EWL 212

GEOHERMAL ENERGY

INDUSTRY BRIEFING PACKET

EARL WARREN LEGAL INSTITUTE
GEOHERMAL COMMERCIALIZATION PROJECT

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WHO WE ARE AND WHAT WE'RE DOING

The Earl Warren Legal Institute, part of the University of California at Berkeley, is a center for law-related interdisciplinary research and public service in areas of national social concern. Since 1975, we have worked with the U.S. Department of Energy and Lawrence Berkeley Laboratory on various projects addressing energy policy and environmental issues. We are now engaged in a major effort to identify current legal, economic and institutional obstacles to commercial development and use of geothermal energy sources.

Geothermal resources -- heat reservoirs beneath the earth's surface -- have received increasing attention in recent years of growing energy consciousness, and much progress has been made toward understanding their nature, extent and uses. Encouraged by federal and state development programs, there now exists an active and growing community of geologists, geophysicists, engineers, drilling companies, developers and end-users of geothermal heat. However, Department of Energy studies indicate that current knowledge and available technology would support substantially broader use of the resource, particularly by private sector commercial, industrial and agricultural concerns.

Accordingly, we are now seeking to determine the knowledge and attitudes of such entities toward geothermal use; the factors which will influence decisions to utilize geothermal or not; the perceived obstacles, if any, to expanded use in their own industries; and the types of government policies or programs which might minimize such obstacles.

The industries we have chosen to approach have been targeted by others as potential geothermal users. However, we recognize that many firms today have little or no knowledge of the resource or of its potential applications. We have therefore prepared the following brief summary as an introduction for some, perhaps a refresher for others, and hopefully a stimulus for an exchange of ideas with all whose views we intend to solicit as our work proceeds.

WHAT IS GEOTHERMAL ENERGY, AND WHAT FORMS DOES IT TAKE ?

Geothermal energy is heat energy stored within the earth. It is useable where it occurs in an extractable form, such as steam or hot water, sufficiently near the surface. It may be manifested at the surface naturally by hot springs, fumaroles, or geysers; often, however, it is not. The U.S. Geological Survey defines the geothermal resource base as the stored heat at temperatures above 15°C (59°F) found at a depth of less than 10 kilometers (roughly the limit of present commercial well-drilling technology).

There are basically three types of geothermal resources: hydrothermal, hot rock, and conduction-dominated resources. Of these, only hydrothermal resources have an available fluid medium to transfer subterranean heat to the surface, and for this reason, a potential for near-term direct applications.

Hydrothermal resources are characterized by the presence of hot waters or vapor near a source of natural subterranean heat -- still molten, or very hot solidified rock. The water or vapor carries the heat upward by convective circulation to the pore spaces of an underground aquifer, or permeable rock reservoir.

In vapor-dominated hydrothermal systems, relatively lower pressure in the aquifer allows the hot water to boil and form vapor. (See Figure 1.) The vapor moves upward, to be superheated further by surrounding hot rock, or to condense into water as it comes into contact with cooler rock, with some of the water moving downward to be vaporized again. In such systems, the vapor usually remains trapped in the reservoir by a low-permeability rock layer (a "cap rock") overlying the aquifer. If the aquifer is penetrated by an open fracture, the vapor may vent at the surface. A well drilled into a vapor-dominated reservoir will produce either dry (superheated) steam or wet steam (a combination of water and vapor).

In a hot water-dominated hydrothermal system, the temperature of the water is too low to boil at subsurface pressures. (See Figure 2.) The water may either be confined or open (without a cap rock). Recharge is effected by cooler groundwater which circulates down fractures at the margins of the system. Assuming adequate pressure or pumping devices, a well drilled into a high temperature, hot water-dominated system will produce hot water at the surface.

Figure 1 - VAPOR DOMINATED GEOTHERMAL RESERVOIR

Figure 2 - HIGH TEMPERATURE GEOTHERMAL SYSTEM

WHERE ARE GEOTHERMAL RESOURCES LOCATED ?

Most known geothermal resources of the kind described above are found in areas of geologically recent volcanic activity. In the United States, known hydrothermal resources are concentrated in the Western states; efforts are now under way to locate similar resource areas in the Eastern seaboard states.

The U.S. Geological Survey and others have mapped areas of known and probable geothermal activity. Over 3.3 million acres of federal lands have been designated as known geothermal resource areas (KGRA's), and over 100 million acres have been identified as prospectively valuable for geothermal development. In addition, state and private entities have determined that certain non-federally owned lands overlie geothermal resources. These survey and mapping activities continue, and private exploration efforts are helping to refine the knowledge gained from them.

Still, information as to specific locations of geothermal resources is quite incomplete, and much work remains to be done toward resource identification. Major resource areas which have been identified so far as potential geothermal development areas are shown on the attached maps. (See Appendix.)

WHAT ARE THE USES OF GEOTHERMAL ENERGY ?

Geothermal uses fall into two broad categories: Electricity generation, and direct heat applications. Electricity generation requires high temperatures (about 150°C minimum) not attainable from most known geothermal resources. Direct heat applications, such as space heating and many agricultural or industrial processes, are feasible at low or moderate temperatures (20°C - 140°C), well within the range of many known resources. (See Table 1.)

Electricity Generation. Geothermal electricity generation began at Lardarello, Italy, in 1904. Today, Italy produces over 400MW* of electricity from geothermal. New Zealand began geothermal generation in 1958, and now produces about 170MW. The United States is currently the world's largest producer of electricity from geothermal, by virtue of a single producing field in Northern California. This field, known as the Geysers, began operations in 1960 and now produces over 500MW; experts forecast an eventual yield of about 2,500MW. Other countries exploring for or utilizing geothermal for electricity generation include the USSR, Japan, Mexico, Iceland, El Salvador, Guadeloupe, Turkey, and Nicaragua.

Direct Use. Geothermal direct heat applications are more prevalent worldwide than electrical applications. Planned or existing direct uses for low and moderate temperature resources include space heating and cooling, pulp and paper processing, lumber and crop drying, sugar refining, greenhousing, aquaculture, livestock raising, fertilizer production, and chemical extraction. Many other commercial and industrial processes dependent upon reliable, low-cost heat are candidates for geothermal use.

Concrete examples of these operations exist throughout the Western United States. Klamath Falls, Oregon and Boise, Idaho have long employed geothermal for space heating hundreds of residences; both cities are now expanding such uses to their downtown commercial areas. In Klamath, the Oregon Institute of Technology campus, Presbyterian Intercommunity Hospital and various commercial enterprises also use the resource for space heating, and Medo-Bel Creamery uses it for milk pasteurization. Honey Lake Farms near Wendel, California, presently operates 30 hydroponic greenhouses on geothermal, and plans to build

*100MW is roughly adequate to power a population center of about 100,000.

175 more. Fish Breeders of Buhl, Idaho and Calaquia, Inc. of Paso Robles, California run large aquaculture operations using geothermal heat. Ore-Ida Foods is proceeding with plans to employ geothermal for potato processing at its large Ontario, Oregon plant. Most of these commercial applications of geothermal direct heat are quite recent; following their example, many more projects are now in the planning or early implementation stage.

TABLE 1

HOW DOES ONE FIND AND ACQUIRE GEOTHERMAL RESOURCES ?

Federal Land. Resource exploration on federal lands is governed by the Geothermal Steam Act of 1970 and regulations issued under it. Exploration involving only "casual use" (i.e., activities which do not appreciably disturb the land, improvements or other resources) may be conducted without a permit upon notification to responsible USGS officials. More intensive exploration (short of core drilling and geothermal development wells) requires a USGS permit. Neither procedure affords exclusive exploration rights or preferential rights to a subsequent geothermal lease of the explored lands.

Leasing of federal geothermal lands is controlled by the U.S. Bureau of Land Management (BLM). Leasing procedures differ depending upon whether or not the area has been designated a KGRA. If it has not, the land is leased on a non-competitive, first come-first served basis. If it has, the land must be leased on a competitive, cash-bonus bid basis. Areas are classified as KGRA's when (1) survey drilling shows that a field is capable of producing commercially usable fluid, or (2) an overlap of 50 percent or more occurs in two applications for non-competitive leases.

State Land. Conditions for exploration and production of geothermal resources on state land vary among the states. Most states have adopted a form of the federal government's access procedure.

Lands identified, by geology, competitive interest, and/or other factors, as being within the state equivalent of the federal KGRA are leased on a competitive bid basis. The types of bid terms vary and may include annual rental, cash bonuses, production royalties, profit shares and exploration commitments.

Lands identified as having low or unknown geothermal resource potential are leased on a non-competitive, first come-first served basis except in Montana and Washington where both KGRA and non-KGRA lands are leased competitively. Several states, such as California and Wyoming, issue a short-term exploration permit containing an option to convert to a development lease if the permitted area is reclassified as a KGRA.

Private Land. Exploration and development of geothermal resources on private lands is a matter for private negotiation and agreement among the involved parties, subject to applicable federal, state and local permitting requirements and environmental regulations.

WHAT ARE THE COSTS OF GEOTHERMAL DEVELOPMENT ?

Because of the site-specific character of geothermal resources, it is very difficult to generalize about development costs. The major cost for most single-site non-electric projects is likely to be for exploration and drilling. In known resource areas, such as Klamath Falls, exploration costs have been negligible and drilling costs relatively low: a typical 300' individual residential well in Klamath Falls costs from \$6000 to \$8000. In other areas, successful commercial entrepreneurs likewise have been able to drill shallow, low-temperature wells with water-well drilling rigs for \$10,000-\$15,000 each. On the other hand, where exploration requires aerial reconnaissance, geophysical studies, test drilling, site selection and lease acquisition, and where production wells involve deep drilling, costs can be as much as \$3-5 million.

The following table presents the estimates of several knowledgeable sources as to typical drilling costs for wells beginning at a depth of about 1600 feet, or 500 meters.

Drilling Costs for Geothermal Wells

<u>Depth (KM)</u>	<u>\$ Total Cost</u>	<u>Average Cost/Meter</u>	<u>Marginal Cost/Meter</u>	<u>Source</u>
0.5	50,000	100	100	Meidav
1.0	150,000	150	200	Meidav
	150,000	150		USGS
2.0	420,000	210	270	Meidav
	300,000	150	150	USGS
	300-520,000	166-216		Rex
3.0	810,000	270	390	Meidav
	500,000	167	200	USGS
	425-770,000	170-260	250	Rex
5.0	1,000,000	200	250	USGS
	635,000-1,055,000	200-230	250	Rex
10.0	5,000,000	500	800	USGS
	2,750,000	300	340	Rex

Source: Sacarto, D., "State Policies for Geothermal Development,"
(National Conference of State Legislatures, 1976, p. 25.)

IS FINANCING ASSISTANCE AVAILABLE FOR GEOTHERMAL VENTURES ?

GOVERNMENT FINANCING

Since 1976, the Federal government has offered three types of financial assistance specifically to encourage commercial geothermal development.

Geothermal Loan Guaranty Program. This program is intended to encourage private financing of geothermal ventures by minimizing the lender's financial risk associated with the development of a new resource. Guaranties are available for loans of up to 30 years to finance exploration, leasing, construction and operation of geothermal facilities. The government may guaranty 100% of the amount borrowed, not to exceed 75% of aggregate project costs; the applicant must contribute a 25% equity share.

Program Research and Development Announcement (PRDA). This Department of Energy program provides grants to private contractors for engineering and economic feasibility studies. Some PRDA studies have been directed to development of specific resource sites (e.g., district heating at Mammoth Lakes, California; integrated livestock meat and feed production at Mountain Home, Idaho). Other studies have focused on technological processes or industry-wide applications (e.g., multiflash feed-and-bleed coupling for the evaporation and crystallization industry).

Program Opportunity Notice (PON). The Department of Energy also offers a cost-sharing program for projects believed to have worthwhile demonstration potential. For the 1978 fiscal year, the PON program funded the initial phases of 8 projects for a total of about \$2 million; some 15 additional projects have been selected for funding this year. PON projects range from municipal district heating installations to sugar refining, greenhousing, aquaculture and industrial processing by private firms.

Apart from these programs tailored specifically for geothermal projects, certain assistance programs offered by the Economic Development Administration and the Farmers Home Administration can be of use for some kinds of geothermal developments.

State assistance programs vary among the states. For example, California and Texas offer direct grants for geothermal demonstration projects; Idaho uses federal revenue sharing funds to assist individuals in preparing grant proposals.

PRIVATE FINANCING

Conventional lending institutions have been somewhat slow to provide risk capital for geothermal ventures. To date, only three commercial banks - Bank of Montreal, Bank of America and Nevada National Bank - have participated prominently in geothermal financing, backed by DOE's loan guaranty program. Other commercial banks, including United California, Security Pacific, Wells Fargo, Bankers' Trust and Chase Manhattan have expressed interest in geothermal financing. Somewhat higher-risk project loans may be available through investment bankers and private placement agencies, but these are increasingly difficult to obtain. Several existing projects have been financed by individuals and groups of investors operating as limited partnerships, and more such operations can be expected as a result of recent tax changes favoring geothermal.

ARE THERE TAX INCENTIVES FOR GEOTHERMAL DEVELOPMENT ?

The National Energy Act of 1978 recognized geothermal as a viable alternative energy source, and provides significant new tax incentives for geothermal development and use. Most relevant in the commercial setting are the following:

Additional 10% Investment Credit. The Act establishes a new 10% tax credit for business investment in certain kinds of alternative energy property. The credit is in addition to the existing investment credit, and applies to equipment employed "to produce, distribute or use energy derived from a geothermal deposit."

Intangible Drilling Cost Deduction. Intangible costs such as wages, fuel, repairs, hauling, and incidental supplies represent a significant portion of field development expenses. The Act extends to geothermal developers the option (long available to oil and gas developers) to deduct these costs as current expenses, rather than to capitalize them.

Percentage Depletion Allowance. The Act extends the percentage depletion allowance, familiar in the oil and gas industry, to geothermal producers. Percentage depletion permits the owner of a producing well to compute deductions as a percentage of income produced, rather than as a function of capital invested; as such, it may result in deductions far exceeding the owner's actual investment over the life of a well.

IS TECHNICAL INFORMATION AND ASSISTANCE FOR GEOTHERMAL DEVELOPMENT AVAILABLE TO THE PUBLIC ?

The U.S. Department of Energy provides information and technical assistance on geothermal use through a variety of programs. Results of DOE funded feasibility studies conducted under its PRDA programs are available to interested, potential users as are proposals accepted by DOE for geothermal demonstration projects. A Self-Start Manual has been developed with DOE funding through the California Energy Commission to provide a means to evaluate and implement direct use applications. Idaho National Engineering Labs operates a DOE "User Assistance Program" which provides lab time and technical direction to potential users, and Oregon Institute of Technology offers a similar "Technical Assistance" program with limited economic and engineering feasibility studies, and field consultation as well. DOE also operates a Geothermal Component Test Facility in East Mesa, California which is available for experimentation to engineers and manufacturers of equipment. The facility provides test pad space supplied with brine, water, compressed air and electricity; three geothermal wells; a machine shop; and a chemistry lab.

Another source of technical information is the Geothermal Resources Council. This private corporation engages in educational research and disseminates information through various publications and symposia. It has also compiled a substantial Registry of consultants, exploration and drilling companies, engineering firms, financial firms, government agencies, suppliers and other geothermal-related organizations.

Various state governments are involved in providing technical information on geothermal energy. California, for example, has created a Geothermal Resources Board which, among other things, coordinates information on the State agencies concerned with geothermal energy.

APPENDIX

MAPS OF GEOTHERMAL RESOURCES

GEOHERMAL RESOURCES

Map of classified geothermal acreage in Rocky Mountain states (from Godwin et al., "Classification of Public Lands," figure 2)

EXPLANATION

Known Geothermal Resources Areas

Areas Valuable Prospectively

California

- 1.....The Geysers
- 2.....Salton Sea
- 3.....Mono-Long Valley
- 4.....Calistoga
- 5.....Lake City
- 6.....Wendel-Amedee
- 7.....Coso Hot Springs
- 8.....Lassen
- 9.....Glass Mountain
- 10.....Sespe Hot Springs
- 11.....Heber
- 12.....Brawley
- 13.....Dunes
- 14.....Glamis

Nevada

- 1.....Beowawe
- 2.....Fly Ranch
- 3.....Leach Hot Springs
- 4.....Steamboat Springs
- 5.....Brady Hot Springs
- 6.....Stillwater-Soda Lake
- 7.....Darrrough Hot Springs
- 8.....Gerlach
- 9.....Moana Springs
- 10.....Double Hot Springs
- 11.....Wabuska
- 12.....Monte Neva
- 13.....Elko Hot Springs

Oregon

- 1.....Breitenbush Hot Springs
- 2.....Crump Geyser
- 3.....Vale Hot Springs
- 4.....Mount Hood
- 5.....Lakeview
- 6.....Carey Hot Springs
- 7.....Klamath Falls

Washington

- 1.....Mount St. Helens

Map of classified geothermal acreage in California, Nevada, Oregon and Washington (from Godwin et al., "Classification of Public Lands," figure 2)

ARIZONA

CALIFORNIA

COLORADO

Colorado hydrothermal resources.

NEW MEXICO

- ☐ XGRA Location (after Stone and Mizell, 1977)
- ⊗ High Temperature Prospect (after Swanberg, 1978)
- ⊙ Areas of low- and moderate-temperature potential (after Swanberg, 1978)
- ⊕ ≥ 2.5 HFU (after Reiter et al, 1975; Reiter et al, 1978)
- ⊙ Hot Springs and Wells, ≥ 65°F (after Summers, 1965, 1972)

Oregon Geothermal Resources

KGRA Known Geothermal Resource Area
 PGRA Potential Geothermal Resource Area

- AREA OF KNOWN WARM WATER USE