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The U.S. Geothermal Industry: Three Decades of Growth

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Abstract *Over the last three decades the U.S. geothermal power-generation industry has grown to be the largest in the world, with over 2700 MW of installed electrical capacity. Growth during the first two decades (1960-1980) was characterized by a single utility's development of one dry-steam resource. After 1983, growth shifted toward independent power producers, and development of water-dominated geothermal resources at several locations. In the absence of significant changes in demand. incentives, or the regulatory process, new geothermal generating capacity, through 1995, will probably not exceed 500 MW. The U.S. geothermal industry must increase its inventory of characterized geothermal reservoirs in order to meet the expected demand for rapid geothermal development before the year 2000.*

Keywords *Dry steam, geothermal, water-dominated*

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INTRODUCTION

Geothermal energy plays a small but important role m the mix of energy sources for electric power generation in the United States. Each year, the electricity generated from geothermal resources accounts for approximately 1 billion[1] dollars of revenue and displaces over 30 million[2] barrels of imported oil. In California, about 7%[3] of the electricity consumed is supplied by geothermal resources.

Geothermal developers and researchers make a distinction between two main types of geothermal reservoirs. Two well-known geothermal systems, The Geysers in California and Larderello in Italy, are classified as dry-steam geothermal fields. In these two low-pressure, single-phase systems. dry steam is the pressure-controlling medium filling the fractured rocks. The pressure increases slightly with depth due to the density of the steam. Initial conditions in The Geysers reservoir at a depth of 1.5 km Included temperatures near 250°C and pressures near 3.3 MPa. Much more common are the water-dominated geothermal fields, where liquid water at high temperature, but also under high (hydrostatic) pressure, is the pressure-controlling medium filling the fractured and porous rocks. The pressure increases along a hydrostatic gradient in the water-dominated reservoirs. Some water-dominated systems may have a small steam cap at the top, and below any steam cap the temperature will often increase along the boiling-point curve with depth.

In dry-steam systems, only steam is produced at the surface, and after the steam is cleaned of rock particles it can go directly to the turbines. This ease of handling led to the early development of Larderello for electrical generation in 1904. The

Geysers became the first U.S. geothermal, electrical development in 1960. In water-dominated geothermal systems, water comes into the wells from the reservoir; and the pressure decreases as the water moves toward the surface, allowing the water to boil. Only part of the water boils to steam, and a separator is installed between the wells and the power plant to separate the steam and water. The steam goes into the turbine, and the water is injected back into the reservoir. The greater capital expense required for separators and injection wells in water-dominated geothermal systems initially delayed their development because they could not compete with lower-cost alternatives such as coal, oil, and gas generation facilities.

Some water-dominated reservoirs, particularly those at temperatures below 175°C, are pumped to produce the water, and also to keep it from boiling. The produced water is circulated through heat exchangers to heat a secondary liquid, usually an organic compound with a low temperature of boiling. The resulting organic vapor then drives a turbine to produce electricity. This type of turbine, where a secondary compound is used, is called a binary power system. Many small binary geothermal plants are installed in the United States.

Begun in 1960 in The Geysers of California, the United States geothermal electric power industry has grown to be the largest in the world, with over 2700 MW of installed electrical-generating capacity (in this article MW only refers to electrical energy). Development in the United States is followed by the Philippines with 890 MW, Mexico with 700 MW. Italy with 545 MW, and New Zealand with 460 MW. The steady growth of geothermal development in the United States from 1960 through 1979 was led by activities at The Geysers, where the field developments of the partnership of Union Oil Company of California, Magma Energy Company, and Thermal Power Company were greatly expanded to provide steam to the Pacific Gas and Electric Company (PG&E) electrical-generation system. This construction made The Geysers field the largest geothermal development in the world. Production from The Geysers peaked in 1988, and pressure declines in the reservoir have limited any further expansion of the field.

Considerable resource exploration and research in areas outside The Geysers between 1972 and 1984 led to explosive growth in geothermal-generation capacity after 1985. Sixty-nine generating facilities are now operating at 18 resource sites in California, Nevada. and Utah. Figure 1 shows the locations of the geothermal power plants in the United States, and Table 1 provides information on the individual generating facilities.

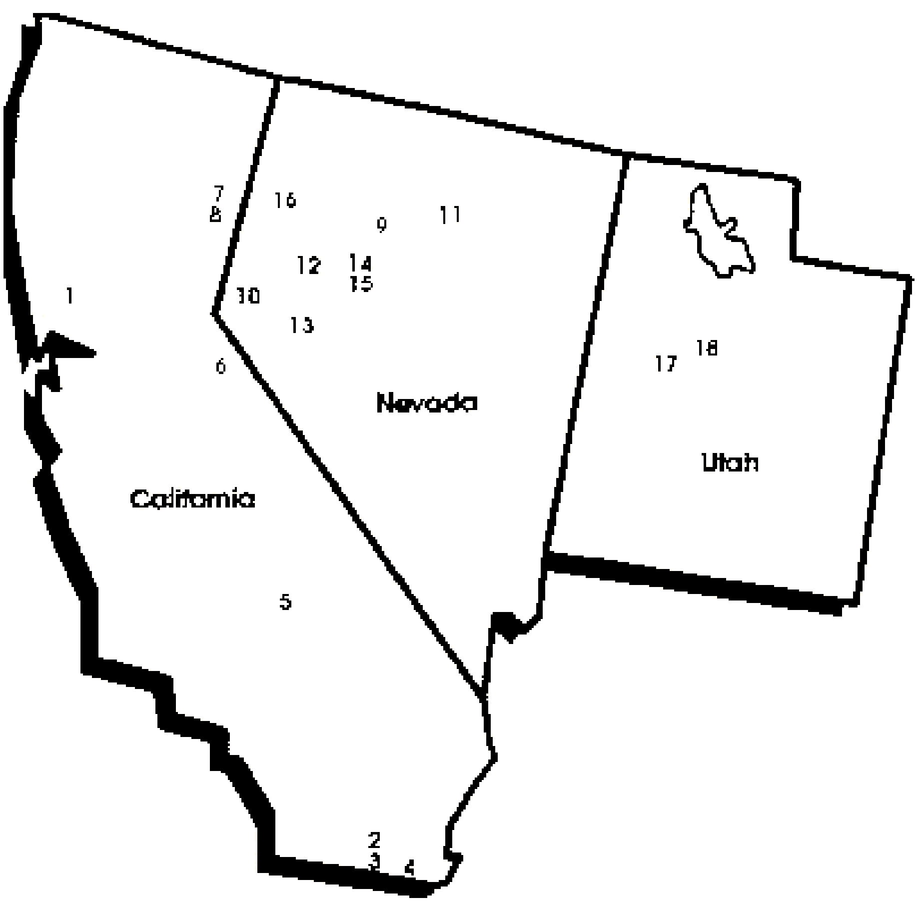


Figure 1. U.S. Geothermal power plant locations:
1. The Geysers
2. Salton Sea
3. Heber
4. East Mesa
5. Coso
6. Casa Diablo
7. Amedee
8. Wendel
9. Dixie Valley
10. Steamboat Hot Springs
11. Beowawe Hot Springs
12. Desert Peak
13. Wabuska Hot Springs
14. Soda Lake
15. Stillwater
16. Empire and San Emidio
17. Roosevelt Hot Springs
18. Cove Fort

DRY-STEAM RESOURCE DEVELOPMENT

The Geysers fumarole area in northern California was discovered in 1847, and within a few years it became a recreation area for residents of San Francisco. In the first attempt at electrical production, two small generators (a few kilowatts) were powered by steam at The Geysers between 1924 and 1938, and several geothermal wells were drilled by the Geysers Development Company and its predecessors from 1924 through 1929 (Anderson and Hall 1973). This early attempt at commercial electrical production was discontinued, because steam generation was not competitive with other available power sources.

The Magma Power Company began the recent, successful well drilling and steam developing operations at The Geysers in 1955; in 1960, PG&E began operating the first large-scale, geothermal, electric-generation plant (Unit 1) in the United States. This turbine was a 1924 vintage, 12.5-MW, General Electric machine modified to use geothermal steam. The unit produced 11 MW of net power and operated successfully for more than 30 years.

Confidence in The Geysers resource grew, and PG&E added additional generating units to the field. For several years, each addition of new turbines had a considerable increase in size (see Table 1). The turbine size reached a maximum with the 134-MW turbine of Unit 13, which began operating in May 1980. Increasing the turbine size created some problems. The larger turbines required the drilling of more wells, increased the delay in return on investment capital, needed more expensive steam gathering lines, and caused a greater loss of income during maintenance. As of 1990, PG&E’s geothermal capacity at The Geysers had grown to 1360 MW. In addition, other utilities have installed 459 MW at The Geysers, and independent power producers have installed 147 MW.

DELAY IN WATER-DOMINATED RESOURCE DEVELOPMENT

Geothermal exploration in water-dominated systems of the western United States began shortly after the exploration in The Geysers. In 1925 and 1926, after drilling 3 wells at The Geysers, pioneer geothermal driller Fred Stone and his company drilled 12 geothermal wells (each less than 1000 ft deep) in the Hot Creek area just east of the present Casa Diablo geothermal field in eastern California (Anderson and Hall 1973). In 1927, the Pioneer Development Company used Fred Stone’s company to drill 3 geothermal exploration wells (maximum depth 1473 ft) at Mullet Island, which is now at the north-east end of the Salton Sea geothermal field in the Imperial Valley of California (Rook and Williams 1943). Competing sources of electricity with better economic returns cooled the ambitions of the early geothermal pioneers.

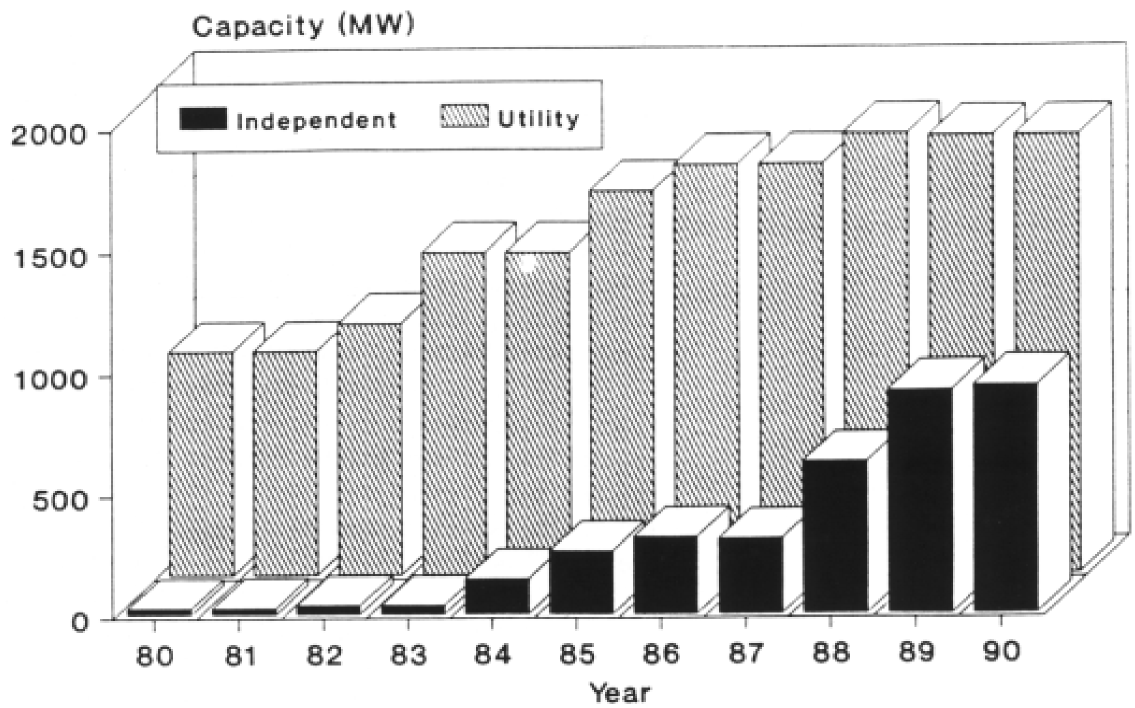
From a global perspective, the first major electrical development of a water-dominated geothermal reservoir took place in 1950 at the Wairakei field of New Zealand. The success at Wairakei and the continued success of PG&E at The Geysers fueled interest in developing the water-dominated resources in the United States. During the period 1957 to 1965, the Magma Power Company and several partners drilled geothermal exploration wells in many areas that now produce electricity. Magma drilled several shallow wells at Casa Diablo, Wendel, and Amedee, California; and Brady Hot Springs, Steamboat, Beowawe, and Wabuska, Nevada; and at Puna, Hawaii. In 1967, both Earth Energy Corporation (later Unocal) and Morton Salt Company had small, experimental geothermal turbines operating at the Salton Sea field, but the silica scaling and high salt content prevented their commercial development of the resource at that time.

In 1975, the U.S. Geological Survey (USGS) conducted a geothermal-resource assessment (White and Williams 1975) that indicated that over 90% of the geothermal resources in the United States are water dominated; of these, 80% are between 100 and 200°C. The USGS assessment documented what was known about the geothermal prospects at that time, and this report was instrumental in expanding interest in developing these resources. The higher degree of risk, greater cost, an adverse regulatory climate, and relative immaturity of the associated technology discouraged development of water-dominated resources through 1976. These impediments were mitigated significantly by actions taken by the federal government in response to the oil shock of 1973.

In order to encourage the development of indigenous resources and the associated technologies, the federal government provided large sums to support research and development (R&D) in these areas. The federal geothermal R&D program was initiated in 1972 by the actions of Congress funding the National Science Foundation for energy research, giving the Atomic Energy Commission broad authority to conduct research on all types of energy resources, and increasing the research effort of the U.S. Geological Survey in the location of energy resources. After passage of the Geothermal Research, Development and Demonstration Act in 1974, the programs of the Atomic Energy Commission and the National Science Foundation (NSF) were placed in the Energy Research and Development Administration (ERDA), and then passed to the Department of Energy (DOE) in 1978. Federal R&D annual funding for geothermal energy at DOE reached a peak of $160 million in 1979. Two later geothermal resource assessments by the USGS documented the greatly expanded information base for geothermal systems in the United States that resulted from the research effort (Muffler 1979; Reed 1983).

During the same period, the federal government also encouraged development of geothermal resources by providing energy tax credits and loan guaranties and creating a more progressive regulatory climate through passage of the Public Utility Regulatory Policy Act (PURPA) of 1978. Sections 201 and 210 of PURPA were designed to encourage development of cogeneration and other small, independent-power projects by establishing a legal framework for the existence of independent (nonutility) power producers and requiring utilities to purchase power form qualifying facilities (QFs). Such producers were limited to a maximum net capacity of 80 MW.

In 1979, the Federal Energy Regulatory Commission (FERC) formulated the set of rules and regulations for implementation of PURPA. FERC directed state regulators to require that utilities purchase power from independent power producers (IPPs) at the utility's full avoided cost and to make the utility's transmission system available to deliver the power to markets. Of particular significance to the geothermal industry was the FERC decision that utilities could be required to pay the QF a capacity charge as well as an energy charge. The rationale for the capacity charge was that, because of the baseload nature of geothermal power, its sale to the utility directly displaced capacity that the utility would otherwise have to build in the future. This led to the California Energy Commission requiring utilities to issue Standard Offer Number Four (SO-4) contracts for purchase of power from independent producers. These long-term contracts (30 years) set prices at the utility's full avoided cost for new baseload capacity. The effect of these incentives on the geothermal industry has been a shift from utility development of a single dry-steam resource to independent development of water-dominated resources at multiple locations. This trend, evident in Figure 2, has resulted in the IPP segment of the industry increasing its capacity from zero to approximately one-third of the total. Production from water-dominated resources is also approximately one-third of total production.



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Plants retired in 85, 87 & 89

Figure 2. Geothermal electric plant ownership by utilities and independent power producers.

RAPID DEVELOPMENT OF WATER-DOMINATED RESOURCES

The first electrical development of a water-dominated geothermal resource in the United States occurred in November 1979, at the East Mesa field in the Imperial Valley of California. The electrical generation facility consisted of a binary application, a Borg Warner double-flow, three-stage turbine using isobutane as the working fluid to drive a 10-MW generator. Several production wells are pumped to produce 655,000 kg/h of brine (approximately 3.5 salt by weight). The brine is delivered at 1.86 MPa and 182°C to the heat exchangers to transfer energy to the isobutane. Later turbine modifications increased the gross output to 13.4 MW of electricity. This plant is named after B. C McCabe. the geothermal pioneer who, with his Magma Power Company, started the U.S. geothermal industry at The Geysers in 1955.

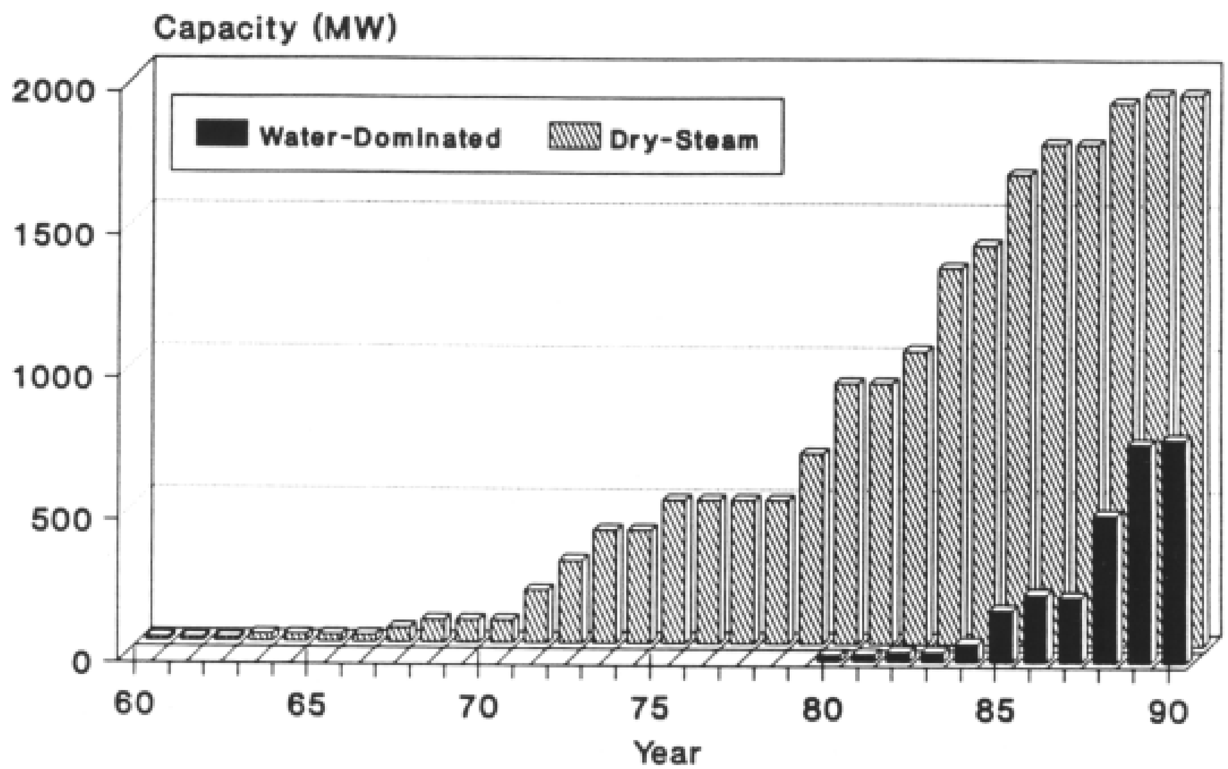
In June 1980, Southern California Edison (SCE) began operation of a 10-MW (gross) experimental power plant at the Brawley geothermal field with steam produced by Unocal (Cedillo and Yamasaki 1981). The high-salinity brines produced ranged between 5 and 25% salt by weight, and reservoir uncertainties led to abandonment of the field after only a few years of production. The turbine and generator were later installed at the Salton Sea geothermal field.

An experimental geothermal generator built by the Department of Energy (DOE) began continuous operation in March 1982, at the Puna geothermal field on the Island of Hawaii (Thomas 1982). This plant produced a maximum of 2.5 MW from steam flashed from the hot water of a single well begun by NSF and completed by ERDA in 1976. Water in the reservoir has temperature above 360°C at a depth of almost 2 km. Production from this well ceased when generation from the plant was discontinued in December 1989, after almost 7 years of operation.

The Geothermal-Loop Experimental Facility (GLEF) in the Salton Sea geothermal field of California is an example of a jointly funded, government and industry, geothermal research facility. Difficulty in handling the high-salinity brines (over 20% salt by weight) in the Salton Sea field was delaying commercial power generation from this high-energy, water-dominated resource. The facility, completed in 1976, was built to determine the technical feasibility of removing salt that formed when steam was flashed from the brine. The crystallizer-clarifier, brine-treatment process developed at the GLEF demonstrated that commercial power generation was technically and economically feasible.

Economic electrical generation from the Salton Sea geothermal field began in June 1982, when Unocal began production from its 12 MW (gross) turbine. Wells in this field produce from depths of about 1 km and reservoir temperatures of about 300°C. The higher-temperature (up to 380°C) brines from greater depths also have higher salinity. One well in this field produces over 1.5 million kg/h of brine, which is equivalent to the generation of 30 MW of electricity (Reed 1989). After 1982. Unocal added two additional generation units for a total gross electrical generation of 83 MW. In December 1985, Magma Power Company began continuous production from their first power plant in the Salton Sea field (40 MW, gross). Magma has since added 3 more generating units to bring their total electrical generation to 145 MW (gross).

After 1980, the United States experienced phenomenal growth in the water-dominated segment of the geothermal industry. Forty water-dominated geothermal generating units (839 MW) were commissioned, a 49% annual compound rate of growth. The industry annual compound growth rate (for both dry-steam and water-dominated capacity) from 1980 through 1990 was 15%. The sharp increase in the number of new water-dominated plants in 1988 and 1989 (see Figure 3) resulted from developers rushing to complete projects before expiration of SO-4 contracts and available tax credits.



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Plants retired in 85, 87 & 89

Figure 3. Growth in U.S. geothermal electric generation capacity by dry-steam and water-dominated resources.

CURRENT INDUSTRY OUTLOOK

The Geysers geothermal field reached its maximum production rate in 1988 of about 2000 MW, and pressure and production rates have declined since then. The Geysers production decline has demonstrated the need for increased water injection to maintain reservoir pressure, and current research is directed toward determining the best method for water injection. Efforts being made to mitigate production decline include a search for additional sources of water to augment injection in this semi-arid area. Other research projects are investigating modifications to turbine operations to increase efficiency. Operations at some of the older, less efficient plants have been suspended, and the steam has been rerouted to more efficient units.

Before the year 2000, a major exploration effort is needed to rebuild the inventory of undeveloped geothermal sites that can be developed rapidly when the economic need occurs. A major period of geothermal exploration culminated in 1979 and 1980, with the DOE cost-shared program for Industry-Coupled Drilling. In that program. DOE used federal funds to share the risk of exploratory drilling (with industry) in 15 prospect areas of Utah and Nevada. The program was highly successful, and eight of those geothermal prospects are now producing electricity. The rapid expansion after 1980 was made possibly by earlier characterization of several geothermal reservoirs, and future development requires that a new selection of geothermal reservoirs be characterized soon.

The availability of SO-4 contracts from California utilities provided the needed economic incentive for development of many previously characterized geothermal sites in California and Nevada. Unfortunately, geothermal exploration has not kept pace with development, and there are now very few geothermal sites that are well characterized for rapid development in the future. To sustain a pace of development similar to that from 1980 through 1990, a major exploration effort is needed to build the inventory of geo-thermal areas.

The most promising new areas for geothermal exploration are in Hawaii and the Cascade Mountains of Washington, Oregon, and northern, California. An area with extensive geothermal exploration, the Basin and Range of Nevada and Utah, still holds the promise of large quantities of undiscovered geothermal resources. Developers have begun construction of a 25-MW geothermal plant in the Puna field of Hawaii and expect to begin electrical generation before the end of 1992. Some developers have speculated that the rift system on Hawaii could yield up to 500 MW. The Glass Mountain field of northern California (southern Cascades) is another area believed to have significant potential. Unocal plans to construct a small plant there and is seeking a power-sales agreement. Other areas of the Cascades are being explored slowly and may eventually provide new areas for geothermal development.

FUTURE GROWTH

A strong market for geothermal electrical generation is anticipated as a result of the Clean Air Act of 1990 and because of the growing concern about global warming. Geothermal development will benefit from the growing need for energy sources with low atmospheric emissions and proven environmental safety. It will not be easy for the geothermal industry to continue a high growth rate of electrical generating capacity from 1990 to the end of the millennium. Most of the easily located geothermal systems, those with hot springs, fumaroles, and geysers at the surface, are already known and many have been developed. In order to locate and characterize hidden geothermal systems that do not reach the surface, new approaches to exploration are needed. The high economic risk of drilling in frontier areas has limited geothermal exploration in recent years.

The economic risk of exploratory drilling may be reduced, researchers believe, through the development of new core hole evaluation technologies. Core drilling became an important method of geothermal exploration after 1980, because the cost is only half that of a large-diameter well to the same depth. Core drilling provides an excellent set of rock samples and fine temperature-gradient information, but it is still necessary to droll a more expensive. Large-diameter well for reservoir testing and evaluation. To take full advantage of the lower cost of core drilling, it will be necessary to develop the methodology and equipment to conduct reservoir testing and evaluation during core drilling.

The demand for electric power has finally caught up with the supply in the western United States, and state regulatory agencies are reinterpreting PURPA to require independent power producers to bid competitively on a cost-only basis. Experts estimate that demand for new capacity will grow again during the next decade, but the current low prices for natural gas make it difficult for geothermal power to compete with gas-fired generation on a cost-only basis.

State regulatory actions under consideration may enhance the competitive position of geothermal IPP projects. Several states are considering requiring weighted cost factors for generation bids, based on environmental and fuel diversity considerations. Other states are expected to follow this trend. California has adopted a renewable "set-aside" of 286 MW, as a temporary measure while the state promulgates rules for the weighted cost factors. Approximately 60% of the new generating capacity added from 1980 through 1990 was at The Geysers (Rannels and McLarty 1990). With further development there unlikely, significant growth in geothermal generating capacity during the next decade will rely on the discovery and production of several new water-dominated geo-thermal fields.

In the absence of significant changes in demand, incentives, or the regulatory process, new geothermal generating capacity during the next 5 years will probably not exceed 500 MW. Growth in the longer term is difficult to predict, but with large estimates of untapped resources (Muffler 1979) and an excellent reputation for rapid and cost-effective development, the geothermal industry has the potential for significant growth.

ACKNOWLEDGEMENTS

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FOOTNOTES

1. Calculated estimate based on 2400 MW, 85% capacity and 6 cents/kWh.

2. Calculated estimate based on 2400 MW, 85% capacity, and 540 kWh/bbl.

3. Calculated estimate based on 2200 MW, 85% capacity, and 1990 total state consumption of 210 billion kWh (2% annual growth factor was applied to California Energy Commission 88 Electricity Report data for 1985 consumption to estimate 1990 consumption).

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Table 1. Location of geothermal power plants in the U.S. (back to Table 1 callout)

Steam Supplier	Plant Name	Start Date	Generating Capacity Gross (MW)	Generating Capacity Net (MW)	Turbine Type	Notes
The Geysers Geothermal Field (Dry-Steam), California, 38°48'N Lat. 122°48'W Long. (Center of field)						
Unocal Geothermal Division and partners	PG&E Unit 1	Sept. 1960	12.5	11	Steam	Retired
	PG&E Unit 2	March 1963	14.1	13	Steam	Retired
	PG&E Unit 3	April 1967	28.8	27	Steam	Retired
	PG&E Unit 4	Nov. 1968	28.8	27	Steam	Retired
	PG&E Unit 5	Dec. 1971	55	53	Steam	
	PG&E Unit 6	Dec. 1971	55	53	Steam	
	PG&E Unit 7	Aug. 1972	55	53	Steam	
	PG&E Unit 8	Nov. 1972	55	53	Steam	
	PG&E Unit 9	Oct. 1973	55	53	Steam	
	PG&E Unit 10	Nov. 1973	55	53	Steam	
	PG&E Unit 11	May 1975	110	106	Steam	
	PG&E Unit 12	March 1979	110	106	Steam	
	PG&E Unit 14	Sept. 1980	114	109	Steam	
	PG&E Unit 17	Dec. 1982	119	113	Steam	
	PG&E Unit 18	Feb. 1983	119	113	Steam	
	PG&E Unit 20	Oct. 1985	119	113	Steam	
Calpine Corporation	PG&E Unit 13	May 1980	138	133	Steam	
	PG&E Unit 16	Oct. 1985	78	72	Steam	
	SMUD GEO #1	Dec. 1983	78	72	Steam	
	Bear Canyon	Oct. 1988	24.4	22	Steam	SO-4
	West Ford Flat	Dec. 1988	30.5	28.7	Steam	SO-4
Coldwater Creek Operating Company	CCPA Unit 1	June 1988	66	62	Steam	
	CCPA Unit 2	July 1988	66	62	Steam	
Mission Energy	Aidlin Plant	May 1989	23.4	20	Steam	SO-4
Santa Fe Geothermal	Sante Fe Unit 1	April 1984	97	95	Steam	SO-4
Northern California Power Association	NCPA Unit 2	Jan. 1983	115	110	Steam	
	NCPA Unit 3	Oct. 1985	115	110	Steam	
R. C. Dick	PG&E Unit 15	June 1979	64	59	Steam	Deactivated
California Department of Water Resources	Bottle rock Plant	Oct. 1984	59	55	Steam	Deactivated
Salton Sea Geothermal Field (Water-Dominated), California, 33°11'N Lat. 115°37'W Long.						
Unocal Geothermal	Salton Sea Unit 1	June 1982	12	10	Single Flash	
	Salton Sea Unit 2	March 1990	19	17.7	Multi Flash	SO-4
	Salton Sea Unit 3	Feb. 1989	53.9	50.8	Dual Flash	SO-4
Magma Power Company	Vulcan Plant	Dec. 1985	39.7	32.4	2 Single Flash	
	Del Ranch Plant	Dec. 1988	38.2	32.4	2 Single Flash	SO-4
	J. J. Elmore Plant	Dec. 1988	38.2	35.8	Dual Flash	SO-4
	Leathers Plant	Dec. 1989	38.2	35.8	Dual Flash	SO-4
Heber Geothermal Field (Water-Dominated), California, 32°43'N Lat. 115°32'W Long.						
Chevron Resources	Heber Flash Plant	Aug. 1985	52	47	Dual Flash	SO-4
East Mesa Geothermal Field (Water-Dominated), California, 32°47'N Lat. 115°15'W Long.						
East Mesa Operator Corporation[a]	B. C. McCabe	Nov. 1979	13.4	12.5	Binary, isobutane	
	East Mesa Unit 1	May 1989	21.7	18.5	Dual Flash	SO-4
	East Mesa Unit 1	June 1989	21.7	18.5	Dual Flash	SO-4
Ormat Energy Systems[a]	Ormesa 1	Dec.1986	29.7	24	30 Binary units	SO-4
	Ormesa 2	June 1987	24	18.5	20 Binary units	SO-4
	Ormesa 1E	Dec. 1988	12.8	8	10 Binary units	SO-4
	Ormesa 1H	Dec. 1989	8.5	6	12 Binary units	SO-4
Coso Hot Springs Geothermal Field (Water-Dominated), California, 36°02'N Lat. 117°48'W Long.						
California Energy Company	Navy 1, Unit 1	July 1987	30	27.5	Double Flash	SO-4
	Navy 1, Unit 2	Nov. 1988	30	27.5	Double Flash	SO-4
	Navy 1, Unit 3	Nov. 1988	30	27.5	Double Flash	SO-4
	Navy 2, Unit 4	Nov. 1989	30	27.5	Double Flash	SO-4
	Navy 2, Unit 5	Dec. 1989	30	27.5	Double Flash	SO-4
	Navy 2, Unit 6	Dec. 1989	30	27.5	Double Flash	SO-4
	BLM East, Unit 7	Dec. 1988	30	27.5	Double Flash	SO-4
	BLM East, Unit 8	Dec. 1988	30	27.5	Double Flash	SO-4

	BLM East, Unit 9	Aug. 1989	30	27.5	Double Flash	SO-4
Casa Diablo Geothermal Field (Water-Dominated), California, 37°39'N Lat. 118°55'W Long.						
Pacific Enterprises[a]	MP #1 Plant	Feb. 1985	12 (max)[b]	10 (max)	2 Binary units	
	MP #2 Plant	Dec. 1990	15 (max)[b]	12 (max)	3 Binary units	SO-4
	PLES #1 Plant	Dec. 1990	15 (max)[b]	12 (max)	3 Binary units	SO-4
Amedee Hot Springs Geothermal Field (Water-Dominated), California, 40°18'N Lat. 120°12'W Long.						
Trans-Pacific Geothermal Corp.[a]	Amedee #1	Nov. 1988	3.2	2	2 Binary units	
Wendel Hot Springs Geothermal Field (Water-Dominated), California, 40°21'N Lat. 120°15'W Long.						
Barber-Nichols Co.[a]	Wineagle	Sept. 1985	0.8	0.7	Binary Unit	
Dixie Valley Geothermal Field (Water-Dominated), Nevada, 39°38'N Lat. 118°06'W Long.						
Oxbow Geothermal Corporation	Dixie Valley	Feb. 1988	62	57	Dual Flash	SO-4
Steamboat Hot Springs Geothermal Field (Water-Dominated), Nevada, 39°23'N Lat. 119°45'W Long.						
Caithness Corporation[a]	Caithness Plant	Feb. 1988	13.2	12.5	Single flash	
Far West Electric Energy Fund, Ltd.[a]	Far West Plant	Oct. 1986	9.4	6.8	9 Binary, pentant	
Beowawe Hot Springs Geothermal Field (Water-Dominated), Nevada, 40°34'N Lat. 116°35'W Long.						
California Energy Company	Oxbow Beowawe	Dec. 1985	17	16.7	Dual flash	SO-4
Desert Peak Geothermal Field (Water-Dominated), Nevada, 39°45'N Lat. 118°57'W Long.						
California Energy Company	Oxbow Beowawe	Dec. 1985	10	9	Dual flash	
Wabuska Hot Springs Geothermal Field (Water-Dominated), Nevada, 39°09'N Lat. 119°11'W Long.						
Tad's Enterprises[a]	Wabuska	Sept. 1984	2.5	1.7	2 Binary units	
Soda Lake Geothermal Field (Water-Dominated), Nevada, 39°34'N Lat. 118°51'W Long.						
Ormat Energy Systems[a]	Soda Lake 1	Dec. 1987	3.6	2.7	3 Binary units	
	Soda Lake 2	Sept. 1990	18	13	7 Binary units	
Stillwater Geothermal Field (Water-Dominated), Nevada, 39°31'N Lat. 118°33'W Long.						
Ormat Energy Systems[a]	Stillwater Plant	April 1989	17	12.5	14 Binary units	
San Emidio Geothermal Field (Water-Dominated), Nevada, 40°24'N Lat. 119°25'W Long.						
Ormat Energy Systems[a]	Empire Project	Dec. 1987	4.8	3.2	4 Binary units	
Roosevelt Hot Springs Geothermal Field (Water-Dominated), Utah, 38°30'N Lat. 112°51'W Long.						
California Energy Company[a]	Blundell Plant	July 1984	23.5	20	Single Flash	
Cove Fort - Sulphurdale Geothermal Field (Water-Dominated), Utah, 38°36'N Lat. 112°33'W Long.						
Mother Earth Industries[a]	Sulphurdale Unit 1	Oct. 1985	2.6	1.8	4 Binary Units	
	Sulphurdale Unit 2	Sept. 1988	2	1.8	Single flash atm. exhaust	
	Bud Bonnett Plant	Oct. 1991	10	8.5	Single flash	

[a] Supplies both brine and steam.
[b] max, Maximum.

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