity, MW	Start Date	Sponsors**
California					
The Geysers	Electricity, Commercial	Natural steam cycle	800	1960-1980	Pacific Gas and Elec. Co., Union Oil Co. of Cal.
Heber	Electricity, Demonstration	Binary cycle	45	1984	DOE, EPRI, San Diego Gas & Elec. Co., Chevron Resources Co.
East Mesa	Electricity, Pilot	Binary cycle	11	1979	Magma Power
Brawley	Electricity, Pilot	Direct-flash steam cycle	10	1980	Southern California Edison Co., Union Oil Co. of Cal.
Heber	Electricity, Commercial	Direct-flash steam cycle	41	1982	Southern California Edison Co., Chevron Resources Co.
Idaho					
Raft River	Electricity, Experiment	Binary cycle	5	1980	DOE
Boise	District heat, Commercial	na	na	1981	DOE, State of Idaho, City of Boise
New Mexico					
Valles Caldera	Electricity, Demonstration	Direct-flash steam cycle	50	1982	DOE, Public Service Co. of New Mexico, Union Oil Co. of Cal.
Nevada, Northern					
Site to be selected	Electricity, Commercial	Direct-flash steam cycle	50	1984	Sierra Pacific Power Co., other Utilities
Utah					
Roosevelt Hot Springs	Electricity, Commercial	Direct-flash steam cycle	20	Pending	Utah Power & Light Co., Phillips Petroleum Co.
Maryland					
Crisfield	Hydrothermal, Exploration	na	na	1979*	Reached 60°C water. DOE
Texas					
Brazoria County	Geopressure, Exploration	na	na	1979	Well complete. DOE