GL00487

ESL-87006-TR

STATUS OF THE U.S. GEOTHERMAL INDUSTRY

and

RECOMMENDATIONS FOR HYDROTHERMAL RESEARCH

by

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SUMMARY AND INTRODUCTION

Hydrothermal resources, one of the several types of geothermal resources, are being actively developed on a worldwide basis. Current hydrothermal electrical generating capacity is about 4,800 megawatts, with the United States accounting for 2,115 megawatts of the total. Current direct uses of hydrothermal energy amount to about 10,000 megawatts, with the U.S. contributing about 400 megawatts. Hydrothermal resources worldwide produce enough energy to displace the use of about 80 million barrels of petroleum annually.

Geothermal development in the United States is presently depressed due to the comparatively low energy costs of today and the excess electrical generating capacity that exists in the West. Growth in geothermal generating capacity in the U.S. is forecast at a rate between 6 and 9 percent per year from the present to the year 2005, with essentially all of this development being in the hydrothermal convective resource type. Contrary to its own policy, the Federal government is not adequately supporting the research and technology development needed to bring the bulk of the known hydrothermal resource base on line. We have a duty to help educate the public and our elected federal officials and others in the Administration to the facts of our energy-based economy and to the importance in using this grace period in energy costs to prepare ourselves as a nation for times of sharply higher energy costs.

STATUS OF U.S. GEOTHERMAL INDUSTRY

The current status of the U.S. geothermal industry has recently been reviewed by Lacy (1986), who confined his remarks to the generation of electricity from hydrothermal resources. It is worthwhile to abstract from his paper to form a clearer understanding of today's situation.

In the early- to mid-1970's, many utilities in the western U.S. were heavily dependent on petroleum for the production of electrical energy. The only diversification from petroleum being seriously considered was rather large nuclear or coal plants. Technology for the generation of electricity from geothermal resources had been demonstrated at only one location, The Geysers in California, a dry-steam resource. There was considerable doubt that this limited experience could be extrapolated to the much more plentiful hot water resource base.

The oil crisis caused energy prices to soar and inflation rates to increase dramatically. Within a matter of months, the utility industry fell into complete disarray. The utilities' response was to explore alternatives to nuclear, coal and oil, a response supported by the regulatory commissions. Among the western states, geothermal energy was an option that many of the utilities found interesting, and this provided impetus for increased exploration and research. The geothermal industry, however, was not able to offer a truly viable generation option using hot water resources. Technology to explore for and assess these resources was not adequate and costs were therefore high. In addition, the long-term performance of the reservoir could not be predicted with confidence and there were no adequate ways to deal with the produced brines from the environmental, scaling or corrosion perspectives. Many of these problems remain to be solved today, although progress has been made in some areas.

During the past five years, important energy conservation measures have been implemented and, in addition, the economy has seen only sluggish growth. These two factors have brought about reduced electrical demand at a time when energy costs are lower. The geothermal industry has, as a result, been going through a period of depression and upheaval. Utilities are dropping, scaling down or deferring plans for new generating capacity while geothermal generation costs have difficulty competing with other generation costs. The industry has been in a mode of retrenchment, and some of the marginal members have dropped out.

Lacy (1986) expects further shakeout of participants in the geothermal industry during the next five years. He believes that the result will be a leaner and stronger group. There will be some geothermal development in this time span, especially at The Geysers. A few larger plants and several wellhead plants can be expected to come on line in other areas. Lacy(1986) also believes that the geothermal industry "has an unprecedented opportunity during the rest of this decade to position itself for a market place that will be wide open in the 1990s". In order to be able to compete effectively in the long term, he believes that the industry will have to: 1) develop more hard cost data so that the utilities can adequately evaluate economics and risk; 2) perform research and technology development to increase materially our ability to define the resource, predict reservoir performance and to decrease the drilling, operating and capital costs; 3) solve some permitting and environmental issues; 4) take steps to ensure adequate water for cooling; and, 5) solve the problem of access to transmission lines.

WORLDWIDE GEOTHERMAL USE

Current Electrical Power Generation

DiPippo (1985) compiled data on the worldwide use of geothermal energy for generation of electric power. His results are summarized in Table 1. All of the producing geothermal systems are of the hydrothermal convection type. Electricity is being generated from geothermal energy in the United States, the Philippines, Mexico, Italy, Japan, New Zealand, El Salvador, Kenya, Iceland, Nicaragua, Indonesia, Turkey, China, the Soviet Union, and on the islands of Guadeloupe, Azores, and Milos, in decreasing order of production capacity. Although the U.S. is out in front at the present time, the Philippines and Indonesia have tremendous power potential which they are working hard to develop. In these and other third-world countries, geothermal exploitation frees petroleum for sale and enables them to obtain much needed foreign exchange. These two countries in particular have rapidly become experts in installing geothermal systems by allowing U.S. companies to participate in development on their soil. The Soviets have also begun to pay attention to their geothermal resources, believed by some to be the largest in the world, especially because the disaster at Chernobyl has apparently produced disenchantment with their large system of nuclear plants. Africa and South and Central America have large, high-temperature resources, but development is very slow due to depressed economies and sometimes hostile governments with many problems. The traditional producers of geothermal energy, Italy, Iceland and New Zealand, are proceeding relatively slowly with new development also. This is mostly a function of planning for their energy needs. Mexico badly needs the power that their geothermal resources could yield, especially in the Mexican volcanic belt close to Mexico City, but they lack the capital for development and have suffered setbacks in their plant at Cerro Prieto in the Mexicali valley. Canada has some potential for geothermal development, but will probably not exercise those options to any great extent until their hydropower resources are more fully exploited.

Current Direct Uses

Direct uses have been made of geothermal energy for many years, mostly for balneology. Gudmundsson (1985) gives the most recent report on worldwide use and Lienau (1986) reports on use in the western U.S. Gudmundsson's (1985) data are summarized in Table 2. At the end of 1984, the installed thermal power of all direct use projects in the world was about 7072 megawatts thermal

(MWt) if only useful thermal power above 35 deg C is considered. Direct-use projects differ greatly from electric power plants when it comes to assigning a capacity value to the installation. Electric power plants have their capacity stamped on the generator. The installed capacity of direct use projects, however, depends on how much the geothermal fluids are cooled. For example, a district heating installation using 500 kg/s of 80 deg C water will have an installed capacity of 84 MWt or 105 MWt, depending on whether the discharge temperature is 40 deg C or 30 deg C. Also, the flow rates and inlet and outlet temperatures in most direct use applications are poorly documented. This means that considerable guesswork is involved in estimating the power and energy values associated with direct-use applications. By neglecting the direct uses for discharge temperatures below 35 deg C, Gudmundsson's (1985) data underestimate the total direct use by some amount that is difficult to establish. As an example of the magnitude of energy used in these very low-temperature applications, the fish farm at Buhl, Idaho, not included in Table 2, uses an estimated 35 MWt at temperatures below 35 deg C. I conclude that, on a worldwide basis, the total energy used in direct heat applications is of the order of 10,000 MWt and that total direct use in the U.S. is of the order of 400 MWt.

The use of geothermal waters for bathing in Japan dominates the statistics on direct uses worldwide. Gudmundsson (1985) found that it was not possible from the survey data returned to him by the responding countries to separate direct uses precisely into catagories. He states, however, that district heating and cooling represent the major portion of direct uses, followed by bathing, greenhouses and other growing and, lastly, industrial processes. Gudmundsson (1985) also estimates that direct uses replace the consumption of about 2.8 million metric tons or about 29 million bbl oil annually. He concludes that many countries have large, untapped resources suitable for direct use, that district heating and cooling will see the largest growth in future years, and that cities that are collocated with resources will have advantages over those that are not if energy supplies again become scarce or expensive.

FORECASTS FOR ELECTRICAL POWER GENERATION

Roberts and Kruger(1986) give results from the tenth annual survey of the utility industry made by the Electric Power Research Institute (EPRI) for the purpose of obtaining estimates of future geothermal capacity. They also show data on projected electric supply and demand compiled by the North American Electric Reliability Council (NERC) and by the Western System Coordinating Council (WSCC). NERC predicts that the net energy load for the whole U.S. will grow at an annual rate of 2.26 percent per year between now and 1994, and WSCC predicts a growth rate in load of 2.33 percent per year over the same interval for 13 western states. For comparison, Table 3 shows the projected electrical generating capacity by fuel type for the whole U.S. and Table 4 shows the same data for the 13 western states. For the U.S. as a whole, geothermal energy presently contributes 0.2 percent of our generating capacity, and by the year 1994, this contribution is expected to grow to 0.5 percent. In the west, geothermal energy provides 1.6 percent of our electrical capacity, and this amount is expected to grow to 2.4 percent by the year 1994. These tables also indicate that the contribution by oil and gas will decrease for the U.S. between now and 1994, and that the growth rate for geothermal energy will be larger than that of any other fuel.

Results from the tenth annual EPRI survey of utilities are shown by region in Table 5. The 1986 data are actual while the rest are utility estimates. The figures are given at three levels of confidence: (1) Announced (An) - either publicly or through PUC-type reports; (2) Probable (Pr) - based on successful demonstration of technology for cost-effective use of liquid-dominated resources; and (3) Possible (Ps) - based additionally on anticipated growth of electricity demand and favorable regulatory treatment. The Gulf states comprise the states with potential resources of geopressured thermal and natural gas deposits, which may produce a minor contribution. The northwest states include the contribution from British Columbia and Alberta. It is noted in Roberts and Kruger (1986) that several of the newest plants are designed to operate with rotary separator turbines or binary cycles, which should accelerate the development of the more numerous moderate-temperature geothermal resources.

We see that, whereas the current geothermal electrical capacity is 2115 megawatts in the U.S., there is the probability of having 6800 megawatts and the possibility of having 10,000 megawatts by the year 2005. These amounts would correspond to annual growth rates of 6.3 percent and 8.5 percent, respectively, in reasonable agreement with the NERC (1985) and WSCC (1986) estimates for geothermal energy. All of these figures tend to confirm Lacy's (1986) conclusions, discussed previously, that geothermal energy has the opportunity to penetrate the market to a much more significant extent in the next decade than it has so far. It is worthwhile noting that none of these surveys anticipate significant development of hot dry rock or magma energy resources in the time frames of the forecasts.

FEDERAL RESEARCH FUNDING

There are critical conditions that must be met if geothermal energy is to make the future contributions predicted. There is a need for research and technology development to reduce costs and risks of developing, installing and operating geothermal plants. The fledgling geothermal industry has been looking to the federal government to provide most of this research, and the federal government is turning an increasingly deaf ear. Whereas the National Energy Policy Plan, published in the fall of 1983, calls for development of a mix of energy resources, with some emphasis on renewable types, the geothermal research budget has been steadily shrinking, as has budgets for all energy research in the

U.S. At $20 million for FY 87, the geothermal budget is now a factor of about 9 less than what it was when the present administration began. In addition, the geothermal budget has been repeatedly cut by the OMB below the recommendations made by DOE, and there are only a few members of Congress that have enough interest in furthering geothermal development to restore moneys. Yet, geothermal energy is the only one of the so-called "renewable" energies that is contributing significantly to U.S. energy needs. Geothermal energy exceeds solar and wind energy combined in both its present-day contribution and in its potential contribution to our energy needs for years to come.

Even the geothermal research program, as small as it is, has its own problems. A significant component of the geothermal budget is now politically directed by Congress and is earmarked for the much more futuristic types of geothermal exploitation systems such as hot dry rock. No one in industry or the government predicts that these resource types will make significant contribution to the energy mix in the United States until well into the next century, if ever. This, of course, will be too late to help with the energy crisis which the world will face in the 1990s. For sound economic and technical reasons, the industry is completely focused on the development of hydrothermal resources. However, the share of the budget allocated by Congress for the hydrothermal research needed and recommended by industry is wholly inadequate for the job.

We are just now beginning to see signs in Washington of an understanding of the adverse impact on our economy that a renewed energy crisis will have. We have a brief period now of plentiful energy during which we can either prepare to ensure an adequate supply of acceptable forms of energy for our future or we can neglect to act and be overtaken again as world energy markets undergo another high-amplitude swing. We are making a very serious mistake to cut energy research budgets at this time.

The U.S. Department of Energy, Geothermal Technology Division, has spent considerable time and effort to determine the research needs and priorities of the hydrothermal industry. These have been documented in a series of reports by the hosts of twice-yearly meetings at Lawrence Berkeley Laboratory that are convened for the purpose of discussing these research needs and priorities. The working committee for these meetings is comprised of representatives of the major geothermal resource companies. The results of these and other similar meetings have been consolidated in a research plan (DOE, 1986). However, it is unlikely that this research plan can be followed for two primary reasons: 1) the funding is inadequate, and 2) the Congress usually specifies how a large percentage of the money should be spent, thereby limiting the prerogatives of the DOE staff and undermining the performance of a rational research program. The hydrothermal research items are usually the most affected by congressional action because it usually directs DOE to shift money to the Hot Dry Rock research budget without adding new money. This forces DOE to take money from other programs.

RESEARCH RECOMMENDATIONS

The primary hydrothermal research needs may be summarized as follows below. Each of these three primary items has been expanded with a great deal of thought given to the individual research tasks needed. These details are given in DOE (1986) and in supporting documents.

1. Research to bring down the cost of drilling a well field. Research should take place on two broad fronts; in learning how to drill more cheaply, and in learning how to site wells more efficiently, so that there are fewer unsuccessful wells. The cost of putting in the well field is about half of the total development cost for generating electric power.

2. Research to increase our ability to predict the long-term behavior of a hydrothermal reservoir and to design better production and injection strategies. Utilities and financial institutions are understandably reluctant to commit money and resources to a geothermal project if long-term production from the resource can not be guaranteed.

3. Research to increase the efficiency of conversion, so that the more plentiful lower-temperature resources can be used. Only the highest temperature resources are economically viable today. If we could use

resource temperatures down to 140 deg C, the usable resource base would be augmented considerably.

In addition to these research needs, both the federal and the state governments need to streamline the permitting process and other aspects of regulation to the maximum extent possible. This will help the developers to hold down costs and enable them to proceed in these highly competitive times.

The economy of the United States is almost totally dependent on having an adequate supply of energy at an acceptable cost. Recent history shows us that when energy costs escalate, inflation increases. Our current low rate of inflation is due in large part to the current worldwide availability of inexpensive energy. When energy costs again go up sharply, as they will do, inflation will increase sharply. The industrial base of our country is presently in worse shape to withstand increased energy costs than it was in the 1970s. If we are to avert economic upheaval as energy costs go up, we must prepare now. Federal funding for energy research will, thus, help to ensure a stable economy in our country. Cuts in all of the energy research budgets are mistakes which must be corrected soon if the results are to be available in time to compensate for increased petroleum prices.

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Table 1

Worldwide Geothermal Electricity Generation

OCTOBER 1985

(AFTER DIPIPPO, 1985)

Country	*Generating Capacity, MW* Operational	Under Const. or Planned
KENYA	45.0	60
EL SALVADOR	45.0	30
NICARAGUA	35.0	35
MEXICO	425.0	865
UNITED STATES	2022.0	1309
CHINA	14.0	–
TURKEY	20.6	–
AZORES	3.0	–
USSR	11.0	230
ICELAND	39.0	–
GUADELOUPE	4.2	–
ITALY	459.0	60
INDONESIA	32.3	965
JAPAN	215.0	108
NEW ZEALAND	167.0	116
PHILIPPINES	894.0	1303
	4431.1 MW	5081 MW

Table 2

Worldwide Geothermal Direct Use

(AFTER GUDMUNDSSON, 1985)

Country	Power (MW)	Energy (GWh)	Load (%)
China	393	1945	56
France	300	788	30
Hungary	1001	2615	30
Iceland	889	5517	71
Italy	288	1365	54
Japan	2686	6805	29
New Zealand	215	1484	79
Romania	251	987	45
Soviet Union	402	1056	30
Turkey	166	423	29
United States	339	390	13
Other	142	582	47
total	7072	23957	39*

* Based on total thermal power and energy

Table 3

U.S. Electrical Capacity by Fuel

(NERC, 1985)

Fuel	Existing 1984 (GW)	(%)	Forecast 1994 (GW)	(%)	Growth (%/a)
coal	262.3	43.4	311.6	43.8	1.74
oil and gas	103.4	17.1	99.0	13.9	-0.43
dual + other	91.3	15.1	98.0	13.8	0.71
water	83.7	13.9	88.1	12.3	0.51
uranium	62.1	10.3	111.7	15.7	6.05
geothermal	1.42	0.2	3.23	0.5	8.56
totals	604.2		711.6		1.65

Table 4

WSCC Electrical Capacity by Fuel

(WSCC, 1986)

Fuel	Existing 1986 (GW)	(%)	Forecast 1996 (GW)	(%)	Growth (%/a)
water	60.0	43.9	63.5	39.6	0.57
oil and gas	35.9	26.3	41.8	26.1	1.53
coal	30.8	22.5	39.1	24.4	2.41
uranium	7.8	5.7	12.0	7.5	4.40
geothermal	2.2	1.6	3.9	2.4	5.89
totals	136.7		160.3		1.61

Table 5

1986 EPRI Utility Geothermal Survey

(Roberts and Kruger, 1986)

	Capacity (MWe) by Year		
	actual	estimated	
	1986	1995	2005
Southwest			
An	67	159	159
Pr		247	730
Ps		597	1845
Northwest			
An	0	0	0
Pr		20	60
Ps		35	145
CA/HI			
An	2048	3509	3509
Pr		4439	6003
Ps		5434	8058
Gulf States			
An	0	0	0
Pr		0	0
Ps		5	20
Total Forecast			
An	2115	3668	3668
Pr		4706	6793
Ps		6071	10068