GEOTHERMAL ORIENTATION HANDBOOK

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Table of Contents

Section		Page
I	GEOTHERMAL RESOURCES	1
	Type and Size of Resource Base	1
	Current Status of Technology	3
	Outlook	9
II	OVERVIEW OF DOE'S GEOTHERMAL PROGRAM	17
	Goal	17
	Strategy	17
	Technology Thrusts	17
	Federal/Industry Roles	19
III	STRUCTURE OF GEOTHERMAL AND HYDROPOWER TECHNOLOGIES DIVISION - GEOTHERMAL PROGRAM	22
IV	GHTD TECHNOLOGY TRANSFER PROGRAM	29
	Need for Technology Transfer Program	29
	Current Program	29
	Technology Transfer Program Management	38
V	GEOTHERMAL LOAN GUARANTY PROGRAM	40
VI	THE INTERAGENCY GEOTHERMAL COORDINATING COUNCIL	42
VII	INTERNATIONAL COOPERATION	45
	Cooperative Agreements	46
	Informal Relationships	46
	Other Initiatives	49
VIII	HISTORY OF THE DOE GEOTHERMAL PROGRAM	50
IX	THE ROLE OF U.S. GEOLOGICAL SURVEY IN GEOTHERMAL DEVELOPMENT	55
X	THE ROLE OF FEDERALLY-OWNED LANDS IN GEOTHERMAL EXPLOITATION	57
	Leasing	57
	Post-Lease Operations	62
XI	THE U.S. GEOTHERMAL COMMUNITY	64
	Federal Agencies	64
	National Laboratories and Universities	64

	Non-Federal Government	64
	Geothermal Industry	68
XII	GEOTHERMAL DEVELOPMENT ABROAD	73

Exhibits

No.		Page
1	Geothermal Energy of the United States	2
2	Known and Potential Hydrothermal Resources	4
3	Summary of U.S. Geothermal Electric Power Plant Capacity by Year, through 1992	10
4	United State Electric Utility Planners' Estimates of U.S. Geothermal Electric Capacity-On-Line in 1990 and 2000	11
5	Number of Deep Wells Completed	13
6	Number of Deep Wells Completed Annually	14
7	Direct Heat Applicatons in Operation	15
8	Comparison of Current and Projected Geothermal Direct Use, 1982 and 2000	16
9	Resource Utilization Status	18
10	Geothermal and Hydropower Technologies Division - Geothermal Program	23
11	Geothermal Program Management	25
12	FY 1984 Milestones for Tactical Tasks of Technology Transfer Sub-Program	30
13	FY 1984 Milestones for Strategic Tasks of Technology Transfer Sub-Program	34
14	Interagency Geothermal Coordinating Council	43
15	Number of International Agreements in Geothermal Energy R&D Between the United States and Other Nations	47
16	Conformance of Geothermal Energy International Arguments with DOE Policy Objectives	48
17	Key Milestones in History of the DOE Geothermal Program	51
18	Budget History of The DOE Geothermal Program	52
19	The DOE Hydrothermal Commercialization Program	54
20	Competitive Geothermal Leasing	59

21	Non-Competitive Geothermal Leasing	61
22	The Geothermal Community in the U.S.	65
23	Overview of Federal Agency Contributions to Geothermal Development	66
24	Interaction Among DOE, Industry, and States in Geothermal Development	69
25	Major Companies Involved in Geothermal Development	72

Appendices

A	Geothermal Electric Power Plants Operational, Under Construction, and Planned in the United States
B	DOE International Cooperative Agreements in Geothermal Energy Research and Development
C	History of DOE Geothermal Program

SECTION I

GEOTHERMAL RESOURCES

TYPE AND SIZE OF RESOURCE BASE

Hydrothermal, geopressured, hot dry rock, and magma are four types of geothermal resources (in order of technological readiness) which can supply large amounts of energy for electric power production and direct heat applications.

Hydrothermal resources include water and steam trapped in fractured or porous rocks. A hydrothermal system is classified as either hot-water or vapor-dominated (steam), according to the principal physical state of the fluid.

Geopressured resources consist of water containing dissolved methane at moderately high temperatures and at pressures higher than normal hydrostatic pressure. Geopressured resources in sedimentary formations along the Texas and Louisiana Gulf Coast are believed to be quite large. Geopressured formations also exist in sedimentary basins elsewhere in the U.S.

Hot dry rock resources consist of relatively unfractured and unusually hot rocks at accessible depths that contain little or no water. To extract usable heat from hot dry rock, the rock must be fractured and a confined fluid circulation system created. A heat transfer fluid is then introduced, circulated, and withdrawn.

Magma resources consist of heat contained in molten or partially molten rock at accessible depths in the earth's crust (< 10 km). Scientific feasibility of heat extraction from magma has been demonstrated in laboratory and small-scale field experiments. Magma may be derived from oceanic spreading centers, from mantle plumes, or from subducted plates, but is generally limited to areas of recent volcanism.

Exhibit 1 indicates that there are between 1,650 and 8,000 quads of recoverable hydrothermal energy in the United States, and 170,000 quads in thermal

EXHIBIT 1

GEOTHERMAL ENERGY OF THE UNITED STATES

	Accessible resource base to 10 km (10^{18} J)*	Accessible resource base to 7 km (10^{18} J)*	Accessible fluid resource base to 6.86 km (10^{18} J)*			Accessible resource base to 3 km (10^{18} J)*			Resource (10^{18} J)*	Electricity (MWe for 30 yr)	Beneficial heat (10^{18} J)
			Sandstone	Shale	Total	>150°C	90°-150°C	Total			
Conduction-dominated											
Land area	33,000,000[a]	17,000,000[b]	—	—	—	—	—	3,300,000[a]	—	—	—
Offshore Gulf Coast	370,000[c]	180,000[c]	—	—	—	—	—	36,000[c]	—	—	—
Total	33,000,000	17,200,000	—	—	—	—	—	3,300,000	—	—	—
Igneous-related											
Evaluated	101,000	—	—	—	—	—	—	—	—	—	—
Unevaluated	>900,000	—	—	—	—	—	—	—	—	—	—
Total	>1,000,000	—	—	—	—	—	—	—	—	—	—
Reservoirs of hydrothermal convection systems (≥90°C)											
Identified	—	—	—	—	—	950[d]	700	1650[d]	400	23,000	42
Undiscovered	—	—	—	—	—	2800-4900	3100-5200	8000	2000	72,000-127,000	184-310
Total	—	—	—	—	—	3800-5800	3800-5900	9600	2400	95,000-150,000	230-350
Northern Gulf of Mexico basin (onshore and offshore)											
Thermal energy	850,000[e]	410,000[e]	11,000	96,000	107,000	—	—	—	270[f]-2800[g]	—	—
Methane energy	—	—	6,000	57,000	63,000	—	—	—	158[f]-1640[g]	—	—
Total	—	—	17,000	153,000	170,000	—	—	—	430[f]-4400[g]	—	—
Other geopressured basins	—	—	—	—	46,000[h]	—	—	—	—	—	—

[a]"Best estimates" of Diment and others (1975, table 14). These values are each approximately 18 percent greater than the values determined by the "basic calculation" of Diment and others (1975, table 13).

[b]Equations on p. 85 and 91 of Diment and others (1975) (assuming an exponential decrease of heat production with depth) give 13,700,000 x 10^{18} J for the "basic calculation". This value is then increased by approximately 18 percent to give a figure comparable to the "best estimates" of Diment and and others (1975, table 14).

[c]Calculated for an area of 135,000 km^2 using the "basic calculation" of Diment and others (1975) and the thermal parameters listed for the coastal plain on their table 13. The result is then increased by approximately 18 percent to give a figure comparable to their "best estimates".

[d]Does not include 1290 x 10^{18} J in National Parks (mainly Yellowstone).

[e]Calculated for an area of 310,000 km^2 using the "basic calculation" of Diment and others (1975) and the thermal parameters listed for the coastal plain on their table 13. The result is then increased by approximately 18 percent to give a figure comparable to their "best estimates".

[f]Plan 3 of Papadopulos, Wallace, Wesselman, and Taylor (1975).

[g]Plan 2 of Papadopulos, Wallace, Wesselman, and Taylor (1975).

[h]From White and Williams (1975, table 28); thermal energy only.

*10^{18} J = 1 quad

Source: Assessment of Geothermal Resources of the United States - 1978, U. S. Geological Survey Circular No. 790

energy and methane in accessible Gulf Coast geopressured reservoirs. The igneous-related accessible resource base of over one million quads includes both hot dry rock and magma. A recent estimate* indicates that magma accounts for about half of the total, hot dry rock nearly half, and hydrothermal fluids the small balance. The geographical distribution of hydrothermal resources is shown in Exhibit 2.

CURRENT STATUS OF TECHNOLOGY

The current status of technologies for defining geothermal reservoirs and producing and utilizing the resource varies with the form and characteristics of the resource. Some conventional technologies developed for other purposes are adequate for some geothermal applications, improvements are still needed in others, and, in some cases, new innovative technologies to maximize the effectiveness and economics of geothermal production and use are in varying stages of development.

For example, surface manifestations of underground dry steam fields are such strong indications of what the subsurface holds that the need for highly sophisticated sounding and measurement exploration techniques is minimal. On the other hand, confirming the existence of a liquid-dominated hydrothermal reservoir lying at greater depths under massive rock structures and estimating its size and characteristics require highly refined geological, geophysical, and geochemical technologies.

Conventional oil and gas drilling technologies have been used to explore for and produce geothermal energy for many years. These methods are extremely costly for geothermal application, however, because of the great depths of hard rock that must be penetrated, the extreme heat encountered, and, particularly in the

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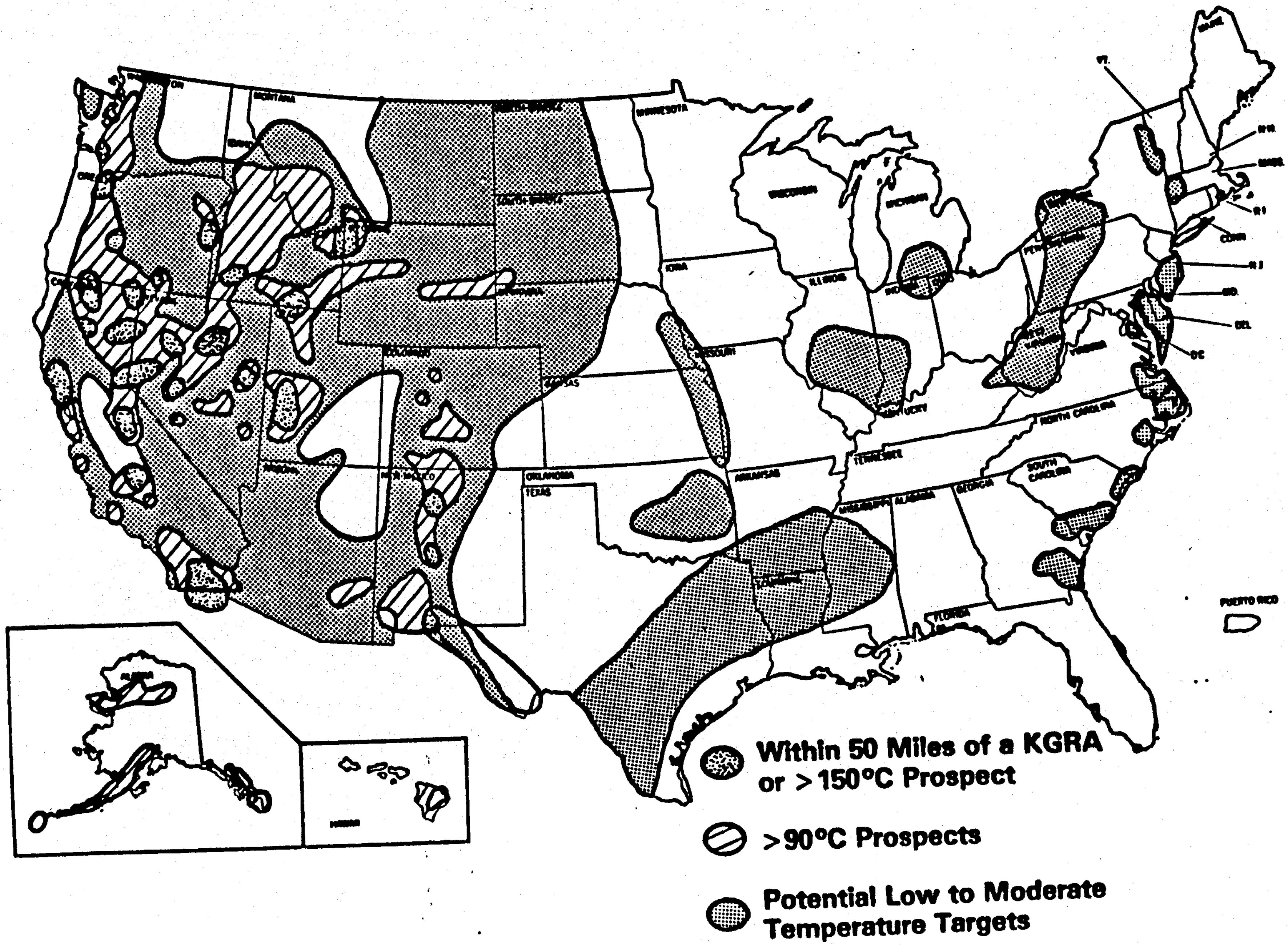
*Muffler, L. J. P., Geothermal Systems: Principles and Case Histories, 6. Geothermal Resource Assessment; John Wiley and Sons, Ltd., 1981.

EXHIBIT 2

Known and Potential Hydrothermal Resources



case of liquid-dominated reservoirs, high levels of corrosive impurities. These problems have not impeded the use of dry steam since conventional power production equipment can be used with this resource, and it is sufficiently profitable to absorb these costs. The technologies for converting the liquid resource to electric power are not as well developed and are only marginally competitive with conventional power generation. Thus, the very high drilling costs must be greatly reduced before the full potential of the abundant liquid resource can be realized.

Conventional power conversion systems require extensive additions before they are suitable for hot water (>200°C) application, and a power cycle not in common use for large power plants must undergo considerable alteration for the use of moderate-temperature resources (150-200°C) to be economic. Earlier DOE programs combined with industry's own efforts have developed the needed refinements for commercial use of the hot fluids, but economic moderate-temperature technology is not yet available.

Common to the use of fluids in either of these temperature ranges is the need to dispose of large quantities of spent fluids to the subsurface. While subsurface injection has been practiced for many years to dispose of liquid wastes, the quantities resulting from power generation with hydrothermal liquids are unusually large and are often contaminated with undesirable chemicals. Today's environmental regulations require that the fluids be injected without damage to the surface or subsurface environment, and the marginal economics of hydrothermal fluid use in power generation dictate cost-effective disposal methods.

Considerable progress in the development of technologies to meet these various needs has resulted from interacting GHTD programs. Geoscience research has produced commercially-available magnetotelluric and passive seismic exploration techniques designed specifically for hydrothermal reservoir evaluation. Reservoir definition and engineering have been advanced by a new method for characterizing fractured reservoirs and realistically predicting their response to production and injection. The reliability of reservoir models has been enhanced by the incorporation of geochemical data on noncondensible gases and dissolved solids present to some extent in most hydrothermal fluids. The end result of these and related achievements is that reservoir predictive models, based on information obtained with improved geoscience techniques, are being used today with some success.

The modifications made in geoscience technologies have been applied and tested in cooperative GHTD/industry reservoir confirmation drilling projects in high-temperature hydrothermal reservoirs. These projects have developed public domain data on 15 prime hydrothermal prospects. DOE-funded state assessments of low-to-moderate temperature reservoirs have resulted in maps of 17 states presenting state-of-knowledge information on their reservoirs in these temperature ranges.

The state-of-the-art of reservoir characterization has been advanced through development of downhole temperature/pressure instruments for low-to-moderate temperature well testing; site-specific calculation of hot water recharge from temperature profiles and contours; and site-specific well testing and modeling.

Improvements resulting from DOE R&D programs are reflected in commercially-available drilling systems and components such as the following:

- Improved drag bit and roller bit drills, incorporating polycrystalline diamonds and new seals and bearings
- Water- and mud-driven turbodrills for directional drilling
- High-temperature electronics and sensors for well logging.

In addition, a comprehensive materials development program has provided additional improvements in drilling components as well as equipment for surface use. This program was initiated due to the serious problems encountered with material failures in geothermal applications. Many materials conventionally used for mechanical components suffer thermal degradation on exposure to the hot fluids, reducing component life and reliability. In addition, the chemicals present in the fluid resource in many hydrothermal reservoirs create costly problems with corrosion, scaling, and other adverse reactions.

The materials program has provided a number of solutions to these problems such as the following:

- High-temperature elastomers and polymer concretes
- Leak-tight metallic seals
- High-temperature downhole cables and cablehead equipment
- Steels for improved drill bit performance
- Pitting resistant alloys.

In addition, standardized fluid sampling and analysis procedures have been developed, and precipitators/clarifiers and scale inhibitors to handle high-salinity, corrosive brines are now commercially available. A cavitating water-jet device for cleaning pipes and heat exchangers is also on the market.

Power conversion systems utilizing the very hot fluid resource (>200°C) are nearing maturity, and several flash-steam generating plants are under construction or planned. As noted previously, this advanced state of development has resulted from the efforts of both DOE and industry.

Heat conversion research has included both operation of pilot-scale binary units and redesign and testing of individual binary components. This work has led to the availability of binary systems for the moderate-temperature fluid, including lower-cost materials, components, and chemical treatments. However, further reductions in cost are needed before this technology can be considered a viable competitor in the marketplace.

The environmental control technology program developed a commercial method for hydrogen sulfide abatement--a catalytic oxidation system--and a partitioning model which is in use at The Geysers for H_2S abatement system design. A direct chlorination process for this purpose was found to be competitive with other more established methods such as the Stretford process. Two new geophysical techniques were developed to increase the understanding of geothermal fluid migration as a means of protecting subsurface drinking water during injection.

Demonstration of viable technologies for the direct use of low-temperature hydrothermal fluids has resulted in a gradual trend to this type of application in the western states. A number of schools, hospitals, and other institutions are realizing annual savings in fuel costs by replacing fossil-fired heating equipment with geothermal systems. There are seven multi-structure district heating systems in operation in this country, and interest is growing in agricultural/industrial uses. All farms of direct use may be impeded, however, by expiration of the energy tax credit at the end of 1985 because of their high up-front costs.

While the potential for commercial use of geopressured resources is not yet established, a major step in this direction has been accomplished in demonstrating the technical feasibility of extracting methane from the brines. The eventual commercial use of the thermal and mechanical energy also contained in the brines will hinge to a large degree on the economics of methane separation since there is an established commercial market for this fuel.

The technical feasibility of extracting and utilizing heat from hot dry rock has been demonstrated on a limited scale at Fenton Hill. While construction of the large commercial scale reservoir is not yet completed, a power cooperative has expressed interest in utilizing the site for power generation when the experiment is concluded.

The scientific feasibility of extracting and utilizing heat from magma sources has been demonstrated, although the technical and economic feasibility remains to be determined.

Under an international agreement with Italy (ENEL), Mexico (CFE), and New Zealand (MWD), DOE sponsored development of a 1 MWe wellhead generator. The helical screw expander developed was tested in each of the participating countries.

Considerable geoscientific information has been gained on the Cerro Prieto field through a bilateral agreement with Mexico. The significance of this information is that this field lies just over the U.S. border from Imperial Valley, California, the area of the most intense geothermal interest in this country outside The Geysers.

OUTLOOK

Geothermal electric plants under construction and planned, as announced by U.S. electric utilities and field developers, through 1992 are shown in Exhibit 3. If all of these plants materialize, the U.S. will have 3,060 MWe of geothermal electric power on line by the end of 1990. More detailed information on current future geothermal power plant capacity is presented in Appendix A.

This can be compared to utility estimates of geothermal electric capacity made in 1983 and previous years in Exhibit 4. These estimates are made annually by the Electric Power Research Institute, the major R&D association of U.S. electric utilities.

It can be seen in Exhibit 4 that the estimates of future capacity have declined in recent years. The peak estimates for 1990 and 2000 were made in 1978 when the DOE budgets for geothermal R&D were reaching their peak, as discussed in Section VIII. The low 1983 estimates can be attributed not only to reduced government spending for alternative energy technology development, but to a nationwide recession which cut severely into venture capital for all

EXHIBIT 3

SUMMARY OF U.S. GEOTHERMAL ELECTRIC POWER PLANT CAPACITY BY YEAR, THROUGH 1992

YEAR	U.S. GEOTHERMAL ELECTRIC POWER PLANT CAPACITY, MW				
	EXISTING	UNDER CONSTRUCTION (Estimated on-line date)	PLANNED ADDITIONS (Estimated on-line date)	ANNUAL TOTAL	CUMULATIVE TOTAL[1]
1983	1271	79	0	1350	1350
1984	--	169	25	194	1544
1985	--	369	59	428	1972
1986	--	110	7	117	2089
1987	--	-	87	87	2176
1988	--	-	393	393	2569
1989	--	-	270	270	2839
1990	--	-	224	224	3063
1991	--	-	160	160	3223
1992	--	-	50	50	3273

[1]Does not include the 78 MW planned by Magma Power

SOURCE: The MITRE Corporation.

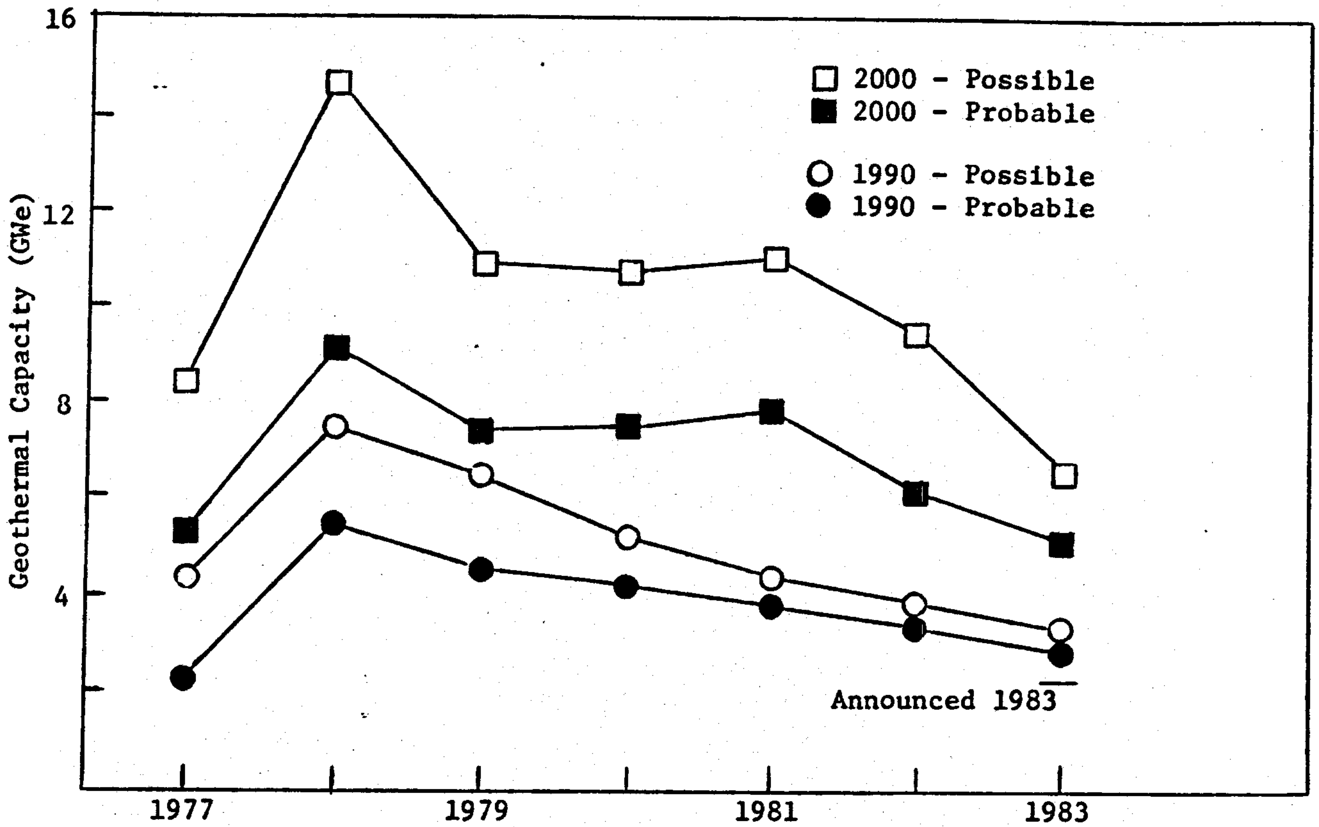


Exhibit 4

UNITED STATES ELECTRIC UTILITY PLANNER'S ESTIMATES OF U.S. GEOTHERMAL ELECTRIC CAPACITY ON LINE IN 1990 AND 2000.

These data from recent Electric Power Research Institute (EPRI) surveys,1977-1983, show industry's estimate of future geothermal electric capacity.

types of alternative energy projects as well. In addition, the "energy crisis" no longer receives the widespread publicity of the late 1970's.

The level of deep well drilling that supports geothermal electric power development is shown in Exhibits 5 and 6. Drilling at The Geysers has increased steadily since 1978. A surge of drilling in other areas, which started in 1978, ended in 1982.

Recent history of U.S. direct heat use is shown in Exhibit 7. These figures are influenced by the presence of the large use of geothermal heat for secondary oil extraction in Wyoming (10,000 Billion Btu/year). Exclusive of that project, installations by the end of 1978 supplied 2,685 Billion Btu/year. Many of those projects were installed prior to 1940.

The identified additions in 1979, 1980, and 1981 represent, respectively, about 20 percent, 8 percent, and 47 percent of the use in place at the end of each previous year. The 47 percent surge in 1981 is due mainly to government funding of a number of feasibiltiy studies and demonstration projects, rather than an effect of natural market forces.

Exhibit 8 provides the perspective on the baseline from which longer-term direct heat use begins. In most states, the 1982 use was less that one percent of the market predicted for the year 2000 by a New Mexico Energy Institute study.

EXHIBIT 5

NUMBER OF DEEP WELLS COMPLETED

	ANNUAL				CUMULATIVE			
	Geysers	Imperial Valley	Other	Total	Geysers	Imperial Valley	Other	Total
1973	22	6	10	38	22	6	10	38
1974	21	7	15	43	43	13	25	81
1975	24	11	13	48	67	24	38	129
1976	23	16	13	52	90	40	51	181
1977	28	8	9	45	118	48	60	226
1978	24	12	24	60	142	60	84	286
1979	30	10	35	75	172	70	119	361
1980	42	9	28	79	214	79	147	440
1981	44	10	29	83	258	89	176	523
1982	43	4	9	56	301	93	188	579

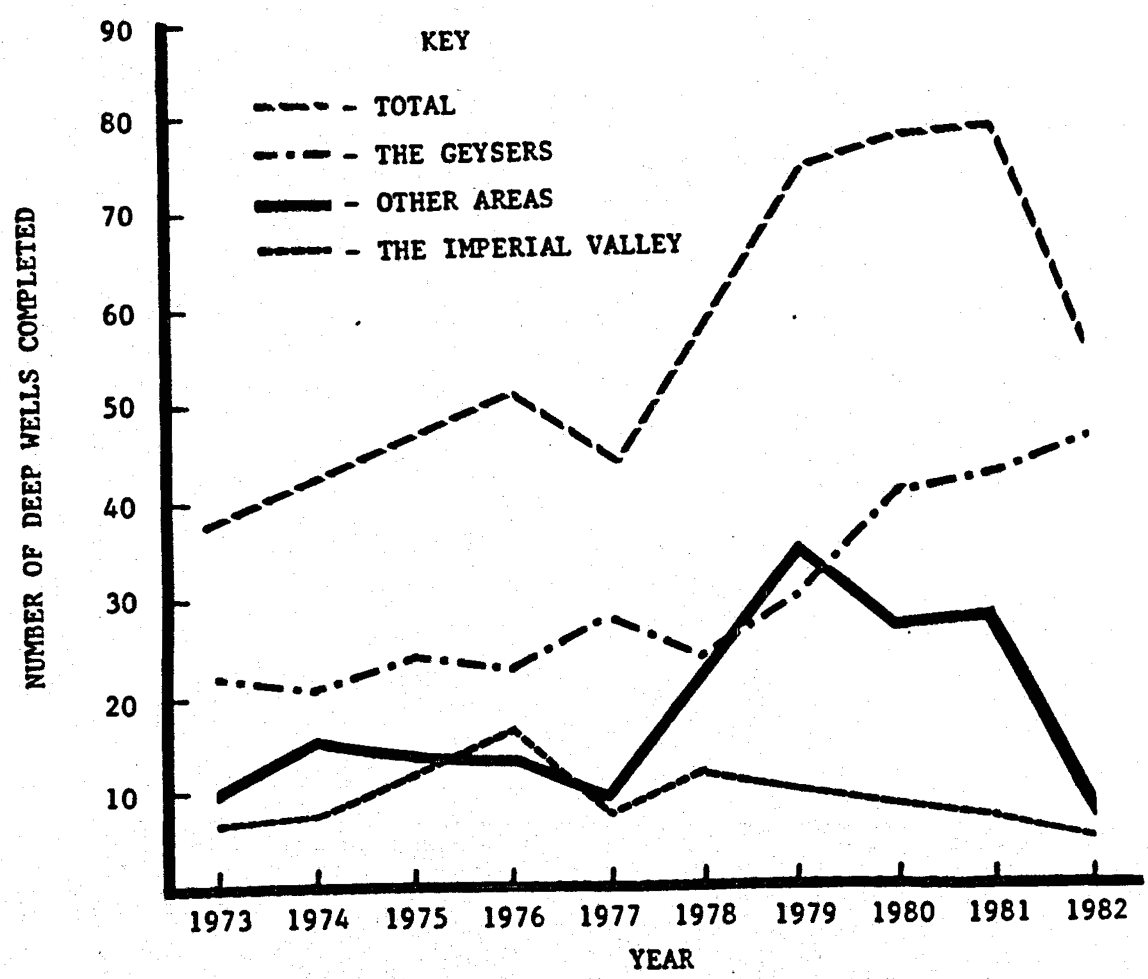


EXHIBIT 6

NUMBER OF DEEP WELLS COMPLETED ANNUALLY

EXHIBIT 7

DIRECT HEAT APPLICATIONS IN OPERATION
(Billion Btu Use/Year)

APPLICATIONS	BY END OF 1978	ADDED IN 1979	ADDED IN 1980	ADDED IN 1981	TOTAL END OF 1981
Agricultural	1,322.0	12.0	30.7	21.4	1,386.1
Aquacultural	788.0	100.5	105.0	106.0	1,099.5
Commercial	85.2	2.0	23.7	242.4	353.3
Industrial	10,137.0	-	101.1	1,162.0	11,640.1
Multiple Use	153.9	418.0	0.3	92.2	666.4
Recreational	17.0	11.9	5.5	27.9	62.3
Residential	182.3	5.7	4.7	11.0	203.7
TOTAL	12,685.4	550.1	271.0	1,662.9	15,169.4

EXHIBIT 8

COMPARISON OF CURRENT AND PROJECTED GEOTHERMAL DIRECT HEAT USE, 1982 AND 2000

STATE	CURRENT USE ($x10^{12}$ Btu/year)	YEAR 2000 POTENTIAL ($x10^{12}$ Btu/year)	ESTIMATED YEAR 2000 PENETRATION* ($x10^{12}$ Btu/year)	PERCENT OF ESTIMATED YEAR 2000 PENETRATION ACHIEVED BY 1982
Alaska	0.048	0.63	0.37	13
Arizona	0.100	74.97	48.18	<1
Arkansas	0.001	3.07	2.18	<1
California	0.538	404.50	265.30	<1
Colorado	0.033	120.84	99.24	<1
Connecticut	0.001	?	?	?
Idaho	1.217	61.47	58.75	2
Montana	0.012	29.69	25.79	<1
Nevada	0.079	39.29	36.90	<1
New Mexico	1.320	38.93	28.28	5
North Dakota	0.012	30.00	28.78	<1
Oregon	0.612	8.84	6.52	9
South Dakota	0.142	13.08	12.13	1
Utah	0.046	91.15	64.33	<1
Washington	0.013	92.00	?	?
Wyoming	11.003	25.07	21.74	51

*Estimates taken from a New Mexico Energy Institute study which assumed the existence of federal tax credits, grants and resource confirmation support.

SECTION II

OVERVIEW OF DOE'S GEOTHERMAL PROGRAM

GOAL

The goal of the Geothermal Program is to build a technology base that will enable the private sector to use the various forms of geothermal resources as they become competitive in the marketplace.

STRATEGY

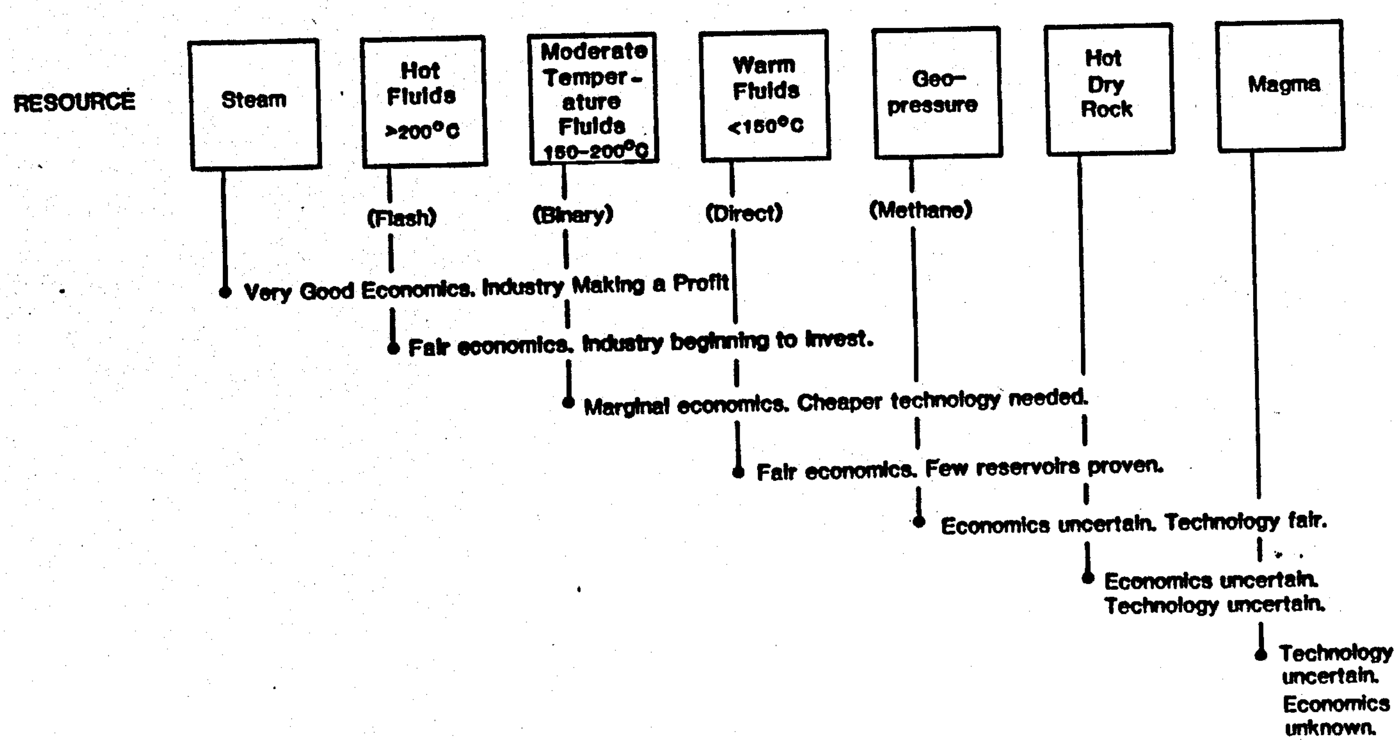
The DOE program strategy is to support appropriate R&D initiatives which will provide tangible technological payoff to industry, ensuring industry's utilization of the results of longer-range R&D needed to exploit all forms of geothermal resources. The Federal role varies, activity by activity, from primary to complementary to minimal partnership with industry. Overall, the DOE program is balanced between the longer-term, high payoff R&D and the more clearly defined technologies which serve to assist industry in meeting near-term technical objectives. DOE works with industry to identify critical technical barriers, and has involved industry in solutions to the barriers and disseminating information developed throughout the industry. In-house national laboratory teams assist this process through the validation of industrial research results as well as through independent research. Further validation is accomplished through working experiments, which also provide a feedback mechanism for subsequent research efforts.

TECHNOLOGY THRUSTS

Exhibit 9 identifies the current state of technological and economic readiness of the various types of geothermal resources. There are seven broad, common-denominator technology areas that cut across these resources and serve them to a greater or lesser extent. Present emphasis is on the technological needs of the hot-water portion of the hydrothermal resource, in order to bring it

EXHIBIT 9

RESOURCE UTILIZATION STATUS



to economic readiness, although critical issues relating to the hot dry rock, geopressured, and magma resources are also being addressed.

Broadly defined technical requirements over the next five years, grouped by major resource type are as follows:

Hydrothermal Resources - R&D directed toward reducing the costs of reservoir definition and field development; capital cost of electric generating facilities; and the technical risks of fluid handling systems failures in order to expand the economically exploitable hydrothermal resource base available for development by the private sector.

Geopressured Resources - Definition of the extent and energy content of the geopressured resource and determination of the technical feasibility and economics of extracting and utilizing chemical (methane), thermal, and mechanical energies contained in geopressured brines by the year 1988.

Hot Dry Rock Resources - Determination of the technical and economic feasibility of extracting geothermal heat from hot dry rock formations by the year 1989.

Magma Resources - Identification and characterization of potentially accessible magma reservoirs by the year 1985, and the determination of the technical and economic viability of extracting heat from molten rock of a magma body by the year 1990.

FEDERAL/INDUSTRY ROLES

DOE will continue to assume a primary role in certain areas of hydrothermal research. Brine injection technology projects will include the development of tracers, geophysical monitoring, and modeling techniques to monitor and predict the migration of spent brines injected into reservoirs; brine particle control and chemical conditioning methods; injection well completion techniques; and fluid/fluid and fluid/rock interactions. As industry progresses in applying these technologies, Federal sponsorship will decrease to a complementary role.

The Federal government will maintain a complementary role with respect to reservoir definition which includes reservoir productivity and longevity assessment and fracture mapping technologies. A minimal role will be continued in support of heat cycle research.

DOE's role in hard rock penetration research will be a complementary one as a follow-on to a primary role for geothermal drilling and well completion technology in prior years. Advanced drilling research involving spalling, melting, and vaporization experiments will be emphasized in addition to accurate borehole mapping and real-time downwell diagnostics technique development. This effort will culminate in DOE/industry cost-shared development of a prototype drilling system incorporating the best of the improvements resulting from this and previous drilling programs.

The Federal government will continue its present primary role in geopressured research through the completion of the current extended flow experiments, using two design wells in Louisiana and Texas, and possibly a deep nonproducing gas well offered by industry, and analysis of the data. When the flow experiments are completed, the test sites will be monitored for possible long-term subsidence. Industry will initiate its own technical and economic evaluation of the utilization of geopressured resources with planned cooperative industry/DOE research on power generation and direct applications. The Federal government will continue to play a complementary role through this research and will provide test sites and access to proven reservoirs.

The Department will continue its primary role in hot dry rock research at Fenton Hill, New Mexico. Efforts are underway to intercept a large new reservoir created in late 1983 and complete an underground loop in order to conduct long-term heat extraction experiments. These experiments will develop information on reservoir longevity and operating performance to provide the technology base needed by industry.

The Federal government will assume a primary position for magma energy extraction research. Magma bodies within accessible depths will be identified and estimates will be made on the cost of drilling into molten rock. In addition, estimates of technology needs and potential cost of energy extraction systems and materials will be made; magma reservoir prospects will be ranked; and the value of continuing magma research will be determined.

All technologies developed or refined will be transferred to industry on a continuing basis.

SECTION III

STRUCTURE OF GEOTHERMAL AND HYDROPOWER TECHNOLOGIES DIVISION

GEOTHERMAL PROGRAM

The current structure and objectives of DOE's Geothermal Program are described in the Multi-Year Program Plan FY 1985 - FY 1988. More detailed discussions may be found in separate multi-year program plans for the following:

- Geopressured Resources Sub-Program
- Brine Injection Technology Sub-Activity
- Reservoir Definition Sub-Activity
- Heat Cycle Research Sub-Activity
- Hard Rock Penetration Activity
- Magma Energy Extraction Activity

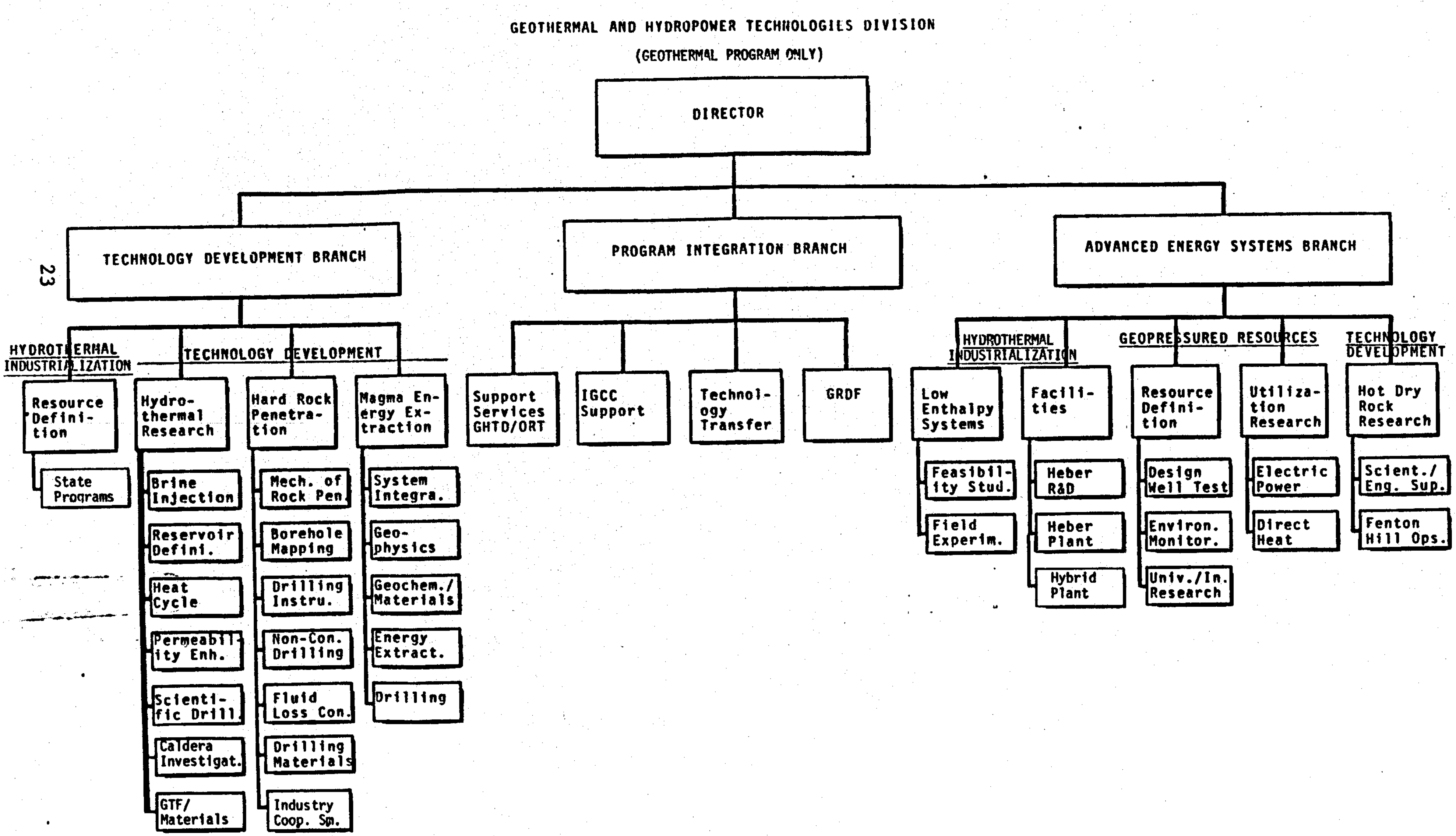
In addition, an amendment of September 1983 to the International Energy Agency implementing agreement under which the hot dry rock activity is carried out provides the most current information on plans for that element of the program. All of these documents are located in Volume I in GHTD's Management Center.

Thus, this section is limited to a summary of the programmatic structure and objectives of the geothermal program which is administered by three branches of GHTD as follows:

- Technology Development (TD)
- Advanced Energy Systems (AES)
- Program Integration

The Program Integration Branch is the administrative arm of GHTD providing support services as shown in Exhibit 10. It also administers the Geothermal

EXHIBIT 10


GEOTHERMAL AND HYDROPOWER TECHNOLOGIES DIVISION
(GEOTHERMAL PROGRAM ONLY)
DIRECTOR
TECHNOLOGY DEVELOPMENT BRANCH
PROGRAM INTEGRATION BRANCH
ADVANCED ENERGY SYSTEMS BRANCH
HYDROTHERMAL INDUSTRIALIZATION
TECHNOLOGY DEVELOPMENT
Resource Defini-tion
State Programs
Hydro-thermal Research
Brine Injection
Reservoir Defini.
Heat Cycle
Permeabil-ity Enh.
Scienti-fic Drill
Caldera Investigat.
GTF/ Materials
Hard Rock Penetra-tion
Mech. of Rock Pen.
Borehole Mapping
Drilling Instru.
Non-Con. Drilling
Fluid Loss Con.
Drilling Materials
Industry Coop. Sm.
Magma En-ergy Ex-traction
System Integra.
Geo-physics
Geochem./ Materials
Energy Extract.
Drilling
Support Services GHTD/ORT
IGCC Support
Technol-ogy Transfer
GRDF
HYDROTHERMAL INDUSTRIALIZATION
GEOPRESSURED RESOURCES
TECHNOLOGY DEVELOPMENT
Low Enthalpy Systems
Feasibil-ity Stud.
Field Experim.
Facili-ties
Heber R&D
Heber Plant
Hybrid Plant
Resource Defini-tion
Design Well Test
Environ. Monitor.
Univ./In. Research
Utiliza-tion Research
Electric Power
Direct Heat
Hot Dry Rock Research
Scient./ Eng. Sup.
Fenton Hill Ops.

Resources Development fund, discussed in Section V, and arranges for the transfer of technology for all program elements, as discussed in Section IV.

The programmatic responsibilities of the Geothermal Technology Development and Advanced Energy Systems Branches are also identified in Exhibit 4. It will be noted that the Geopressured Sub-Program is the only one of the three sub-programs totally under the direction of one branch. The activities, and sub-activities, under the other two sub-programs -- Hydrothermal Industrialization and Geothermal Technology Development -- are divided between the Technology Development and Advanced Energy Systems Branches. For cross-reference, the structure of each sub-program is shown in its entirety in Exhibit 11, again matched with the GHTD HQ branch with program management responsibility.

When DOE field operations offices issue contracts and retain technical authority, they have direct project management responsibility. Thus, the appropriate field offices are also identified in Exhibit 11.

Several of DOE's national laboratories serve as GHTD's research arm under contracts with the field offices. The areas of field office and national laboratory participation in the geothermal program can be summarized, by technology, as follows:

HYDROTHERMAL

- Field Operations Offices
  - San Francisco - Injection technology, reservoir definition, drilling materials development, scientific deep drilling project
  - Idaho - Injection technology, reservoir definition, heat cycle, geothermal state planning, hybrid binary/wood power plant
  - Albuquerque - Mechanics of rock penetration, borehole mapping, drilling instrumentation, non-conventional drilling techniques
- Laboratories
  - INEL - State planning activities, injection technology, heat cycle research

EXHIBIT 11

GEOTHERMAL PROGRAM MANAGEMENT

Sub-Program	Activity	Sub-Activities	HQ Program Management	Field Office Technical Management
Hydrothermal Industrialization	Resource Definition	State Reservoir Programs	TD[1]	ID/SAN
	Low Enthalpy Systems	Feasibility Studies	AES[2]	ID, NV, SAN
		Direct Heat Field Experiments		
	Facilities	Heber Binary Plant	AES	SAN
		Heber R&D		
		Honey Lake Hybrid Plant		ID
Geopressured Resources	Resource Definition	Design Well Tests	AES	NV
		Environmental Monitoring		
		University and Industrial Research		

[1]Technology Development Branch
[2]Advanced Energy Systems

EXHIBIT 11, Continued

Sub-Program	Activity	Sub-Activities	HQ Program Management	Field Office Technical Management
Geopressured Resources (continued)	Utilization Research	Power Generation Experiment	AES	NV
		Direct Heat Project		
Geothermal Technology Development	Hot Dry Rock Research	Fenton Hill Site Operations	AES	ALB
		Scientific and Engineering Support		
	Hydrothermal Research	Brine Injection Technology	TD	ID, SAN
		Reservoir Definition		SAN
		Heat Cycle Research		ID, SAN
		Permeability Enhancement		ALB
		Caldera Investigations		SAN
		GTF/Materials		
		Scientific Drilling		
	Hard Rock Penetration Research	Mechanics of Rock Penetration	TD	ALB
		Borehole Mapping		
		Drilling Instrumentation		
		Non-conventional Drilling Technology		

EXHIBIT 11, Continued

Sub-Program	Activity	Sub-Activities	HQ Program Management	Field Office Technical Management
Geothermal Technology Development (continued)		Fluid Loss Control	TD	ALB
		Drilling Materials Research		
		DOE/Industry Prototype Drilling System		
	Magma Energy Extraction	System Integration	TD	ALB
		Geophysics		
		Geochemistry/Materials		
		Drilling Technology		
		Energy Extraction		

- LBL - Reservoir definition, brine injection, resource definition

- LLL - Brine injection

- PNL - Brine injection

GEOPRESSURED

- Field Operations Office

  - Nevada - All geopressure activities

- Laboratories

  - LBL - Resource definition
    ORNL - Environmental support

HOT DRY ROCK

- Field Operations Office

  - Albuquerque - Fenton Hill site operations, engineering/scientific research

- Laboratory

  - LANL - Same as Albuquerque Operations Office

MAGMA

- Field Operations Office

  - Albuquerque - System integration, geophysics, geochemistry and materials, extraction concepts, drilling

- Laboratory

  - Sandia - Same as Albuquerque Operations Office

In their project management capacity, the field offices have the direct responsibility for preparing and implementing Quality Assurance (QA) Implementation Plans to cover all projects under their jurisdiction for compliance with DOE Order 5700. 6B. Headquarters program managers are responsible for systematic monitoring of field office QA performance. The Department's order is in final preparation at this writing; copies may be obtained from the Office of Quality Assurance on 353-5623.

SECTION IV

GHTD TECHNOLOGY TRANSFER PROGRAM

NEED FOR TECHNOLOGY TRANSFER PROGRAM

The Stevenson-Wydler Technology Innovation Act and DOE Order 5800.1 have mandated that GHTD develop a long-term integrated Technology Transfer Program. Other factors contributing to the timeliness of a formal technology transfer program include the growth of the geothermal industry infrastructure; the increasing involvement of state and local governments in support of industry activities; and the development of a broader geothermal technology base through the accumulation of the results of federal R&D and information developed by the non-federal sectors.

CURRENT PROGRAM

The FY 1984 program thrust is two-fold. Selected technology transfer activities/methodologies that have been effective in the past as an integral part of GHTD R&D will be continued under the direction of the new technology transfer sub-program element. These activities, called "tactical tasks," will insure a smooth transition to the fully focused Technology Transfer Program of FY 1985 and beyond. Other technology transfer efforts, called "strategic tasks," will lay the groundwork for the long-term effort. By addressing the strategic tasks in an orderly step-by-step fashion, the Technology Transfer program can optimize its efforts and assure cost effectiveness.

Milestone charts of "tactical" and "strategic" tasks are shown for the period beginning in FY 1984 in Exhibits 12 and 13.

Tactical Tasks - FY 1984

- Support topical reviews and workshops, involving the Federal as well as the non-Federal sector, in the planning of future research and development programs.

EXHIBIT 12

TECHNOLOGY TRANSFER PROGRAM

MILESTONE CHART

"TACTICAL TASKS"

Activity	1st Qtr 1984	2nd Qtr 1984	3rd Qtr 1984	4th Qtr 1984
o GHTD/GRC Workshop on Patents, Proprietary Information and Licensing				◆
o EPRI Annual Geothermal Meeting Session on DOE-Sponsored Research for Geothermal Powerplants			◆	
o GHTD/GRC Workshop on Geothermal Economics			◆	
o American Institute of Architects Convention	◆			
o 9th Stanford Workshop on Geothermal Reservoir Engineering	◆			
o Geopressure Industry Forum		◆		
o GHTD Geothermal Program Review II Conference	◆			
o Groundwater Geothermal Workshop	◆			
o Earth Coupled Heat Pump Workshop	◆			
o Groundwater Heat Pumps Workshop		◆		
o 4th Annual Energy Conference		◆		

EXHIBIT 12 (Continued)

TECHNOLOGY TRANSFER PROGRAM

MILESTONE CHART

"TACTICAL TASKS"

Activity	1st Qtr 1984	2nd Qtr 1984	3rd Qtr 1984	4th Qtr 1984
o Conference on District Heating Systems in France	◆			
o Conference on Pumping Systems for use in New Zealand	◆			
o Industry/Lab Workshops			◆	
o GHTD Technology Transfer Workshop			◆	
o Geothermal Test and Evaluation Facilities Announcements			◆	
o GHTD/GRC Review and Update of TIC's UC-66			◆	
o GHTD R&D Results Display for Seminars and Presentations			◆	
o Technology Transfer Session at GRC Annual Meeting 1983	◆			
o Technology Transfer Session at GRC Annual Meeting 1984				◆
o GHTD/CEC Update of Geothermal Glossary of Terms			◆	

EXHIBIT 12 (Continued)

TECHNOLOGY TRANSFER PROGRAM

MILESTONE CHART

"TACTICAL TASKS"

Activity	1st Qtr 1984	2nd Qtr 1984	3rd Qtr 1984	4th Qtr 1984
o Inventory Recent R&D Projects			◆	
o Categorize R&D Projects		◆		
o Prepare Abstracts on Key R&D Projects			◆	
o Advertise Availability of Abstracts in GRC Bulletin		▬	▬	▬
o Prepare a Series of Articles on Major Technology Developments for GRC Bulletin		▬	▬	▬
o Technical Exchanges at Demonstrations and Test Facilities		▬	▬	▬
o Establish a New Technology Transfer Section in the Geothermal Progress Monitor	◆			
o Develop Technical Information Center Energygrams on GHTD Final Reports	▬	▬	▬	▬
o Education/Training of Geothermal Engineers	▬	▬	▬	▬
o GHTD/DOD Technology Transfer	▬	▬	▬	▬
o Geo-Heat Center Support	▬	▬	▬	▬
o Cooperative/Cost-Shared R&D other than Demonstrations and Test Facilities	▬	▬	▬	▬
o Demonstrations/Pilot Plants	▬	▬	▬	▬

EXHIBIT 12 (Continued)

TECHNOLOGY TRANSFER PROGRAM

MILESTONE CHART

"TACTICAL TASKS"

Activity	1st Qtr 1984	2nd Qtr 1984	3rd Qtr 1984	4th Qtr 1984
o Geothermal Test Facilities				
o Geopressure Geothermal Design Well Testing				
o Geothermal Loan Guaranty Program				
o International Technology Transfer				

EXHIBIT 13

TECHNOLOGY TRANSFER PROGRAM

MILESTONE CHART

"STRATEGIC TASKS"

Activity	1984	1985	1986	1987	1988
o Private Sector Interest and Needs Evaluation	◆				
o Target Group Characterization and Selection	◆				
o R&D Project Identification	◆				
o Mechanism Selection and Implementation	●				
o Program Monitoring and Effectiveness Measurement					
o Program Coordination					

- 2-day Technology Transfer Workshops with industry participation in conjunction with the DOE/GHTD Program Review

- GHTD/GRC Workshop on Patents, Proprietary Information, and Licensing

- GHTD/GRC establishment of Technology Transfer Committee

- EPRI Annual Geothermal Meeting Session on DOE-Sponsored Research for Geothermal Powerplants

- DOE/GRC Workshop on Geothermal Economic/Policy Issues

- GHTD/CE series of Direct-Use Workshops with building and community Systems

- Support Industry Workshops at participating national laboratories to acquaint key industry leaders with current geothermal research and available and near-term technologies developed in the laboratories.

- Publicize private-sector access to geothermal test and evaluation facilities at participating laboratories.

- Initiate GHTD/GRC review and update of the Technical Information Center's UC-66.

- Fund a visual presentation of DOE/GHTD research results for display at professional and technical conferences and seminars.

- Provide support to annual Geothermal Resources Council meeting.

  - Sponsor a Technology Transfer Session at 1984 Meeting

- Initiate GHTD/CEC Update of Geothermal Glossary of Terms.

- Seek further publicity on the GHTD R&D Program through mechanisms such as:

  - Inventory of recent R&D projects

  - Categorization of R&D projects

  - Preparation of abstracts on all R&D projects

  - Advertizing of abstract availability in GRC Bulletin

  - Preparation of a series of articles on major technology developments for GRC Bulletin

- Establish a new technology transfer section in the Geothermal Progress Monitor.

- Monitor performance of Technical Information Center in disseminating final project reports; develop Energygrams.

- Provide for education/training of geothermal engineers.

  - Stanford, Brown, University of Utah, University of Houston graduate research programs

- Promote GHTD/DOD transfer of technology.
  - Identify geothermal applications at military bases and on military-owned land.
- Continue technology transfer and technical assistance at Geo-Heat Center at OIT.
- Publicize demonstrations/pilot plants.
  - Geothermal Test Facility at East Mesa
  - Hawaii 3 MWe Pilot Plant
  - Lost Circulation Test Facility at Sandia
  - Geothermal Pump Test Facility with REDA, Kobe, Centrilift
  - Heber Binary Plant in cooperation with SDG&E, IID, EPRI, SCE, CDWR, CEC
  - Fenton Hill HDR Test Site in cooperation with West Germany and Japan.
  - Honey Lake Geothermal/Wood Hybrid Plant.
- Publicize DOE test facilities available for industry testing.
  - Geothermal Test Facility
  - Geothermal Pump Test Facility
  - Lost Circulation Test Facility
- Promote transfer of international technology.
  - HDR Technology Exchange with Japan and West Germany
  - Cerro Prieto Cooperative Agreement
  - Information Exchange Agreements through IEA

<u>Strategic Tasks - FY 1984</u>

- <u>Evaluation of Private-Sector Interest and Needs</u>

  This will consist of determining the breadth and depth of general private-sector interest and needs for an effective technology transfer program and the degree to which the private-sector will actively participate in and respond to the program.

- <u>Target Group Selection and Characterization</u>

  Since the entire technology transfer effort is geared towards the potential user groups, the ability to accurately isolate and characterize groups interested in technology developments is critical to the program's success.

- <u>R&D Project Identification</u>

  Documentation of the problem areas being addressed by specific R&D projects will help to identify appropriate technology transfer options and define the potential audience. A catalogue of past, current, and planned research will describe the objectives, status, and remaining problems in each area and highlight any special technology transfer efforts already in place.

- <u>Mechanism Selection and Implementation</u>

  GHTD, in developing its long-term Technology Transfer Program, is taking into account changes in industry status and level of technology development in selecting the most effective technology transfer mechanisms. The list of acceptable mechanisms will be essentially the same, but the applicability of specific mechanisms may vary over time according to resource type or technology.

- <u>Program Monitoring and Effectiveness Measurement</u>

  A formal technology transfer program monitoring capability is needed to identify and evaluate specific accomplishments and setbacks during program implementation. Although it is very difficult to measure the impact of technology transfer, it is possible to develop methods for determining the impact by comparing program results to initial objectives of the R&D.

- <u>Program Coordination</u>

  Coordination of the technology transfer program with other relevant programs and organizations must be maintained throughout the program implementation stage to avoid duplicative efforts and promote increased effectiveness of the program.

In summary, GHTD's current technology transfer effort includes the development of a focused Technology Transfer Program that encompasses near-, mid-, and long-term industry needs. Its goal is to support the timely industry adoption of geothermal energy into the Nation's energy supply mix.

TECHNOLOGY TRANSFER PROGRAM MANAGEMENT

A vital component in all technology transfer programs is effective program management to prevent overlapping activities and ensure program implementation and integration. In addition, a commitment to long-term objectives must be made to allow the technology transfer time to occur. These requisite conditions--successful program management and integration of long-term objectives--have been taken into account in delegating technology transfer responsibilities within the GHTD management structure as follows:

Headquarters

GHTD headquarters, with input from field offices and laboratories, will set the Technology Transfer Program goals, establish milestones and budget, and organize implementation activities in concert with its responsibility for the overall geothermal R&D program.

Field Offices

The field offices are responsible for promoting and overseeing regional activities, for reporting to headquarters the specific needs of industry in their areas, and for ensuring technology transfer of the particular R&D activities under their domain.

Laboratories/ORTA's

Each Federal laboratory has established an Office of Research and Technology Applications (ORTA). The purpose of the ORTA's is to provide information and technical assistance to state and local governments, and to cooperate with and assist the Center for the Utilization of Federal Technology and other organizations which link the R&D resources of that laboratory and the federal government as a whole to potential users. The laboratories are also encouraged to involve industry as much as possible in the R&D process.

Contractors/Subcontractors

Every effort is being made to involve private industry and state and local governments in the technology transfer process. The most direct means of implementing this policy is to allow competitive procurement of contracts that could lead to commercialization in the near term.

Industry Associations

GHTD is interacting with several industry associations in support of its technology transfer effort. A primary example of this type of exchange is GHTD's relationship with the Geothermal Resources Council (GRC). The GRC is a non-profit technology transfer organization, and is not directly affiliated with the Federal government. The GRC works in concert, however, with DOE and other geothermal interests to further technology development and industry growth. The GRC sponsors annual conferences, industry review panels, seminars, a monthly journal, and is a clearinghouse for geothermal information and status. The GRC is also a major link between DOE and industry.

SECTION V

GEOTHERMAL LOAN GUARANTY PROGRAM

The Geothermal Loan Guaranty Program was established in 1974 by Public Law 93,410, the Geothermal Energy Research, Development, and Demonstration Act. Modifications were made in the program by P.L. 95-238 and 96-294.

The objective of the program is to assist the private sector in accelerating commercial development and use of geothermal energy by minimizing the financial risks associated with new technology and reservoir uncertainties. Geothermal loan guaranties are provided through the Geothermal Resources Development Fund of $500 million. The guaranties may cover up to 75 percent of loans made to the private sector, and 90 percent of project costs of municipalities and public cooperatives. They thus help reduce a lender's financial risk in making credit available for construction and operation of geothermal facilities, R&D projects, and field exploration. Total values of loan guaranties to an individual borrower are limited to $200 million so that other borrowers and lenders have access to the guaranty. Guaranties are provided for both electric and non-electric projects.

The guaranties issued (as of July 1984) include:

- Northern California Power Agency - $45.0 million, 110 MWe power plant at The Geysers
- Republic Geothermal, Inc. - $9.03 million, field development at East Mesa, California
- Westmorland Geothermal Associates - $29.1 million, field development at Westmorland, California
- Geothermal Food Processors, Inc. - $3.5 million, vegetable drying operation at Brady Hot Springs, Nevada
- California - Utah (CU-1) - $49.4 million, field development at Brawley, California
- Boise Geothermal Inc. - $2.3 million, space heating

- Niland/Parsons and RGI - $99.6 million, field development and 25 MWe power plant at Niland, California

- Oregon Trail Mushrooms - $6.5 million, mushroom growing, Vale, Oregon.

Thus, the current status of the loan guaranty authority is as follows:

($ in millions)

Legislated Loan Guaranty Authority		$500.0
Total Loan Guaranties Issued	- $244.4	
Conditionally Approved Guaranties	- 45.0	
Remaining Loan Guaranty Authority		
Pending Applications (Crescent Valley - $41; Coso - $60)	- $101.0	
Potential Follow-Ons (East Mesa - $78; CU-1 - $25.6)	- $103.6	
	$494.0	$500

SECTION VI

THE INTERAGENCY GEOTHERMAL COORDINATING COUNCIL

The Geothermal Energy Research, Development, and Demonstration Act of 1974 (P.L. 93-410) established a Geothermal Energy Coordination and Management Project. The Project was authorized to:

- Coordinate and manage national geothermal energy R&D programs
- Determine and evaluate geothermal resources
- Develop exploration, extraction, and utilization technologies
- Administer a loan guaranty program.

The Project is the responsibility of the Interagency Geothermal Coordinating Council (IGCC). The IGCC brings together all of the Federal agencies with responsibilities related to geothermal energy development, and serves as a forum for interagency program coordination and information exchange. It develops Federal program plans and goals, and defines actions and policies to be followed by Federal agencies to accomplish these goals.

The structure and membership of the IGCC are shown in Exhibit 14. The Council is chaired by an assistant Secretary of the Department of Energy, and is composed of six major subgroups. The Staff Committee, chaired by a representative of DOE, supports the Council and manages the other groups. The agency members of the Staff Committee are appointed by the Council and represent suborganizations of those Federal agencies on the Council.

The Budget and Planning Working Group coordinates budgets and agency plans for geothermal energy activities. The Group is responsible for coordinating the annual program plans and budgets of the Council agencies and other agencies participating in the Federal Geothermal Program, identifying programmatic and policy issues for Council consideration, monitoring and reporting on the progress of the Federal program, and preparing the Annual Reports of the IGCC.

EXHIBIT 14

Interagency Geothermal Coordinating Council
Acting Chairman: Patrick Collins
Acting Assistant Secretary for Conservation and Renewable Energy, DOE
Council Members:

- Asst. Sec, DOI
  Garrey Carruthers
- Asst. Sec., Treas
  Manuel H. Johnson
- Asst Admin., EPA
  Courtney Riordan
- Asst. Sec., USDA
  John B. Crowell, Jr.
- Asst. Sec., DOD
  Lawrence Korb
- Asst. Sec., DOC
  Fred Knickerbocker
- Asst. Sec., HUD
  Stephen J. Bollinger

Staff Committee
Chairman:
Dr. James C. Bresee, DOE
Committee Members:

- EPA
  David R. Berg
- DOI
  George Brown
- USDA
  Sidney Gray
- Treasury
  Eleanor Bryan
- DOD
  Dennis Hannemann
- DOC
  J.F. Gustaferro
- HUD
  Truman Goins

Budget & Planning Working Group
Chairman:
Ralph Burr, DOE
Working Group Members:

- HUD
  Truman Goins
- DOI
  N.J. Bassin
  Sumner A. Dole, Jr.
  Karl Duscher
  Thomas Henrie
  Don Klick
  Wayne Fernellius
  Daniel Shaw
  Daniel B. Dick
- DOC
  J.F. Gustaferro
- USDA
  Sidney Gray
- DOD
  Dennis Hannemann
- DOE
  David Moses
  Frank Emerson
  Diane Pirkey
  William Wheelock
  Charles Mandelbaum

Institutional Barrier Panel
Chairman:
Vacant: DOE
Panel Members:

- Fed. Energy Reg. Comm.
  Bernard B. Chew
- DOC
  Joseph Gustaferro
- Treasury
  Seymour Fiekowsky
- USDA
  Sidney Gray
- EPA
  David R. Berg
- DOI
  Robert Lawton
  Daniel B. Dick
  N.J. Bassin
  Sumner A. Dole, Jr.
  Fred P. Crafts
- Council of Env. Qual.
  James Mackenzie
- DOE
  James Busse
- HUD
  Truman Goins

Leasing & Permitting Panel
Chairman:
Karl Duscher, DOI
Panel Members:

- DOI
  Robert Conover
  Gerald R. Daniels
  Sumner A. Dole, Jr.
  Kenneth Lee
- USDA
  Sidney Gray

Environmental Control Technology Panel
Chairman:
David R. Berg, EPA
Panel Members:

- DOI
  Sie Ling Chiang
  N.J. Bassin
  Sumner A. Dole, Jr.
  Alan Kover
  Karl Duscher
- DOE
  David Allen
  Gerald Katz
- USDA
  Sidney Gray
- HUD
  Truman Goins

The Group is chaired by a representative of DOE, and its membership includes representatives of each of the Council agencies.

The Institutional Barrier Panel is responsible for assessing legal, environmental, regulatory, and other aspects of geothermal energy, including nongovernment aspects. The Panel is chaired by a DOE member.

The Leasing and Permitting Panel has responsibility for reviewing, analyzing, evaluating, and reporting on existing and proposed legislation and regulations relating to the leasing and permitting of geothermal resources and development on public lands. The Panel provides recommendations to the Council on matters of interdepartmental concern in the area of Federal lands management affecting geothermal resource development. The Panel is chaired by a representative of the Department of the Interior.

The Environmental Controls Panel assesses the adequacy of existing controls for geothermal energy systems, reviews ongoing programs to develop environmental controls, and identifies areas for increased or reduced Federal support. The Panel reviews issues covering pollutant abatement, subsidence, seismicity, and associated areas. A representative of the Environmental Protection Agency chairs the Panel.

SECTION VII

INTERNATIONAL COOPERATION

There is no official DOE policy on its international activities since foreign policy is in the domain of the State Department although DOE does participate actively in international energy affairs. As a result, DOE has certain limited policy objectives, implicit though they be. In their approximate order of importance these objectives include:

1. enhance DOE technical programs by enlarging the talent and/or data pool
2. save time and money through cost and/or task sharing
3. increase national security by encouraging and accelerating a transition by the US and its allies from dependency on imported oil and gas
4. improve the market potential of US technology by developing foreign familiarity with US expertise, products, and institutions
5. improve relations between the US and other nations.

DOE's principal mechanism for achieving its objectives is participation in cooperative activities with counterpart agencies in other countries. These activities are usually conducted under the aegis of an implementing agreement. Bilateral agreements are direct country-to-country understandings; multilateral agreements typically are made through the auspices of a sponsoring organization such as the International Energy Agency (IEA). Cooperative agreements vary with the particulars of each activity, but as a rule each activity calls for the expenditure of resources (i.e., time, money, manpower) by the participants.

The policy objectives are also served through less formal channels of communication such as conferences, symposia and workshops, and exchanges of of information/personnel within the international research community. These forms of technology transfer tend to be intermittent and haphazard, but they are usually inexpensive and can be productive.

COOPERATIVE AGREEMENTS

The cooperative agreements involving geothermal energy in which DOE and its predecessor agencies have participated are listed in Appendix B. Exhibit 15 identifies those countries with which DOE and its predecessor agencies have had ties, either through bilateral or multilateral agreements. Over the years some countries have participated in more than one agreement. The most numerous associations have been with Italy, Japan, Mexico, and W. Germany. Of these only W. Germany lacks major domestic geothermal resources.

The degree to which each agreement seems to meet DOE policy objectives is shown in Exhibit 16. Very few agreements satisfy all five objectives, but many agreements predate the objectives and were made with different purposes in mind. On the whole the agreements conform to the basic tenets of DOE policy.

INFORMAL RELATIONSHIPS

Besides the official ties exemplified by cooperative agreements, less formal relationships have often developed among DOE, its contractors, and foreign research organizations. These interactions have taken the form of simple information exchanges, visits by technical personnel, jointly sponsored seminars, and international conferences. Quite often these activities are a precursor to fullfledged cooperative agreements. For example, the bilateral agreement with Mexico to study the Cerro Prieto field began as exchanges of visits and technical information between staff from the Commission Federal de Electricidad and Lawrence Berkeley Laboratory.

The national laboratories have been particularly active in fostering international cooperation in energy research. The efforts by one laboratory, Los Alamos National Laboratory (LANL), the world leader in the field of hot dry

EXHIBIT 15

NUMBER OF INTERNATIONAL AGREEMENTS IN GEOTHERMAL ENERGY R&D BETWEEN THE U.S. AND OTHER NATIONS

	Agreement Status			
Country	Inactive[1]	Active	Negotiation	Total
Mexico	3	-	1	4
Italy	3	1	-	4
Japan	2	1[2]	-	3
W. Germany	2	1[2]	-	3
United Kingdom	2	-	-	2
New Zealand	2	-	-	2
Iceland	2	-	-	2
Switzerland	1	-	1	2
Portugal	2	-	-	2
Sweden	1	-	-	1
Canada	1	-	-	1
France	1	-	-	1
USSR	1	-	-	1
Greece	1	-	-	1

1 Agreement officially terminated or open-ended without any ongoing activity

2 Extension of agreement under negotiation

EXHIBIT 16

Conformance of Geothermal Energy International Agreements to DOE Policy Objectives (A - agreement achieves objectives; P - agreement partially achieves objectives; blank - no apparent effect.*

Agreement	Objectives 1	2	3	4	5
1. NATO-CCMS	-	-	A	-	A
2. Less Developed Countries	-	-	P	A	A
3. MAGES	A	P	-	-	-
4. Italy (CRN) Bilateral	-	-	-	-	-
5. Geothermal Equipment	A	A	P	A	P
6. Iceland Bilateral	A	-	P	-	-
7. Japan Bilateral	-	-	-	-	P
8. Mexico Bilateral	A	A	P	P	P
9. USSR Bilateral	-	-	-	-	-
10. Hot Dry Rock Technology	A	A	P	P	-
11. Italy (ENEL) Bilateral	P	P	-	-	-

* See page 41 for objectives.

rock research, has attracted an extraordinary number of foreign visitors. Knowledge gained by their visiting scientists has enabled other countries, such as W. Germany, France, Japan, and the United Kingdom, to form their own hot dry rock research programs. LANL's efforts aided in consummation of the IEA multilateral agreement on hot dry rock technology.

OTHER INITIATIVES

Countries with which DOE has discussed closer ties in geothermal research, besides those listed in Exhibit 16, include Argentina, Rumania, China, and Taiwan. In addition, DOE was approached more recently by representatives of Switzerland and the United Kingdom to initiate cooperative hot dry rock research. Under these proposals the U.S. would not be obligated to commit substantial new funds to the cooperative efforts; each side would simply keep the other informed of its findings through exchanges of data and personnel.

During November, 1977, DOE participated in a foreign initiative as a member of a trade mission to Central America to promote U.S. goods and services for geothermal development. An international trade specialist from the Department of Commerce, joined with representatives of five companies and DOE personnel for the two-week tour to Costa Rica, Guatemala, Nicaragua, and Mexico. The mission was rated a success since several companies made equipment sales, and others established valuable business contacts. However, the initiative was never followed up with missions to other parts of Latin America.

SECTION VIII

HISTORY OF THE DOE GEOTHERMAL PROGRAM

The major milestones in the history of the Federal geothermal research and development program are outlined in Exhibit 17. A full discussion of these events is contained in Appendix C.

The budget history of the program, shown in Exhibit 18, reflects major changes in national priorities as well as administrative policies on government spending. In April of 1977, in response to growing national concern over impending energy shortages and prices, the president submitted a major message on energy to the Congress which strongly emphasized the development of alternative energy sources. He directly addressed geothermal energy and said that steps would be taken by the Federal government to foster its development. The first subsequent FY budget for the geothermal program, FY 1978, more than doubled its authorized funding over the FY 1977 budget of $53 million. The budget hit its peak of $158 million the following year, and remained high -- $149 million for 1980 and $137 for 1981 -- until the first budget prepared by a new administration for 1982. This action can be attributed in large measure to two factors -- 1) the budget-cutting process instituted throughout the Federal government, and 2) dilution of public pressure for alternative energy supplies by increased oil availability and reduced costs.

The budget history also reflects changes in strategy and policy within the program itself. Although the concept of involving industry in geothermal development had been implicit from the outset of the Federal program, early emphasis was on basic and applied research at the Atomic Energy Commission and National Science Foundation. (See Exhibit 17.) Commercialization was first phased in at the Energy Research and Development Administration in 1975, but was kept closely tied to basic research. It was not until the program was moved to DOE

EXHIBIT 17

KEY MILESTONES IN HISTORY
OF THE DOE GEOTHERMAL PROGRAM

1971	Geothermal program initiated in Atomic Energy Commission (AEC) under AEC Act amendment mandating research into energy sources other than nuclear power
1972	Geothermal program moved to National Science Foundation (NSF) subsequent to its Research Applied to National Needs (RANN) study of geothermal resources
1973	U. S. Geological Survey (USGS), AEC, and NSF prepared the first Federal Geothermal Program Plan
1974	Geothermal Energy Research, Development, and Demonstration Act (P.L. 93-410) enacted which also established the Geothermal Loan Guaranty Program
	Energy Reorganization Act (P.L. 93-438) enacted authorizing creation of the Energy Research and Development Administration (ERDA)
	Federal Nonnuclear Energy Research and Development Act (P.L. 93-577) enacted mandating that ERDA conduct a comprehensive program of basic and applied research and development of geothermal energy (and other energy resources), including demonstration of practical applications
1975	ERDA formed; Division of Geothermal Energy (DGE) staff drawn primarily from NSF, AEC
1978	DOE formed pursuant to Department of Energy Act (P.L. 95-238); DGE continued to manage geothermal program
1979	Division of Geothermal Resource Management (DGRM) was created under the Assistant Secretary for Resource Applications with the mission to commercialize geothermal energy utilization; research and development continued in DGE under the Assistant Secretary for Technology Development
1981	DOE reorganization merged DGE and DGRM into the Geothermal and Hydropower Technologies Division

EXHIBIT 18

BUDGET HISTORY OF THE DOE GEOTHERMAL PROGRAM

($ in millions)

	Hydrothermal Resources	Geopressured Resources	Geothermal Technology Development	Other	Total
FY 1976	$13.3	$ 0.3	$14.5	$3.2	$ 31.4
TQ*	5.0	0.8	4.7	1.3	11.8
FY 1977	23.7	6.6	17.8	4.9	53.0
FY 1978	54.5	16.5	35.2	1.7	108.0
FY 1979	70.9	27.7	57.6	1.8	158.0
FY 1980	70.4	36.0	41.0	1.8	149.2
FY 1981	55.4	31.9	47.9	2.3	137.5
FY 1982	31.2	16.7	20.4	1.6	69.9
FY 1983	33.0	8.4	14.4	1.3	57.6
FY 1984	2.0	5.0	21.4	1.0	29.4
FY 1985	-0-	3.5	22.6	1.0	27.1

*Three-month period when Federal government changed its fiscal year start from July 1 to October 1.

in 1977 that a formal commercialization program was established to promote early use of hydrothermal resources for both power generation and direct uses. The functions of this multi-faceted program are identified in Exhibit 19.

The FY 1978 budget was the first to reflect this major shift in emphasis and the creation of the Division of Geothermal Resource Management under the Assistant Secretary for Resource Applications. The funds for that year, shown in Exhibit 18 under the current term "Hydrothermal Resources," totaled more than those allocated to all the other program elements combined. The budget for commercialization rose to over $70 million for FY 1978 and remained at nearly that peak for FY 1980.

By FY 1981, however, a policy decision had been made to rely on the marketplace and the incentives of the National Energy Act for geothermal energy "industrialization." Even the term had changed since further direct use programs were not anticipated. Exhibit 18 reflects the continued reduction of funds for industrialization from that time, and no funds are allocated for FY 1985. The focus now is almost solely on technology development to permit utilization of all four types of resources.

EXHIBIT 19

The Hydrothermal Commercialization Process

	Developmental Phase	Barriers	Organizations/Entities Involved	DOE Activities for Removing Barriers
FIELD DEVELOPMENT	GEOPHYSICAL SURVEY	- Lack of Existing Data and Maps - Deficiencies in Equipment and Procedures - Non-Existence of a Well Established Geothermal Exploration Industry	o USGS o Exploration Service Companies o Developers	- Reservoir Identification Data Base Development (USGS) - Dissemination of Geophysical Information - Development of Improved Instruments and Techniques
	LEASING	- Exclusion of Certain Federal Lands - Limits on Acreage - Long Time for Processing Applicatior - Conflicting Regulations - Lack of Uniformity in Resource Definitions - Inadequate or Inappropriate State Laws	o USGS o BLM o USFS o USFWS o State and Local Agencies	- Increased Acreage Limits - Phased Developmental Reviews - Review and Revision of KGRA Criteria - Time Limits for Processing Leases and Permits - State Law Project - Coordination with Land Management Agencies
	EXPLORATION	- Delays in Permitting - High Costs - Lack of Financing for Small Developers - Difficulty in Confirmation - Inadequate Technology - Lack of Available Drilling Rigs	o Developer o Drilling Companies o Exploration Service Companies o Regulatory Agencies	- Elimination of Discriminatory Tax Treatment - Reservoir Confirmation Drilling Support - Development of Improved Drilling and Completion Methods - Development of Improved Interpretation Techniques - Development of Improved Tools for Well Logging
	RESOURCE CHARACTERIZATION AND MANAGEMENT	- Uncertainty about Fluid Characteristics - Uncertainty about Reservoir Life - Inadequate Reservoir Engineering Models	o Developer o Exploration Service Companies o State Agencies	- Development of Improved Tools for Measurements - Development of More Accurate and Reliable Reservoir Assessment and Engineering Models - Preparation of Reservoir Case Histories - Reservoir Confirmation Drilling - State-Coupled Resource Assessments
MARKETING	SALE AGREEMENT BETWEEN DEVELOPER/ UTILITY (USER)	- Lack of Interest by Utilities - Restrictive Regulations - High Perceived Risk/Regulated Rate of Return - Lack of Understanding of Market	o Developer o Utility o Non-Utility Power Producers o Broker o Regulatory Agencies	- Market Studies and Comparative Analysis - Loan Guarantees - Outreach Program to Educate Small Utilities - Coordination with REA - Regulatory Exemptions and Tax Credits for Non-Utility Power - Promotion of Brokering Activities - Provision of More Favorable Rate Treatment - Reservoir Insurance - Cost-Sharing for Reservoir Demonstration Plants and Oil Backout - Development of Small Power Plants - FERC Interconnection Authority
PLANT CONSTRUCTION & OPERATION	PLANT DESIGN AND CONSTRUCTION AND FIELD PRODUCTION	- Lack of Standardization - Lack of Operating Experience - High Cost and Risk - Delays in Permitting - Lack of Cooling Water - Marginal Productivity or Temperatur	o Utility o A & E Firm o Contractor o Equipment Suppliers	- Development of Improved Standardized Equipment - Plan Design Handbooks and Seminars - Demonstration of New Technology and Components - Streamlining of Permitting - Loan Guarantees
	PLANT OPERATION AND PROTECTION OF THE MANAGEMENT	- Lack of Operating Experience - Stringent Environmental Standards - Fluid Disposal Problems - Unproven Environmental Control Technology	o Utility o Regulatory Agencies	- Demonstration of Operation of Cost-Shared Plants - Environmental Data Base Development - Improved H_2S Control Technology - Formulation of Appropriate Regulations - Development of Methods for Fluid Disposal
	TRANSMISSION OF POWER TO ELECTRIC GRID	- Separation Between Power Plant and Consumer - Difficulties in Wheeling Power	o Utility o Regulatory Agencies	- Provision of Favorable Rules for Wheeling Power

SECTION IX

THE ROLE OF U.S. GEOLOGICAL SURVEY IN GEOTHERMAL DEVELOPMENT

When interest in the geothermal resource developed in the early 1970's and the Federal geothermal program was born, the U.S. Geological Survey (USGS) had a ready-made base of knowledge on geothermal fluids, volcanoes, and the thermal structure of the earth's crust. Since that time, the Survey has provided the bulk of the knowledge available on the location, size, and temperatures of U.S. reservoirs.

Three key publications have synthesized the results of a myriad of individual projects to address the principal objective of the Survey's Geothermal Research Program -- a quantitative assessment of the Nation's geothermal resources. Publication of Geological Survey Circular 726, "Assessment of Geothermal Resources of the United States - 1975" (White and Williams, 1975), represented the first such national assessment based on a consistent, well--documented methodology, supported by tabulated data on the physics and chemistry of known geothermal systems. Geothermal resources were calculated as that fraction of thermal energy stored in the crust that might be recoverable at the surface, with reasonable assumptions of future technology and economics.

Three years later, after the Geothermal Research Program had existed long enough to have completed studies of several of the principal geothermal systems, an updated assessment was published as Geological Survey Circular 790, "Assessment of Geothermal Resources of the United States - 1978" (Muffler, 1979). These documents differ in some details because of the large body of new data amassed between 1975 and 1978.

In 1983, a similar document entitled "Assessment of Low Temperature Geothermal Resources of the United States -- 1982" was published. This document, USGS Circular 892, covers the Nation's geothermal resources with temperatures of less than 90°C. These fluids are primarily suitable for direct heat applications.

The resource definition programs of GHTD, and its predecessors, have emphasized site-specific reservoir confirmation and evaluation in prior efforts to commercialize the resource. The USGS assessment mandate, on the other hand, requires it to concentrate its efforts on more generic and regional studies, aimed at the characterization and fundamental understanding of all types of geothermal systems and at an overall national assessment of the distribution and magnitude of geothermal resources. The programs of the two agencies are complementary and closely coordinated. USGS has implemented much of the GHTD work.

For example, USGS has conducted a GHTD-funded multidisciplinary study of the Cascades Range of the Pacific Northwest. Geophysical, geochemical, and hydrologic data were gathered and research drilling performed in order to assess the potential of this area where indicated hydrothermal systems are masked near the surface by a cooler shallow zone. Electrical and seismic surveys are continuing at the Newberry Caldera in the area.

USGS is also participating in the GHTD magma energy extraction research. The Survey has previously identified magma sources potentially reachable with current technology. Additional geologic studies will provide information to serve as a basis for selecting final candidates for the site of magma experiments.

The Survey also maintains a scientist, currently Ray Wallace, at GHTD HQ for day-to-day liaison activities. In addition, Mr. Wallace is developing recoverability estimates for geopressured resources.

SECTION X

THE ROLE OF FEDERALLY-OWNED LANDS IN GEOTHERMAL EXPLOITATION

It is estimated that over 90 percent of the identified hydrothermal resources in this country lie beneath Federally-owned land. This occurrence derives from the fact that they are located in far western states where the Federal Government retains title to a large portion of the states' acreage -- e.g., 84 percent in Alaska and 86 percent in Nevada.

This land has been available for decades for oil and gas and other mineral development through a leasing system. However, it was not until passage of the Geothermal Steam Act (P.L. 91-581) in 1970 that the Department of the Interior was authorized to lease the land for geothermal development and to supervise all geothermal operations taking place on the land.

Until recently, this twofold authority was divided between two agencies within the Department. The Bureau of Land Management (BLM) acted as lessor and the U.S. Geological Survey (USGS) had the role of post-lease "policeman." Now, however, both responsibilities lie within BLM, although the regulations for both may still be found in separate parts of the Code of Federal Regulations:

- Title 43, Part 3200, Geothermal Resources Leasing
- Title 30, Parts 270 and 271, Geothermal Resources Operations and Unit Plan Regulations

LEASING

Geothermal leases may be issued on all Federal lands available for leasing, including lands controlled by BLM and the national forests administered by the U.S. Forest Service. BLM actually issues all leases, but cannot lease Forest Service lands without its consent. National parks, wilderness areas, wildlife refuges, and similarly protected areas are not available for leasing.

There are two types of leases -- competitive and non-competitive. Competitive bidding is required for land which is designated as a Known Geothermal Resources Area (KGRA). The complex criteria for this designation are spelled out in the Steam Act, but, in general, they mean that 1) there is good indication of a commercially-viable resource present, or 2) the acreage covered by two non-competitive lease applications overlapped by 50 percent or more, creating what is called a "competitive interest" KGRA. Competitive lease sales are held for specific tracts of land after the potential environmental effects of geothermal development on the area are reviewed, their sale value is determined, and public notice is issued.

For a number of years, the sale of attractive parcels in the KGRA's was subject to considerable delay due to extensive review of the potential environmental consequences of issuing leases in specific areas required by both the National Environmental Policy Act (NEPA) and BLM and Forest Service regulations. Now, however, nearly all of this acreage that can be leased has been offered.

A summary of competitive bidding by state is shown in Exhibit 20. The U.S. Government has collected over $76 million in bonus bids from competitive geothermal lease sales since the program began in 1974, with bids ranging from $1 per acre to over $11,000 per acre. The latter bid and other extremely high ones nearly all reflect the degree of interest in The Geysers area in California.

Anyone may file a non-competitive lease application for any available Federal land, although it will be rejected if the applied-for acreage includes any KGRA land. The application must be accompanied by a $1 per acre rental for the first year of the lease term plus a filing fee.

The issuance of individual non-competitive leases was also subject to lengthy delays due to the environmental review process. Delays of two years

EXHIBIT 20

COMPETITIVE GEOTHERMAL LEASING, BY STATE,
TOTAL ACREAGE LEASED, BY YEAR

STATE	1974-1976	1977	1978	1979	1980	1981	1982	1983	TOTAL
Arizona	0	0	0	0	0	0	780	0	780
California	36,937	2,856	4,395	6,959	10	84,914	168,411	40,568	347,350
Colorado	5,036	0	0	0	0	0	0	0	5,036
Idaho	24,903	6,985	0	0	0	0	1,833	5,901	39,612
Nevada	120,996	36,663	9,322	24,298	20,419	15,304	0	0	227,002
New Mexico	32,564	48,065	8,767	7,063	0	13,835	4,391	7,007	121,692
Oregon	68,872	0	5,818	0	32,630	0	16,411	4,706	128,438
Utah	76,539	12,788	1,658	0	0	0	9,230	0	100,215
Washington	0	0	0	0	0	0	2,307	0	2,307
Total Acres Leased	365,847	107,357	29,960	38,320	53,059	114,053	203,363	58,182	972,432

and more were common. Now, however, by regulation, BLM has categorically exempt noncompetitive leases from this review where there will be subsequent NEPA compliance prior to development. A similar policy is being tested by the Forest Service. Such action is justified by the fact that surface disturbance occurs on only one in 10 non-competitive leases, and drilling activity is very rare.

As a result of this move, issuance of leases on BLM-admistered land is relatively timely, although lease/no lease decisions by the Forest Service are still subject to considerable delay in some areas. Despite the best efforts of the service to expedite leasing, the competing interests for the use of the forests are making this change very difficult.

Exhibit 21 summarizes the non-competitive leasing activity by state as of September 30, 1983, showing BLM/Forest Service breakdowns. This is the last in the series of such summaries to be prepared; subsequent changes can be expected to be very gradual.

Some of the applications shown rejected in Exhibit 21 were refused on the basis of the environmental sensitivity of the acreage applied for. This occurrence accounts for only a small percentage, however, and the large bulk of rejections is due to purely procedural reasons such as applicant failure to properly execute the application.

In order to foster the earliest development on geothermal leaseholds, each lease includes provisions requiring "diligent exploration" until there is a well or wells capable of commercial production on the leased land. "Diligent exploration" means the annual expenditure of specified sums of money per acre for such activities as geochemical surveys, core drilling, or drilling of test wells. The lessee is permitted to pay $3 per year per acre in additional rental in lieu of these expenditures. This provision of 43 CFR, 3203.5 was amended in the Federal Register of 20 April 1983.

EXHIBIT 21

NONCOMPETITIVE GEOTHERMAL LEASING
MONTHLY SUMMARY STATUS REPORT

AS of: September 30, 1983

STATE	APPLICATIONS: FILED BLM	FILED FS	FILED SUBTOTAL	WITH DRAWN	REJECTED	AWAITING ACTION BLM	AWAITING ACTION FS	REFUSED	LEASES: ISSUED BLM	ISSUED FS	ISSUED SUBTOT	ACRES BLM	ACRES FS	ACRES SUBTOTAL
ALASKA	-	14	14	-	-	-	14	-	-	-	-	-	-	-
ARIZONA	109	91	200	72	35	16	36	8	32	1	33	55,844	1,920	57,764
CALIFORNIA	906	686	1,592	658	333	77	250	36	139	99	238	242,681	185,942	428,623
COLORADO	122	129	251	152	19	2	23	5	43	7	50	52,064	10,433	62,497
IDAHO	696	370	1,066	357	199	1	159	79	266	5	271	451,044	9,263	460,307
MONTANA	38	66	104	67	28	-	3	-	6	-	6	10,687	-	10,687
NEVADA	2,339	37	2,376	774	454	64	5	98	969	12	981	1,771,040	21,540	1,792,580
NEW MEXICO	706	42	748	392	109	9	0	35	201	2	203	347,767	3,826	351,593
OREGON	698	893	1,591	423	356	4	378	0	258	172	430	404,287	339,206	743,493
UTAH	757	113	874	281	177	5	8	23	364	12	376	684,353	14,655	699,008
WASHINGTON	1	447	448	207	88	1	120	0	0	32	32	0	63,143	63,143
WYOMING	26	143	169	141	17	-	7	-	-	4	4	-	7,448	7,448
EASTERN STATES	-	12	12	-	1	-	-	-	-	11	11	-	19,744	19,744
TOTALS	6,398	3,043	9,441	3,524	1,816	179	1,003	284	2,278	357	2,635	4,019,767	677,120	4,696,887

The primary lease term is 10 years. If commercial quantities of geothermal steam/fluids are produced or utilized within the primary term, the lease will remain effective so long as commercial production or utilization continues, up to another 40 years. The lessee has a preferential right to another 40-year term if certain conditions are met.

The leased land may be utilized for power generation or direct use applications. The CFR amendment spelling out utilization procedures was published in the Federal Register of 20 April 1983.

The amount of the royalty to be paid to the government on the geothermal steam/fluid produced is set in the lease. It may range from 10 to 15 percent of the value of the energy produced and five percent of the value of most byproducts. It is collected by the Minerals Management Service.

Federal lands may be explored for geothermal manifestations without a lease. Geoscientific surveys may be carried out and shallow temperature gradient holes may be drilled under a Notice of Intent to Conduct Geothermal Resource Exploration Operation permit, commonly called the "NOI."

The major remaining obstacle in the Federal geothermal leasing program is the limitation on the amount of acreage that may be held by any one person or company in any one state. Legislation has been pending in Congress for about five years to increase the current limitation of 20,480 acres to 51,200 acres, the current limitation on oil and gas leases.

POST LEASE OPERATIONS

Once a lease is obtained, the lessee becomes subject to the ground rules found in the above-referenced CFR Title 30. He may still conduct preliminary exploration under an NOI, but before any deep drilling or production can occur, he must file a plan of operation for each successive stage of development and receive approval for the activity. The regulations were first interpreted to require an environmental review for each plan. Thus, the sequence of filing of plan, environmental review, and approval/rejection was a revolving cycle.

This process has now been eased to some extent, and thereby the delays it frequently caused. This improvement was brought about by the categorical exemption of surface exploration from the BLM NEPA requirements, and conditionally exempting subsequent actions from environmental review if the potential consequences of the proposed action have already been covered in a previous review. For example, approval of a plan for production is exempt when it is derived from a plan for utilization which was covered by an environmental document.

BLM also has the power originally given to USGS to halt production under emergency conditions and to enforce compliance with all applicable environmental regulations and the formal orders issued by USGS governing operations involving drilling, pipelines, and surface facilities. These orders are called Geothermal Resources Operations Orders, or GRO's. One year of site-specific baseline environmental data must be collected before a plan for production may be submitted.

SECTION XI

THE U.S. GEOTHERMAL COMMUNITY

The U.S. geothermal community consists of the four groups of entities identified in Exhibit 22 -- Federal agencies, non-federal governments, the for-profit, or industrial sector, and non-profit entities.

FEDERAL AGENCIES

The contributions by Federal agencies to geothermal development in this country are identified in Exhibit 23. While all of these services may impact development to some extent, the most important assistance provided to industry can be summarized as follows:

- Technology development by DOE
- Resource assessment by USGS
- Leasing of Federal land for geothermal exploitation and oversight of development operations by BLM.

NATIONAL LABORATORIES AND UNIVERSITIES

As noted in Section III, the non-profit national laboratories along with universities serving as their sub-contractors can be considered the research arm of DOE. The laboratory expertise is first integrated into the planning of the GHTD R&D program to ensure that the program is balanced and meets the needs of those who will utilize the technologies developed. The laboratories are then responsible for accomplishing assigned R&D under various program elements. In organizing their R&D programs, they contract some work to universities, or to commercial firms when products are involved.

The major laboratories which support DOE programs and the major technical areas assigned to them are identified in Section III.

NON-FEDERAL GOVERNMENTS

The major participation in geothermal development by non-federal governments is provided primarily by states, with some exceptions such as Imperial

EXHIBIT 22

THE GEOTHERMAL COMMUNITY IN THE U. S.

Federal Agencies

- Energy
- Interior
- Agriculture
- Environmental Protection Agcy.
- Treasury
- Commerce
- Defense
- Housing & Urban Development

Non-Federal Governments

- State
- Local
- City/Township
- Regulatory Commissions

For - Profit Entities

- Utilities
- Developers
- Service Industries
- Component Manufacturers
- Other Contractors

Non-Profit Entities

- Scientific Labs
- Universities
- Other

Source: Geothermal Energy, Research, Development, and Demonstration Program, 4th Annual Report, Interagency Geothermal Coordinating Council, June 1980

EXHIBIT 23

OVERVIEW OF FEDERAL AGENCY CONTRIBUTIONS TO GEOTHERMAL DEVELOPMENT

SECTOR	CONTRIBUTIONS
DEPARTMENT OF ENERGY	
Geothermal and Hydropower Technologies Division	Prototype technologies Technology transfer Resource assessment Cost-shared projects
Geothermal Resources Development Fund	Guarantied loans
DEPARTMENT OF THE INTERIOR	
Bureau of Land Management	Land for development Supervision of operations (to ensure best use of the resource and provide public protection)
U. S. Geological Survey	Identification, characterization, and quantification of geothermal resources in the U. S. Geohydrological studies of subsidence and seismic activity related to geothermal development
Fish and Wildlife Service	Recommendations for biological and ecological protection in both pre- and post-lease phases of development

EXHIBIT 23, Continued

SECTOR	CONTRIBUTIONS
DEPARTMENT OF AGRICULTURE	
U. S. Forest Service	Land for development
TREASURY DEPARTMENT	Loans under the guarantied loan program through Federal Financing Bank; administration of the tax incentives applicable to geothermal development
DEPARTMENT OF COMMERCE	
Economic Development Administration	Potential funding or loan guarantees to stimulate business development (geothermal projects would not receive special consideration because of their use of the resource)
DEPARTMENT OF DEFENSE	Assessment of geothermal potential for use at military installations; installation of electric power generation facility at China Lake Naval Weapons Center, California; construction of direct use heating system at naval base in Iceland; plans for other direct uses
DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT	Funding for community planning and development projects utilizing alternative sources of energy; four feasibility studies for geothermal district heating and cooling systems; two under development

County, California. The major state contributions, identified in brief in Exhibit 24, are as follows:

- Assessment of the geothermal resource base within the state, funded by DOE, and other scientific participation by the various state geology departments.
- Collection of pertinent technical information by the state energy offices which also perform a "public relations" role for geothermal development.
- Issuance of leases on state-owned land for geothermal development. Some states, notably Idaho, have a very liberal leasing policy and have leased large amounts of acreage.
- Issuance of environmental permits which allow the construction and operation of geothermal facilities. This function, if properly executed, will ensure that geothermal operations do not degradate the environment and create public antipathy to geothermal development.

On the adverse side, state water right laws in the water-short western states may tend to hinder geothermal development in some areas. The provisions of the law itself and the attitude of the state officials administering it should be among the first concerns of a potential developer.

GEOTHERMAL INDUSTRY

The geothermal industry consists of hundreds of industrial firms, although their size, commitment, profitability, and level of activity vary widely. In its present form, the industry is dominated by a core group of traditional companies with well-defined programs oriented toward electric power generation. Another distinct group, consisting of companies and joint ventures attracted by geothermal direct heat opportunities, has started to emerge.

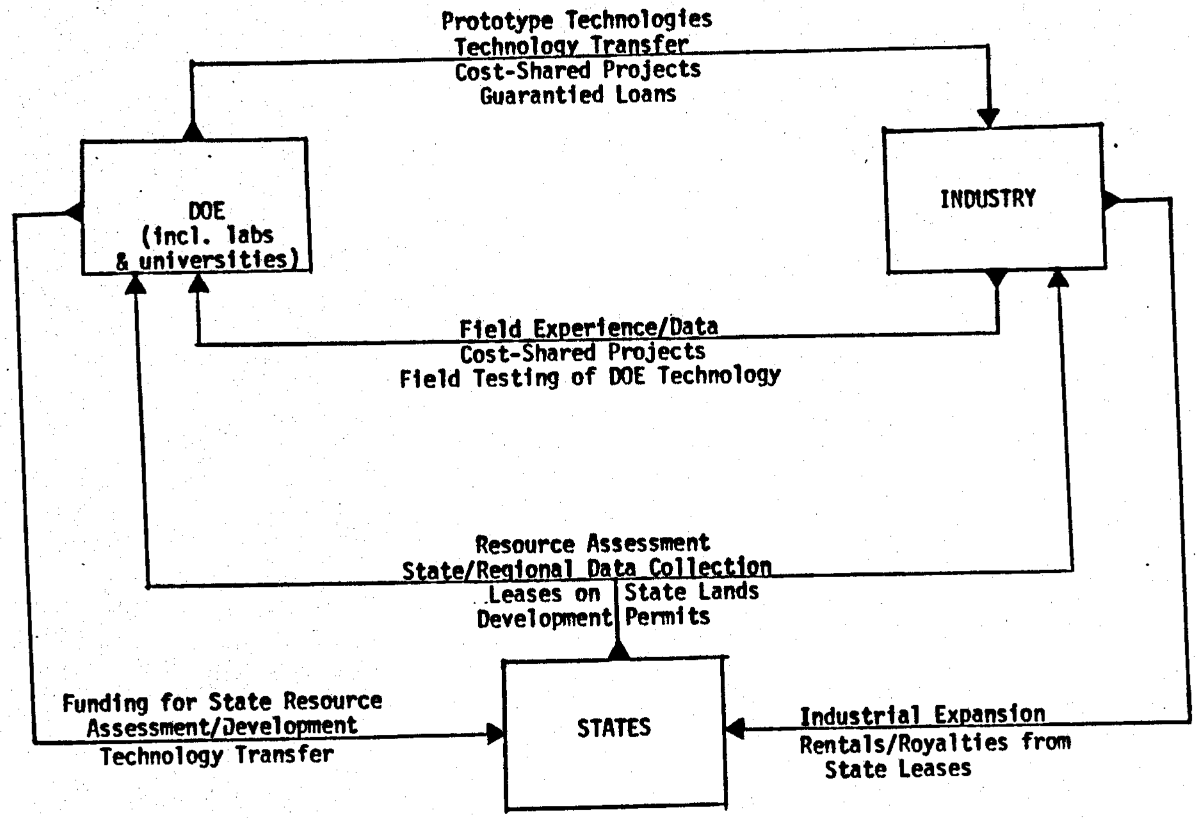


EXHIBIT 24

INTERACTION AMONG DOE, INDUSTRY, AND STATES IN GEOTHERMAL DEVELOPMENT

The core group of traditional companies has evolved as a result of the pioneering efforts to develop the steam-dominated hydrothermal resource of The Geysers. This group is composed primarily of four distinct types of industrial entities that are oriented to particular phases of development. Most of the companies in the categories described below have assumed more than one role and thus have been engaged in more than one phase of resource development.

- Energy companies include both small and large firms, including large oil companies, whose mission is to supply energy. Their geothermal efforts are focused on producing steam or fluids for electric power generation. These firms have been very active in exploring for and developing the resource rather than in building power plants or using the geothermal energy.
- Geothermal companies have usually been formed for the express purpose of developing geothermal energy. Though generally small, some have affiliations with large energy companies. Their current role ranges from exploration support to production, including promotion of joint action between energy companies as operators and utilities or non-utility firms as users.
- Engineering companies include both small, special-purpose engineering companies that are pioneering certain plant design concepts or components and large A&E firms that design and build geothermal plants as well as other energy-generating plants. They are often the technical link between the developer/operator and the final user of the resource. In some cases, they market geothermal energy to users (generally utilities) and even underwrite project risks.
- Electric energy suppliers, the most significant users in the current industry structure, include regulated and nonregulated utilities,

municipalities, and some large industries with a substantial need for electric power. U.S. users are currently located exclusively in the west near major geothermal resources.

The traditional core of the industry has established industrial components with well-defined roles, accepted technological objectives, and limited geographical orientation. The evolving part of the industry -- that portion involved in developing direct applications of geothermal heat -- is currently somewhat unfocused, loosely structured, and characterized by differentiated and distributed markets.

It is in the use of the resource that the electric and non-electric segments of the industry basically difffer. The principal non-electric users are firms seeking access to geothermal energy, small resource owners wishing to develop and use themselves or sell the resource, and engineering companies or companies formed as general promoters/developers to put together complete development packages. Unlike the established industry, which has electric power production as the common objective and focuses on specific centralized markets (i.e., utilities), the direct heat industry is interested in a wide variety of applications at dispersed locations. Many of the activities of the evolving direct heat segment of the industry were originally oriented around government-sponsored and funded programs.

The interaction among DOE, state governments, and industry in geothermal development is shown in Exhibit 24. Major companies in the geothermal development industry are identified in Exhibit 25.

EXHIBIT 25

MAJOR COMPANIES INVOLVED IN GEOTHERMAL DEVELOPMENT

A&E/ DESIGN	DEVELOPERS/ OPERATORS	UTILITIES/ INDUSTRY USERS
• Fluor Power	• Union Oil	• Pacific Gas & Electric
	• Chevron Oil	• San Diego Gas & Electric
	• Magma Energy	• Southern California Edison
	• Grace Geothermal	• National Rural Electric Cooperative
	• Republic Geothermal	• Northern California Power Agency
	• Geothermal Resources International	• Dravo
	• Pacific Energy	• Parsons Engineering

SECTION XII

GEOTHERMAL DEVELOPMENT ABROAD

This section consists of a paper presented to the 11th Energy Technology Conference in March 1984 by Ronald DiPippo of Southeastern Massachusetts University.

DEVELOPMENT OF GEOTHERMAL ELECTRIC POWER PRODUCTION OVERSEAS

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INTRODUCTION

The purpose of this paper is: (1) To provide a thumbnail sketch of the historical development of geothermal energy as a source of electricity; (2) to describe some of the factors that have impeded the growth of geothermal power; (3) to offer a snapshot of the worldwide state of affairs in geothermal power generation; (4) to highlight some of the interesting developments overseas; and (5) to venture a few guesses as to future prospects. Also a short but useful reading list is included for those readers in need of a more detailed review.

HISTORY

Geothermal electric power generation was born in 1904 when Prince Piero Ginori Conti harnessed the natural steam that issued from the earth in Italy's Tuscany region to drive a 15 kW reciprocating steam engine/generator set. The DC power provided electric light for the boric acid factory at Larderello which was in the business of extracting minerals from the geothermal fluids. In a real sense, Conti was the pioneer of industrial/geothermal cogeneration.

During the more than 70 years since then, Italy has steadily increased its use of geothermal steam for power generation to the point where the easily tapped resources at Larderello and the nearby fields have been essentially fully exploited, and attention is now focused on more challenging, liquid-dominated and highly-mineralized geofluids.

Until the 1960's, Italy stood as the only country putting geothermal energy to use for electricity generation although several countries, such as Iceland and Japan, had traditionally used geothermal energy for direct heating applications. The decade of the 1960's saw worldwide geothermal power begin to appear in significant amounts. New Zealand, the United States, Japan, the Soviet Union, and Iceland all completed power plants, and at the beginning of the 1970's, there were about 700 MW of installed geothermal capacity among those six countries.

During the 1970's, even more nations joined the geothermal group: Mexico, El Salvador, Turkey, the Philippines, China, Indonesia, and the Azores (Portugal). By far the most significant developments during this period took place in the Philippines where the Oil Crisis of 1973 spurred a serious effort to reduce their dependence on foreign oil through rapid development of indigenous energy resources.

So far the 1980's have seen the construction of the first geothermal power plant on the African continent, further development of the abundant geothermal resources in Central America, and continued expansion in the Philippines, Mexico, and Indonesia. Based on recent and projected growth rates, it is likely that there will be at least 8500 MW of geothermal power capacity on line worldwide by the year 1990. Table 1 traces the growth of geothermal capacity from 1950 to the present.

IMPEDIMENTS TO GROWTH

In spite of enormous estimates of the size of the geothermal resource worldwide, only a tiny fraction has as yet been developed to the commercial level. Only the most readily accessible and most easily manageable resources have been exploited for several reasons.

Materials Inadequacies Geothermal fluids can be highly corrosive and/or scaling, causing failure of wells, pipes, heat exchangers, turbines, valves, etc. Exotic alloys and complex chemical treatment systems can solve these problems technically, but often at unacceptably high cost.

Imperfect Understanding of Reservoirs A huge research effort has been directed toward modeling fluid flow in reservoirs, but it is still difficult to calculate with confidence the behavior of a geothermal reservoir under production conditions particularly over the long term. This raises the level of risk for a power plant developer who must count on a secure and predictable flow of geofluid for 20-30 years. This has been underscored recently by the failure of the Baca project in New Mexico.

Site-Specific Nature of Resources Each geothermal prospect is different in every regard. Although standard techniques have been devised for exploration, they must be adapted to a wide variety of geographies. It is not possible to design a standard power plant for all geothermal resources; each must be tailored for the physical and chemical properties of the particular geofluid.

Cheap Sources of Electricity Cheap alternatives such as hydroelectricity and oil-fired plants held back geothermal development through the middle part of this century. In some countries hydropower, where available, is still the preferred method of generation.

Worldwide Economic Problems Most recently the deep economic recession has dampened geothermal developments in nearly all countries. Funding for projects typically must come from such organizations as the World Bank, the United Nations Development Program, the Asian Development Bank, the Interamerican Development Bank, the European Economic Community, and the European Investment Bank. Without such aid, countries and electric power companies would not be able to afford the large initial capital investments required for geothermal projects.

Environmental Impact Although not a major impediment in most countries (outside the U.S.), concerns about the environment have delayed construction of power plants, notably in Japan and New Zealand. Owing to the toxic nature of some of the impurities found in geofluids, proper disposal techniques are required in sensitive areas.

Political Instability and Civil Wars Regional unrest in Central America and several African states has seriously interfered with the growth of geothermal energy. For example, good prospects in El Salvador, Nicaragua, Guatemala, and Costa Rica are not being exploited. These kind of political problems often accompany economic problems, and it is difficult if not impossible to separate them.

GREATEST DEVELOPMENTS

Outside the United States, the most progress in putting geothermal steam/hot water to use for electricity generation has taken place in the Philippines, followed by Italy, Japan, Mexico and New Zealand. Table 2 summarizes the worldwide status of geothermal plants as of the end of 1983. There were 139 separate plants generating a total of just under 3400 MW. Within the next two years this could exceed 5800 MW.

Philippines Four fields are now producing power: Tongonan, Tiwi, Mak-Ban (Makiling-Banahaw), and Palimpinon (Puhagen). See Figure 1. Table 3 lists the plants. All four fields are being extended and several new areas are being developed. It is expected that power will soon be coming from the Bacon-Manito and Daklan fields. Within two years, there could be over 1700 MW on line, constituting over 18% of the electric power of the Philippines.

Italy Forty small units generate over 450 MW in three general areas: Larderello, Travale and Monte Amiata. See Figure 2 and Table 4. The plants are relatively simple since the resources are all dry-steam type. The steam is, however, laden with significant amounts of noncondensable gases such as carbon dioxide, which in some cases dictates the use of noncondensing turbines. Two liquid-dominated reservoirs are being drilled, Latera and Mofete, and small plants should be installed at each site in the near future.

Japan Over 227 MW is installed in eight plants ranging in size from the 3 MW unit at the Suginoi hot-spring resort hotel to the 55 MW Hatchobaru double-flash plant. See Figure 3. Japan operates a variety of types of plants as can be seen from Table 5. In the late 1970's, the government conducted research on two 1 MW binary-type plants in preparation for larger commercial units, but none has been built to date. The plants at Kakkonda and Hatchobaru will each be replicated in the near future. As the world's most volcanically active country, Japan's geothermal potential is staggering...several tens of thousands of megawatts. It seems likely that only a tiny fraction of this will ever be developed owing to the economics and environmental constraints.

Mexico Two huge fields, Cerro Prieto and Los Azufres, now produce electric power, and a third, Los Humeros, is expected to come on line in the near future. See Figure 4. Cerro Prieto will eventually support 1000 MW. It lies just south of the international border between Mexico and the U.S., and both Southern California Edison and San Diego Gas and Electric have purchased rights to future power from Cerro Prieto. Within the next 12 months, an additional 440 MW will be installed at Cerro Prieto II and III, two 110 MW units at each. Los Azufres is a unique reservoir, the northern sector being liquid-dominated and the southern sector being vapor-dominated, producing dry or even superheated steam. Several 55 MW units are planned for this area. Table 6 gives the present plants in Mexico.

New Zealand The first ever commercial production of electricity from geothermal energy using a liquid-dominated resource took place in New Zealand. The Wairakei plant had an installed capacity of 192.2 MW, but recently has been partially decommissioned due to a decline in reservoir pressure. It now stands at 157.2 MW. See Table 7. There is no pressing need for more electricity in New Zealand now, and thus several good prospects are essentially on hold. These include: Ohaaki (Broadlands) where a plant is expected in 1988, Ngawha, and Mokai. See Figure 5. Extensive research into the nature of geothermal reservoirs has been conducted at the fields in New Zealand, greatly advancing our understanding of this complex subject.

AREAS OF EXPECTED GROWTH

Besides those countries mentioned in the preceding section, we expect to see measurable growth in several countries assuming the economic recovery continues and spreads throughout the nations of the world.

Central America This region could become essentially independent of imported fossil fuels for electricity generation by exploiting their hydro and geothermal potential. El Salvador, Nicaragua, Costa Rica, Guatemala, Panama, and Honduras all possess valuable geothermal prospects. It is tragic that present political differences stand in the way of cooperative efforts that could improve living conditions in a major way.

Indonesia This heavily populated and underdeveloped country has about 10,000 MW of geothermal electric potential. Under the right conditions, a rapid growth pattern similar to that seen in the Philippines could be initiated and sustained. Huge resources exist on Java, Sulawesi, and Sumatra; other areas with potential exist on five other islands.

East Africa Many countries have geothermal resources by virtue of their location near the rift zones: Kenya, Djibouti, and Ethiopia, in particular. Several fields in Kenya have been identified and significant growth could occur, most of it within the Olkaria field already generating 30 MW with another 15 MW under construction.

Others Some of the better prospects include: Greece, Turkey, Chile, Guadeloupe, Saint Lucia and Dominica.

READING LIST

BULLETIN, Geothermal Resources Council: monthly publication, GRC, P.O. Box 1350, Davis, CA 95617.

TRANSACTIONS, Geothermal Resources Council: annual publication, GRC, P.O. Box 1350, Davis, CA 95617.

Proceedings: Seventh Annual Geothermal Conference and Workshop, Electric Power Research Institute: 3412 Hillview Avenue, Palo Alto, CA 94304. Also Proceedings from earlier meetings.

Proceedings of the 5th New Zealand Geothermal Workshop-1983, University of Auckland Geothermal Institute: Auckland, New

Zealand. Also Proceedings from earlier meetings.

Geothermal Energy as a Source of Electricity, R. DiPippo, U.S. Department of Energy, U.S. Government Printing Office, DOE/RA/28320-1, 1980, Washington, DC 20402.

TABLE 1 HISTORICAL DEVELOPMENT OF GEOTHERMAL POWER: INSTALLED MW CAPACITY SINCE 1950
(Dates in parentheses mark first commerical power plant)

COUNTRY	1950	1960	1970	1980	1983
ITALY (1913)(1)	210	290	376	421	457
NEW ZEALAND (1958)	0	80	203	203	167
UNITED STATES (1960)	0	11	78	930	1284
JAPAN (1966)	0	0	35	175	228
SOVIET UNION (1967)	0	0	5	5	11
ICELAND (1968)	0	0	3	41	41
MEXICO (1973)(2)	0	0	0	150	205
EL SALVADOR (1975)	0	0	0	95	95
TURKEY (1975)	0	0	0	0.5	20
PHILIPPINES (1977)	0	0	0	446	781
CHINA (1977)(3)	0	0	0	2	8
INDONESIA (1978)	0	0	0	2	32
AZORES (1979)	0	0	0	3	3
KENYA (1981)	0	0	0	0	30
NICARAGUA (1983)	0	0	0	0	35

(1)Small plant first operated in 1904; (2)Pilot plant operated in 1959; (3)Experimental unit first operated in 1970.

TABLE 2 WORLDWIDE GEOTHERMAL POWER PLANTS AS OF END OF 1983

		GENERATING CAPACITY, MW	
COUNTRY	No. UNITS	INSTALLED	EXPECTED 1985
UNITED STATES	24	1283.7	2122.3
PHILIPPINES	19	781.0	1718.5
ITALY	40	457.1	502.1
JAPAN	8	227.5	282.5
MEXICO	10	205.0	700.0
NEW ZEALAND	10	167.2	167.2
EL SALVADOR	3	95.0	95.0
ICELAND	5	41.0	41.0
NICARAGUA	1	35.0	35.0
INDONESIA	3	32.25	32.25
KENYA	2	30.0	45.0
TURKEY	2	20.5	40.5
SOVIET UNION	1	11.0	21.0
CHINA	10	8.136	11.386
PORTUAL (AZORES)	1	3.0	3.0
FRANCE (GUADELOUPE)	0	0	6.0
Totals:	139	3397.386	5822.736

TABLE 3 PHILIPPINE GEOTHERMAL PLANTS

PLANT NAME	LOCATION	YEAR	MW	PLANT TYPE
TONGONAN:	Leyte			
Wellhead unit		1977	3.0	Single flash
Units 1-3		1983	3x37.5	Single flash
TIWI	Luzon			
Units 1-6		1979-82	6x55	Single flash
MAK-BAN:	Luzon			
Units 1-4		1979-80	4x55	Single flash
PALIMPINON:	S. Negros			
Wellhead units 1-2		1980	2x1.5	Single flash
Units 1-3		1983	3x37.5	Single flash
		Total:	781.0	

TABLE 4 ITALIAN GEOTHERMAL PLANTS

PLANT NAME	YEAR	No. UNITS	MW(1)	TYPE(2)
LARDERELLO 2	--	4	58.0	C
BAGNORE 1	1945	1	3.5	NC
BAGNORE 2	1945	1	3.5	NC
TRAVALE 2	1946	1	3.0	NC
LAGONI ROSSI 1	1960	1	3.5	NC
VALLONSORDO	1961	1	0.9	NC
PIANCASTAGNAIO	1969	1	15.0	NC
LARDERELLO 3	1969	5	111.0	C
GABBRO	1969	1	15.0	C
CASTELNUOVO	--	4	50.0	C
SERRAZZANO	--	5	47.0	C
SASSO 2	--	3	10.2	NC
SASSO 2	--	1	12.5	C
LAGO 2	--	3	33.5	C
MONTEROTONDO	--	1	12.5	C
TRAVALE 1	1973	1	15.0	NC
RADICONDOLI	1979	2	30.0	C
SAN MARTINO 1	1980	1	9.0	C
LAGONI ROSSI 3	1981	1	8.0	C
MOLINETTO	1982	1	8.0	C
LA LECCIA	1983	1	8.0	C
		Total:	457.1	

(1)Plant totals; (2)All plants are Dry Steam type, C = condensing, NC = noncondensing turbine.

TABLE 5 JAPANESE GEOTHERMAL PLANTS

PLANT NAME	LOCATION	YEAR	MW	PLANT TYPE
MATSUKAWA	Honshu	1966	22.0	Dry steam
OTAKE	Kyushu	1967	12.5	Single flash
ONUMA	Honshu	1973	10.0	Single flash
ONIKOBE	Honshu	1975	25.0(1)	Single flash
HATCHOBARU	Kyushu	1977	55.0	Double flash
KAKKONDA	Honshu	1978	50.0	Single flash
SUGINOI	Kyushu	1981	3.0	Single flash
MORI	Hokkaido	1982	50.0	Double flash
		Total:	227.5	

(1)Currently rated at 12.5 MW.

TABLE 6 MEXICAN GEOTHERMAL PLANTS

PLANT NAME	LOCATION	YEAR	MW	PLANT TYPE
CERRO PRIETO I:	Baja, California			
Units 1-4		1973-79	4x37.5	Single flash
Unit 5		1981	30	Double flash
LOS AZUFRES:	Michoacan			
Wellhead Units 1-2		1982	2x5.0	Dry steam
Wellhead Units 3-5		1982	3x5.0	Single flash
		Total:	205	

TABLE 7 NEW ZEALAND GEOTHERMAL PLANTS

PLANT NAME	YEAR	MW	PLANT TYPE
WAIRAKEI:			
Unit 1	1959	11.2	IP-NC(1)
Unit 4	1959	11.2	IP-NC
Units 7-10	1959-60	4x11.2	LP-C
Units 11-13	1962-63	3x30.0	Double flash
KAWERAU	1961	10.0	Single flash
	Total:	167.2	

(1) All Wairakei units are flash steam; Units 2, 3, 5, 6 have been decommissioned; IP-NC = intermediate pressure, noncondensing turbine; LP-C = low pressure, condensing turbine.

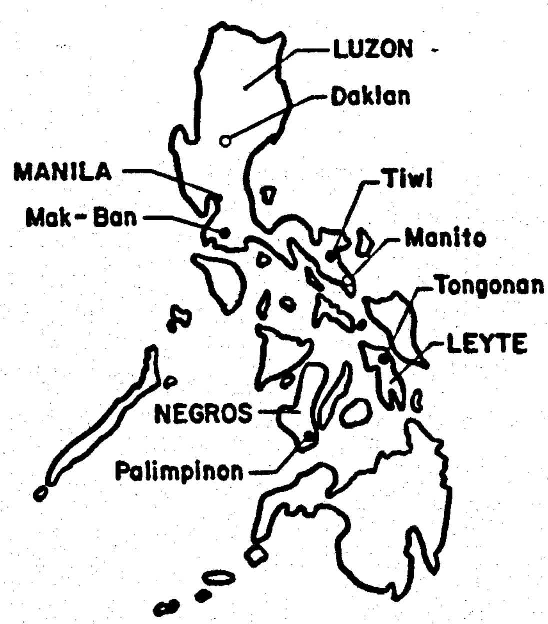

Fig. 1 Philippine geothermal plants. Note: Large filled circles = operating plants; large open circles = plants in planning.

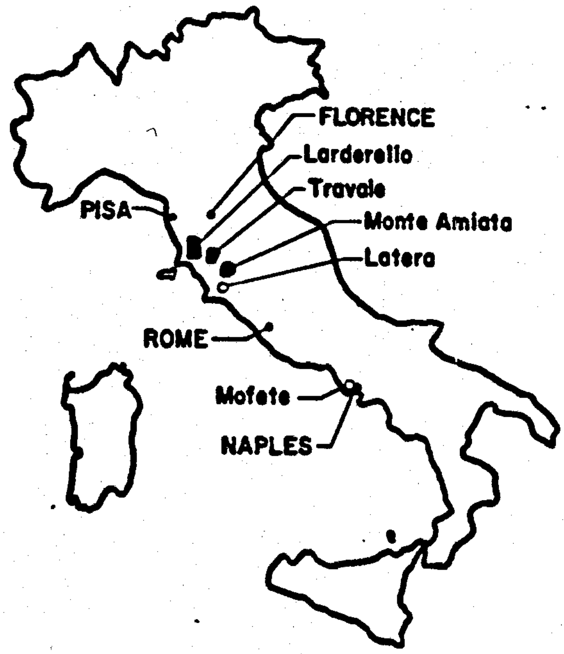

Fig. 2 Italian geothermal plants. Note: Larderello area includes many small plants; Travale area includes plants at Travale and Radicondoli; Monte Amiata area includes plants at Bagnore and Piancastagnaio.

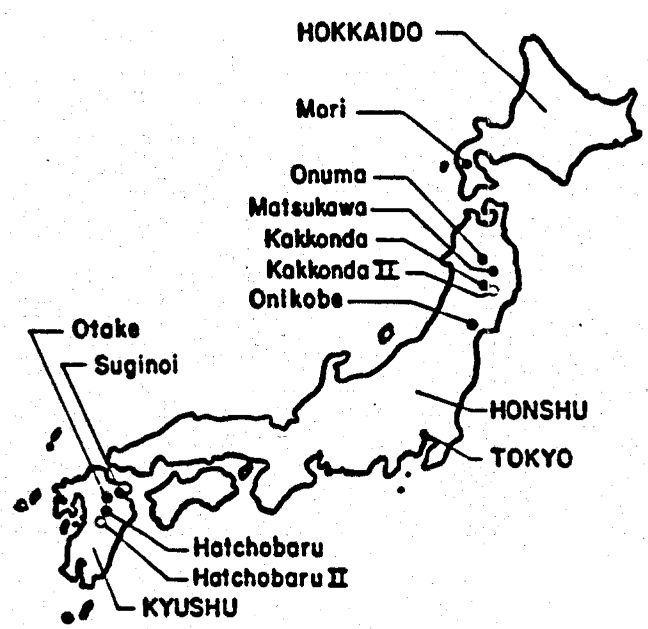

Fig. 3 Japanese geothermal plants. See note for Figure 1.

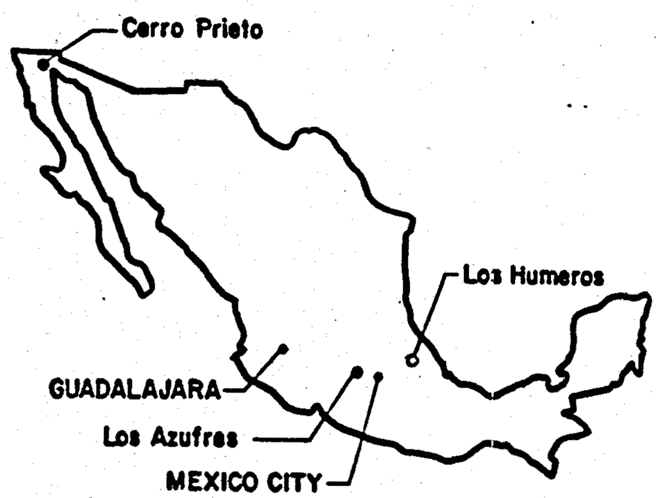

Fig. 4 Mexican geothermal plants. See note for Figure 1.

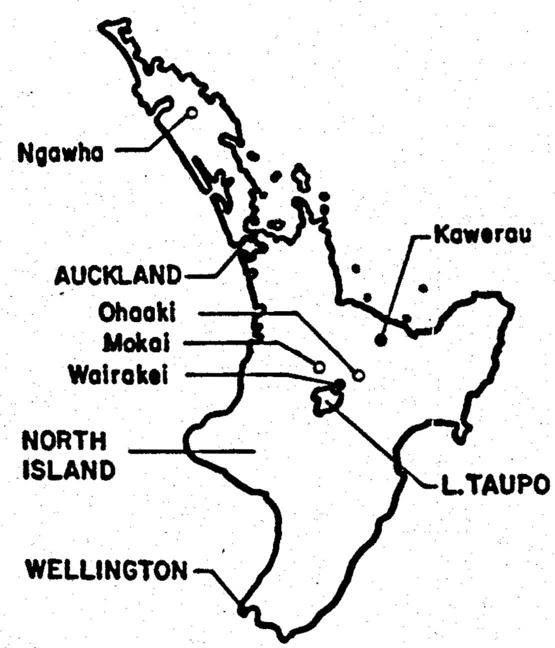

Fig. 5 New Zealand geothermal plants. See note for Figure 1.

GEOTHERMAL ELECTRIC POWER PLANTS OPERATIONAL IN THE UNITED STATES

LOCATION	PLANT NAME	UNIT NUMBER	PLANT TYPE	UTILITY	YEAR ON-LINE	CAPACITY MW	CUMULATIVE CAPACITY MW
CA-GE	Geysers	1	DS	PG & E	1960	11	11
CA-GE	Geysers	2	DS	PG & E	1963	13	24
CA-GE	Geysers	3	DS	PG & E	1967	27	51
CA-GE	Geysers	4	DS	PG & E	1968	27	78
CA-GE	Geysers	5	DS	PG & E	1971	53	131
CA-GE	Geysers	6	DS	PG & E	1971	53	184
CA-GE	Geysers	7	DS	PG & E	1972	53	237
CA-GE	Geysers	8	DS	PG & E	1972	53	290
CA-GE	Geysers	9	DS	PG & E	1973	53	343
CA-GE	Geysers	10	DS	PG & E	1973	53	396
CA-GE	Geysers	11	DS	PG & E	1975	106	502
CA-GE	Geysers	12	DS	PG & E	1976	106	608
CA-GE	Geysers	15	DS	PG & E	1979	55	663
CA-GE	Geysers	13	DS	PG & E	1980	135	798
CA-GE	Geysers	14	DS	PG & E	1980	110	908
CA-IM	East Mesa	1	DB	SDG & E	1980	10	918
CA-IM	Brawley Demonstration		SF	SCE	1980	10	928
HI-PU	Puna		SF	HELCO	1981	3	931
CA-IM	Salton Sea Demonstration		SF	SCE	1982	10	941
CA-GE	Geysers	15	DS	PG & E	1982	110	1051
CA-GE	Geysers	13	DS	PG & E	1983	110	1161
CA-GE	Geothermal Project	2	DS	NCPA	1983	110	1271

SOURCES: The MITRE Corporation.
GRC Bulletin Vol. 12, No. 05, 05/00/83.
Department of the Interior, Bureau of Land Management, Office of the Deputy Minerals Manager - Geothermal, Monthly Geothermal Report; April 1983.

GEOTHERMAL ELECTRIC POWER PLANTS UNDER CONSTRUCTION IN THE UNITED STATES

LOCATION	PLANT NAME	UNIT NUMBER	PLANT TYPE	UTILITY	RATED CAPACITY MW	ESTIMATED YEAR ON-LINE	STATUS[1]
CA-MA	Mammoth Geothermal	1	B	SCE	7	1983	+
CA-GE	SMUDGEO	1	DS	SMUD	72	1983	+
UT-RH	Milford	1	SF	UPL	20	1984	-
CA-IM	Geothermal	1	U	SCE	5	1984	+
CA-IM	Geothermal	1	U	SCE	9	1984	+
CA-GE	Oxy Geothermal		DS	PG & E	80	1984	-
CA-GE	Bottle Rock		DS	CDWR	55	1984	-
CA-IM	Niland	1	DF	SDG & E	24	1985	-
CA-IM	Heber Binary		B	SDG & E/ IID	45	1985	-
CA-IM	Niland Geothermal		DF	SCE	25	1985	-
CA-GE	Geysers	16	DS	PG & E	110	1985	-
CA-GE	Geothermal Project	3	DS	NCPA	110	1985	0
CA-GE	South Geysers		DS	CDWR	55	1985	-
CA-GE	Geysers	20	DS	PG & E	110	1986	-

TOTAL 727 MW

[1]Key to symbols:

+ Construction more than 50 percent complete

− Construction less than 50 percent complete

0 Approval pending

SOURCES: The MITRE Corporation.
GRC Bulletin Vol. 12, No. 05, 05/00/83.
Department of the Interior, Bureau of Land Management, Office of the Deputy Minerals Manager - Geothermal, Monthly Geothermal Report; April 1983.
Western Systems Coordinating Council Coordinated Bulk Power Supply Program, 1982-1992; April 1983.

U.S. GEOTHERMAL ELECTRIC POWER PLANTS PLANNED ADDITIONS THROUGH 1992

LOCATION	PLANT NAME	UNIT NUMBER	PLANT TYPE	UTILITY	PLANNED CAPACITY MW[1]	ESTIMATED YEAR ON-LINE
CA-GE	Wild Well		DS	PG & E	5	1984
CA-CO	Coso	1	SF	U.S NAVY	20	1984
CA-GE	MSR	1	DS	MID, SNCL	10	1985
CA-IM	Heber		B	SCE[2]	49	1985
CA-MA	Mammoth Geothermal	2	B	SCE	7	1986
CA-IM	Niland	2	DF	SDG & E	50	1987
CA-IM	Geothermal	1	U	SDG & E	37	1987
CA-GE	Geysers	22	DS	PG & E	110	1988
CA-GE	Geysers	19	DS	PG & E	55	1988
CA-IM	Geothermal		U	SCE	50	1988
CA-IM	Niland Geothermal		DF	SCE	24	1988
CA-IM	North Brawley	2	SF	LDWP	44	1988
CA-GE	Geysers	21	DS	PG & E	110	1988
CA-GE	Wildhorse State		DS	SMUD	70	1989
CA-GE	CCPA	1	DS	MID, SNCL	40	1989
CA-GE	Geysers	23	DS	PG & E	110	1989
CA-IM	Geothermal		U	SCE	50	1989
CA-GE	Hot Water Geothermal	1	F	PG & E	50	1990
CA-GE	Dunlavy		DS	SMUD	35	1990
CA-GE	CCPA	2	DS	MID, SNCL	20	1990
CA-GE	MID	1	DS	MID	25	1990
CA-IM	North Brawley	3	F	LDWP	44	1990
CA-IM	Geothermal		U	SCE	50	1990
CA-GE	Hot Water Geothermal	2	F	PG & E	50	1991
CA-GE	Geysers	24	DS	PG & E	110	1991
CA-GE	Hot Water Geothermal	3	F	PG & E	50	1992

[1] Magma Power holds permits for two plants (28 MW and 50 MW) at the Salton Sea Area; no other details are available.

[2] To be developed by Chevron Resources, Inc.

SOURCES: The MITRE Corporation.
GRC Bulletin Vol. 12, No. 05, 05/00/83.
Department of the Interior, Bureau of Land Management, Office of the Deputy Minerals Manager - Geothermal, Monthly Geothermal Report; April 1983.
Western Systems Coordinating Council Coordinated Bulk Power Supply Program, 1982-1992; April 1983.

APPENDIX B

DOE International Cooperative Agreements in Geothermal Energy Research and Development

Title	Type	Participating Countries	Term	Description	Status
NATO-CCMS Geothermal Pilot Study	Multilateral Agreement	Canada, FRG, France, Greece, Iceland, Italy, Luxembourg, Mexico, New Zealand, Nicaragua, Philippines, Portugal, Turkey, UK, USA	Nov. 1973 - June 1980	Pilot Study composed of 5 sub-studies: o computer information systems o direct application of geothermal energy o reservoir assessment o small power plants o hot dry rock concepts	Studies completed and published. Terminated in 1980; no direct follow-on.
International Energy Development Program for Less Develop- Countries (IEDP-LDC)	Multilateral Agreement	Argentina, Egypt, Peru, Portugal, S. Korea, USA	Sept. 1977 - Sept. 1980	Aimed at providing overall energy resource assessments and development plans for selected LDCs. Purpose of agreement is to reduce dependence on imported oil and encourage use of indigenous resources especially renewables.	Assessment report completed for Egypt and Peru in 1979. No record of additional work.

APPENDIX B, Continued

Title	Type	Participating Countries	Term	Description	Status
Not Specified	Bilateral Agreement	USSR, USA	1974-1979	Geothermal co-operation comes under umbrella agreement for co-operation in energy R&D. Exchanges of visits and conferences with Soviet scientists and engineers are specified.	Preliminary discussions with Soviets were held, but political climate forestalled substantive exchanges of information. Agreement expired.
Implementing Agreement for a Programme of Research, Development and Demonstration on Hot Dry Rock Technology	Multilateral-IEA Agreement	FRG, Japan, USA	Oct. 1979 - Sept. 1983	Contracting Parties agree to support Fenton Hilll Hot Dry Rock Geothermal Project conducted by Los Alamos National Laboratory. Work includes construction and testing of 35 MWt hot dry rock system plus supporting research to complete technology base.	Technical problems caused schedule delays of 12-15 months. Agreement was extended for 2 years in 1983.

Title	Type	Participating Countries	Term	Description	Status
Agreement Between ERDA and ENAL on Cooperation in the Field of Geothermal Energy Research and Development	Bilateral Agreement	Italy (ENEL), USA (DOE)	June 1975 - open	Broad-based cooperation in geothermal R&D became concentrated in five project areas: 1. Stimulation and hot dry rock 2. Utilization of hot brine resources 3. Reservoir physics and engineering 4. Deep drilling 5. Environmental control technology Projects largely concerned with studying Italian fields, notably Lardarello. DOE provides technical expertise in each project area to assist ENEL with date collection and analysis.	During the first term of the agreement DOE provided significant technical input to geothermal field development in Italy. Projects 2,3, and 5 were quite active during this period; little effort was expended under projects 1 and 4. The current term is scheduled to expire in 1986 - activities at this time involve information exchange with occasional visits between the two countries.

Title	Type	Participating Countries	Term	Description	Status
Program of Research and Development on Man-Made Geothermal Energy Systems (MAGES)	Multilateral Agreement - IEA	FRG, Japan, Sweden, Switzerland, United Kingdom, USA	Oct. 1977 - open	Agreement to consist of series of Tasks aimed at designing, building, testing, and operating MAGES. Task I, an in-depth systems analysis of the MAGES concept, was completed and published in 1980. FRG was lead country for Task 1.	Proposed cooperative studies as limited follow-on to Task I were turned down in April 1982 by IEA Renewable Energy Working Party. Agreement inactive.
Agreement Concerning Cooperative Information Exchange Relating to Development of Geothermal Energy	Bilateral Agreement	Italy (CRN/ ENEL), USA	May 1976 - May 1981	The parties agree to exchange geothermal information in computer compatible format. Types of information include location, size, characteristics of wells and fields, heat transmission data, and bibliographic references. Each party is responsible for collecting information from different areas of the world.	Level of exchange originally envisioned was never achieved. This situation probably due to diverging interests of parties. Agreement terminated without renewal.

APPENDIX B, Continued

Title	Type	Participating Countries	Term	Description	Status
Programme of Research, Development, on Geo- thermal Equipment	Multilateral Agreement-IEA	Italy (ENEL), Mexico (CFE), New Zealand (MWD), USA (DOE)	May 1979- May 1982	Annex I of agree- ment provides for testing and demon- stration of a 1MW wellhead generator A helical screw expander system developed under DOE sponsorship was chosen for testing in each of the partici- pating countries.	Testing in all countries was concluded in early 1983. Agreement remains in effect till terminated by mu- tual consent. No additional tasks have been proposed.
Arrange- ment between the USAEC and the Icelandic Natural Energy Authority to Exchange Information on the Util- ization of Energy From Geothermal Sources	Bilateral Agreement	Iceland, USA	Nov. 1973- Nov. 1978	Information ex- change is provided for nonelectric applications of geothermal energy along with advanced technology in heat conversion systems.	Agreement expired; no further official activity.

Title	Type	Participating Countries	Term	Description	Status
Cooperation between the United States of America and Japan in the Field of Geothermal Energy Applications	Bilateral Agreement	Japan (AIST), USA (DOE)	June 1978-June 1988	Provides for general exchanges of information and personnel between the two countries.	Agreement superceded on May 2, 1979, when an umbrella agreement on energy R&D was signed. There has been only limited exchanges of scientific personnel since that time.
Cooperative Program at the Cerro Prieto Geothermal Field	Bilateral Agreement	Mexico (CFE), USA (DOE)	July 1978-July 1982	Activities involve study of Cerro Prieto field (Mexico) in the areas of geology/hydrology, geophysics, geochemistry, reservoir engineering, reinjection, and subsidence.	Agreement expired; informal cooperation continues. New agreement under negotiations.

APPENDIX C

HISTORY OF THE FEDERAL GEOTHERMAL PROGRAM

Geothermal energy has been used in the United States in isolated cases since the late 1800's. However, serious commercial interest did not arise until the late 1960's, when growing concerns over diminishing energy resources led to demands for the development of new, cleaner sources of energy such as solar and geothermal. Since then, both legislative and program actions have been directed at stimulating the development of geothermal energy.

The first Federal program activity was undertaken by the USGS in 1969, when it compiled a limited assessment of geothermal resources. This assessment was drawn from basic research that the USGS has been conducting since 1945 to assess national resources.

Legislative action followed shortly thereafter with the passage of the Geothermal Steam Act of 1970 (PL 91-581). The Act establishes guidelines for leasing and production, and for the judicious use and conservation of geothermal resources. The Act states:

- ...the Secretary of the Interior may issue leases for the development and utilization of geothermal steam and associated geothermal resources (1) in lands administered by him, including public, withdrawn, and acquired lands, (2) in any national forest or other lands administered by the Department of Agriculture through the Forest Service, including public, withdrawn, and acquired lands, and (3) in lands which have been conveyed by the United States subject to a reservation to the United States of the geothermal steam and associated geothermal resources therein.

- If the production, use, or conversion of geothermal steam is susceptible of producing a valuable by-product...the Secretary shall require substantial beneficial production or use thereof...(except) in the interest of conservation of natural resources.

- ...the lessee will...use all reasonable precautions to prevent waste of geothermal steam and associated geothermal resources...

The Geothermal Steam Act also provides broad authority for the Secretary to issue regulations governing geothermal operations on leased Federal lands, including conservation of resources, protection of the environment and protection of the public interest.

By 1971 there was momentum enough to start a geothermal program in the Atomic Energy Commission. The AEC Act had been amended to mandate research into energy sources other than nuclear power. The Division of Applied Technology included Coal, Electrical Storage, Solar, and Geothermal offices. Even though the main emphasis was placed on geothermal technology, there was an attempt to relate the program to industrial applications. At approximately the same time, the National Science Foundation considered geothermal energy in its Research Applied to National Needs project. NSF thereafter became the lead agency for geothermal activities. In 1973 the USGS, AEC, and NSF prepared the first coordinated Federal geothermal program plan.

As the need for even more rapid development of geothermal energy technologies as well as resources became evident, the Congress enacted the Geothermal Energy Research, Development, and Demonstration Act of 1974 (PL 93-410), which affirmed the potential benefits to the Nation of geothermal energy development and defined the major components of a coordinated Federal program to realize these benefits. The Act states that:

- ...geothermal resources...which have extremely large energy content...are known to exist; (but)...technologies are not presently available for the development of most of these geothermal resources, but technologies for the generation of electric energy from geothermal resources are potentially economical and environmentally desirable, and the development of geothermal resources offers possibilities of process energy and other nonelectric applications...

- Federal financial assistance is necessary to encourage the extensive exploration, research, and development in geothermal resources which will bring these technologies to the point of commercial application...

- The Federal Government should encourage and assist private industry through Federal assistance for the development and demonstration of practicable means to produce useful energy from geothermal resources with environmentally acceptable processes.

To achieve this goal, the Congress established through the Act the Geothermal Energy Coordination and Management Project (now identified as the Interagency Geothermal Coordinating Council) and directed the Project to develop and report to the Congress a coordinated Federal program. The Program Definition Report (ERDA-86) was submitted and published in October 1977. The Program directed by Congress included demonstration plants, loan guaranties, and extensive lists of other necessary activities to be undertaken, including regional and national resource surveys, drilling research, information clearinghouses in the states, development and recommendation of policy, and environmental impact assessments. It also authorized the National Science Foundation to encourage international participation in educational programs to train the personnel necessary for these expanding activities.

The wide range of the functions and activities named in PL 93-410 and other energy legislation, and the importance of their success to the Nation, led the Congress to enact the Energy Reorganization Act of 1974, which established the Energy Research and Development Administration (ERDA). The responsibilities of the new agency included:

- exercising central responsibility for policy planning, coordination, support, and management of research and development programs respecting all energy sources

- encouraging and conducting research and development, including demonstration of commercial feasibility
- engaging in and supporting environmental, biomedical, physical and safety research related to the development of energy sources and utilization technologies
- taking into account...other public and private research and development activities
- participating in and supporting cooperative research and development projects
- making available for distribution, scientific and technical information concerning the manufacture or development of energy
- creating and encouraging the development of general information to the public on all energy conservation technologies and new energy sources
- encouraging and conducting research and development in energy conservation...toward the goals of reducing total energy consumption...and toward maximum possible improvement in the efficiency of energy use
- encouraging and participating in international cooperation in energy and related environmental research and development
- helping to ensure an adequate supply of manpower for the accomplishment of (energy R&D programs)
- encouraging and conducting research and development in clean and renewable energy sources.

Responding to the urgency of the Nation's energy challenge, the Congress further classified and enlarged the scope of ERDA's responsibilities in the Federal

Non-nuclear Energy Research and Development Act of 1974 (PL 93-577), which emphasized that "proper priority" must be given "to developing new non-nuclear energy options to serve national needs, conserve vital resources, and protect the environment." Besides reiterating the high priority to be given to energy conservation and the importance of taking the environmental and social consequences of proposed programs into account, the Act required that ERDA submit a comprehensive program plan each year to the Congress. It repeated the directive of PL 93-410 that commercial demonstrations of geothermal energy technologies and environmental control systems be accelerated; called for joint Federal/industry experiments, demonstration plants, and corporations, along with other forms of Federal assistance; and required the promulgation of "regulations establishing procedures for submission of proposals to (ERDA) for the purposes of this Act."

Seeing the rapid growth of energy programs in the past decade, Congress acted to consolidate the energy-related functions and responsibilities of several different agencies, primarily ERDA, FEA, and the FPC, under the aegis of the Department of Energy, creating a cabinet post for this important area of Government activity. The DOE Organization Act of 1977 (PL 95-91) consolidated and updated earlier Acts, giving ongoing and new programs continued guidance and support. The objectives of the Act are:

- to achieve...effective management of energy functions...and to promote maximum possible energy conservation measures

- to provide for a mechanism through which a coordinated national energy policy can be formulated and implemented

- to place major emphasis on the development and commercial use of solar, geothermal, recycling and other technologies utilizing renewable energy resources.

The Act also emphasized the importance of coordinated efforts with the states, local entities, the public, private industry, and other nations, and it reiterated the Congress' concern with protection of the environment.

Originally ERDA's orientation to geothermal energy was primarily technological. Although demonstration projects were envisioned, no funds were appropriated for them. The ERDA activities were aimed at electric power production, almost entirely to the exclusion of nonelectric uses. A formal commercialization program was established only with the organization of the Department of Energy (DOE) in 1977; however, the concept of involving industry in geothermal development had been implicit from the beginning of Federal involvement in geothermal activities. In 1975, ERDA's Division of Geothermal Energy (DGE) had started to phase in commercialization activities, but kept these activities closely tied to basic research. In 1979, the Division of Geothermal Resource Management was created under the Assistant Secretary for Resource Applications of DOE; research and development continued in DGE under the Assistant Secretary for Energy Technology. Subsequently, DGE was placed within Resource Applications as well.

Legislative efforts continued to provide economic incentives for the development of geothermal resources. The Crude Oil Windfall Profits Tax Act (PL 96-223) of 1980 provides tax credit increases over those provided by the National Energy Act. The investment tax credit for geothermal equipment is increased to 15% in excess of the normal 10% and extended through 1985. The residential credit is increased to 40% of the first $10,000 in expenditures for geothermal equipment, for a maximum of $4,000. Finally, a tax credit is provided equal to 10% of the cost of cogeneration equipment. Geothermal systems designed to tap waste heat or steam would qualify.

The Energy Security Act (PL 96-294) was enacted in June 1980. Title VI, the Geothermal Energy Act of 1979, contains the following major provisions:

(1) An $85 million five-year program under which the Federal government will share the risks of drilling for commercially viable geothermal resources. Loans will cover 50% of the cost of surface exploration and drilling and 90% of the cost of a project to use geothermal for space conditioning or process heat. The loans will be repayable out of project revenues and will be wholly or partially forgivable if a project is unsuccessful. Because the high economic risk perceived by drillers and developers is considered to be one of the major forces slowing development, the reservoir confirmation loan program is expected to accelerate the rate of exploration for and confirmation of geothermal reservoirs. Authorization is $5 million for FY 81 and $20 million for each of fiscal years 1982 through 1985. (NOTE: While this level of funding was authorized, it was not appropriated beyond 1981.)

(2) A program authorizing DOE to grant low-interest forgivable loans to cover up to 90% of the cost of feasibility studies and regulatory applications and up to 75% of the construction costs of nonelectric systems. Five million dollars is authorized for feasibility studies in FY 81.

(3) A DOE study to examine the need for and feasibility of a Federal reservoir insurance and reinsurance program. On the basis of the report, Congress will determine whether to authorize a program of insurance or reinsurance against the risk of reservoir failure after investment of at least $1 million has been made in reservoir development and use. The direct insurance would be provided only where the developer could not obtain private insurance at reasonable premiums.

(4) Modification of Geothermal Loan Guaranty Program (GLGP). The law extends the life of the GLGP from 1984 to 1990 and provides an increased level of assistance under the program. Loan guarantees for loans to municipalities and public cooperatives will be increased from 75% to 90% of project costs. PL 96-294 also includes provisions to expedite processing of loan guarantees; such reforms include a four-month deadline for processing applications, requirements to give faster consideration to applicants for nonelectric projects, and a requirement to eliminate duplicative Environmental Impact Statements under NEPA for loan guaranty applications. (NOTE: The increased level of spending was not appropriated.)

(5) A provision requiring consideration of the use of geothermal energy in new Federal buildings or facilities in areas designated by DOE.

(6) New authorities under PURPA. The law explicitly includes geothermal facilities of 80 MWe or less in the small power producer category under the Public Utility Regulatory Policies Act (PURPA). Geothermal facilities qualifying as small power producers are eligible for interconnection, wheeling of power through grid transmission lines, exemption from the Federal Power Act and the Public Utility Holding Company Act, and other utility orders as determined by FERC. Multiple geothermal units at a site are also eligible for exemption from public utility regulation, provided their combined capacity does not exceed 140 MWe. The law also allows utility-owned plants to qualify for these exemptions and for wheeling and interconnection.

Currently several bills are pending before Congress that would increase acreage limitations on Federal geothermal leasing, redefine KGRA's, and deal with leasing and development in lands adjacent to national parks.