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GEOTHERMAL POWER GENERATION IN THE UNITED STATES

1985 THROUGH 1989

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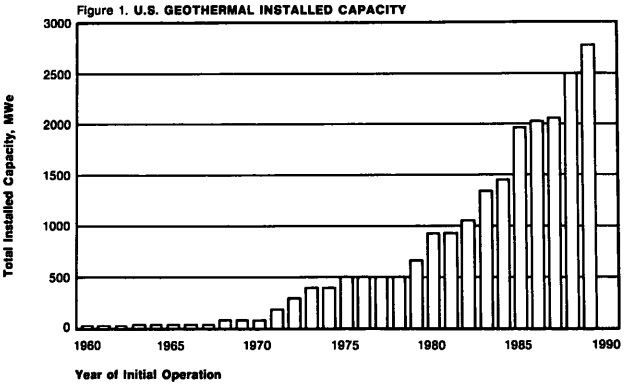
ABSTRACT

The United States has used geothermal energy for the production of electricity since 1960 and has the largest installed capacity of any country in the world. During the 1980s, expansion at The Geysers and emergence of the "hot water" segment of the industry fueled explosive growth in generating capacity. Geothermal development in the U.S. during the second half of the decade is reviewed, and development over the next five years is forecast.

INTRODUCTION

Geothermal energy continues to play a small but important role in the electric generation fuel mix of the United States (see Table 1). Over the last five years the U.S. geothermal industry has experienced rapid growth in generating capacity as well as a continued shift from utility development of steam resources to independent development of liquid dominated resources. Figure 1 compares the annual capacity growth rates for 1960 through 1989.

Figure 1. U.S. GEOTHERMAL INSTALLED CAPACITY



CURRENT GENERATION CAPACITY

TOTAL FOR UNITED STATES

In 1985 through 1989 inclusive, the construction of 38 new geothermal power plants in the United States has resulted in a 91% increase (1,326 MW_e) in the installed capacity, from 1.45 GW_e to 2.77 GW_e in 64 plants. The principal driving forces behind this rapid growth have been continued demand for additional capacity, a favorable regulatory climate, technological advances and a good understanding of various sites from previous exploration. Table 2 lists current U.S. geothermal plants as well as those expected on line in the near future.

In the U.S. the primary cycle type has been dry steam, but during the second half of the 1980s an increasing portion of new development has occurred in liquid dominated resources where single flash, double flash and binary cycles have been utilized. Prior to 1985 less than 4% of the installed capacity was at liquid dominated sites (Table 3). Approximately 45% of the new development utilized the flash cycle and 12% the binary cycle. This brings the total hot water capacity to 806 MW_e, or 29% of the total installed capacity. Since the majority of the hydrothermal geothermal resource base in the United States is liquid dominated this trend is expected to continue.

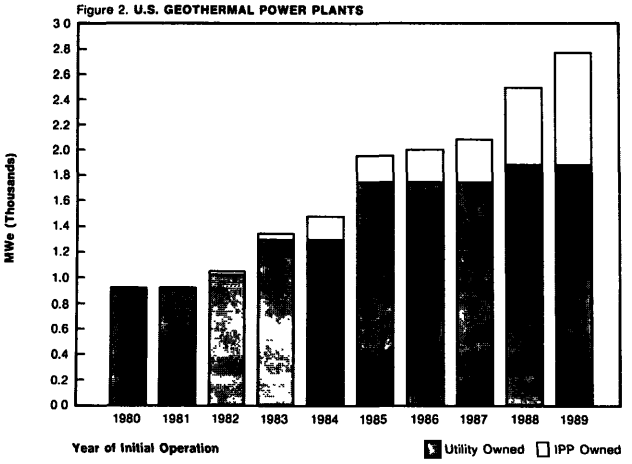
UTILITIES

As owners of approximately 68% of the net geothermal capacity, utilities continue to be the dominant operators of geothermal power plants. Their direct involvement continues to be focused at The Geysers with Pacific Gas & Electric Company (PG&E) having the largest operation. During the five year period, eight of the 38 new plants (557 MW_e) were built by utilities. Utilities also purchase and distribute geothermal power generated by independent power producers (IPP), and some utilities have formed subsidiaries that are pursuing geothermal development projects in partnerships with IPPs.

INDEPENDENT POWER PRODUCERS

Most of the increase in capacity was in plants owned and operated by independent power producers. A total of 769 MW_e was installed by independents. This segment of the industry was stimulated by the enactment of the Public Utilities Regulatory Policy Act of 1978 (PURPA). The act allowed some independent (non-utility) entities to produce power without being regulated

as a utility, and required utilities to purchase power from them or wheel their power to another utility for purchase. As a result, an opportunity was created for entrepreneurs to enter the geothermal power generation industry. Figure 2 shows how the IPPs have increased their share of total capacity over the past 5 years.



CALIFORNIA/STEAM PLANTS

Eight new geothermal steam plants totaling 574 MW_e were built in The Geysers dry steam field bringing the total installed capacity there from 1,397 MW_e to 1,971 MW_e (see Table 4). This 41% growth in generating capacity has placed increasing demands upon the reservoir. During this period operators have experienced a reduction in steam pressure and flow. A steam shortage equivalent to approximately 400 MW_e has been reported there. Industry, in cooperation with the Department of Energy, is considering possible solutions to the various problems at The Geysers.

CALIFORNIA/HOT WATER PLANTS

Geothermal development in California, outside The Geysers, has been quite active. Eighteen new hot water plants with a total capacity of 636 MW_e were completed during this period, bringing the total installed hot water capacity from 30 MW_e to 666 MW_e (see Table 4). Although most of the activity was in the Salton Sea, Heber and East Mesa areas, recent efforts at Coso Hot Springs have resulted in significant increases there. Unlike The Geysers, these resources are liquid dominated, and flash steam and binary technologies are employed. In addition, a new 30 MW_e hybrid (wood waste and geothermal) plant at Honey Lake attributes 20% of its net capacity to geothermal.

HAWAII

Efforts to develop the promising resource on Hawaii slowed after the first experimental plant began producing power there in 1980. Recently, however, efforts to develop the resource have picked up, and a new 25 MW_e plant is expected to be constructed in the near future. The state of Hawaii is continuing with its feasibility study of transmitting power from a potential 500 MW_e development project on the island of Hawaii via undersea cable to the islands of Maui and Oahu.

NEVADA

Four new flash and five new binary geothermal power plants have begun operation in Nevada in the past 5 years. Altogether, 111 MW_e of new capacity have been brought on line during this period, bringing the total installed capacity from 2 MW_e to 113 MW_e (see Table 4). A 13.5 MW_e expansion of the Soda Lake plant is imminent, and an additional 7 MW_e is planned for the Caithness plant during 1990.

UTAH

Over the past 5 years, investigations of several prospects in Utah resulted in the construction of two new power plants with a total capacity of 5 MW_e, bringing the total installed capacity to 25 MW_e. A 7.5 MW_e expansion is underway at the Cove Fort steam plant. Other promising sites have been identified and will probably be developed when the economic environment is favorable.

POTENTIAL SITES FOR FUTURE DEVELOPMENT

Over 200 geothermal resource locations with either proven ability or recognized potential for electric power generation have been identified in United States Geological Survey Circular 790 (Muffler, 1979). Although 13 states are included in the listing, over 50% of the sites are in just four states - California, Idaho, Nevada and Oregon. Seventeen locations in 4 states currently have some installed capacity.

A 1985 Bonneville Power Administration (BPA) study by Bloomquist, et al., screened over 1,200 sites in Idaho, Montana, Oregon and Washington. Of these sites, 64 were judged capable of supporting one megawatt or more of electric power generation for 30 years. The study speculated that Oregon and Idaho each may have tremendous capacity potential. It was estimated that sites in Washington and Montana are capable of supporting only small amounts of capacity.

A 1989 Northwest Power Planning Council study (Geyer, et al., 1989) estimated lower potential capacity for the Pacific Northwest (but higher for Washington) than the 1985 BPA study had estimated. A total potential capacity of approximately 5,000 MW_e in Oregon, Idaho and Washington was estimated in the more recent study. Considerable exploration, assessment and confirmation remains to be done in this area of the U.S. before its true potential can be judged.

Information on rock type and fluid chemistry for most of these sites is not available. Geothermal resources are generally associated with young volcanics, but reservoirs are often encountered in sedimentary zones due to convection of thermal waters. Concentrations of dissolved solids in geothermal fluids encountered in the U.S. range from several hundred parts per million at some sites up to 300,000 parts per million at the Salton Sea area.

GEOTHERMAL DRILLING

Geothermal drilling associated with electric power generation for the years 1985 through 1989 is depicted in Table 5. Of the 592 wells drilled in the U.S., 472 (or 80%) were located in California. At The Geysers, 203 wells (or 43% of the state total) were drilled during this period. Sharp declines in drilling activity at The Geysers occurred in 1988 and 1989. Coso and East Mesa each experienced increased drilling activity during the middle part of the five year period but experienced a slowdown in 1989 as project expansions neared completion.

Nevada, with 75 wells, was the only other state with a significant amount of drilling activity during the period. Activity peaked in 1986 and has declined since.

Drilling activity in Utah picked up considerably in 1989 with five exploration wells and three production wells, all in the Cove Fort area.

After very little activity in Oregon during 1987 and 1988, five exploration wells were drilled in 1989. Current exploration interests of several companies are focused on the Cascade Mountains in Oregon, and drilling activity there is expected to increase somewhat.

In Hawaii, almost no new drilling activity has taken place over the last five years. Kapoho State 1A, drilled in 1985, was the last well drilled there, until an exploratory well was begun in November of 1989. Imminent development of a planned 25 MW_e plant on the island of Hawaii, if permitted, may spur drilling activity over the next year or two.

PROFESSIONAL PERSONNEL

An estimate of the number of professional personnel involved in geothermal activities in the U.S. is provided by domestic membership of the Geothermal Resources Council (GRC), with 1,031 members as of 1990. Table 6 provides both domestic and foreign GRC membership data for the years 1985 through 1990. Following a substantial increase of 30% in 1986, domestic membership suffered declines for three successive years, but rebounded sharply in 1990. Foreign membership in GRC doubled in 1986, and since then has equalled between 13% and 15% of domestic membership. The large increase in membership, both domestic and foreign, in 1986 is probably due in large part to the success of the 1985 GRC international symposium in Hawaii. It is estimated that trends in the GRC membership are indicative of trends in professional personnel. However, it is also estimated that GRC membership represents only a fraction of the total geothermal professionals.

OUTLOOK

The high growth rate of geothermal capacity experienced in the 1980s is not expected to be sustained throughout the 1990s. Decreased growth in demand, low prices for natural gas, and an evolving regulatory climate will likely impact the potential for new development.

State regulatory agencies are reinterpreting the Public Utility Regulatory Policy Act (PURPA) to require independent power producers to bid competitively for supplying new capacity on a cost-only basis. Previously utilities had been required by the Federal Energy Regulatory Commission (FERC) under PURPA mandate to pay for new capacity at the full avoided cost to the utility regardless of the cost of the IPP. The full avoided cost is the cost of electricity from new (unconstructed) utility plants which the utility would have to build if new additional capacity were not made available by IPPs. Investor-owned utilities in California have proposed a multi-attribute bidding system for new capacity. The system is designed to compare alternative power projects based on their benefit to ratepayers. Several characteristics of the bidding system will favor alternative projects over geothermal projects.

The recent decision by the Federal Energy Regulatory Commission to allow an independent power producer to build a large gas-fired central plant in Virginia is another shift in the regulatory climate which may impact future geothermal development. Initial capital expenses ($ per KW_e) for gas-fired plants are less than for geothermal plants. If natural gas prices remain low, gas-fired generation may be less expensive (cents per KWh) than geothermal generation, and geothermal plants may be squeezed out by gas-fired plants in cost-only based bidding systems for new capacity.

There has been some speculation that in the future regulatory agencies may require that social and environmental costs be included in the cost of power. Geothermal development could be expected to become more competitive under such a pricing scheme. However, such an occurrence is not imminent and remains highly speculative.

Of the new generating capacity added during the 1980s, approximately 61% was at The Geysers. During 1985 through 1989 The Geysers accounted for approximately 44% of all new generation capacity. Because of recent concerns with reservoir productivity, its previous growth rate of new capacity is not expected to be sustained over the next five years. This factor combined with the changing regulatory climate and lack of

demand for power will probably curtail growth over the next five years.

Projects currently under construction or in advanced stages of planning/financing account for 101 MW_e of new capacity, which should be on line by the end of 1990. The state of Hawaii expects the first 50 MW_e of their planned 500 MW_e development to come on line in 1995. Some additional small increments of capacity may be added in the Salton Sea area, Coso, East Mesa, Long Valley, Nevada and Utah by 1995. Exploration activity has increased in Oregon, but any significant development there is not expected to occur before 1995.

In the absence of any significant changes in demand and/or the regulatory climate, new geothermal generating capacity added by the end of 1994 will probably be in the range of 350 MW_e to 500 MW_e, with a most probable estimate of 400 MW_e, bringing the total projected U.S. capacity to 3,170 MW_e. This low growth scenario challenges U.S. firms to export U.S. geothermal technology to facilitate development in other countries, and the industry is currently undertaking an organized, concerted effort to do so.

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TABLE 1 - PRESENT AND PLANNED PRODUCTION OF ELECTRICITY[1]

	Geothermal[2]		Fossil Fuels		Hydroelectric		Nuclear	
	Capacity GW_e	Utilization TWh/yr	Capacity GW_e	Utilization TWh/yr	Capacity GW_e	Utilization TWh/yr	Capacity GW_e	Utilization TWh/yr
Operating at beginning of 1985	1.5[3]	8	485	1,794	89	281	79	384
Operating at beginning of 1990	2.8	15	492	1,974	91	264	97	529
Total projected use by 1995	3.2[4]	20	504	2,285	94	305	103	558

[1] Source: Capacity: Energy Information Administration, Annual Energy Outlook 1990, p.46. Generation and Hydroelectric and Geothermal Capacity in 1989: EIA, Office of Coal, Nuclear, Electric and Alternate Fuels, Data Systems Branch. Generation and Hydroelectric and Geothermal Capacity in 1995: EIA, CNEAF, Data Analysis and Forecasting Branch. Hydro includes both conventional and pumped storage.

[2] Includes estimates of both utility power plants and independent power plants owned by others.

[3] Source: Meridian Corporation

[4] The installed geothermal capacity in the U.S. is estimated to grow by 350 - 550 MW_e over the next five years. For the purposes of this table a value of 400 MW_e was selected. Because of the increasing portion of IPPs the assumed capacity utilization was increased.

TABLE 2 - (Continued)

Locality	Power Plant Name	Year	No. of units	Status[2]	Type of unit	Plant Rating (MWe)
EAST MESA	GEM 1 (MCCABE)	1980	1	O	Binary	13
	GEM 2 & 3	1989	2	O	D Flash	34
	ORMESA I	1986	26	O	Binary	24
	ORMESA II	1988	20	O	Binary	17
	ORMESA IE	1988	10	O	Binary	8
	ORMESA IH	1989	12	O	Binary	6
SUBTOTAL						102
HEBER	HEBER BINARY PROJECT	1985	1	N	Binary	45
	HEBER DUAL FLASH PROJ.	1985	1	O	D Flash	47
SUBTOTAL						92
COSO HOT SPRINGS	NAVY PLANT #1, UNIT 1	1987	1	O	D Flash	30
	NAVY PLANT #1, UNITS 2&3	1988	2	O	D Flash	50
	BLM EAST, UNITS 1 & 2	1988	2	O	D FLash	48
	BLM WEST	1989	1	O	D Flash	28
	NAVY PLANT #2,UNIT 4,5,6	1989	3	O	D Flash	80
	LADWP - COSO	1994	1	P	D FLash	20
SUBTOTAL						256
MONO-LONG VALLEY	MAMMOTH PACIFIC I	1984	2	O	Binary	7
	MAMMOTH PACIFIC II	1990	1	P	Binary	12
	MAMMOTH PACIFIC III	1994	1	P	Binary	12
	PLES UNIT 1	1990	1	P	Binary	12
	MAMMOTH-CHANCE B	1992	1	P	Binary	10
SUBTOTAL						53

TABLE 2 - UTILIZATION OF GEOTHERMAL ENERGY FOR ELECTRICAL GENERATION IN DECEMBER 1989[1]

Locality	Power Plant Name	Year	No. of units	Status[2]	Type of unit	Plant Rating (MWe)
CALIFORNIA						
GEYSERS	JOSEPH W AIDLIN	1989	2	O	D Steam	20
	BEAR CANYON CREEK	1988	2	O	D Steam	20
	BOTTLE ROCK	1985	1	O	D Steam	55
	COLD WATER CREEK	1988	2	O	D Steam	120
	NCPA #1	1983	1	O	D Steam	106
	NCPA #2	1985	1	O	D Steam	106
	OXY GEOTHERMAL 1	1984	2	O	D Steam	80
	PG&E #1	1960	1	O	D Steam	11
	PG&E #2	1963	1	O	D Steam	13
	PG&E #3	1968	1	O	D Steam	27
	PG&E #4	1968	1	O	D Steam	27
	PG&E #5	1971	1	O	D Steam	53
	PG&E #6	1971	1	O	D Steam	53
	PG&E #7	1972	1	O	D Steam	53
	PG&E #8	1972	1	O	D Steam	53
	PG&E #9	1973	1	O	D Steam	53
	PG&E #10	1973	1	O	D Steam	53
	PG&E #11	1975	1	O	D Steam	106
	PG&E #12	1979	1	O	D Steam	106
	PG&E #13	1980	1	O	D Steam	134
	PG&E #14	1980	1	O	D Steam	114
	PG&E #15	1979	1	N	D Steam	57
	PG&E #16	1985	1	O	D Steam	113
	PG&E #17	1982	1	O	D Steam	113
	PG&E #18	1983	1	O	D Steam	113
	PG&E #20	1985	1	O	D Steam	113
	SMUDGEO #1	1983	1	O	D Steam	72
	WEST FORD FLAT	1988	2	O	D Steam	27
SUBTOTAL						1,971

TABLE 2 - (Continued)

Locality	Power Plant Name	Year	No. of units	Status[2]	Type of unit	Plant Rating (MWe)
SALTON SEA	DEL RANCH	1988	1	O	D Flash	34
	ELMORE 1	1988	1	O	D Flash	34
	LEATHERS 1	1989	1	O	D Flash	34
	SALTON SEA UNIT 1	1982	1	O	S Flash	10
	SALTON SEA UNIT 2	1990	1	P	D Flash	18
	SALTON SEA UNIT 3	1989	1	O	D Flash	50
	VULCAN	1986	1	O	D Flash	34
SUBTOTAL						214
WENDEL-AMEDEE	HONEY LAKE	1988	1	O	Binary	30
	AMEDEE GEOTHERMAL	1987	2	O	Binary	2
	WINEAGLE PROJECT	1985	2	O	Binary	1
SUBTOTAL						33
NEVADA						
BEOWAWE	BEOWAWE	1985	1	O	D Flash	15
BRADY-HAZEN	DESERT PEAK	1985	1	O	D Flash	9
DIXIE VALLEY	OXBOW	1988	1	O	D FLash	50
SAN EMIDIO DESERT	EMPIRE GEO PROJECT	1987	4	O	Binary	3
STILL WTR/SODA LK	SODA LAKE GEO PROJECT	1988	3	O	Binary	3
	SODA LAKE II	1990	14	P	Binary	13
	STILLWATER GEO PROJECT	1989	14	O	Binary	13
STEAMBOAT SPGS	STEAMBOAT GEO I	1986	9	O	Binary	6
	STEAMBOAT GEO IA	1988	1	O	Binary	1
	CAITHNESS/SEQUA VENTURE	1988	1	O	S Flash	11
	CAITHNESS II	1990	1	P	S Flash	7
WABUSKA	WABUSKA	1984	2	O	Binary	2
SUBTOTAL						133

TABLE 2 - (Continued)

Locality	Power Plant Name	Year	No. of units	Status[2]	Type of unit	Plant Rating (MWe)
UTAH						
COVE FT-SULPHURDALE	COVE FORT GEO #1	1985	4	O	Binary	3
	COVE FORT STEAM PLANT	1988	1	O	S Flash	2
	COVE FORT STEAM #2	1990	1	P	S Flash	8
ROOSEVELT HOT SPG	BUNDELL I	1984	5	O	S Flash	20
SUBTOTAL						33
HAWAII						
PUNA	HGP-A	1981	1	O	S Flash	2
	PUNA GEOTHERMAL VENTURE	1990		P	D Flash	25
	PUNA UNIT	1995		P		50
SUBTOTAL						77
GRAND TOTAL						2,964

[1] Source: Geothermal Progress Monitor - Report No. 11, December 1989, Meridian Corporation

[2] Status = O Operational
N Not Operating
P Planned

TABLE 3 - GEOTHERMAL CAPACITY BY CYCLE TYPE

	Installed Capacity, MW_e		
Cycle Type	12/31/84	Increment	Total 12/31/89
Dry Steam	1,397	574	1,971
Double Flash	0	577	577
Single Flash	32	13	45
Binary	22	162	184
TOTAL	1,451	1,326	2,777

TABLE 4 - GEOTHERMAL CAPACITY BY STATE

	Installed Capacity, MW_e		
State	12/31/84	Increment	Total 12/31/89
California			
Dry Steam	1,397	574	1,971
Hot-Water	30	636	666
Nevada	2	111	113
Utah	20	5	25
Hawaii	2	0	2
TOTAL	1,451	1,326	2,777

TABLE 5 - GEOTHERMAL DRILLING ACTIVITY FOR POWER GENERATION
JANUARY 1, 1985 TO JANUARY 1, 1990

Location	Year	Observation	Exploration	Production	Injection	Total
California						
The Geysers	85	3	0	47	4	54
	86	1	1	45	0	47
	87	4	0	45	3	52
	88	9	0	22	0	31
	89	4	0	15	0	19
Coso	85	0	3	0	0	3
	86	1	0	2	1	4
	87	2	0	9	2	13
	88	13	0	28	6	47
	89	5	0	17	4	26
East Mesa	85	0	0	2	0	2
	86	0	0	2	1	3
	87	0	0	8	3	11
	88	5	0	17	6	28
	89	0	0	6	10	16
Salton Sea	85	2	0	6	4	12
	86	10	0	3	0	13
	87	8	0	70	0	15
	88	1	0	12	13	26
	89	2	0	5	4	11
Other	85	21	0	0	1	22
	86	2	0	3	2	7
	87	0	2	3	2	7
	88	0	1	0	0	1
	89	0	2	0	0	2
Nevada	85	8	5	2	2	17
	86	18	2	7	3	30
	87	4	1	6	3	14
	88	2	3	8	2	15
	89	0	0	4	5	9
Utah	85	0	3	0	0	3
	86	0	1	1	0	2
	87	0	2	0	0	2
	88	0	2	0	0	2
	89	0	5	3	0	8

Table 5 - (Continued)

Location	Year	Obser-vation	Explor-ation	Produc-tion	Injec-tion	Total
Oregon	85	0	1	0	0	1
	86	0	8	0	0	8
	87	0	2	0	0	2
	88	0	0	0	0	0
	89	0	5	0	0	5
Hawaii	85	0	1	0	0	1
	86	0	0	0	0	0
	87	0	0	0	0	0
	88	0	0	0	0	0
	89	0	1	0	0	1

Table 6 - GEOTHERMAL RESOURCES COUNCIL MEMBERSHIP

Year	Domestic Members	% Change Domestic	Foreign Members	Foreign % of Domestic
1985	837		75	9.0
1986	1089	30.1	159	14.6
1987	1032	-5.2	155	15.0
1988	940	-8.9	136	14.5
1989	830	-11.7	110	13.3
1990	1031	24.2	147	14.3