Fourth Annual Report

Geothermal Energy Research Development and Demonstration Program

Interagency Geothermal Coordinating Council

Member Agencies

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Hawaii Wellhead Generator Project

PREFACE

This is the Fourth Annual Report to Congress of the Interagency Geothermal Coordinating Council (IGCC), a body established by Congress to facilitate residential, industrial, commercial and utility sector use of geothermal power. This report summarizes the Federal program's goals, strategy, plans, and achievements; in addition, it describes geothermal development by state and local governments and, where available, by the private sector. Although its legal mandate and primary purpose is to inform the U.S. Congress, the report is also designed for use by the public.

To accommodate the rapidly changing role of the Federal government in bringing geothermal energy on-line, the IGCC has been restructured in the past year. The Departments of Commerce, Defense, and Housing and Urban Development have been added to the Council, and the National Science Foundation, at its request, has been removed from full membership (although it will continue to participate on special committees as needed). Following a review, the IGCC abolished the Research and Technology Panel and the Resource Panel, and created the Environmental Controls Panel and the Leasing and Permitting Panel.

It is the firm belief of the IGCC that geothermal energy is a clean, safe, and economical source of power, and is one of the most promising alternatives to conventional energy. Electrical power production from the higher quality hydrothermal resources and direct heat applications from the lower quality resources are technologically available today. Widespread geothermal power will become increasingly available as research and development yield technologies appropriate to electrical power production from lower fluid temperatures and to discovery of new sites.

Geothermal energy has the potential to expand quickly to meet near-term domestic needs. By the year 2000, geothermal energy could contribute significantly to the domestic and international energy supply.

Dr. Ruth M. Davis, Chairman
Interagency Geothermal Coordinating Council

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EXECUTIVE SUMMARY

Geothermal energy is one of the cleanest, safest, and most economically attractive energy sources available, and its contribution both to increasing domestic energy supplies and to reducing the United States' dependence on imported oil can be significant.

The Interagency Geothermal Coordinating Council (IGCC)'s goals for energy production in the year 2000 are electricity production equivalent to 2.2 quads of fossil fuel input (about 1 million barrels of oil per day) direct heat use equivalent to 1 quad of fossil fuel input (about 500,000 barrels of oil per day), and methane production of 3 quads. Categorized by resource type, these goals are 25,000 MWe capacity from hydrothermal electric power, 2,000 MWe from the heat from geopressed resources, 1 quad of direct heat use from hydrothermal resources, and methane production from geopressed resources of 3 quads. Goals for energy from hot dry rock have not been set, but potential production estimates have been made: about 700 MWe and 0.007 quads of direct heat per year are possible by the year 2000 (see Table ES.1).

Meeting these goals will make significant contributions to national energy needs. The National Energy Plan (NEP-II, May 1979, Medium World Oil Price Case) projects energy consumption of 119 quads and end use of 85 quads for the year 2000. When the hydrothermal goals are compared to the NEP-II's projected growth in demand between 1985 and 2000, the geothermal contribution will be over 4 percent of the increased electricity supply and about 10 percent of the increased supply for direct heat.

The IGCC believes these production goals to be achievable given a very aggressive Federal program, but the most important factor affecting the accomplishment of these goals will be the aggressive involvement of the private sector. Activity by the private sector has been growing steadily. For example, during 1979 utility companies publicly announced their intention to build hydrothermal electric generating plants totaling more than 1,000 MWe from hot water resources. This, along with the announced expansion of dry steam generating capacity at The Geysers to 1,900 MWe, will produce installed capacity of about 3,000 MWe by 1985.

The level of Federal funding for geothermal development has remained nearly constant over the last 3 years. However, changing roles within the IGCC member agencies has led to some fluctuations in their budgets (see Table ES.2).

Indications are that the pace of geothermal development is rapidly accelerating and that even more plants will be built and more resources developed by the middle of this decade than previously estimated, barring unforeseen environmental problems. Much of the acceleration in the pace of development results from the efforts of the various member agencies of the IGCC, coupled with increased private sector activity. The following events are of particular significance:

- The first production of geothermal energy on Federal lands occurred in FY 79 at The Geysers, California. In addition, BLM and USGS are establishing new licensing regulations for Federal lands. The Forest Service and BLM will implement staged leasing, which will result in increased leasing in some western areas in the near future.
- Drilling has increased in the private sector, stimulated by the tax incentives granted by the National Energy Act. DOE awarded a loan guarantee to Republic Geothermal, Inc., for exploration and testing of its large hydrothermal electric plant at East Mesa. The \$9 million loan guarantee enabled 4 reinjection and 7 production wells to be drilled and it is estimated that the project will produce 64 MWe for 25 years. A well drilled in Brazoria County, Texas, under the geopressured resource definition program is now ready for long-term production testing.
- Significant steps were taken to improve the functioning of various Federal agencies and offices and to better coordinate the Federal program. The Streamlining Task Force released its report in January of 1979. Many of its recommendations have since been implemented or introduced in legislation now before Congress. The report itself was well received and has been a key supporting document in justifying legislative and regulatory action.
- The Insurance Company of North America announced that it will insure geothermal reservoirs beginning in 1980. This policy is expected to make new venture financing easier to obtain. Additionally, legislation now before Congress, if passed, will dramatically improve prospects for geothermal commercialization by reducing some drilling risks and by accelerating the Federal leasing program.
- Use of the geothermal resource for space heating and industrial and agricultural applications is also beginning to grow. There are numerous small-scale projects throughout the United States; for example, DOE is supporting 23 field experiments to test new applications. The projects already under way will triple the present 1.5 trillion Btu output by 1985.
- Environmental uncertainty continues to pose a potential impediment to development in some areas. However, in the last year several new air pollution control processes were tested, and the nature of the problems of different resource types became better known. In particular, an H₂S abatement process developed by EIC Corporation shows promise for ameliorating problems at

vapor-dominated reservoirs, and will recover sulfur as a useful byproduct.

Programs throughout the Federal agencies are monitored and coordinated by the IGCC. In the past year, the Council itself has grown, adding representatives from the Departments of Defense, Commerce, and Housing and Urban Development, but losing representation from the National Science Foundation. The Resource Panel and the Research and Technology Panel were abolished because their missions had been accomplished. Two more were formed: the Leasing and Permitting Panel will evaluate legislation and regulation and make recommendations in matters involving Federal land management and geothermal development; and the Environmental Controls Panel will assist the Council in identifying means to ease environmental impediments to geothermal commercialization, by formulating priorities for environmental controls research and development, and by facilitating coordination of this research.

In addition to the achievements highlighted above, a number of advances were made in technology; demonstration plants, field applications, and Federal use; resource identification, assessment, and exploration; leasing; environmental controls; loan guarantees; policy development; and international programs. Highlights in each of these areas are given below.

Technology Development

A 100 kWe direct contact power system has been installed and is now being tested at Marysville, Ark. The system is designed to produce electric power from low-temperature resources (96°C). The economics of electrical generation from moderate-temperature resources (177°C) are expected to be significantly improved by the use of an advanced (thermal pump) binary system. The design of this system has now been completed and is expected to be nearly one-third more efficient than conventional binary cycles.

The costs of drilling are expected to be lowered by the use of newly designed bits. In one test at The Geysers, a specially designed bit drilled 30% longer than conventional drill bits in hot, hard, fractured rock.

Geothermal well stimulation was successful at Raft River, Idaho, and increased production threefold. Also at Raft River, a pilot plant with a 5 MWe turbine generator is now about 80% complete. This project will use energy from a moderate-temperature (150°C) hydrothermal resource to generate electricity for a utility's power grid.

Advances were also made in successfully field testing the 1 MWe helical screw expander generating unit in minerals recovery research, in logging and in de-scaling.

Demonstration Plants and Field Experiments

In FY 77 Congress authorized DOE to carry out a commercial-scale geothermal demonstration project using a hot water hydrothermal resource. The design for a plant at Baca Ranch (Valles Caldera, N.M.) is now well

under way and the EIS has been approved. DOE, Union Geothermal, and Public Service Company of New Mexico are cooperating in this project. In the Puna District of Hawaii, the HGP-A Geothermal Wellhead Generator is currently being built. This geothermal resource should be producing electricity by the summer of 1981.

The Geothermal Loop Experimental Facility at Niland, California, has established the feasibility of using flash steam binary systems to produce electric power from high-temperature, high salinity resources. This project, which was cost-shared by DOE and the San Diego Gas and Electric Company, was so successful that it has prompted Magma Power to decide to build a 10-20 MWe plant on the site by late 1982, and if that plant is successful, a 50 MWe plant by the end of 1984.

DOE is currently funding 11 feasibility studies of direct heat applications and 15 direct use field experiments. The most visible success in the field application program has been in Boise, Idaho, where the Federal program helped the city obtain access to Federal land, awarded planning grants to developers, and sought out users for the geothermal resource.

On military lands, geothermally derived power is expected to be provided at China Lake Naval Weapons Center at Coso, California, and geothermal space heating at Hill Air Force Base, Utah, and at Keflavik Naval Station, Iceland. All three projects are on schedule.

Resource Identification, Assessment, and Exploration

The USGS completed a major update of its assessment of domestic geothermal resources, and published the results in January 1979 as USGS Circular 790. The update reaffirms the existence of a very large resource base for hydrothermal, geopressed, and hot dry rock energy sources, and estimates the magnitude and distribution of hydrothermal and geopressed resources.

In FY 79, nine companies participated in DOE's industry-coupled case study program to obtain reservoir data. The program cost-shares drilling projects with private industry and 12 sites are now being investigated for possible exploratory drilling. In the state-coupled program, low- and moderate-temperature resources are being defined in cooperation with nearly all 37 states that have identified a resource potential. Geothermal gradient drilling in the Atlantic Coastal Plain has delineated several probable geothermal reservoirs. DOE will implement a new phase of the program, to be called User-Coupled Drilling, in which a developer and user team will share the cost of surface exploration and drilling to locate and confirm that a reservoir could be developed commercially.

A major cooperative project was initiated by USGS and DOE to characterize and assess the geothermal resources of the Cascade Mountains in the Pacific Northwest and to define and evaluate geothermal reservoirs of Mount Hood (Ore.). This project is expected to last several years.

A deep test well drilled at Crisfield (Md.) for reservoir evaluation encountered warm water at 4,000 feet, 56°C, with a potential flow rate of

325 gallons per minute. One or two more deep exploratory wells are planned for the Atlantic Coastal Plain during FY 80. The present hot dry rock program was formally instituted at the beginning of FY 79 when DOE began drilling on a 40-50 Megawatt thermal (MWt) energy extraction loop at Fenton Hill. In FY 80, this drilling will be completed. See Table ES.3 for a summary of drilling activity.

Leasing

In response to a Presidential directive to "streamline leasing and environmental review procedures to remove unnecessary barriers to development of geothermal resources", the IGCC established a Streamlining Task Force in 1978. This Task Force released its report, "Geothermal Streamlining Recommendations", in January 1979, with 19 specific recommendations.

These recommendations can be synthesized into three categories:

- Making explicit the priority of the geothermal program relative to other mineral programs in the respective surface management agencies
- Impressing upon the management of the Departments of the Interior and Agriculture the need for adequate funding and manpower to implement the recommendations outlined by the Task Force
- Taking immediate, recognizable action on the Task Force recommendations and providing feedback to the public and private sectors.

By the end of FY 79, leases for over 2.8 million acres of Federal lands had been issued (see Table ES.4). However, to reach IGCC's goals for the year 2000, 20 to 40 million acres will have to be explored by 1990, about half of that on Federal lands.

In FY 79, the U.S. Forest Service was in the process of advising its regional foresters of a reorientation in minerals policy. The policy change reflects concern within the Chief's Office over excessive delays, duplicative stages of review, and conservative decisions regarding mineral leasing--including geothermal leasing. The new policy discourages delaying leasing decisions until final land management plans have been approved. As a key means of streamlining leasing procedures, a pilot test of staged leasing (where exploration is approved in the first stage, but approval for development is deferred) was approved for use in Oregon and Washington State National Forests. A successful outcome would encourage staged leasing elsewhere on Forest Service lands.

In FY 80, the removal of two major obstacles to Federal leasing will be the focus of BLM's activity. First, regulations will be drafted to allow reissuance of 383 relinquished leases. Second, a new environmental assessment procedure to match the level of review to the proposed activity will be implemented. These two changes, accompanied by a legislative

increase in the maximum acreage limitation, could very substantially affect the amount of acreage leased.

Environment

Environmental concerns associated with geothermal energy are becoming better defined and are now seen as imposing potential constraints on the development of certain resource areas. Several research programs have gone far to characterize process residuals and their environmental threats. What has emerged is an understanding that controls are needed to mitigate environmental impact before some resource areas can be developed. For example, the lack of adequate controls systems for hydrogen sulfide (H_2S) emissions is delaying expansion of electricity generating capacity at The Geysers in Northern California, and may impede large-scale development in Valles Caldera (New Mexico) and in Hawaii, where the standards are very low.

The development of environmental controls and regulations has continued. Guidelines and regulations for hazardous waste were repropoed on December 18, 1978, by EPA under the Resource Conservation and Recovery Act. Under the criteria of these regulations, drilling wastes and brine treatment residues would probably be classified as hazardous wastes.

Regulations for underground injection programs by states were repropoed on April 20, 1979, under the Safe Drinking Water Act. The regulations allow states to exempt geothermal groundwater aquifers from classification as drinking water sources because they produce geothermal energy.

In response to recent court actions, EPA has proposed amendments to the current Prevention of Significant Deterioration (PSD) regulations. The effect of the amendments would be to exempt most geothermal sources because the emission of concern (H_2S) is not a criteria pollutant. These proposed amendments are in the comment period.

The prospect of adequate environmental controls for hydrogen sulfide (H_2S) improved with the successful initial tests of the EIC process for scrubbing hydrogen sulfide from geothermal steam. As the result of a coordinated effort by DOE, EPA and industry, a demonstration prototype system, to scrub 100,000 pounds of raw steam per hour was started at the Geysers. Initial results are very encouraging.

Activities addressing environmental concerns are continuing. For example, the characterization of solid wastes and testing of solid waste management practices has been started, and methods for monitoring ground water impacts are continuing. To aid in ranking these and other activities, the IGCC established the Environmental Controls Panel to focus and coordinate controls-related research, development, and oversight.

Policy Development

The IGCC believes that legislative remedies are needed to accelerate geothermal energy development. Therefore, it has supported the development of omnibus legislation. In FY 79, these legislative efforts culminated in four bills on Capitol Hill: S. 1388, introduced by Senator

Frank Church, and its companion H.R. 5187, introduced by Reps. Udall and Santini; and S. 1339, introduced by Senator McClure, and its companion H.R. 4471, sponsored by Rep. Stephen Symms. These bills would provide leasing timetables, allow more land to be leased to developers, and provide economic incentives in addition to those already in existence.

Geothermal Loan Guaranty Program (GLGP)

Four loans have been guaranteed by DOE. Republic Geothermal, Inc., obtained a loan of \$9 million from the Bank of America for development at East Mesa, Cal. Westmorland Geothermal Associates received a \$29 million loan from the Bank of America to explore, test, and develop the Westmorland resource in Imperial Valley (Cal.). Geothermal Food Processors, Inc., borrowed \$3.5 million from the Georgia State Teachers Retirement System, with Bankers Trust as the trustee, for use in a food-drying project at Brady Hot Springs (Nev.). California-Utah 1 borrowed \$1.8 million from the Bank of Montreal (Cal.) for resource exploration and testing in Brawley (Imperial County, Cal.). These loans cover 75 percent of the project costs. Additional projects are under review.

International Activities

Under bilateral agreement between the U.S. and the Federal Republic of Germany, German scientists will participate in the Los Alamos Scientific Laboratory's hot dry rock program, and will contribute about 20% of the amount budgeted annually by DOE for this research, up to \$2.5 million per year.

During FY 79 in Italy, following information exchange and site visits from DOE personnel, wells were selected for hydrothermal field stimulation tests. Because reservoir uncertainty is a major factor hindering the development of geothermal energy, a cooperative project with Italy was instituted in 1978 to collect and evaluate data for reservoir modeling at Larderello, Radicondoli, and Bagnore. These projects are proceeding on schedule. Mexico and the United States continued their cooperative investigations of the geophysical and hydrological characteristics of the Cerro Prieto field, which is similar to those in California's Imperial Valley. A geothermal technology exchange project is currently being negotiated with the Japanese government.

* * * * *

The IGCC can report with confidence that geothermal resources will contribute significantly to meeting domestic energy needs. The Council has increased coordination among its member agencies, and has sought to ensure that all offices with mandates relative to geothermal development are involved in its activities. It has spearheaded efforts to make Federal lands more available and to make commercial ventures more economically attractive. Its members now work effectively with the private sector in programs and projects to put power on-line, and thus show the nation that geothermal energy is a viable source of power in the near term.

Table ES.1

NATIONAL GEOTHERMAL UTILIZATION GOALS AND ESTIMATES (QUADS/YEAR)^a

	1985	1990	2000	2020
<u>GOALS</u>				
<u>Hydrothermal</u>				
Electric Applications ^b	0.24	0.6	2.0	4.0
Direct Thermal Applications	0.10	0.2	1.0	6.0
<u>Geopressured^c</u>				
Electric Applications ^b	0.001	0.006	0.16	0.4
Direct Thermal Applications	-	-	-	-
Methane ^d	<u>0.02</u>	<u>0.1</u>	<u>3.0</u>	<u>7.0</u>
GOALS TOTAL (Rounded)	0.361	0.906	6.16	17.4
<u>ESTIMATES</u>				
<u>Hot Dry Rock</u>				
Electric Applications ^b	0.001	0.003	0.06	0.5
Direct Thermal Applications	<u>0.001</u>	<u>0.001</u>	<u>0.007</u>	<u>0.6</u>
HOT DRY ROCK TOTAL	0.002	0.004	0.067	1.1

^a A quad as used here is a quadrillion Btu (10^{15}) per year and is equivalent to 472,000 barrels of oil per day for 365 days.

^b Based on MWe goals. Equivalent fossil fuel input to produce estimated MWe, based on an assumed capacity factor of 0.8 and an equivalent efficiency of fossil fuel plants of 0.33.

^c As yet, the markets for nonelectric applications of geopressured energy sources are not well enough defined to establish meaningful objectives.

^d These values are highly dependent on the results of several current research programs. If the results are positive, achieving 1 quad of energy in the year 2000 will require 600 to 1000 wells, each producing 50,000 barrels of brine per day. The 1985 goal could be met with 20 producing wells.

Table ES.2

**FEDERAL FUNDING FOR
GEOTHERMAL ENERGY**
(in \$ thousands)

ORGANIZATION UNIT	ACTUAL FY 1977	ACTUAL FY 1978	ACTUAL FY 1979	ESTIMATED FY 1980	REQUESTED FY 1981
Department of Agriculture					
U.S. Forest Service	40	678	775	750	739
Department of Defense					
Navy	758	542	924	17,100	17,800
Air Force	15	0	13	21	2,400
DOD Total	773	542	937	17,121	20,200
Department of Energy					
Energy Technology	53,326	105,962	142,637	138,428	142,000
Resource Applications			9,737	9,026	10,000
Office of Energy Res.	1,900	2,800	3,200	3,400	4,000
Environment	3,862	3,896	3,167	2,303	2,949
Geothermal Loan Guaranty					
Fund (Administrative					
Expenses)	380	410	189	1,180	1,091
DOE Total	58,468	113,068	158,930	154,534	160,040
Department of Interior					
Fish and Wildlife	200	200	200	74	74
Bureau of Land Mgmt.	2,500	2,300	2,585	2,600	2,600
Bureau of Mines	528	550	1,050	800	400
Water and Power Res.Serv.	2,557	1,800	555	910	60
Geological Survey,					
Geothermal Res. Program	9,384	10,184	12,043	10,092	7,569
Geological Survey,					
Geothermal Evaluation					
and Lease Regulation	1,512	1,854	2,194	1,994	1,994
DOI Total	16,681	16,888	18,627	16,470	14,423
Environmental Protection Agcy.	600	670	750	750	750
National Science Foundation	200	175	70	0	0
Total Federal Geothermal Program Budget	76,782	132,021	180,089	189,696	196,152

Table ES.3

GEOTHERMAL DRILLING ACTIVITIES, 1975-79

CLASSIFICATION	1975	1976	1977	1978	1979
Producible	37	39	25	30	30
Suspended	2	8	17	15	6
Abandoned	7	5	5	4	11
Injection	0	0	3	5	0
Observation	0	13	2	4	8
Unknown	0	0	0	0	25
TOTAL	46	65	52	58	80

Sources:

1975 - 1978 estimates are from Geothermal Energy Magazine Annual Drilling Summaries.

1979 estimates are from the Geothermal Progress Monitor Drilling file. These include 9 wells for which spud dates but no completion dates or footage were reported by 2/15/80.

Table ES. 4

FEDERAL LEASING STATUS, CUMULATIVE

AS OF SEPTEMBER 30, 1979

Type	Leases		Lease Applications		Applications Rejected		Applications Withdrawn	
	Number	Acres	Number	Acres	Number	Acres	Number	Acres
Noncompetitive								
Bureau of Land Management...	1,274	2,220,936	5,126*	10,500,000*				
U.S. Forest Service.....	58	93,736	2,189*	4,800,000*				
Sub total.....	1,332	2,314,672	7,315*	15,300,000*	1,517*	3,150,000*	2,360*	5,300,000*
Competitive								
Sub total.....	296	510,453						
TOTAL.....	1,628	2,825,125	7,315*	15,300,000*	1,517*	3,150,000*	2,360*	5,300,000*

*Number of applications are reasonably accurate but acreage totals may range in error to about 2 percent.

50 MWe Geothermal Demonstration Plant

CHAPTER I. INTRODUCTION

This report describes progress during Fiscal Year 1979 (FY 79) and near-term plans of the Federal government for promoting the use of geothermal energy. In 1979 the United States produced about 62 quadrillion Btu (quads) of energy. Of these about 21 quads were from petroleum; 20 were from natural gas; 15 were from coal; 3 were from hydroelectric; 3 were nuclear; and about 0.1 was "other," which included geothermal, biomass, and solar energy. Geothermal energy contributed 62 trillion Btu, yet this form of energy has a great potential to assist in the future energy needs of the United States.

In order to keep energy imports at a manageable level, we must again resume an annual increase of domestic energy production of about 1.25-1.5 quads per year. By the year 2000 the nation must be producing about 90-92 quads of energy to maintain present per capita consumption. No one fuel source appears to have the potential to produce that much energy. Geothermal, solar, coal, nuclear, agricultural waste, and gasohol must all augment an aggressive conservation program. The geothermal energy of the nation, if vigorously produced, could supply as much as 0.1 quad each year to this 1.25-1.5 quad.

While geothermal energy will not solve the United States' energy problem by itself, it will make a major contribution to relieving energy supply shortfalls in some regions. Geothermal energy is one of the cleanest, safest, and sometimes most economically attractive energy sources available, and presents the further advantage of being available now for the higher quality resources. Research programs are making possible its more widespread use.

The IGCC goals for energy production in the year 2000 are electricity production equivalent to 2.2 quads of fossil fuel input (1,056,000 barrels of oil per day equivalent), direct heat use equivalent to 1 quad of fossil fuel input (472,000 barrels of oil per day equivalent), and methane production of 3 quads. Meeting these goals will make significant contributions to national energy needs. The National Energy Plan (NEP-II, May 1979, Medium World Oil Price Case) projects for the year 2000 energy consumption of 119 quads, and end use of 85 quads. When the hydrothermal goals are compared to the NEP-II projected growth in demand between 1985 and 2000, the geothermal contribution will be 4 percent of the increased electricity supply and about 10 percent of the increased supply for direct heat.

By the year 2000, more than 25 percent of California's electricity could come from geothermal sources. Twenty percent of the nation's natural gas use could come from methane from geopressed aquifers.

This report contains a number of important findings:

- Geothermal development by the private sector is increasing
- A very aggressive Federal program is needed to ensure that the specified goals are met

- Successful coordination of Federal, state, and private sector planning and activities has improved
- Recent technology advances have reduced the cost and risk associated with geothermal development
- Geothermal energy is economically competitive today at many sites, and on the verge of being so at other sites
- Environmental, legal, and socioeconomic constraints may impose impediments on development at specific technically attractive sites

The commercial development of geothermal energy is relatively new. Consequently convincing the appropriate decisionmakers and end-users that geothermal resources should be used in their projects will not be easy, for commitment to this energy resource still involves financial risks.

A. SCOPE OF GEOTHERMAL ENERGY

Geothermal energy sources are concentrations of thermal energy stored in subsurface rocks and fluids that are heated by underlying molten rock or radiogenic plutons. Some of these resources can be tapped by drilling, and the hot fluids brought to the surface for generation of electric power or for direct uses of heat from the thermal fluids.

- Hydrothermal sources 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. Hydrothermal resources are used both for electric production and for direct thermal applications.
- Geopressured resources consist of water at moderately high temperatures at pressures higher than normal hydrostatic pressure. This water contains dissolved methane. Geopressured sources 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. Commercial-scale utilization of these resources may begin in the late 1980'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 power 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. Commercial-scale utilization of hot dry rock resources may begin in the 1990's.

Geothermal energy has been used in this country on a very limited scale since the end of the 19th century. Fluids from a geothermal system in

Boise, Idaho, began heating homes there in 1894. The city, with DOE help, is currently expanding development of that system. It now heats about 145 homes, and will eventually be used for a community-wide system, beginning with a major downtown redevelopment project. In 1960, use of geothermal resources for generation of electric power began at The Geysers field in California and use has increased steadily. Present development provides steam for 663,000 kilowatts of electric capacity. Nonelectric uses consume about 1.5 trillion Btu per year for space heating and industrial and agricultural processes in more than a dozen states.

During the past year utility companies announced that they intend to build electric power generating plants totaling more than 1,000 MWe from high-temperature hot water resources. These plants, plus announced additional plants extending high-temperature dry steam-generating capacity at The Geysers to 1,900 MWe, should produce installed generating capacity of about 3,000 MWe by 1985. The most efficient and timely development of geothermal resources will depend on the coordinated efforts of Federal, state, and local governments, industry, consumer and environmental groups, and private citizens.

B. THE INTERAGENCY GEOTHERMAL COORDINATING COUNCIL

Figure I.1 depicts the geothermal community in the United States, those entities with a direct stake in developing geothermal energy sources. Federal responsibilities and programs are divided among a number of agencies, whose activities are coordinated through the Interagency Geothermal Coordinating Council (IGCC), formally established by a Charter adopted in November 1977.

The IGCC got its start when Congress established the Geothermal Energy Coordination and Management project in Public Law 93-410, enacted September 3, 1974. 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
- Demonstrate appropriate technologies
- Administer a loan guaranty program
- Develop commercialization strategies.

PL 93-410 delegated certain functions to specific agencies, for example, Department of the Interior, National Science Foundation, Department of the Treasury. The Project became the responsibility of the IGCC in 1974 when Congress established the Energy Research and Development Administration (ERDA) in the Energy Reorganization Act. The IGCC brings together all the Federal agencies that encourage development of geothermal

FIGURE I. 1

THE GEOTHERMAL ENERGY COMMUNITY IN THE U.S.

resources by private industry, and serves as an effective means for exchanging information among government agencies and formulating Federal policies. It develops detailed Federal program plans and goals, and defines actions and policies to be followed by Federal agencies to accomplish these goals.

C. HISTORY OF THE FEDERAL GEOTHERMAL PROGRAM

Although geothermal energy has been used in the United States since 1894 (see Table I.1), serious commercial interest did not begin until the late 1960's. The genesis of Federal geothermal activity can be said to have been the USGS's limited assessment, in 1969, of geothermal resources. This assessment was drawn from basic research conducted by USGS on a limited scale since 1945 as a part of its charter to assess national resources. At about the same time, the Bureau of Reclamation was looking at these resources as a means of mineral extraction.

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.

In early 1975 all of AEC's and the bulk of NSF's programs were transferred to the Energy Research and Development Administration (ERDA), created by the Energy Reorganization Act of 1974. The Non-nuclear Energy Research and Development Act of 1974 gave ERDA considerable additional authority, including incorporation of the geothermal program previously established by the Geothermal Research, Development, and Demonstration Act of 1974. ERDA was given programmatic geothermal functions, and also was given the authority to coordinate all geothermal activities of Federal agencies. DOI retained its traditional role of national resource assessment and leasing of Federal lands.

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 non-electric 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

Table I.1

SIGNIFICANT EVENTS IN THE DEVELOPMENT OF GEOTHERMAL ENERGY
IN THE UNITED STATES

- 1894 District Heating in Boise, Idaho
- 1900 Hot Water to Homes in Klamath Falls, Oregon
- 1916 Power Generation at Geysers Resort
- 1927 First Exploratory Geothermal Wells Drilled in Imperial Valley, California, by Pioneer Development Company
- 1959 Small Pilot Plant Operated Near Niland, California on Sinclair No. 1 Well
- 1960 Commercial Electricity Generated from Dry Steam at The Geysers (Cal.)
- 1970 Geothermal Steam Act Passed
- 1972 NSF Becomes Lead Agency for Federal Geothermal Programs
- 1973 USGS, AEC, NSF Prepare First Federal Geothermal Program
- 1974 Geothermal RD&D Act Passed
First Federal Lands Leased
- 1975 ERDA Formed; Division of Geothermal Energy Formed Primarily from NSF, AEC
USGS Releases First National Geothermal Resource Estimates and Inventory
- 1977 DOE Formed; DGE Kept Intact
- 1978 NEA Tax Act Passed
EPA Issues Pollution Control Guidelines for Geothermal Energy Development
Successful Hot Dry Rock Experiment Conducted (New Mexico)
First Geothermal Crop-Drying Plant (Nevada)
- 1979 USGS Releases Updated National Geothermal Resource Estimates and Inventory
10 MWe Plant Built by Industry at East Mesa (Cal.)
Streamlining Task Force Recommends to IGCC Measures to Speed Federal Leasing
First Production from Federal Lands, at The Geysers (Cal.)

Secretary for Energy Technology. Late in the year, it was announced that DGE would be moved to Resource Applications as well.

D. ORGANIZATION OF FOURTH ANNUAL REPORT

This Report describes the measures taken in FY 79 to stimulate commercial development of electricity from geothermal resources and direct applications of geothermal heat. Unlike previous Reports, this document includes descriptions of private sector development as well as public sector activities. Due to the proprietary nature of much of the industry's work, however, it is not possible to obtain information about all facets of private development. Statements about private sector achievement, therefore, are indicative but not comprehensive.

This Report describes:

- The geothermal strategy and plan
- Utilization goals, estimates, and resource potential
- The Federal program for commercialization, technology development, policy development, and international activities
- Environmental developments
- Regional, state, and local government accomplishments, status, and plans
- Industry activity in geothermal development.

Direct Contact Binary Plant

CHAPTER II. NATIONAL UTILIZATION GOALS AND ESTIMATES

This chapter presents the IGCC's goals and examines estimates of the level of geothermal energy production at various dates in the future. It looks at future geothermal energy production in four ways:

- The goals or target levels of production, selected by the IGCC
- Expected levels of production, as viewed from the perspective of various forecasters, independent of the IGCC goals
- The resource base, and amount of geothermal energy available for extraction
- Costs of production, specifically the relationship of cost and expected production levels for hydrothermal resources.

A. NATIONAL GEOTHERMAL UTILIZATION GOALS

The IGCC's estimates of the achievable commercial utilization of geothermal resources in the United States are presented in Tables II.1 and II.2. These goals provide a basis for framing Federal, state, and local policies and for determining measures necessary to increase the use of geothermal energy.

The goals incorporate knowledge of existing and planned geothermal development. They are based in part on the quantity of the exploitable geothermal resources in the United States, and in part on estimates of how rapidly the resources could be exploited in a technically feasible manner. Some consideration is made of the relative cost of geothermal versus other energy forms. Environmental problems are assumed not to be major impediments affecting the goals.

The hydrothermal electric goal for 1985 is 3,000 MWe. Approximately 2,500 MWe capacity is on line or firmly planned to be on line by 1985. Intentions have been announced to build other plants, but firm plans have not been made. To meet the 1985 goal, decisions would have to be made within the next year or so to build about 500 MWe additional capacity. An aggressive, supportive Federal program can accomplish this.

The hydrothermal electric goals are 25,000 MWe of generating capacity on line in 2000 and 50,000 MWe in 2020. Meeting these goals will require continued aggressive exploration through 2010, identification of new prospects, technology to produce electricity from reservoir fluids down to 150°C, and a financial climate that ensures that successive 100 MWe plants will be installed at three-year intervals at each prospect, until the currently estimated production capacity of each prospect is developed. The methods used to set these goals are described in Appendix C.

The hydrothermal direct heat utilization goals are 1 quad/yr in 2000 and 6 quads/yr in 2020. Reaching these goals will require continued exploration and assessment of the lower temperature resources, reservoir

Table II.1

NATIONAL GEOTHERMAL UTILIZATION GOALS (BY APPLICATION)

<u>Electric Power Capacity (MWe)</u>	<u>1980</u>	<u>1985</u>	<u>1990</u>	<u>1995</u>	<u>2000</u>	<u>2010</u>	<u>2020</u>
Hydrothermal	663	3,000	7,000	14,000	25,000	38,000	50,000
Geopressured (thermal) ^a	0	10	70	500	2,000	3,500	5,000
Hot Dry Rock	<u>0</u>	<u>10</u>	<u>35</u>	<u>135</u>	<u>700</u>	<u>1,900</u>	<u>6,800</u>
Total MWe (Rounded)	663	3,000	7,100	14,600	28,000	43,000	62,000
Fossil Fuel Equivalent Energy (in quads)	0.05	0.24	0.6	1.2	2.2	3.4	4.9
<u>Direct Thermal Applications^c</u>							
Hydrothermal	0.01	0.1	0.2	0.4	1.0	3.0	6.0
Hot Dry Rock	0.00	0.001	0.001	0.004	0.007	0.015	0.6
<u>Geopressured Methane</u>	<u>0.00</u>	<u>0.02</u>	<u>0.1</u>	<u>0.7</u>	<u>3.0</u>	<u>5.0</u>	<u>7.0</u>
TOTAL (Rounded)	0.06	0.40	0.9	2.3	6.2	11.5	18.5

^aGeopressured hydraulic energy assumed devoted to on-site parasitic loads.

^bBased on above totals. Equivalent fossil fuel input to produce "Total MWe," based on an assumed capacity figure of 0.80 and an equivalent efficiency of fossil fuel plants of 0.33.

^cFrom hydrothermal and hot dry rock systems only. Goals not set for geopressured (see Table II.2).

Table II.2

NATIONAL GEOTHERMAL UTILIZATION GOALS (BY RESOURCE TYPE)
(QUADS/YEAR)

	1980	1985	1990	1995	2000	2010	2020
<u>Hydrothermal</u>							
Electric Applications ^a	0.05	0.24	0.6	1.1	2.0	3.0	4.0
Direct Thermal Applications	0.01	0.1	0.2	0.4	1.0	3.0	6.0
<u>Geopressured</u>							
Electric Applications ^a	0.00	0.001	0.006	0.04	0.16	0.3	0.4
Direct Thermal Applications ^b	-	-	-	-	-	-	-
Methane	0.00	0.02	0.1	0.7	3.0	5.0	7.0
<u>Hot Dry Rock (Estimates only)^c</u>							
Electric Applications ^a	0.00	0.001	0.003	0.01	0.06	0.15	0.5
Direct Thermal Applications	<u>0.00</u>	<u>0.001</u>	<u>0.001</u>	<u>0.004</u>	<u>0.007</u>	<u>0.015</u>	<u>0.6</u>
TOTAL (Rounded)	0.06	0.4	0.9	2.3	6.2	11.5	18.5

^aBased on MWe goals. Equivalent fossil fuel input to produce estimated MWe, based on an assumed capacity factor of 0.80 and an equivalent efficiency of fossil fuel plants of 0.33.

^bAs yet, the markets for nonelectric applications of geopressured energy sources are not well enough defined to establish meaningful objectives.

^cThese are not yet set as goals; only estimates of production are possible at this time.

confirmation, substantial user education and technical assistance, and some degree of relocation of commercial and industrial users.

The goals for energy from geopressured resources are 2,000 MWe and 3 quads/yr methane production by 2000, and 5,000 MWe and 7 quads/yr methane production by 2020. Reaching these goals will require proof of the technical feasibility of resource exploitation by about 1983, no significant adverse findings from ongoing environmental studies (primarily waste disposal), and no significant degree of subsidence in production areas. To meet these goals, utilization of offshore resources may be needed.

Goals have not been set for hot dry rock, but potential productivity estimates for electricity and direct heat have been made. About 700 MWe and 0.007 quads/yr are possible by 2000, 6,800 MWe and 0.6 quads/yr by 2020. Meeting these goals will require extensive characterization of the hot dry rock resource, the development of effective and economical technology for extracting thermal energy, and significant improvements in technology for drilling deep holes in hot hard rock.

Reaching the 1985 goal of 0.1 quads/yr for direct heat use will require that the pace of the development activity be increased above current levels. One well with a flow rate of 500 gallons/minute can feed a direct heat system (with a 60 percent conversion efficiency and a 38°C temperature drop) that will produce about 1.3×10^{11} Btu/yr of heat for end use. To produce the equivalent of one quad (10^{15} Btu) of fossil fuel equivalent input per year would require the use of about 2,300 major production wells. To meet the 0.1 quad goal would require drilling perhaps 500 potential production wells and 200 additional wells for injection in six years, or about 115 major wells per year.

It seems unlikely that this goal can be met without a very strong Federal program. The current pace of development seems unlikely to support this goal. Plans have been proposed for about 0.005 quad of new development through 1985 (Geothermal Progress Monitor Report #1, January 1980). The geothermal industry drilled about 60 major wells in 1978, of which most were in high-temperature (potential electric) prospects and about half in the Geysers steam-electric field. Attaining the direct heat goal would require a tripling of current geothermal drilling rates for that purpose alone. Planned direct heat project starts would have to increase by a factor of 20 within the next 2 to 3 years.

The 1985 direct heat use goal of 0.1 quads per year is achievable if current activities are accelerated during the next few years. Four coordinated efforts could boost geothermal energy use fiftyfold from the current level of about 0.002 quads per year. These efforts are: the geothermal loan guarantee program, commercialization projects, Federal reservoir definition projects, and private industry efforts.

The geothermal loan guarantee program, by working at budget levels already authorized, could guarantee 15 new projects of 0.001 quads per year. The direct heat commercialization program would share the costs of 60 projects, 22 of which are already funded and in progress. Together, these projects would require about 60 new wells, and result in 0.0005 quads per average use per project. The reservoir definition program would share

Table II.3

SUMMARY OF NONELECTRIC USE ON-LINE, 1979*

AREA OF USE	NUMBER OF USERS	FUNDING (\$000)				BTU/YEAR (10 ⁹)
		FEDERAL	STATE	LOCAL	PRIVATE	
SPACE AND PROCESS USES	180	63,992	6,692	6,014	1,071	1,386.2
BATHS AND POOLS	90		2	9	73	51.8
ENHANCED OIL RECOVERY	1				unknown	10,000.0
TOTAL	271	63,992	6,694	6,023	1,144	11,438.0

*Based on data in the Geothermal Progress Monitor, Issue Number 1, December 1979.

Table II.4

COMPARISON OF HYDROTHERMAL ELECTRIC FORECASTS
(MWe On-Line by End of Stated Year)

FORECAST	DATE	BASIS	1979	1980	1985	1990	1995	2000
IGCC Goals ^a	1979	Resource Potential and Economics		663	3,000	7,000	14,000	25,000
DGRM ^b	1979	General Knowledge of Developer/ Utility Plans	663	941	2,470	3,330	-	-
EPRI Forecast ^c	1979	EPRI R&D Plans	-	-	6,000	9,650	-	25,000
EPRI Survey ^d	1979	Survey of Industry Estimates:						
		- Announced	-	-	2,057	2,242	-	2,832
		- Probable	-	-	2,564	4,577	-	7,288
		- Possible	-	-	2,999	6,443	-	10,888
NRC CONAES	1979	Panel of Experts						
Geothermal		- Business as Usual	-	860	1,480	2,520	-	5,500
Resource		- Moderately Accelerated Development	-	970	2,160	3,500	-	8,400
Panel ^e		- Strongly Accelerated Development	-	1,180	2,620	6,600	-	16,100
		- Crash Development	-	1,380	3,130	9,900	-	26,600
Commerce Department ^f	1977	"Most Likely" Supply/Demand Balance	-	1,000	2,000	-	-	20,000
EIA Annual Report 1978 to Congress 1978 ^g	1978	Mid Range Economic Growth and Oil Price Case	-	-	2,600	4,500	6,200	-

^aTable II.1 this report.

^bGeothermal Progress Monitor Report #1, December 1979.

^cEPRI New Energy Resource Department Strategy Paper, January 1979.

^dV. Roberts and P. Kruger, Geothermal Resources Council Transactions, Vol. 3, September 1979.

^eGeothermal Resources and Technology in the United States, National Academy of Sciences, 1979.

^fForecast of Likely U.S. Energy Supply/Demand Balances for 1985 and 2000 and Implications for U.S. Energy Policy, U.S. Department of Commerce, 20 January 1977.

^gU.S. D.O.E. Energy Information Administration, Annual Report to Congress 1978, Vol. 3, Supplement 1.

the costs of about 50 projects. Each successful project is estimated to use 0.0005 quads per year.

The projects above are assumed to stimulate one private sector project for every two projects with substantial Federal involvement. These "leveraged" projects would number about 60 successful projects averaging 0.0005 quads per year per project.

Summed across these four efforts, there would be about 210 attempted new project starts, of which about 160 would be successful. About 300 new wells (about 180 successful) would be drilled during calendar years 1980 through 1984, an average of about 60 new wells for direct use per year. Together these would produce 0.1 quads per year.

B. ESTIMATES OF GEOTHERMAL UTILIZATION

Most of the estimates of geothermal energy utilization that can be made with a reasonable degree of confidence are for hydrothermal electric applications. The resource assessment work of the U.S. Geological Survey and announced plans of field developers and electric utility companies provide a useful basis for estimating rates of development.

In contrast, estimates of hydrothermal nonelectric use, geopressed methane production, and extraction of other energy from geopressed and hot dry rock resources are clouded by uncertainties concerning the size of the producible resource, co-location of resources and markets, and the economics of production. Table II.3 presents current estimates of the current geothermal energy as a nonelectric energy source.

Estimates of geothermal hydrothermal electric utilization in the United States from a number of recent assessments are shown in Table II.4. The IGCC hydrothermal electric goals from Table II.1 are included for comparison.

For the near term, through 1985, the results of the Electric Power Research Institute (EPRI) survey of electric utilities provide the most interesting results. Announced plans of utilities indicate a minimum of 2,000 MWe on line by the end of 1985, with 2,500 MWe viewed as probable, and 3,000 MWe seen as possible.

There appears to be broad consensus from these estimates that by 1990, about 3,500-4,500 MWe could be installed given moderate stimulation, while an intense effort might result in somewhere between 7,000-10,000 MWe.

Developments of resources after 1990 are difficult to predict due to lack of knowledge about the general economic climate and scarcity of knowledge about the number and size of hydrothermal resources in unexplored areas.

Forecasts for installation of hydrothermal electric plants by the end of 2000 fall in the range of 11,000-25,000 MWe. Cost estimates and scheduling exercises suggest that about 13,000-15,000 MWe could be developed from known resources by the year 2000 (see Appendix D). The IGCC goal for the year 2000 of 25,000 MWe assumes that many new high-quality

resources will be discovered in the next decade. Almost all of the capacity installed through 1985 will be in California. Installed capacity at The Geysers field will still predominate. Significant development of resources in the Imperial Valley, California, and in other western states is expected in the 1985-1990 period.

The Division of Geothermal Resource Management is estimating market share and market penetration of hydrothermal resources for direct heat utilization. These estimates require careful analyses for the co-location of resource and potential markets, and the match between resource characteristics and end-use temperature and heat rate needs.

The National Resource Council's (NRC) Geothermal Resource Panel (Reference e in Table II.4) estimated that direct heat use by 2000, from all forms of geothermal resources, will be less than 1 quad, even if crash development occurs. That panel identified a low degree of co-location between resource and cities, and lack of mobility of industrial users as major limits to growth of direct heat use. More recent studies, however, suggest that this goal can be met with an aggressive program.

The potential for hydrothermal electric generation for the years 1985, 1990, and 1995 was integrated into the projections made for Energy Information Administration's Annual Report to Congress 1978, published in mid-1979.

These projections are sensitive to a wide variety of parameters, including GNP projections, supplies of conventional fuels, and world oil prices; and are based upon the assumption that the governmental policies in force at the end of 1978 will continue unchanged. They should be regarded only as representative projections, but do provide some insight into the potential extent of application of electric generation using hydrothermal energy.

The input parameters relating to specific resources that were used for projecting hydrothermal electric generation were derived from a study done by the Mitre Corporation for the DOE geothermal program, and were provided to EIA by DOE's Office of Policy and Analysis.

In all of the projections, the vast majority of hydrothermal electric generation takes place in California, Nevada, and Arizona, with a small amount of generation in the Gulf Coast. In a few projections and years, a small amount of generation occurs in the Rocky Mountain States.

For the near term (1985), total U.S. hydrothermal electric generation is relatively insensitive to the projection parameters. This is to be expected, since commitments have already been made for most facilities likely to be operating by 1985.

Projected hydrothermal electric generation for 1990 and beyond is relatively sensitive to the availability of domestic supplies of alternative fuels. Low domestic supplies of conventional fuels (principally oil and natural gas), coupled with high world oil prices, could raise hydrothermal electric generation by more than 25 percent.

Most 1995 hydrothermal electric generation capacity projections are on the order of 6,200 MWe. Low supplies of domestic oil and gas or a nuclear moratorium could raise generation by 50 to 60 percent.

A summary of estimates of the energy recoverable from geopressured geothermal resources in Louisiana and Texas made by LSU in 1978 are shown in Table II.5. The estimates of producible methane range from near zero to 52,000 quads. These estimates differ, because very little is known concerning how much brine can be produced from wells, the reservoir characteristics of each geopressured aquifer, the economics of production and reinjection, and the degree to which environmental effects such as ground subsidence could restrict production from specific fields along the Gulf Coast.

C. GEOTHERMAL RESOURCE POTENTIAL IN THE UNITED STATES

In FY 79, the U.S. Geological Survey (USGS) published an update of its national geothermal resource assessment (USGS Circular 790, "Assessment of Geothermal Resources of the United States-1978," January 1979). Taken from this document, Table II.6 shows the current estimated potential of geothermal resources in the United States. The estimates include offshore geopressured resources, reported for the first time. In considering the energy estimates in this table, care must be taken to differentiate between the accessible resource base (total thermal energy in the ground to specified depth) and the resource (thermal energy that could be extracted economically within a reasonable time). To emphasize this important distinction, the resource estimates have been enclosed in a box with a bold line.

Circular 790 attempted the first tabulation of data of low-temperature (less than 90°C) geothermal waters at depths less than 1 km. It was not possible to quantify the amount of geothermal energy in the ground or the amount of energy that might be recovered. Such low-temperature waters appear to be widely available over much of the country and should have significant potential for space heating and agricultural applications. The USGS is increasing its effort to better understand waters in the low to moderate ranges (20°-150°C) and with more adequate data supplied by the DOE state-coupled program will complete an assessment within the next two years.

It should be noted that the geothermal resource assessment, because of its high level of aggregation, should not be used to establish specific reserve figures for short-term investment and marketing decisions. By its nature, this resource assessment is designed to be useful to industry and government in developing long-term policy and strategies. It is prepared using uniform methodology and data analysis to estimate the amount of thermal energy that might feasibly and economically be extracted from the earth at some future time.

Figure II.1 shows those areas in the U.S. that have been identified as having known or potential hydrothermal resources. Data for this map were derived from the regional and national assessments performed by the USGS and from state and site-specific assessments performed under the DOE state-coupled program. The western U.S. has the greatest potential for

Table II.5

SUMMARY OF RECOVERABLE GEOPRESSURED ENERGY ESTIMATES
(Louisiana-Texas Gulf Coast, Onshore and Offshore)¹

SOURCE	THERMAL QUADS	GAS QUADS	ELECTRICITY (MW centuries)
Brown-Hudson		2,400-52,000	
Dorfman-Texas (Texas only)			20,000
Dorfman-Texas		256	
Elmer-Tractor	529-2,058	2,000	
Gould-Intercomp (onshore Texas only)		150	33,000
Hawkins-LSU (Louisiana only)	19.5	13.6	
Hise-LSU		125	
House-Livermore		222	5,990
Jones-LSU		1,146	
Myers-Livermore		.0001-1,000	0.1-100,000
Papadopoulos-USGS (Plan 2)	1,424	768	38,140
(Plan 3-lower bounds) (onshore only)	77.38		2,880
Trehan-MITRE			100,000
U.S. ERDA-Definition Report		500-2,000	33,400-110,000
U.S. ERDA-MOPPS		150-2,000	
Wilson-Dow (Texas only)		45.6	8,000

¹From: B. Wilkins, Office of Advanced Studies and Research, Louisiana State University,
Baton Rouge, Report #ORO-5442-1, February 1978.

Table II.6

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 Offshore gulf coast	33,000,000 ^a 370,000 ^c	17,000,000 ^b 180,000 ^c						3,300,000 ^a 16,000 ^c			
Igneous-related: Evaluated Unevaluated	101,000 900,000										
Reservoirs of hydro- thermal convection systems (90°C): Identified Undiscovered						950 ^d 2,800-4,900	700 3,100-5,200	1,650 ^d 3,000	400 2,000	23,000 72,000-127,000	42 184-310
Northern Gulf of Mexico Basin (onshore and offshore): Thermal energy Methane energy	850,000 ^c	410,000 ^c	11,000 6,000	96,000 57,000	107,000 63,000				270 ^f -2800 ^g 15 ^{8f} -1640 ⁸		
Other geopressed 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 $11,700,000 \times 10^{18}$ 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 others (1975, Table 14).
- c. Calculated for an area of $135,000 \text{ km}^2$ 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 their "best estimates."

- d. Does not include 1290×10^{18} J in National Parks (mainly in Yellowstone).
- e. Calculated for an area of $310,000 \text{ km}^2$ 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 Papadopoulos, Wallace, Wesselman, and Taylor (1975).
- g. Plan 2 of Papadopoulos, Wallace, Wesselman, and Taylor (1975).
- h. From White and Williams (1975, Table 28): thermal energy only.

*Table 20 of USGS Circular 790, Assessment of Geothermal Resources of the United States, 1978.

** 10^{18} J 1 quad.

Figure II.1

Known and Potential Hydrothermal Resources

hydrothermal development, particularly for use in electrical power generation and direct heat applications that require relatively high temperatures. The Atlantic Coastal area and the southeastern U.S. contain a number of prospective targets for development as low- to moderate-temperature heat sources.

D. HYDROTHERMAL SUPPLIES AND ESTIMATED COSTS

Utilization estimates depend on a number of factors, including the available supply of geothermal energy, the economics of energy extraction, the economics of energy conversion, and estimates of future demand for electricity and heat. The resource assessment activities of the U.S. Geological Survey and a number of economic studies were used for supply and cost estimates for hydrothermal electric and hydrothermal direct heat applications. These are presented in this section to demonstrate that hydrothermal resource supplies are large and economical. Supply and cost curves for geopressed geothermal and hot dry rock resources are much more uncertain, and are not described here.

The hydrothermal supply estimates presented here are based on application of economic studies to resource estimates in USGS Circular 790, published in early 1979. Circular 790 describes both estimates of the energy potential at known specific hydrothermal sites, and estimates of inferred resources yet to be located.

Figures II.2, II.3, and II.4 present the estimates of potential electric energy at the 52 known prospects. These known prospects could supply about 21,000 MWe of capacity for a 30-year period. About half of the known hydrothermal electric resource is located in California, and almost all of the rest of it is in six other western states: New Mexico, Nevada, Oregon, Utah, Idaho, and Hawaii.

Six of the known locations appear to be able to support more than 1,000 MWe each for 30 years. These are the Salton Sea area, California; Valles Caldera (Baca Ranch), New Mexico; Mono-Long Valley, California; Westmorland, California; The Geysers, California; and Lake City-Surprise Valley, California.

Costed supply curves for hydrothermal electric and direct heat uses are shown as Figures II.5 and II.6. These estimated curves were prepared by applying engineering cost models to the physical characteristics (volume, temperature, depth) of the known hydrothermal resources in USGS Circular 790.

Resources with estimated temperatures greater than 150°C are assumed to be used for electricity production, and lower temperature (90-150°C) resources are assumed to be used for direct heat applications. The USGS estimates that the undiscovered hydrothermal electric resource is about four times the known resource, while the undiscovered direct heat resource is about five times the known resource. The hydrothermal electric cost model and the direct heat cost model were prepared by the Mitre Corporation and Battelle Pacific Northwest Laboratories, respectively. The detailed assumptions used in these costing models are described in Appendix D.

Figure II. 2
ELECTRIC ENERGY COMPARISON
OF IDENTIFIED HYDROTHERMAL SYSTEMS
≥150°C

Figure II. 3
POTENTIAL ELECTRICAL ENERGY (MWe for 30 years from known hot water hydrothermal systems $>150^{\circ}\text{C}$)*

*Twenty Largest Prospects (calculated from Circular 790, Table 5).

Figure II. 4

POTENTIAL FOR ELECTRIC ENERGY (MWe FOR 30 YEARS) FROM KNOWN HOT WATER HYDROTHERMAL SYSTEMS ($>150^{\circ}\text{C}$)*

*Twenty Largest Anomalies, Aggregated by State (calculated from Circular 790, Table 5).

Figure II. 5

COST CURVES FOR GEOTHERMAL (HYDROTHERMAL) ELECTRICITY

1,000 MWe For 30 Years of Reservoir Capacity (Cumulative) - Known & Inferred Resources*

* Does not include The Geysers. Upper horizontal axis assumes inferred sites to come in at cost of and in proportion to discovered sites. (Based on USGS estimates). Assumptions for this table are discussed in Appendix D.

Figure II.6

COMPOSITE NONELECTRIC RESOURCE AVAILABILITY CURVE¹

The electric cost curve (Figure II.5) is based on the installation of 50 MWe plants of double-flash design at high-temperature prospects and binary-cycle plants at moderate-temperature prospects. The cost estimates include the incentives provided for in the 1978 National Energy Act (NEA). The upper of the two curves is based on the costs of available technology. The lower curve includes estimates of the cost-reducing impacts of the improved technology that are expected to result from Department of Energy geothermal research and development programs and used in commercial installations by 1990.

The electric cost curves assume that installation and operation proceeds with no problems, and with no elaborate environmental controls. Exploration costs are not included, since these can be very high for a first plant and relatively low for additional plants. These assumptions imply that the cost of power from the first plant at each site could be significantly higher than (perhaps even double) the cost shown here. Costs are measured in 1979 dollars.

The direct heat cost curve assumes that one-third of the available lower temperature resources will be used for urban district heating, for suburban district heating, and for industrial process heat. This cost curve reflects the efficiency of utilization, which should be taken into account in comparisons with the costs of competing energy resources. For example, the efficiency of utilization for space heating with oil is between 50 and 70 percent, but the efficiency of utilization for space heating with geothermal is nearly 100 percent. At current prices, with current technology, 20 quads of identified resource and 120 quads of identified plus undiscovered resource are available at \$6 per million Btu (Figure II.6); 80 quads of identified resource and 540 quads of identified plus undiscovered resource are available at \$13 per million Btu. Detailed assumptions used in these costing models are described in Appendix D.

Estimates for direct applications assume current technology only. If the recent achievements and projected breakthroughs in low-cost, high-efficiency technology are figured in, the costs will become even more competitive.

Raft River, Idaho, Well Test

CHAPTER III. GEOTHERMAL DEVELOPMENT STRATEGY

The aim of the Federal geothermal program is to transform the many types of geothermal resources into an array of technically, economically, and environmentally sound commercial ventures. Federal strategies reflect the different conditions of technical and economic readiness of the three resource types (hydrothermal, geopressured, and hot dry rock). The commercial attractiveness of these resource types depends on the physical characteristics of the local resource and the costs of energy extraction and utilization technology. For example, the relative costs increase with the depth of the resource and decrease with higher temperatures.

At this time, the hydrothermal resource is the most likely candidate for active commercial use. Electricity is produced at The Geysers, California, and could be produced economically at a number of other sites in the West. Hydrothermal direct heat is being used at a number of western sites, and could be used now at many more sites, including some in the eastern United States.

Hydrothermal energy has great potential in the near term. The extent of its use will depend upon continued cost-reducing impacts of R&D, cost-effective environmental controls, the level and type of Federal and state financial incentives, and the cost of alternative energy sources. For the longer term, successful development of technology to use lower temperature fluids for electric power production is needed.

Geopressured energy use is viewed as a mid-term probability. Current Federal strategy emphasizes the recovery of methane gas dissolved in the geopressured water. Because of the relatively low temperatures and the high cost of wells, the thermal and hydraulic energy are not economically recoverable in the near term without methane recovery. High well costs and existing state conservation laws may make it necessary to recover all three forms of energy simultaneously at most sites.

Specific technical and economic uncertainties must be resolved for the geopressured resource to be developed in the near term, including the amount and rate of production of fluid that can be produced from each well and reservoir, the methane content of the fluid, the potential for subsidence due to fluid withdrawal, availability of acceptable fluid disposal systems, and potential environmental effects. If findings are favorable, commercial development of the geopressured resource might begin as early as 1990.

Extensive use of energy from hot dry rock is considered to be a long-term possibility. Basic to the extraction of hot dry rock energy is the fracturing of the hot rock and creation of a circulating fluid loop. For such processes to be economical, improvements in both drilling and fracturing technologies are required. Commercial deployment of the resulting technology is expected to occur around the year 2000.

Because commercialization of the hydrothermal resource is much further along than commercialization of the other resource types, knowledge gained from experience with the hydrothermal resource in the

near-term can be applied later to the geopressured and hot dry rock resources.

The principal Federal geothermal strategies are outlined below. Some items apply to all types of resources; others are tailored to the needs of specific resource types.

A. ALL RESOURCE TYPES

1. To identify and quantify the approximately 80 percent of the estimated U.S. geothermal resource not yet located, the strategy is to accelerate the characterization of the various types of geothermal resources and reservoirs.

2. To reduce the uncertainties associated with estimates of the identified locations, the strategy is to intensify regional resource assessments and reservoir confirmation to meet near- and mid-term power-on-line goals.

3. To assist with technology improvements (which are likely to reduce geothermal energy costs, expand the economically competitive resource base and lead to more rapid commercialization), the strategy is to continue an already aggressive research and development program.

4. To speed the implementation of new projects, the strategy is to propose ways in which Federal leasing and permitting processes can be simplified.

5. To encourage state participation in geothermal development, the strategy is to assist states in site-specific planning and outreach activities.

6. To encourage potential nonelectric users to initiate projects, the strategy is to develop means to reduce front-end risks and to provide general technical assistance.

7. To assess the environmental impacts of geothermal energy development (which are relatively benign compared to conventional nonrenewable resources) that could delay exploitation or expansion, the strategies are

- a) to establish appropriate environmental regulations to support the development of geothermal resources
- b) to continue close monitoring of environmental effects at each resource area to insure minimal impacts
- c) to develop control technology and procedures for mitigating problems such as hydrogen sulfide emissions, subsidence, noise, and disposal of brines
- d) to determine the acceptable level of environmental effects.

8. To encourage capital investment through risk-sharing, the strategy is to provide Federal loan guarantees.

B. HYDROTHERMAL

1. To encourage widespread acceptance of hydrothermal energy as a practical energy source, the strategy is to develop a program to increase public awareness and to provide technical and planning assistance to users.

2. To improve estimates of the nature and size of identified hydrothermal systems, the strategy is to improve geothermometers and geophysical techniques.

3. To better define temperature, flow rate, and total heat content of reservoirs and make risks acceptable to developers and users, the strategy is to provide cost-sharing assistance to the first production wells in each reservoir.

4. To stimulate both electric and direct heat applications of conventional technology for hydrothermal use, the strategy is to provide technical assistance and economic incentives, including cost-shared demonstration projects.

5. To facilitate technology transfer and education, the strategy is to encourage companies to participate in field projects.

C. GEOPRESSURED

1. Although the geopressured resource contains methane, thermal, and hydraulic energy, the methane has the greatest economic value and thus is the economic determinant. Therefore the strategy is to focus on methane recovery, with thermal and hydraulic energy treated as potentially valuable byproducts. A corollary strategy is to develop systems to recover all three forms of energy in economically useful ways.

2. Since the geopressured resource could be very large, but little is known about its recoverability, the strategy is to collect the needed reservoir performance data through a series of high-rate, long-term flow tests of geopressured wells during the next 3-4 years. These tests also will resolve uncertainties related to potential environmental impacts of geopressured production.

3. To identify the potential location in areas other than the Gulf Coast, the strategy is to assess data from other sedimentary basins where geopressures have been measured or indicated.

D. HOT DRY ROCK

Hot dry rock resources could be enormous and therefore significant in the long term. But technology is at the earliest stage of all three resource types. The strategy is to continue evaluation of the resource potential, which will more fully define the extent to which the energy extraction technology can be applied nationwide. In addition, energy extraction experiments are needed to refine the technology and to decrease costs. Development of drilling and fracturing technology for high temperatures will be emphasized in the near-term.

1. 10/1/10
2. 10/1/10
3. 10/1/10
4. 10/1/10
5. 10/1/10
6. 10/1/10
7. 10/1/10
8. 10/1/10
9. 10/1/10
10. 10/1/10

HOT DRY ROCK GEOTHERMAL ENERGY EXTRACTION CONCEPT

Hot Dry Rock Geothermal Energy Extraction Concept

CHAPTER IV. THE NATIONAL GEOTHERMAL ENERGY PLAN

OVERVIEW

This section describes the roles of Federal, state, and local governments in support of national geothermal resource development strategy and goals.

The Geothermal Research, Development, and Demonstration Act of 1974 (Public Law 93-410), in assigning roles to the several agencies discussed herein, gave ERDA (now DOE) lead responsibility for the Federal geothermal program, and established interagency cooperation through the Geothermal Energy Coordination and Management Project, now the Interagency Geothermal Coordinating Council (IGCC). This body serves as the vehicle to develop a comprehensive Federal geothermal program. Since a significant number of non-DOE agencies within the Federal establishment have retained substantial responsibilities within the Federal program, coordination remains of prime importance.

Federal Policy Coordination

The Interagency Geothermal Coordinating Council is composed of representatives from several departments--Energy, Interior, Agriculture, Treasury, Commerce, Housing and Urban Development, Defense, the National Science Foundation, and the Environmental Protection Agency. Other agencies are represented on panels and working groups as the need arises.

The history and current organizational arrangements of the IGCC are detailed in Appendix A.

The IGCC coordinates various national geothermal programs. The IGCC is charged with ensuring that the missions and activities of specific Federal agencies are sufficient to meet the needs of the geothermal development in the area of resource evaluation, technology development and demonstration, and the development of commercialization strategies. The Council also provides support to the Geothermal Loan Guaranty Program.

Briefly the responsibility of the Council, in accordance with the provisions and intent of PL 93-410, is to:

...coordinate those Federal plans, activities, and policies which are related to or impact on geothermal energy, including ancillary activities of agencies not represented in the Council membership...The Council, through the Chairman, may make recommendations to the appropriate agencies and the President with regard to alternative policies or actions considered necessary or desirable to expedite the development and utilization of geothermal energy resources.

Five major subgroups comprise the IGCC. The Staff Committee supports the Council and manages the Panels and Working Group. The Budget and Planning Working Group coordinates budgets and general agency plans, and

prepares the IGCC Annual Report. The Institutional Barriers Panel recommends changes in laws, governmental policy, and procedures to enhance the development of geothermal energy. The Environmental Controls Panel, newly formed this year, makes recommendations based on its evaluation of environmental concerns and regulations that may affect geothermal commercialization. The Leasing and Permitting Panel, also formed this year, evaluates legislation and regulations pertaining to geothermal leasing and permitting.

Federal Funding

Federal geothermal outlays and budgets for FY 78 through FY 81 are shown in Table IV.1. The status of the Geothermal Resource Development Fund and Guaranty Authority is presented in Table IV.2. The total budget has remained almost constant over the last three years.

Program development and modification are closely coupled with the Federal budget cycle. Implementation of new policies often means new regulations, whose development may take from one to three years, including preparation of any required environmental impact statement (EIS). New policies requiring funding but no new regulations are subject to the regular and supplemental appropriations schedules of the Congress. Only those actions that do not require significant changes in funding or in regulatory policies can be fully implemented in less than a year.

Integrated Plan

The Federal Agencies, working in cooperation with states and local governments and the private sector, seek to stimulate and support the use of geothermal energy as soon as possible. Since many parties are involved, the plan is complex and requires continued coordination. The basic responsibilities of the parties are shown in Table IV.3. Several agencies are involved with each major activity and nearly all agencies are involved with more than one activity.

Table IV.4 presents Federal responsibilities in more detail, and outlines state and local government and private activities as well.

A. FEDERAL AGENCIES

The United States Geological Survey (USGS) of the Department of the Interior (DOI), and the Division of Geothermal Energy (DGE) in DOE, maintain active programs for the exploration, assessment, and confirmation of geothermal resources. Additionally, the Water and Power Resources Service (DOI) conducts exploratory geothermal investigations and water supply studies.

The USGS conducts a continuing broad assessment of U.S. geothermal resources of all types--hydrothermal systems of various temperature ranges, geopressured zones and hot dry rock regimes. This assessment identifies regions where such resources are known or are believed to exist; determines characteristic geologic, hydrologic, geochemical, and geophysical parameters of these resources; develops scientific basis for

Table IV.1

FEDERAL FUNDING FOR
GEOTHERMAL ENERGY

(in \$ thousands)

ORGANIZATION UNIT	ACTUAL FY 1977	ACTUAL FY 1978	ACTUAL FY 1979	ESTIMATED FY 1980	REQUESTED FY 1981
Department of Agriculture					
U.S. Forest Service	40	678	775	750	739
Department of Defense					
Navy	758	542	924	17,100	17,800
Air Force	15	0	13	21	2,400
DOD Total	773	542	937	17,121	20,200
Department of Energy					
Energy Technology	53,326	105,962	142,637	138,428	142,000
Resource Applications			9,737	9,026	10,000
Office of Energy Res.	1,900	2,800	3,200	3,400	4,000
Environment	3,862	3,896	3,167	2,303	2,949
Geothermal Loan Guaranty Fund (Administrative Expenses)	380	410	189	1,180	1,091
DOE Total	58,468	113,068	158,930	154,534	160,040
Department of Interior					
Fish and Wildlife	200	200	200	74	74
Bureau of Land Mgmt.	2,500	2,300	2,585	2,600	2,600
Bureau of Mines	528	550	1,050	800	400
Water and Power Res.Serv.	2,557	1,800	555	910	60
Geological Survey, Geothermal Res. Program	9,384	10,184	12,043	10,092	7,569
Geological Survey, Geothermal Evaluation and Lease Regulation	1,512	1,854	2,194	1,994	1,994
DOI Total	16,681	16,888	18,627	16,470	14,423
Environmental Protection Agcy.	600	670	750	750	750
National Science Foundation	200	175	70	0	0
Total Federal Geothermal Program Budget	76,782	132,021	180,089	189,696	196,152

Table IV.2

GEOTHERMAL RESOURCES DEVELOPMENT FUND AND GUARANTY AUTHORITY

	<u>Fund</u>	<u>Authority</u>
Unexpended Appropriations, Carried Forward from FY 1978	\$ 44,210,263	\$
New Guaranty Authorization, FY 1980		50,000,000
FY 1979 Guaranty Authorization		300,000,000
Value of Loans Guaranteed		43,465,000
Guaranty Authorization Carried to FY 1980		306,535,000
Administrative Expenses Incurred* (1979)	496,701	
Guaranty Fees Collected in FY 1979	<u>118,715</u>	
Unexpended Appropriation Carried to FY 1980	\$ 43,832,277	
Guaranty Fees Collected in FY 1977 and FY 1978 and Deposited in Miscellaneous Receipts	131,842	
Guaranty Fees Deposited in Miscellaneous Receipts which will be Transferred to GRDF	80,702	

*Contractor and consultant costs necessary to assist in evaluating technological, geophysical, financial, marketing, management and legal data submitted with guaranty applications and to assist in monitoring guaranteed projects.

Table IV. 3

BASIC RESPONSIBILITIES OF FEDERAL AGENCIES

Produce Energy

- DOE/RA
- DOC/EDA
- DOD
- HUD
- USDA/Fm HA

Stimulate Energy Production

- DOE/RA
- DOC/EDA
- HUD
- USDA
- DOT

Support Energy Production (Institutional Aspects)

- DOE/RA
- DOE/Env
- DOE/FERC
- EPA
- DOI/BLM
- DOI/USGS
- DOI/FWS
- USDA/FS

Make Federal Geothermal Resources Available

- USDA/FS
- DOE/RA
- DOI/BLM
- DOI/USGS

Reduce Costs and Risks (Research and Development)

- DOE/RA
- DOE/ER
- DOE/Env
- EPA
- DOI/BOM
- DOI/USGS
- DOI/FWS
- DOD

Improve Resource Estimates

- DOE/RA
- DOI/USGS
- DOI/WPRS

Table IV.4

DETAILED ACTIVITIES OF FEDERAL, NON-FEDERAL AND PRIVATE SECTORS

ACTIVITY	FEDERAL AGENCY'S ROLE	STATE AND LOCAL GOVERNMENT'S ROLE	PRIVATE ROLE
PRODUCE ENERGY	DOE/RA		
	o Guarantee Loans	o Cost Share Projects	o Cost Share Projects
	o Cost-Share Field Demonstration Projects		
		o Construct Facilities	o Construct Facilities
	DOC/EDA		
	o Award Grants on Projects		o Provide Capital
	DOD		
	o Construct Facilities For Own Use		o Provide Management
	HUD		
	o Award Grants for Projects		
STIMULATE ENERGY PRODUCTION	USDA/Farmers Home Administration		
	o Award Grants for Projects		
	DOE/RA		
	o Disseminate Information	o Disseminate Information	o Broker Projects
	o Give Technical Assistance		
	o Award Planning Funds to States	o Plan	
	o Provide Reservoir Confirmation Assistance	o Provide Appropriate State Geothermal Rights Laws	
	DOC/EDA		
	o Award Grants for Planning	o Provide Tax Incentives	
	HUD		
	o Allocate Planning Funds		
	USDA		
	o Allocate Planning Funds		
	DOT		
	o Administer Tax Incentives		

Table IV.4 (Cont.)

ACTIVITY	FEDERAL AGENCY'S ROLE	STATE AND LOCAL GOVERNMENT'S ROLE	PRIVATE ROLE
SUPPORT ENERGY PRODUCTION (INSTITUTIONAL ASPECTS)	DOE/RA		
	o Provide Environmental Assessments and Impact Statements on DOE Projects (including Loan Guarantee Projects)	o Formulate State Environment Regulations	o Provide Environmental Data Requested
	o Make Recommendations on New Legislation	o Issue Required Permits and Approvals	o Apply for Permits and Approvals
	o Facilitate International Technology Exchange	o Formulate Public Utility Commission Regulations and Decisions	
	DOE/Environment		
	o Review EAR's and EIS's		
	o Write Environmental Development Plans		
	o Write Area Environmental Assessments	o Cooperate with Federal Environmental Review Processes	
	DOE/FERC		
	o Issue Power Production Decisions on Geothermal Power Projects	o Cooperate with Federal Permitting Procedures	
	EPA		
	o Formulate Environmental Regulations		
	DOI/BLM		
	o Undertake Environmental Reviews before Leasing		
	DOE/USGS		
	o Monitor Environmental Impacts after Leasing		
	DOI/FWS		
	o Provide Environmental Reviews as Requested by DOE, BLM, USGS, and FS		

Table IV.4 (Cont.)

ACTIVITY	FEDERAL AGENCY'S ROLE	STATE AND LOCAL GOVERNMENT'S ROLE	PRIVATE ROLE
SUPPORT ENERGY PRODUCTION (INSTITUTIONAL ASPECTS) Con't.	USDA/FS <ul style="list-style-type: none"> o Provide Environmental Reviews and Assessments for Forest Service Lands o Consent to Leasing on FS Lands o Review Development Permits and Approvals 		
MAKE FEDERAL GEOTHERMAL RESOURCES AVAILABLE	DOE/RA <ul style="list-style-type: none"> o Set Production Goals o Promulgate Regulations 	o Cooperate with Federal Leasing Procedures	o Apply for Lease Applications
	DOI/BLM <ul style="list-style-type: none"> o Lease Competitive BLM and FS land o Process Noncompetitive Lease Applications 	o Issue Permits and Approvals	o Bid on Competitive Leases
	DOI/USGS <ul style="list-style-type: none"> o Review Development Plans o Provide Permits and Approvals o Evaluate Resource Areas to Determine Competitive Lease Sales 		o Meet Requirements for Permits and Approvals
	USDA/FS <ul style="list-style-type: none"> o Process Noncompetitive Lease Applications o Review Permits and Approvals 		
	DOE/RA <ul style="list-style-type: none"> o Build Hydrothermal Demonstration Plants o Undertake Materials Research and Development o Undertake Drilling Research and Development o Develop Environmental Technology o Develop Geopressured Technology o Develop Hot Dry Rock Technology o Undertake Geochemical Engineering Research and Development o Improve Reservoir Evaluation and Exploration Technology 	o Conduct Research	o Conduct Research
REDUCE COSTS AND RISKS (RESEARCH DEVELOPMENT AND DEMONSTRATION)			o Provide Insurance
			o Assume Risks

Table IV.4 (Cont.)

ACTIVITY	FEDERAL AGENCY'S ROLE	STATE AND LOCAL GOVERNMENT'S ROLE	PRIVATE ROLE
REDUCE COSTS AND RISKS (RESEARCH DEVELOPMENT AND DEMONSTRATION) Con't.	DOE/Energy Research		
	• Perform A Basic Research		
	DOE/Environment		
	• Environmental Technology		
	EPA		
IMPROVE RESOURCE ESTIMATES	• Develop Environmental Technology		
	DOI/Bureau of Mines		
	• Perform Geothermal Brine Research		
	• Develop Standard Test Methods for Geothermal Materials		
	• Field test Site-specific Materials		
	DOI/USGS		
	• Improve Resource Assessment and Exploration Concepts		
	DOD		
	• Perform Construction Materials/ Corrosion Research		
	DOE/RA		
	• Explore Potential of Hot Dry Rock Resources	• Conduct State Resource Assessments	• Conduct Reservoir Assessments
	• Conduct Cost-Shared Hydrothermal Reservoir	• Cost-share Federal Reservoir	• Cost-Share Federal
	• Assessment with States	Assessments	Reservoir
	DOI/USGS		Confirmation
	• Characterize various types of geothermal systems		• Provide Wells of Opportunity
	• Assess resources on a regional basis and update and refine national inventory		
	DOI/WPRS		
	• Explore Resources		

geophysical and geochemical techniques to model these resources; and estimates geologic parameters, depths, areal extent, temperature ranges, and quantities of thermal energy. Emphasis is on the entire geothermal system encompassing one or more individual reservoirs that are the focus of DOE studies. Results provide fundamental knowledge for a better understanding of the nature, distribution, and energy potential of U.S. geothermal resources and for reliable estimates to establish national goals for geothermal energy utilization.

A major product of this assessment, USGS Circular 790, "Assessment of Geothermal Resources of the United States - 1978," was published in FY 79. This report is an update and expansion of the previous national inventory, Circular 726, published in 1975. The USGS plan includes further updated inventories of those resources for which there was scanty data in 1978, specifically low-temperature hydrothermal systems, geopressed zones outside the Gulf Coast, and hot dry rock regimes, as well as improved estimates of the undiscovered geothermal resources.

In contrast, DGE focuses its resource studies on specific prospects within the broad areas defined by the USGS. The DGE program characterizes geothermal reservoirs. The major parameters are boundaries, porosity, permeability, temperature, pressure, chemistry, productivity, and longevity. In particular, DGE reservoir definition programs involve:

- Working with industry and the states to locate and confirm hydrothermal reservoirs for electric power production and direct heat applications
- Defining the location, magnitude, and production characteristics of the substantial geopressed geothermal resources of the U.S. Gulf Coast
- Defining the locations and characteristics of attractive hot dry rock prospects.

The DGE plan also seeks improvement in the tools and techniques needed to accomplish exploration and assessment. Geoscience technology, developed primarily for hydrocarbon and mineral exploration, is often unsuitable for geothermal work, especially where high temperatures are encountered. The adaptation of geoscience equipment and techniques to geothermal conditions will improve the effectiveness and reduce the costs of geothermal reservoir definition activities. The plan for DGE is to continue the existing program at the same pace as last year. For the USGS, proposed reduction in funding would severely delay assessment of several major regions and suspend the assessment of lower temperature hydrothermal systems.

The goal of the complementary USGS and DGE program is to ensure that U.S. geothermal resources are discovered, evaluated, and characterized, and that exploration and reservoir assessment technologies are developed to increase the accuracy and reduce the costs of these activities.

The Department of Defense (DOD) recognizes the significant quantity of potential geothermal energy resources on DOD lands, and the importance

of developing these resources. However, the co-use of lands for geothermal development and military activities will be very difficult at best.

The first step in identifying the magnitude of the problem is to assess the probable size of the DOD geothermal resource holdings. Toward that end, DOD has a program of resource assessment and exploration including geologic, geophysical, and shallow well drilling. This ongoing program continues to add to the data base.

In addition, DOD has a legal-institutional program to identify and sort out the obstacles confronting both DOE and industry in the development of geothermal resources. The final output of this program, coupled with the DOD assessment program, leads to initial field development by DOD and industry for a specific field. Ideally, this initial development is under DOD's direct control, as at China Lake Naval Weapons Center (Coso, Cal.), to facilitate a good DOD/industry working agreement.

Leasing of Geothermal Resources

At present, approximately 2.8 million acres of Federal lands have been leased for geothermal development. An additional 4 million acres have been applied for and another 1.3 million acres of known geothermal resource area (KGRA) lands have yet to be offered for competitive sale. Leasing this much land will take about 5 years of leasing activity at the current pace. However, both BLM and the Forest Service have started procedures to accelerate this pace.

The exploration and development of this unleased acreage would lead to between 3,000 MW and 10,000 MW of geothermal energy on-line by the end of this century. The KGRA lands are thought to include high-quality geothermal resources. Acceleration of the rate of leasing these lands is needed to meet utilization goals.

BLM will soon implement a phased environmental review procedure as proposed by the USDA. Phased environmental review should speed leasing significantly by removing the requirement for analysis of full development before leasing. BLM is also considering establishing time and page limits for its environmental reviews, in line with Council of Environmental Quality guidelines.

Four Federal entities have leasing responsibilities: the Bureau of Land Management (DOI), the U.S. Geological Survey (DOI), the U.S. Forest Service (USDA), and the Leasing Policy Development Office (DOE).

The Department of Interior's involvement in geothermal resource development precedes DOE's by several years, dating from the passage of the Geothermal Steam Act of 1970. Leasing did not begin, however, until January 1974, after the programmatic environmental impact statement was completed.

BLM and USGS share major responsibilities within DOI. BLM sets terms and conditions for surface protection, reclamation, and adherence to various environmental laws; USGS assures compliance. BLM completes prelease environmental reviews, administers competitive lease sales, and

issues leases. USGS evaluates all parcels for KGRA designation, evaluates competitive parcels to establish minimum acceptable bids before BLM offers them for sale, approves and monitors all post-lease operations, and collects royalties.

- The Fish and Wildlife Service provides biological expertise to the Federal surface management agencies (BLM, FS, and USGS) in both pre- and post-leasing phases. These actions involve biological and ecological input to environmental studies, resource assessments, recommended stipulations, mitigation practices, design and development of baseline and monitoring programs, lease selections or alternatives, and evaluations of compliance requirements.

The U.S. Forest Service's (FS) primary role is to evaluate the possible impacts of leasing in National Forests on surface resources and uses, and to develop terms and conditions to assure that those impacts are eliminated or mitigated to the maximum reasonable extent.

The Forest Service must give its consent and specify terms and conditions for geothermal leasing on National Forest System lands. Because of potential conflict between geothermal resource development and other surface uses, and because of a general low emphasis on geothermal resource development, the FS has tended to take a cautious, low-priority approach to geothermal leasing. Increased private and government interest in geothermal resources over the past two years has lead the FS to reevaluate its priorities. In recognition that decisions on leasing have been slow, the FS recently began to encourage more diligent action on lease applications within two years. Although new procedures are not fully approved and implemented, they include the following concepts:

- Leasing decisions should be made before completion of Land Management plans, unless plans are nearly complete.
- Leasing decisions must be scheduled promptly, and interested parties must be notified of reasons and expected length of any delays.
- Actions must be scheduled within certain reasonable time limits, while allowing flexibility for special circumstances.
- Interested parties will be notified of adverse decisions on leasing so that they may file appeals.

When the Department of Energy was established, certain responsibilities for energy resources on Federal lands were transferred from DOI to the Leasing Policy Development Office (LPDO) of DOE. LPDO has the responsibility to promulgate regulations which relate to the:

- Fostering of competition for Federal leases
- Implementation of alternative bidding systems

- Establishment of diligence requirements
- Setting of production rates for Federal leases
- Specifying of procedures, terms, and conditions for the acquisition and disposition of Federal royalty interests taken in kind.

Additionally, LPDO is responsible for approving the terms and conditions relevant to the above functions for leases to be issued by DOI.

A Memorandum of Understanding (MOU) between DOE and DOI was concluded in September of 1978. In accordance with this MOU, LPDO sets production goals for energy mineral resources on Federal lands to be used by DOI to determine their leasing programs and lease planning schedules. These production goals are to be revised every two years.

LPDO activities planned for FY 80 will include:

- Establish geothermal energy production goals and ensure that the leasing program and schedule developed by DOI achieves these goals
- Identify leasing and regulatory problems that hinder achieving the production goals
- Analyze and propose changes in leasing policy and regulations to promote geothermal production
- Identify geothermal areas affected by Federal land withdrawals and their potential impact on geothermal energy production
- Promulgate regulations for issuing noncompetitive leases where no bids are received on KGRA tracts offered for competitive lease.

The plan is to accelerate the pace of leasing geothermal land.

Development of Geothermal Technology

DOE's Division of Geothermal Energy (DGE) supports programs to improve the technology for energy extraction and use. DGE is responsible for the research, development, and demonstration of geopressed and hot dry rock resources, and bridges the gap between the broad geothermal resource assessment role of USGS and the role of the Division of Geothermal Resource Management (DGRM) to bring about vigorous commercial development of hydrothermal resources.

The DGE technology development program pioneers techniques, equipment, and materials for exploitation of geothermal resources; reduces the costs of the technology to make geothermal development competitive; and encourages the establishment of industry-wide standards for geothermal materials and equipment.

The emphasis this year is:

- Improved drill-bits and advanced drilling systems for use in hard rock, high temperatures, and corrosive downhole environments
- Downhole motors, seals, bearings, and pumps designed to operate under geothermal conditions
- Drilling fluids and cements adapted to high temperatures and corrosive conditions
- Stimulation technology to increase the productivity of geothermal wells and reduce the number of wells required for each geothermal plant
- Engineering technology for geothermal reservoirs to measure productivity and longevity by early testing, and to maximize energy recovery
- Advanced energy conversion systems to reduce capital costs and to enable economic exploitation of moderate-temperature reservoirs
- Technology for extracting heat from hot dry rock resources.

Additionally, the Bureau of Mines (DOI), through an interagency agreement with DOE, supports research on construction materials for handling geobrine and the corrosion behavior of iron-, nickel-, and titanium-base alloys in geothermal fluids.

Environment

The Environmental Protection Agency (EPA) has Federal responsibility for developing environmental standards and regulations. EPA has published a manual of "Pollution Control Guidance for Geothermal Energy Development" that discusses current Federal regulations bearing on geothermal commercialization and reviews the Agency's current thinking on other environmental concerns and on control options. At this time, EPA has no specific geothermal regulations in force, although existing standards and regulations limit allowable levels of pollutants in the atmosphere, receiving waters, and the land. The EPA has an internal working group that examines the need for regulations affecting geothermal energy systems and the impact of regulations on the industry.

The EPA, FWS, and DOE (EV and DGE) study the environmental issues surrounding geothermal energy use, and develop mitigating methods. Studies range from baseline environmental monitoring of potential geothermal resource areas to control technology development and demonstration. Efforts are also underway to develop data bases on which reasonable standards may be based. The Environmental Controls Panel, newly established by the IGCC and chaired by EPA, is aiding in the coordination of related environmental control efforts by EPA, DOE, USDA, and DOI.

In FY 79, EPA assumed the mandate formerly exercised by the Council on Environmental Quality (CEQ) to oversee the environmental aspects of Federal non-nuclear energy research. In addition, the EPA conducts research on all matters of environmental concern.

The Fish and Wildlife Service (FWS) has responsibilities for the management and wise use of the nation's fish and wildlife resources and the habitats upon which these resources depend. Particular responsibilities include migratory birds, certain marine species, endangered and threatened animal and plant species, and protection and management of the National Wildlife Refuge System.

The objective of the Service's program is to conserve, protect and enhance fish and wildlife and their habitat and facilitate balanced development of geothermal resources by timely and effective provision of fish and wildlife information and recommendations.

The Fish and Wildlife Service's primary role is to provide continuing biological assistance and technical support to other Federal agencies, State and local governments, and private industry, and assist them in developing an ecologically sound industry.

To meet these mandated responsibilities, the Service conducts programs to:

- Develop ecological information and techniques to be used to facilitate environmentally balanced geothermal development programs
- Identify specific impacts on fish and wildlife resources and techniques to minimize adverse impacts
- Provide technical support to other Federal agencies to insure adequate consideration of fish and wildlife resources in energy development considerations.

The role of DOE's Assistant Secretary for Environment (ASEV) is to ensure that development and commercialization of geothermal energy is environmentally and socially acceptable, with minimal risk to health and safety. Included in the mission are activities that:

- Conduct R&D projects concerning environment, health, and safety
- Perform systems assessment and policy analysis of geothermal development from environmental, health, and safety perspectives
- Assure that DOE geothermal programs comply with environmental and safety laws, regulations, and policies.

The Assistant Secretary also regularly updates an Environmental Development Plan, which details environmental concerns and the R&D

necessary to meet those concerns. The Environmental Protection Agency, in turn, assesses the sufficiency and timeliness of ASEV's R&D activities and recommends additional studies as needed.

The USGS, as a part of its resource studies, analyzes geohydrological data to gain a fundamental understanding of the processes that result in subsidence and increased seismic activity due to geothermal development.

The Water Resources Council (WRC) assesses water resource requirements and water supply availability in commercial applications of energy technologies. As a precondition of Federal assistance, WRC provides DOE with site-specific assessments of water use and evaluations of the environmental, social, and economic impacts of the dedication of water resources for commercial application.

The plan is to continue to assess the need for environmental regulations, and, if needed, to process them quickly.

Hydrothermal Resource Commercialization

Following an extensive review within DOE in 1978, hydrothermal technology was deemed ready for active commercialization. To help private industry develop this resource, the Division of Geothermal Resource Management (DGRM) was established under the Assistant Secretary for Resource Applications of DOE. DGRM identifies those market sectors and localities that could benefit most from geothermal energy. It conducts feasibility studies and provides technical assistance to states and industry to encourage the rapid use of the hydrothermal resource.

Authorized by the Energy Tax Act of 1978 and 1979, the program provides tax incentives to developers and users. To complement these tax incentives, DGRM supports a three-phased program to stimulate initial geothermal development. This first phase consists of a forgivable loan or grant program (for nonelectric use) to finance the drilling of the first well in a new area. Uncertainty about the quality of the resource and costs of the first well are often major deterrents to initial development, and such a loan program reduces that risk to developers. The second phase provides for the cost-sharing of economic and technical feasibility studies for specific geothermal applications. These studies will supply the information needed by potential users to make decisions regarding their investments in geothermal energy. The third phase provides loan guarantees to support the construction of facilities.

Another major program supports development through the widespread and aggressive dispersion of information about geothermal energy and through the provision of technical assistance by regional contractors.

The Federal Energy Regulatory Commission of the Department of Energy, while having no statutory functions in geothermal development, is concerned with regulatory and policy development activities that can reduce the impacts of near-term energy shortages. In this function, it conducts programs to overcome institutional barriers to geothermal commercialization.

DOE's Division of Geothermal Energy (DGE) provides hydrothermal commercialization support through the following methods.

Demonstration, Pilot, and Experimental Facilities. Demonstration plants, generally built at commercial scale, confirm full technical feasibility of systems for generating electric power from geothermal reservoirs; provide economic data for capital and operating expenses of plants under commercial conditions; and test the capacity of institutional and regulatory climates to accommodate commercial geothermal development. DGE demonstration plants are cost-shared by government and industry. Their operation provides valuable "hands-on" experience to a growing industry and lends credibility to the technical, economic, and institutional data generated by each plant.

Pilot plants, built at a subcommercial scale, establish the technical feasibility of advanced concepts and provide information on economics of operating the plants. Although industry involvement in such projects is welcomed, DGE does not expect equal cost- and risk-sharing by industry.

Experimental facilities provide realistic field conditions for tests of components, materials, systems, and techniques intended for commercial service. These facilities are available to both government and industry clients.

Direct Heat Applications Experiments. Few major technical barriers impede the commercial exploitation of geothermal resources for the space heating, industrial processing, or agricultural purposes. Rather, unfamiliarity of industry with these resources retards the rate of their development. To overcome this obstacle and to provide real-world data on system design, performance, and economics, DGE supports a substantial number of demonstration experiments which utilize geothermal heat for practical results. In general, each nonelectric experiment is a self-contained unit much smaller than a geothermal electric power plant. Support for such projects is determined on a competitive basis. Although user cost-sharing is required, the government pays the largest portion of the cost. All of the direct heat demonstrations are user-operated.

The emphasis on stimulating early development is supported by cooperative efforts of the Departments of Energy, Interior, and Agriculture to identify and lease high-priority geothermal areas located on Federal lands. A recent DOE/DOI Memorandum of Understanding required that DOE establish goals for production from Federal lands and that DOE facilitate leasing of the necessary resources.

Geopressured Resource Studies

DOE's Division of Geothermal Energy (DGE) has the lead role in determining the technical, economic, and environmental feasibility of extracting methane, electricity, and end-use heat from the geopressured geothermal resource on the Gulf Coast of Louisiana and Texas. The program concentrates on flow tests of wells drilled into geopressured reservoirs. Within the next three years, these flow tests will provide enough knowledge to determine whether extraction of energy from geopressured formations is commercially feasible.

DGE works closely with USGS's geopressured resource assessment program in developing the broad geohydrological framework to define the occurrence of these resources, and in analyzing the legal, economic, and institutional framework for development. These analyses form the basis for resource development scenarios. Studies of legal issues and potential markets are continuing.

Extensive geopressured resource definition is in progress. The description of the geopressured aquifers is based on geophysical logs from wells originally drilled for oil and gas, on flow tests of a few existing wells, and on tests of new wells in the most promising geopressured aquifers. The new wells will be designed to handle high rates of fluid production during long-term tests. The interpretation of logs and flow tests is accompanied by analytical models of fluid properties and methane production from these reservoirs.

DGE is conducting studies of possible environmental effects, particularly of land subsidence and induced seismicity, from sustained high-volume production of geopressured brine. Injection as a means of disposing of geopressured fluids is also being studied. Environmental assessment and monitoring of well sites in Louisiana and Texas will be accelerated to keep pace with the geopressured drilling and flow tests.

Hot Dry Rock Resource Studies

DGE has responsibility for evaluating the nationwide potential for application of the hot dry rock (HDR) technology and for supporting the development of new technical approaches for extracting energy from this source. The major objectives of the DGE program are 1) to determine the potential of the HDR resource, 2) to determine the potential for widespread use of the HDR resource, and 3) to effect commercial exploitation of this resource before the year 2000. Technical and economic feasibility studies to be undertaken through 1986 will determine the scope of DGE's future development efforts. DGE evaluates areas and sites throughout the country where HDR energy extraction technology could be applied.

A memorandum of understanding between DGE and the USGS provides for geological and geophysical studies to determine hot dry rock resource potential. Feasibility studies investigate HDR heat extraction techniques. High-temperature materials and equipment are developed and tested, along with upgrading of downhole instrumentation and commercial drilling techniques. Experiments with techniques designed to extract thermal energy from HDR deposits are conducted in the field. The first experimental site is at Fenton Hill, N.M.

Federal Tax Policy

In developing and implementing Federal tax policies, the Department of the Treasury has a significant impact on the commercial utilization of geothermal resources.

Tax incentives, in the form of intangible drilling cost deductions and a depletion allowance, were included in congressionally proposed energy legislation, which became the National Energy Act (NEA) of 1978.

The NEA eliminated what had been the principal deterrent to investment in geothermal resource development projects, that is, uncertain tax treatment. The NEA explicitly authorizes intangible drilling cost deductions and a percentage depletion allowance for geothermal resources, and provides tax credits through 1984 for residential and business users of geothermal energy, with the exception of public utilities. It allows deregulation of geopressured methane and gives the Federal Energy Regulatory Commission (FERC) certain powers to order wheeling and interconnection for electricity from geothermal plants, and to exempt geothermal plants that qualify as cogenerators or small-power producers from public utility regulation. These provisions have resulted, for the first time, in substantial attention within the financial community to investment in geothermal projects.

The Department of Energy is authorized to conduct continued research and make recommendations in the area of Federal tax policy.

B. STATES

While state activities are too detailed to enumerate here, each state with a significant potential for geothermal energy development must fulfill and coordinate a number of development and regulatory roles for development to take place. These include:

- Issuing state permits for exploration and development
- Examining existing state legislation to determine applicability to geothermal development
- Evaluating and authorizing state-level tax incentives for geothermal development
- Resolving water and mineral rights and regulatory issues where laws designed for other resource uses do not include or actually impede geothermal development
- Coordinating state and local activities to discover and develop the most beneficial uses and sites for geothermal development
- Anticipating and monitoring environmental and use impacts of geothermal development to ensure that these comply with state regulations
- Interacting with the Federal government to ensure that Federal policies and regulations will be beneficial to geothermal development in each state
- Providing funds to meet cost-sharing requirements of Federal field demonstration projects.

The states can obtain assistance from DOE by obtaining contract and grant funds for state and site-specific planning. Additional funds are available to cost-share with the states in reservoir assessment projects.

C. LOCAL GOVERNMENTS

County and city governments promote suitable development of geothermal energy use within their local domains while balancing requirements for geothermal development with other local needs. This can be accomplished in many cases by including geothermal elements in a community's master development plan.

One instance where local government leadership is especially valuable is in the promotion of centralized geothermal district heating systems. Based on experience in Iceland and Europe, these systems are very desirable when a sufficient amount of heat use is available from a common well or set of wells. To start such a system economically, usually one of two large buildings must be connected at the outset. Municipal office buildings, schools, and civic centers can provide the nucleus, with smaller users connecting to the system after its reliability and economics have been demonstrated.

Municipal utility staff are usually familiar with the simple technology used in geothermal direct heat systems, and municipal bonds can finance such projects advantageously. Local governments can and have been finding start-up help with DOE funds for feasibility studies, and cost-shared development of feasible projects. Substantial technical assistance is also available on a much more informal basis from DOE-supported regional centers.

D. PRIVATE SECTOR

The private sector is the primary focus of geothermal energy development. It is here that most specific projects are conceived, financed, and built. The many active roles of the private sector include: investment, exploration, field development through drilling, sale of steam, purchase of steam and hot water, operation of electric plants, improvement of drilling equipment, and provision of reservoir insurance. Federal and state sponsored geothermal activities are intended to foster an active private sector geothermal industry, rather than compete with it.

The most noticeable activities in the private sector center around continued development of The Geysers field and the beginnings of geothermal electric development at sites in the Imperial Valley, California. Near-term potential shortfalls in electricity supply in California will provide a strong impetus for continued geothermal resource development.

The private sector also influences the Federal program by providing members for the Geothermal Subcommittee of the Energy Research Advisory Board. This Committee reviews the plans for the Federal program and advises the Secretary of Energy on the program.

1. The first of these is the
fact that the system is not
self-sufficient.

2. The second is the fact that
the system is not self-sufficient
in the sense that it does not
produce enough to cover its own
costs.

3. The third is the fact that

the system is not self-sufficient
in the sense that it does not
produce enough to cover its own
costs.

Geothermal Test Well Locations

New Wells

- ① Dow #1 Sweezy
- ② Amoco #1 Sweet Lake
- ③ Lafourche Crossing

Wells of Opportunity

- ④ Edna Delcambre #1
- ⑤ Beulah Simon #2
- ⑥ Tenneco Fee N#1
- ⑦ Fairfax Foster Sutter #2

CHAPTER V. THE FEDERAL PROGRAM

OVERVIEW

The principal barriers to commercialization of geothermal energy are uncertainty about reservoir performance during extended production; the lack of economic technologies for all but the highest quality resources; the ambiguous status of ownership of geothermal fluids; the slow pace of current leasing; permitting, and licensing procedures; the site-specific acceptability of waste fluid disposal and other environmental control measures; and user inexperience with the resource. Divided among various agencies and offices, the Federal geothermal program works, whenever possible, in close communication with energy companies and other potential users of the geothermal resource. This chapter describes these and other aspects specifically, but does not consistently identify the agencies responsible for program execution. The reader is referred to Table IV.4, which describes these missions.

A. COMMERCIALIZATION

The hydrothermal commercialization program of DOE seeks to accelerate commercial utilization of hydrothermal resources for electric power and for direct heat applications, thereby displacing fossil fuels. This program formulates geothermal commercial development plans, develops a national progress monitoring system, assesses the market penetration potential for hydrothermal resources, and identifies direct heat markets suitable for early penetration. Further activities encompass development planning in cooperation with local and state officials and potential users, support for economic and engineering feasibility studies, continuing interagency coordination and policy development, and outreach programs to acquaint potential users with the availability and competitive cost of hydrothermal energy and with the availability of financial assistance through various Federal programs. The program also seeks to make States a principal partner in implementing the Federal program by funding State commercialization and planning teams.

Outreach

Except for a small group of technical specialists, few people understand the range of possible applications of geothermal energy. DOE/RA now has a pilot-level outreach program, which by FY 81 will become a full-scale, aggressive program. One phase aims to inform potential users and developers and their support groups of geothermal energy's costs, benefits, safety, reliability, and environmental effects. A second phase reaches out to the general public, trade, industrial, and professional associations, and other large groups capable of making primary financial commitments to geothermal development.

By lending financial and technical assistance to a few projects, the Federal government hopes that use of geothermal energy will spread. For example, Federal funds are helping the city of Klamath Falls (Ore.) to design and build an extensive geothermal space heating system, which

initially will serve more than 100 private commercial buildings. Other cities are following suit: in Boise (Ida.), city officials, community leaders, and residential developers are doing detailed planning for a district heating system. In Marlin (Tex.), the Torbett-Hutchings-Smith Memorial Hospital will soon have geothermal heat, and a ranch near Rapid City (S.D.) is already geothermally heating its ranch buildings as well as drying grain and providing warm water for its stock. Nine district heating systems are now being funded and seven other projects may be expanded into district heating systems.

DOE is working closely with the paper pulp and food processing industries in their investigations into the feasibility of geothermal energy use. As these studies continue, the subtleties of energy use within an industry are revealed. A paper pulp industry project now in progress is concentrating on three areas: surveying the techniques used in industry to make capital investment decisions; developing the technical and economic evaluation methodology; and collecting data from pulp and paper plants.

The outreach program seeks to gain commitments for prospective development from business and community leaders. This involves working with trade associations and professional societies, and helping communities find other forms of Federal assistance to enhance their own investments. Such brokering activity is increasing, and public and private entities other than DOE are becoming interested in funding geothermal experiments.

Direct Heat Applications

The principal goal of the direct heat applications program in DOE is to build a direct-use infrastructure by funding selected direct heat applications. The most visible success of the program is in Klamath Falls (Ore.), where DOE funding, combined with city, county and state funding, enabled most of the initial stages of a project to heat the city's downtown area geothermally. DOE funds were used for well drilling, pipelines, and software design. Two production wells have been drilled and pipeline is now being procured. The design stage has begun. In early 1981, the system will go into effect, heating 14 Federal buildings in downtown Klamath Falls. After one year, DOE funding and management will cease. Although the project has not yet sought commercial sponsors, a survey of the city's business community revealed overwhelming support for the concept. Project sponsors estimate that 115 buildings could tap into the grid in the near term. The city has recently applied to the Department of Housing and Urban Development for a Community Development Block Grant to extend the system to its economically depressed areas.

Direct heat applications are divided into four groups: industrial applications, district heating, space heating, and agricultural uses. Each project goes through five phases: an environmental report, reservoir confirmation, system design, construction and installation or retrofit, and operation.

The first solicitation for direct use field experiments was issued in 1977; 22 proposals were received. Eight of these proposals were selected for contracts, with the Federal share of the cost varying from 46 percent to 80 percent. A total of \$2.1 million was obligated in FY 78 for the initial phases of these projects, resulting in commitments of \$2.9 million in FY 79 and \$650,000 in FY 80 to complete these projects.

A second solicitation was issued in FY 78, resulting in 40 proposals, of which 15 were selected for initial FY 79 funding of \$4.9 million. Approximately \$10 million in FY 80 and \$5 million in FY 81 will be required to continue these projects. Federal cost-sharing amounts to about 60 percent of total project costs.

Of the 23 contracts underway in FY 79, the majority are for space and district heating, while three are directed at agriculture, and three involve industrial processing. Table V.1 presents the potential energy of these projects--the equivalent of 900,000 barrels of oil per year would be displaced.

First Solicitation Projects

(1) Space Heating--Torbett-Hutchings-Smith Memorial Hospital, Marlin, Tex. This project will augment space and water heating. Geothermal fluids will be pumped from a known hot water reservoir, using a new well to be drilled as part of this project. The well has been drilled and tested, and design is under way. The project will operate in the fourth quarter of 1980.

(2) Space Heating--Phillips Schools, Haakon, S.D. Schools will be heated with geothermal water from a well to be drilled into the Madison aquifer. The government is sharing costs for design, construction, and start of operations for the complete system. The well has been drilled and the system designed. The system will be operational in the second half of 1980.

(3) Space Heating--St. Mary's Hospital, Pierre, S.D. The heating system will be augmented with a system drawing hot water from the Madison aquifer. Extension of the system to a nearby commercial complex is anticipated. The well has been drilled and the system is being designed. The system will be operational in the second half of 1980.

(4) Agricultural Use--Rapid City, S.D. A low-temperature geothermal resource will be used to supply heat to ranch buildings and will also be used to dry grain and to provide warm stock water for ranch use. The reservoir has been confirmed, the system designed, and construction begun. The system will be operational in the first quarter of 1980.

(5) District Heating--Monroe, Utah. A district heating system will be built, based on the development of a known hydrothermal resource in the area. The project will provide production wells and design and construction of the system. The well has been drilled and design begun. The system will be operational in the fourth quarter of 1981.

(6) Industrial Use--Ore-Ida Foods, Ontario, Ore. Ore-Ida planned to use a geothermal energy resource to retrofit a fossil fuel system for food processing and space heating in its potato processing plant. A well was drilled to significant depth in preparation for testing the reservoir. However, insufficient water was found and the project was abandoned.

(7) District Heating--Klamath Falls, Ore. This project will entail design and construction of an extensive geothermal space heating

Table V.1

POTENTIAL ENERGY PRODUCED BY FIELD DEMONSTRATION PROJECTS

	<u>$\times 10^9$</u> Btu/yr
District Heating	
Klamath Falls, Ore.	300
Susanville, Cal.	41
Boise, Ida.	2070
El Centro, Cal.	2
Elko, Nev.	38
Monroe City, Utah	32
Reno, Nev.	18
Madison County, Ida. ¹	680
Pagosa Springs, Colo.	32'
Institutional	
THS Hospital, Tex.	11
Navarro College, Tex.	35
Utah State Prison, Utah	11
Montana State Hospital, Mont.	69
St. Mary's Hospital, S.Dak.	19
Haakon School, S.Dak.	5
Klamath Falls YMCA, Ore.	5
Agribusiness/Agriculture	
Utah Roses, Utah	75
Kelly Hot Springs, Cal.	24
Aquafarms, Cal.	17
Circle Ranch, S.Dak.	36
Industrial	
Ore-Ida, Ida.	335
Holly Sugar, Cal.	1300

¹Includes potato processing plant.

system in the central business district of Klamath Falls. As a city-owned-and-operated system, initially it will serve 14 office buildings, but will expand to 115 private commercial buildings. The system will initially include one production well, one reinjection well, approximately 2 miles of transmission line, retrofitting equipment for all 14 government buildings, and control equipment. The reservoir has been confirmed and the system designed. The system will operate in early 1981. The city has applied for a Community Development Block Grant from HUD, to extend the system to economically depressed areas.

Second Solicitation Projects

(1) Heating—Utah State Prison, Salt Lake City, Utah. Using the Crystal Hot Springs, one building of the Utah State Prison will be heated with geothermal fluids. This demonstration will form the nucleus of a system that can be expanded to service the heating requirements of other existing and planned facilities. The contract was negotiated in June 1979; negotiations are now being conducted for land for the well site. The project will operate in mid-1981.

(2) Multiple Uses—Madison County, Ida. A joint venture by Madison County, Idaho, and Rogers Food, Inc., for this project will develop geothermal energy for municipal space heating and industrial food processing. The contract was negotiated in June 1979. Reservoir confirmation studies were begun, and the system will operate in the fourth quarter of 1981.

(3) Multiple Uses—Moana, Reno, Nev. An apartment complex will be retrofitted with a geothermal space and water heating system using thermal waters in the Moana District, a known geothermal resource. The contract was awarded in June; reservoir confirmation studies are under way. The system will operate the first quarter of 1981.

(4) District Heating—Pagosa Springs, Colo. An extensive geothermal heating system will be developed within the town of Pagosa Springs. Designed to permit expansion of other businesses and homes beyond the town limits, this system provides hot water for space heating to 12 public buildings and schools, 25 private buildings, and several homes. The well is being tested in preparation for system design. The system will operate the third quarter of 1981.

(5) Direct Uses—Elko, Nev. Under the ownership of a heat source company, geothermal fluid from the Elko KGRA will provide space, service water, and process heating to several buildings within the city. The contract was awarded in July 1979, and reservoir confirmation studies have been completed. The system will operate the first quarter of 1982.

(6) Direct Use—Salt Lake City, Utah. Six acres of floral greenhouses will be converted from oil and gas heating to a geothermal system. The contract was awarded in April 1979. Reservoir confirmation has been completed in preparation for drilling. The system will operate in the third quarter of 1980.

(7) District Heating--Boise, Ida. The city of Boise and the Boise Warm Springs Water District will develop a large-scale space heating system using geothermal energy to demonstrate the technical, economic, and organizational feasibility of using low-temperature fluids in a multijurisdictional endeavor. The DOE contract was awarded in June 1979; participants are arranging additional financing. The system will operate the third quarter of 1983. An additional \$500,000 was provided by the Economic Development Administration.

(8) Space Heating--Warm Springs Hospital, Butte, Mont. Utilities at a hospital will be partially converted to use geothermal energy instead of natural gas. The project continues state-funded studies to determine the feasibility of converting to a geothermal resource, and to more fully define the resource on hospital property. It will involve drilling of wells and design of the modification of the hospital's hot water and space heating system. The contract was awarded in March 1979. Reservoir confirmation is now taking place. The system will operate the second quarter of 1981.

(9) Space Heating--Navarro College, Corsicana, Tex. Using a known resource, the contractor will retrofit two buildings: the college student union and the Navarro County Memorial Hospital, to augment the existing space and water heating requirements. The contract was awarded in January 1979. One well is being tested, in preparation for drilling another well. The system will operate the third quarter of 1981.

(10) Agricultural Uses--Kelley Hot Springs, Cal. Using two wells, the Geothermal Power Corporation will demonstrate geothermal direct applications to a livestock feed production system and hog feed lot operation. The contract was awarded in June 1979, and well testing was begun. The system will operate the second quarter of 1982.

(11) District Heating--Susanville, Cal. The city will use Susanville's geothermal resource to heat 17 existing public buildings. A parallel effort will expand the city system and develop a commercial park. The contract was awarded June 1979. Well drilling is in the preparation. The system will operate the first quarter of 1982.

(12) Agricultural Use--Aquafarm Prawn Raising, Mecca, Cal. A commercial fish farmer will expand an existing geothermal supplied system to raise giant Malaysian prawns. The contract was awarded in mid-1979. Reservoir studies have been conducted. The system will operate the fourth quarter of 1980.

(13) Space and Water Heating--YMCA, Klamath Falls, Ore. Geothermal fluids from a recently drilled well will provide space heating and hot water for the YMCA building. The existing fossil fuel system will remain as a backup or booster system. The contract was awarded in April 1979. The well, previously drilled, was completed and tested. The system will operate the second quarter of 1980.

(14) Industrial Use--Holly Sugar Geothermal Project, Brawley, Cal. This project involved the design, installation, and operation of a geothermal energy system to be used directly for process heat. The contract was awarded in April 1979. Reservoir confirmation studies were

done in preparation for drilling. The system will operate the first quarter of 1982.

(15) Space Heating and Cooling--Geothermal Core Field Experiment, El Centro, Cal. Heber's geothermal resources will provide space cooling and heating, and domestic hot water to the community center at El Centro. This project is intended to serve as the core for a future district heating and cooling system for the city. The contract was awarded in April 1979, and preparations made to drill the well. The system will operate the second quarter of 1981.

Feasibility Studies

This program funds studies to determine the technical and economic feasibility of proposed hydrothermal applications. These are done in conjunction with potential users. Feasibility studies fall into one of three categories: industrial processing (food processing, sugar production, fertilizer production, mineral processing and other studies); district heating (heating systems for communities by public or private utilities and for smaller users); and agribusiness and aquaculture (production and processing of food at the farm).

DOE is currently funding 11 feasibility studies of direct application, including process heat for frozen food production, process heat for corn sweetener production, process heat for methanol and ethanol from farm products, process heat for hosiery production, process heat for tungsten mining and processing, and district heat for other applications. These studies were chosen from among 77 proposals received in response to the Engineering and Economic Feasibility solicitation made early in FY 79. The large number of responses is extremely encouraging.

Since the geothermal program began, 23 such studies have been completed--7 of space and district heating, 10 of industrial processing, and 6 of agribusiness or aquaculture. Results from 17 completed studies were analyzed for factors influencing decisions to invest in direct use processes. The cost of energy from geothermal sources was shown to be competitive with fuel-oil-based energy if at least 20 percent of the energy from the wells is used. A typical application would meet this qualification. Eight of these studies comprised 20 separate applications: food processing (12), space heating (4), crop drying (3), and a long-distance pipeline (1). All the resources studied were located in the western United States, in particular in California, Oregon, and Colorado.

The Forest Service, in conjunction with DOE, the California Department of Water Resources, and Geoproductions, Inc., is looking at the feasibility of using geothermal energy and wood chips from forest waste at Honey Lake to produce electric power. Lands in Toiyabe, Inyo, and Lassen National Forests will be evaluated for possible geothermal development.

In FY 79 the following studies were completed:

- A district heating and cooling system for El Centro, California, now part of the specific application program.

- A combined direct thermal and augmented district heating system for Susanville, California, also now part of the specific application program.
- A large resort complex in the San Luis Valley, Colorado, combining agriculture and space heating. The final report is expected in FY 1980.
- A school complex in Edgemont, South Dakota, exploring feasible use of the Madison Aquifer water.
- A vertically integrated meat and feed production facility for Mountain Home, Idaho. This study was moved to a different site, then incorporated into the specific application program at Kelley Hot Springs, California.
- A study of cane sugar production in Hawaii, showing the system to be technically feasible but only marginally profitable if based on private financing.

B. FEDERAL USE OF GEOTHERMAL ENERGY

The Department of Defense is under the same mandates as the rest of the Federal sector to conserve energy and switch to alternate fuels. The direct use of geothermal energy as well as the use of geothermally generated electricity are significant factors in achieving the mandated goals.

Several direct use projects are either in the planning or initiation stage and one at the Naval Station, Keflavik, Iceland, is about to be constructed. There the entire Navy base will be converted to geothermal heating.

At NWC China Lake, Coso, California, the Navy is using a private entrepreneur to explore the resource, develop the field, construct an electric power plant, and operate it at no cost to the Navy. The Navy has agreed to buy all power produced from the plant. Through this effort a previously untapped resource will be used and, if successful, should attract more developers to the remainder of the Coso resource when it is offered for development.

DOE is attempting to help other agencies identify buildings and facilities that could use geothermal energy for heating and cooling. Primary emphasis has been on DOD, but contacts have also been established with the U.S. Postal Service and other Federal agencies.

Adak Naval Station, Adak, Alaska

The Adak Geothermal Project is considering three different types of geothermal energy systems, each based on an assumed reservoir temperature range:

- Space heating, using either above-ground insulated fiberglass pipelines or in-ground insulated steel pipelines.
- Flash steam electrical power generation, using geothermal fluids either at a central power plant or via individual wellhead generating units, either system producing a 25 MWe gross output
- A binary geothermal electrical power plant, where the geothermal fluids would heat a secondary (binary) fluid to operate the electrical generating equipment, producing a 25 MWe gross output.

Of the systems analyzed, the most attractive are the wellhead generating units, which have been tested at ambient temperatures ranges as low as 160°C. Equipment can be fabricated in the lower 48 states, thus eliminating much of the cost of installation and construction at Adak. A wellhead unit system has the best payback period of all the systems and could be operational within 5 years from the date the reservoir is defined.

The primary question remaining is which system can the geothermal resource of Adak support? This question can only be answered by drilling the initial production-size wells to test the reservoir characteristics. The estimated cost for drilling the first production hole at Adak is \$8.5 million, due to the high cost of drilling rig mobilization. This high cost makes the whole project unattractive until fuel costs increase significantly. If that increase occurs, the project will be reevaluated.

China Lake Naval Weapons Center (NWC), Coso, California

Based on geological surveys by the USGS, China Lake personnel, and others, the Coso area of China Lake NWC was designated a known geothermal resource area (KGRA) with an estimated resource potential ranging up to 4,600 MWe. About 90 percent of the high-grade resource lies within NWC boundaries; however, some of the area is fee-owned lands. The Navy has two objectives--to protect its military mission capability, and to develop the resource. Accordingly, the decision has been made that the Navy will develop fee-owned lands for its own use while allowing the Bureau of Land Management to lease the remainder of the resource, subject to appropriate constraints. The Navy proposes to hire a private contractor to further explore, develop the field, build a power plant, and own and operate it at the contractor's expense. Under this plan, the Navy will retain ownership of the resource and the electricity generated by the resource. The contractor will be paid for the electricity produced. The Navy filed a draft environmental impact statement for this undertaking in November 1978 and has completed the contractual package.

Initially, the minimum amount of power the Navy will accept will be the entire requirement of the Weapons Center. After this requirement has been satisfied, the contractor may pick up additional loads, up to a maximum of 75 MW. Development beyond 75 MW will be at the option of the Navy.

Technical proposals for this project have been evaluated and at this printing the Navy is asking for pricing. A contract should be awarded by the end of FY 79.

Fallon Naval Air Station, Fallon, Nevada

For Fallon, USGS studies give a reasonable assurance of a good geothermal resource potential; indeed, some geothermal applications have already been implemented in the immediate area of this base.

The Navy is now conducting heat flow studies to determine the extent of the resource on U.S. lands. In FY 80 the resource analysis will be completed. Current indications are that a geothermal project is definitely feasible and that geothermal electric power production is likely. If a substantial resource is proven, the Navy can produce excess power and wheel it to other DOD locations.

Hill Air Force Base, Utah

In a joint project between the Department of Energy and the Department of Defense, the availability of geothermal resources at Hill AFB will be developed. In addition to evaluating Hill's geothermal energy potential, this effort will broaden the scientific knowledge about reliable techniques for detecting hot water sources in faults along the populous Wasatch Front.

The project is divided into two phases. Phase I will identify and initiate use of the geothermal resource. Phase II, predicated on the success of Phase I, would expand the application to other areas of the Base. In Phase I, DOE will take responsibility for surface exploration and geological interpretations, followed by exploratory production and, if necessary, reinjection well drilling. DOD will design and construct the distribution system and modify the facility heating, if necessary, and will prepare a system performance report. Phase II will be entirely the responsibility of DOD.

Two holes are being drilled to test geologic structures, one to a depth of about 2,000 feet and the other about 3,000 feet. The scientific team from the University of Utah that performed the initial geological, geochemical, and geophysical studies at the Base is also managing the test hole drilling. Interpretation of the results from these test hole wells is scheduled for early FY 80. Phase I development is estimated to last 36 months.

Keflavik Naval Station, Iceland

Geothermal resources have been used to heat Iceland's capital city, Reykjavik, for 50 years. The United States is committed by a 1974 Memorandum of Understanding to join with the Icelanders in developing geothermal heat sources.

Sudurnes Regional Heating Corporation (SRHC), a local entity, is developing geothermal wells and distribution lines to towns near Keflavik. Distribution lines now connect the Svartsengi plant area with towns on the

Reykjanes peninsula; connection of Icelandic buildings is well advanced. However, the hookup of U.S. facilities of geothermal heat has been minor to date.

In FY 80, a military construction project will start conversion to geothermal energy by providing connection charges to SRHC. Most of the conversions of Navy boiler rooms and heating systems will be programmed next year. However, should installation of heating mains proceed at a pace permitting usable connections to some Navy buildings in FY 80, a portion of this project will be assigned to initial conversion work, now planned for FY 81. The total budget for connection and conversion is \$35 million.

Norfolk Naval Station, Norfolk, Virginia

The demand potential for geothermal space heating at Norfolk appears to be excellent. However, before wells to define the resource are drilled, resource criteria must be established. The Navy is currently developing a program to identify the potential heating load at the Norfolk Naval Station--its location, resource temperature requirements, and flow requirements. In addition, site-specific legal, institutional, and environmental problems must be resolved. The Navy will then proceed with development if the project is still feasible.

Williams Air Force Base, Arizona

In 1973, a private firm drilled two geothermal wells to a depth of 10,000 feet, approximately 1 mile from Williams. These wells demonstrated a hydrothermal resource of around 150°C. In June 1979, the Department of Energy completed a feasibility study for the Air Force, exploring the potential applications of geothermal energy at Williams.

The study concluded that both a central cooling plant and an electrical power plant are promising candidates for geothermal use; the choice will depend on the quantity and quality of the resource. The economic analysis projected a potential payback period of 11-15 years.

The Air Force has prepared a conceptual plan that divides the project into two development phases. Phase I encompasses exploratory production well drilling, and Phase II, follow-up drilling and design and construction of the central plant. Management and financial arrangements to accomplish these phases are being developed.

C. INTERNATIONAL ACTIVITIES

The pace of commercialization of geothermal energy in the United States is affected by the status of geothermal development in foreign countries. Some countries can supply technologies and materials to U.S. developers, while other countries are supplied by U.S. manufacturers. In this latter case, U.S. manufacturers can achieve a scale of production sufficient to stay in business, while also supporting the national commitment to help those countries develop their own energy resources.

Table V.2

WORLDWIDE GEOTHERMAL ELECTRICITY GENERATION
(to 1984)

Country	Present Capacity (MWe)	Planned Expansion (MWe)
China	4.5	--
El Salvador	60.0	385.0
Iceland	64.0	--
Indonesia	0.3	--
Italy	420.6	400.0
Japan	168.0	250.0
Kenya	--	35.0
Mexico	153.0	140.0
New Zealand	202.6	150.0
Philippines	224.2	1105.0
Taiwan	0.3	--
Turkey	0.5	14.0
USSR	5.0	58.0
United States	674.0	1401.0
TOTAL	1977.0	3938.0

Based on information gained from such international activities, Federal commercialization strategy and program plans are adjusted to reflect needs peculiar to U.S. manufacturers trading abroad.

At present, worldwide installed capacity is 1977 MWe, with planned additions of 3938 MWe (see Table V.2).

At least 20 other countries have active geothermal energy programs, and through multilateral and bilateral agreements the United States participates in international programs. Generally, the agreements call for the exchange of information, exchange visits of scientists, and selection of areas for cooperative activities. In some cases, agreements have led to more active cooperative research and development programs.

Multilateral Programs

A 15-month study called "Man-Made Geothermal Energy Systems" (MAGES) is being conducted by the International Energy Agency (IEA). Six of the nineteen IEA participants (the United States, the Federal Republic of Germany, Sweden, Switzerland, Japan, and the United Kingdom) are active in MAGES, which explores hot dry rock systems and equipment. In FY 79, the first phase was successfully completed. As a result, under a new bilateral agreement between the United States and the Federal Republic of Germany, German scientists will participate in the Los Alamos Scientific Laboratory's (LASL) hot dry rock project, and will contribute about \$2.5 million per year.

In FY 79, the United States, Mexico, New Zealand, and Italy signed a cooperative agreement, under the auspices of the IEA, to test a U.S.-produced wellhead generator unit, the helical screw expander that was successfully operated at Roosevelt Hot Springs, Utah, in FY 79.

Bilateral Agreements

Formal bilateral agreements exist between the United States and Italy, Mexico, Germany, El Salvador, Taiwan, New Zealand, Egypt, Peru, and Japan.

U.S.-Italy. There are two separate geothermal agreements with Italy. The first involves reservoir stimulation and computer modeling, environmental control technology, and seismic studies. The second provides for continued data exchange through computerized information systems.

In FY 79, well selection for hydrothermal field stimulation tests was completed, following information exchange and site visits. Data collection and evaluation for reservoir modeling at Larderello, Radicondoli, and Bagnore are on schedule. Collaboration in environmental research is proceeding as planned, and H₂S will be monitored after an air quality and meteorological monitoring network for the Larderello field is established. Information was exchanged on materials and geochemistry, deep drilling problems, drill muds, and high-temperature cements. The United States provided monitoring equipment for radon and H₂S emissions. In addition, seismic instrumentation was installed in Torre Alfina, Latera, and Cesano.

U.S.-Mexico. The U.S.-Mexico bilateral geothermal agreement has produced a cooperative program to collect and analyze field data for reservoir engineering studies. In FY 79, cooperative investigations on the geophysical and hydrological characteristics of the Cerro Prieto field continued. Proceedings of the First Symposium on the Cerro Prieto Field (held in 1978) were published. A dynamic model of the field is being developed and should aid in understanding the field interactions with regional aquifers, particularly as affected by reinjection of geothermal fluids. Discussions are under way to extend these cooperative efforts to other geothermal fields.

U.S.-Japan. An implementing agreement between DOE and the Agency for Industrial Science and Technology of Japan, signed in FY 78, provides for development and evaluation of the geothermal resource data base, new techniques for resource assessment, drilling and fracturing volcanic studies, transportation of steam and hot water for direct use, evaluation of reservoir life, and environmental studies. The first executive coordinating committee meeting was held in May 1979. Both countries presented information about their domestic programs and discussed possible cooperative projects. Japan expressed an interest in exchanging information on binary conversion systems and in participating in the LASL hot dry rock project. A geothermal technology exchange project is currently being negotiated with the Japanese government.

U.S.-New Zealand. A draft geothermal agreement between the United States and New Zealand is being negotiated. Areas of cooperative study will include drilling and completion, instrumentation, chemistry and materials, stimulation, reservoir engineering, two-phase flow, and brine disposal.

Other bilateral agreements provide for information exchange, resource assessment support, cooperative economic analyses, and exchange visits between the United States and El Salvador, Taiwan, New Zealand, Egypt, and Peru. Continuing participation by the United States in the IEA activities, in possible future NATO-CCMC cooperative studies, and in other international meetings is expected to lead to additional bilateral agreements.

Other International Activities. Many nations are assigning increasingly greater priority to the development of indigenous energy sources, including geothermal energy. The growth of these potential markets is generating some export competition among countries with developed geothermal technology.

The early phase of development has commonly been financed by grants from the United Nations Development Program. Financing for the later phases of development has been provided by international development financing institutions such as the International Bank for Reconstruction and Development and the Inter-American Development Bank, sometimes in combination with vendor financing supplied by major equipment manufacturers.

The U.S. geothermal industry has, historically, concentrated on domestic markets. Geothermal technology has been exported primarily because large energy corporations or architectural and engineering firms

have used existing sales networks or foreign contacts. Now other U.S. companies are awakening to the potential for export of geothermal expertise, especially in less developed countries (LDCs), but little information is available about the base and potential size of foreign markets.

During exploration and feasibility studies, U.S. drilling companies have enjoyed leadership, and geophysical and geological firms are competitive with those from other countries. During field development and production, established firms with local contacts often have a significant economic advantage over firms that must bring in operating equipment and personnel. During design and construction of the power plant, American architectural and engineering firms are at a disadvantage because they cannot finance equipment quickly enough to be competitive with other countries that export geothermal technology, particularly Japan, Italy, New Zealand, or France; these countries benefit from a tradition of close government-business cooperation.

It is unclear whether a Federal geothermal technology export policy would assure U.S. firms a role in the growing international market. To determine the answer, data on potential geothermal markets must be aggregated. A review of existing cooperative agreements may point the way to opportunities for international marketing.

During FY 79, DOE sponsored a number of studies:

- To define the potential commercial market for U.S. industry in foreign countries
- To investigate policy options and implications for the United States in such markets, particularly the costs and benefits that export expansion would have for domestic commercialization
- To determine the conditions under which the American geothermal industry would be interested in participating in foreign geothermal development
- To assess receptivity of LDCs to marketing of U.S. technology
- To define the relevant legal, institutional, social, and environmental constraints

These studies will be completed in FY 80. Preliminary findings indicate that many large U.S. energy companies prefer overseas geothermal projects because power plants can be developed more quickly than in the United States. However, smaller companies, without resources to sustain operations abroad, will remain focused on the U.S. market. (Tax considerations, in particular tax treatment of overseas earnings, have a significant impact on the investment posture of energy companies.)

U.S. financial institutions are cautious toward international geothermal projects. Therefore, funds for major near-term geothermal activities must come from internal financing (e.g., a large oil company), be backed by the host country, or be fully guaranteed by some other

institution (e.g., the Overseas Private Investment Corporation). The extent and structure of geothermal investments in developing countries may be limited by the availability of foreign reserves or by ceilings on foreign borrowing imposed by the host country or by the International Monetary Fund.

The preliminary studies noted above are delineating the structure of the energy sector in less developed countries. Because energy distribution networks and capital are limited, the appropriate scale of geothermal applications is often much smaller in LDCs than in developed countries. The 50-100 MWe commercial-scale power plants of developed countries may be too large for many sites in LDCs, where wellhead generators in the 1-5 MWe range are more appropriate. Whether U.S. firms are willing to undertake the effort and expense of retooling for smaller applications will therefore be an important factor in export policy.

On the other hand, nontechnical, noneconomic benefits may flow from transfers of geothermal technology abroad, since many countries are grappling with second-generation issues relevant to geothermal commercialization in the United States. In particular, public and private sectors cooperate in areas such as the protection of fragile environments, interface of geothermal applications with conventional utility systems (such as cascading or cogeneration), geothermal steam pricing, and brokering of geothermal projects.

D. TECHNOLOGY DEVELOPMENT

Geothermal energy recovery is accomplished with technology similar to oil and gas industry technology, but geothermal temperatures and fluid characteristics, exceeding those for which oil field equipment was designed, shorten equipment lifetimes and pose safety hazards. Surface heat recovery equipment adapted to geothermal use from existing steam technology is expensive and inefficient. And environmental problems cause unique difficulties. Therefore, technology specifically tailored to geothermal conditions is needed. The objective of the geothermal technology development program is to solve these problems. The program consists of four major areas: reservoir assessment technology, well drilling and completion technology, energy extraction and conversion technology, and geochemical engineering and materials.

The purpose of reservoir assessment technology is to more accurately predict, locate, and measure reservoirs. Relying on the industry to point out key technical problems, the government carries out research in exploration technology, reservoir engineering, logging instrumentation, and log interpretation.

Reservoir engineering systematically provides data to models that predict longevity and productivity. Case histories of producing geothermal fields serve as a basis for this modeling. For example, a case history of a comprehensive set of exploration techniques deployed at Roosevelt Hot Springs, Utah, helped evaluate the various techniques (geological, geochemical, and geophysical) used in delineating the

confirmed reservoir. This case history was compiled in FY 79; case histories for other geothermal sites are in process.

A numerical model for simulating two-phased flow in geothermal wells was developed and validated by comparison with field data. The model will enable detailed evaluation of geothermal systems, estimation of reserves (from depletion analyses), estimation of effects of injection on energy recovery, and studies of the effects of gases on reservoir depletion.

A test at the Valles Caldera (New Mexico) geothermal field successfully demonstrated electronic logging tools that functioned for 18 hours at a depth of 8,000 feet (16.5 hours at 242°C and 1.5 hours at 282°C). Previously, tools could not function above 180°C. The logging program is demonstrating to industry how to upgrade the logging capability to 275°C. The program continues to provide calibration facilities for industrial equipment and to improve interpretation of geothermal rock properties from borehole logging.

The purpose of well drilling and completion technology is to reduce the cost of geothermal drilling and to improve well completion techniques. In stage one, improvements in drill bits, downhole motors, and drilling fluids will demonstrate the technology that will make a 25 percent reduction in drilling costs possible by 1983. In stage two, a new drilling system is expected to enable a 50 percent reduction in geothermal drilling costs by 1986.

In FY 79:

- A third-generation unsealed roller cone bit, designed specifically for drilling hot, hard, fractured rock was tested at The Geysers (Cal.). The new bit drilled 30 percent longer than conventional bits drilling the same formation at equivalent temperatures. Use of this new bit can save a minimum of 4 percent on total well costs.
- A field test of the downhole replaceable chain drill bit proved successful. This test confirmed the cost benefit of changing the cutting surface of the bit downhole. Commercialization is under way.
- A new technique for removing scale from pipe was demonstrated. This new de-scaling system uses cavitating jets to remove scale from geothermal power plants; it provides a nondestructive, inexpensive, fast method for cleaning heat exchanger surfaces, flash tanks, and piping.
- Plans for an advanced drilling system were formulated, based in part on advice gathered at a workshop of 50 participants from industry, universities, and the government.

The FY 80 program is expected to bring about the commercialization of the chain-drill bit, advances in the use of man-made diamond materials, and the evaluation of candidate technology for advanced drilling systems.

The purpose of energy extraction, conversion, and stimulation technology is to reduce electric generating costs, particularly for moderate-temperature geothermal fluid. Extraction and conversion technologists improve performance and reduce costs of binary heat exchangers. Stimulation technologists develop new equipment and techniques for use in high-temperature geothermal environments, to improve formation permeability.

Major program accomplishments of FY 79:

- After a successful field test in Utah, the 1 MWe helical screw expander wellhead electric generation system was refurbished and made available to the International Energy Agency for testing at geothermal fields in Mexico, Italy, and New Zealand.
- Design of an advanced gravity head binary system is complete; major components have been ordered. This system is expected to be nearly one-third more efficient than conventional binary cycles, and could markedly improve the economies of electricity generation from moderate-temperature resources.
- A 500 kWe skid-mounted binary power system was installed at East Mesa and has undergone preliminary testing. The system is designed for moderate-temperature resources, and uses direct-contact heat exchangers.
- A 100 kWe direct-contact power system was built and moved to a test site in Marysville, Arkansas. Two months of preliminary shakedown and test runs have been completed. The system is designed for low-temperature resources.
- Several months of unattended continuous operation of the 60 kWe binary plant at Raft River have provided new data on the reliability of binary system operation with low-temperature fluids.
- A well at Raft River was successfully stimulated, increasing production threefold.
- Equipment was installed to carry out the joint DOE/EPRI heat-exchanger equipment tests at the East Mesa geothermal component test facility.
- A comprehensive source book, Utilization of Geothermal Energy for Electric Power Production,

edited by Brown University, was completed and will be published in FY 80.

Numerous studies have determined that binary cycles offer the greatest potential for reducing the costs of generating electricity from the moderate-temperature geothermal resource; thus the DOE conversion technology program is heavily oriented toward binary conversion cycles. Direct-contact heat exchangers and advanced process design are areas of particular interest. The gravity head binary system is expected to yield a significantly higher utilization efficiency by improving heat transfer characteristics and reducing parasitic loads due to feed pumps. Beginning late in FY 80, hardware for the gravity head system will be tested in a special large-diameter well at East Mesa, Cal.

An active geothermal well stimulation program was started in FY 79 with the successful hydraulic fracturing of a well at Raft River, Idaho. New tools and techniques will be used in the explosive stimulation of a well at the Geysers Geothermal Field in California. Newly developed high-temperature explosives will be used in an attempt to increase fracture permeability and to increase the flow of fluids to the wellhead.

The extraction of heat from geothermal fluids requires the handling and disposal of large volumes of water. Because the chemistry of geothermal waters is to a large extent site-specific, the problems of scale control, erosion, and corrosion require a detailed design to balance technical and economic subsystems for each potential site. The purpose of geochemical engineering and materials technology, therefore, is to address the special character of geothermal fluids and their interaction with other materials.

Fluid chemistry programs develop monitoring and control instruments, fluid control technology, and economic fluid disposal procedures that reduce scaling and cost of use. Materials development programs tailor borehole and conversion equipment to geothermal use. As noted above, oil field equipment is poorly suited to geothermal use; this is primarily because materials are degraded by the high temperatures and fluid chemistry.

In FY 79, flash tanks and pipes lined with polymer concrete were tested in East Mesa's severe scaling environment. Carbonate scale did not adhere to the polymer surface, thereby offering a potential remedy to the scaling program in a portion of the brine-handling equipment at East Mesa and other geothermal fields with high carbonate content in the water.

A handbook analyzing materials available for use in geothermal electric applications has been published to aid in the design of geothermal power plants. The handbook is being enlarged to include process and space heating applications. The new edition will be available in the summer of 1980.

Materials constitute a large part of the capital costs of low-temperature process and space heating applications. Less expensive construction materials are being developed as part of a wide range of elastomers and metals for use in the geothermal environment. Specifically, new cements for completing wells and new materials for seals are also being developed.

In FY 80, geothermal materials research will concentrate on materials for localized corrosion and wear resistance, hot-hardness and fatigue-resistant bearing and drill bit applications, and pipes made of alternative materials. This research, as well as continuing programs in seal and cable materials, is essential to the reliability of downhole pumps, instrumentation, motors, and piping systems.

Geobrines Research. Begun in 1973 under the direction of the Bureau of Mines, geobrines research has been carried out in two areas: mineral recovery and construction materials.

In minerals recovery research, a process flow scheme using hydroxide bulk precipitation techniques was devised and assembly of a process development unit at Niland (Cal.) to demonstrate the technique was started. Studies showed the sensitivity of zinc recovery to pH and temperature, and lithium recovery to aging. A new study was started, using a selective sulfide process to recover lead and zinc from high-salinity geobrines.

In FY 80, tests on the bulk precipitation technique will be completed and results evaluated. Bench scale research will be continued on processing variables to improve zinc and lithium recovery, as well as in the selective sulfide technique for recovering lead and zinc.

A study on control of silica scale formation from geobrines flow and its effect on mineral recovery was completed and a final report is in preparation. Other studies on the effect of geobrines scaling behavior will continue.

The Bureau began to collect data on the compositions of Western geobrines. Evaluation of additional geobrines compositions will continue and new brines will be considered for future minerals recovery research.

Completion of a project to screen materials of construction for geothermal brine operations is scheduled for FY 80. An agreement was signed with DOE to provide additional support in evaluating 4,000 samples of 20 iron-, nickel-, and titanium-based alloys tested in FY 78 at the Bureau of Mines' Salton Sea facility.

Corrosion/Deposition Studies. Corrosion and deposition are common to nearly all geothermal sites. However, each site has its own distinctive character. Most sites produce significant quantities of sulfur-containing gases such as H_2S which, when combined with moisture and air, form very corrosive acids. Geothermal fluids and emissions can be particularly corrosive, because of the aggressiveness of dissolved gases and chemical species associated with the geothermal fluid.

The purpose of the corrosion studies is to assess the impact of geothermal fluid on equipment and develop, where necessary, methods for mitigating such impacts. The corrosion study being conducted by the Navy at Coso (Cal.) seeks to establish corrosion evaluation techniques. Equipment is needed to evaluate effects of geothermal fluids on mechanical materials at remote Navy sites and the effects of airborne mists and aerosols on existing aircraft and electronic communication equipment. Measurement techniques will determine the nature and extent of geothermal emissions at given sites where visibility of other site-specific conditions is crucial to Navy mission performance.

In research on materials of construction for geobrine operations, evaluation of the corrosion behavior of the 20 iron-, nickel-, and titanium-base alloys (tested in FY 78 at the Bureau of Mines' Salton Sea facility) was started. Approximately 4,000 samples are involved. Maximum and average pitting corrosion rates were measured on 12 of the alloys, and an initial evaluation of localized corrosion effects was made. An agreement was signed with the Department of Energy to provide additional support for this evaluation, which will be completed in FY 80.

In FY 80, DOE will continue process R&D for lower cost H_2S and fluid treatment and procedures. Additionally, prototype components designed and manufactured from alternate materials will be field tested and demonstrated in small nonelectric and electric systems.

Hydrothermal Technology Development

DOE builds and tests facilities to demonstrate that the use of hydrothermal resources is technically feasible, economically sound, and environmentally acceptable. Demonstration will show that geothermal water use is feasible, provides vital engineering and economic data, and fosters the business infrastructure necessary for the private sector to continue Federal initiatives.

The specific objectives of the demonstration projects are:

- To operate by the end of FY 82 a commercial-scale electric plant capable of generating electricity from a superheated water hydrothermal resource
- To demonstrate with high confidence by FY 83 that a low-to-moderate salinity geothermal reservoir can provide an adequate supply of hot water for the extended operation of an electric plant
- To demonstrate by 1985 that the environmental effects of the construction and operation of an electric plant are acceptable
- To demonstrate by 1985 the production of electric power from hot water resources at a commercially competitive cost
- To demonstrate at Federal facilities the technical feasibility of selected nonelectric applications

The following hydrothermal experimental facilities are under construction or are being planned.

Raft River Facility. A pilot plant now being built has a 5 MWe turbine generator with a binary Rankine power cycle, and will use energy from a moderate-temperature hydrothermal resource (150°C) to generate electricity for a utility power grid. The objectives of the project are to compare costs and methods of geothermal power generation to those of conventional systems, to verify cost assumptions; and to supply valuable information on the geothermal reservoir, plant equipment, and plant operations for use in planning future generation systems. Work on the current construction contract is about 80 percent complete. The system is to be fitted with a turbine generator set, and additional well tests are to be undertaken. An Elliott turbine is scheduled for January 1980 delivery. This plant is expected to be operational by the end of FY 80.

At the Raft River site, geothermal energy was used not only in the fermentation of sugar beet syrup, but also in the distillation of the alcohol formed in the process. The process was carried out at about 116°C .

The world's first successful extraction of spearmint oil using conventional steam distillation processes with moderate temperature hydrothermal fluids was conducted at the Raft River facility. A good collocation of product and geothermal resources exist because Idaho, Washington, and Oregon produce the bulk of spearmint oil for the nation. Another first is the completion of testing for the first successful well fracturing experiment in Well 4, where artesian flow was increased from 50 to 150 gpm. Hydraulic fracturing is a standard method used by oil and gas drillers, but this is a first-time application for geothermal.

50 MWe Demonstration Plant. In FY 77, Congress authorized DOE to carry out a geothermal demonstration project using a hot water hydrothermal resource. The project entails construction and operation of a commercial-scale (50 MWe gross output) electric power plant. The plant will also serve as a "pathfinder" for the regulatory process and other legal and institutional aspects of geothermal development. A cooperative agreement between DOE, Union Geothermal of New Mexico, and Public Service Company of New Mexico was signed in August 1979. The final EIS was prepared for release in January 1980. Plant design is under way at Baca Ranch (N.M.) and an order for a turbine has been placed.

HGP-A Geothermal Wellhead Generator. This project will evaluate the feasibility of using a wellhead generator to produce baseload electrical power. The generator will use the geothermal fluid from geothermal well HGP-A in the rift zone of an active volcano in the Puna District of Hawaii. The major power plant components will be mounted in such a way that they can be moved to other sites at some future date. The project is expected to lead to commercial applications of wellhead generators in remote areas of the western continental United States and Hawaii.

Construction of this facility is progressing and a turbine generator is on order. The geothermal well, which required recementing, is expected to begin operating in the first quarter of FY 80.

Geothermal Loop Experimental Facility (GLEF). Located near Niland (Cal.), the GLEF has established the feasibility of using flash-steam binary systems for electric power production from high-temperature, high-salinity resources. The project is being cost-shared with the San Diego Gas and Electric Company.

The first GLEF was constructed in 1975, and operated 1,000 hours before it was shut down for removal of accumulated scale, which took approximately two weeks. New plant designs incorporating redundant flash trains are expected to increase the plant's production capacity from well below 75 percent to over 85 percent, and to reduce energy production costs to below 38 mills/kWh in the 50 MWe size.

Recently developed preinjection treatments have effectively eliminated injection clogging problems. Additionally, problems of scaling and corrosion have been addressed and solved. Facility testing was completed FY 79. The data derived from the facility has prompted Magma Power Co. to agree to operate a 50 MWe plant on the site by late 1984.

Geothermal Component Test Facility (GCTF). This facility provides moderate-temperature, moderate-to-low-salinity geothermal fluid and supporting services to experimenters for testing of equipment and components used in advanced geothermal systems. Located at East Mesa (Cal.), the GCTF is currently being used by several DOE-sponsored and independent experimenters; it will be operational until demand for its use diminishes. Both Federally and commercially developed components are being tested.

Geopressured Technology Development

The program to develop the geopressured resource is divided into two activities: reservoir definition and environmental research.

Thousands of wells have penetrated geopressured aquifers in search of oil and gas in other horizons in the Gulf Coast sediments; the magnitude of the geothermal resource is being defined and delineated by logs from these wells. These studies, along with seismic surveys and core analyses, have located 70 areas with high potential for geopressured production. These studies are being supported by programs to test wells of opportunity (wells penetrating geopressured formations that will not be tested by the operator) and design wells drilled by DOE specifically to test geopressured aquifers.

A major accomplishment for FY 79 was DOE's successful drilling of a well in Brazoria County (Tex.). The well is completed and ready for long-term testing.

Other accomplishments:

- Two wells of opportunity tested in Louisiana produced brine saturated with methane.

- Delineating of geopressed aquifers was essentially completed in FY 79; this work will serve as the basis for drilling and testing programs in coming years.

Mapping, including the assembly of a computerized data base, will continue in FY 80. Emphasis will be placed on resolution of the large identified reservoirs, mapping deeper formations, and extending the work to previously unmapped areas. The sites proposed for tests of existing wells and for drilling of new wells will also be evaluated within this program.

About 10 new geopressed wells are planned through 1984; the same number of existing wells could be subjected to short-term tests. Increased funding in FY 80 will support the increased rate of new drilling, and the testing of wells drilled in FY 79. Somewhat less will be expended in FY 80 to support resource definition (mapping), because this part of the program is relatively mature. Environmental assessment and monitoring of well sites in Texas and Louisiana will be accelerated to keep pace with the test programs.

Hot Dry Rock Technology Development

The hot dry rock program evaluates the energy potential of the resource and supports development of new technical approaches for extracting energy from hot dry rock. After successful operation of a 5 MWt loop at the Fenton Hill site in New Mexico in 1978, the program was expanded to include a 40-50 MWt demonstration.

As a result of this program, DOE:

- Began Phase II drilling a 20-50 MWt energy extraction loop at Fenton Hill
- Began intensive site-specific evaluations near Mountain Home, Ida., and Crisfield, Md., for selection of additional experimental locations
- Began a two-year, industrial-economic study
- Completed a preliminary legal study.

Field projects evaluating the energy potential and characterizing sites have become vigorous and growing program elements. The Fenton Hill project is the largest of these, comprising analytical and laboratory support and, as appropriate, instrument and equipment development. Careful environmental surveillance at the test site and in the vicinity continues to support the thesis that HDR is one of the most environmentally benign energy sources.

In FY 81, the Phase II drilling at Fenton Hill will be completed, and steps will be taken to establish a 20-50 MW system. Future development and proving of an HDR reservoir at Fenton Hill will be conducted under an international agreement between the United States and the Federal Republic

of Germany (FRG). The FRG will contribute 25 percent of DOE's budget for the Fenton Hill project, up to a maximum of \$2.5 million per year. The initial agreement will remain in effect for 4 years.

Based on data from resource evaluation and site characterization, a second HDR site will be selected in FY 81, to continue experiments in energy extraction technology.

E. RESOURCE IDENTIFICATION, ASSESSMENT, AND EXPLORATION

The objectives of the Federal resource identification program are to

- Characterize the geological nature of each type of geothermal system and the reservoirs within these systems
- Estimate the location, distribution, and energy content of individual geothermal systems and reservoirs
- Inventory the identified portion and predict the undiscovered portion of the nation's geothermal resources
- Confirm the existence and commercial potential of high- and moderate-temperature reservoirs suitable for electric power generation
- Confirm low- and moderate-temperature prospects that show potential for direct heat applications.

To achieve these objectives, DOE and the U.S. Geological Survey (USGS) undertake national, regional, and in cooperation with individual states, site-specific assessments of the geothermal resource (with emphasis on the hydrothermal resource). In addition, exploratory drilling programs have begun in several regions where a strong interest in direct heat has been exhibited, but where appropriate resources have not yet been confirmed.

National Geothermal Resource Update

The USGS completed a major update of its assessment of U.S. geothermal resources, and published the results in January 1979 as USGS Circular 790. The update reaffirms the existence of very large energy contents for hydrothermal, geopressured, and hot dry rock resource bases. (For more information, see Chapter II of this Report.) DOE's state-coupled program (see below) has increased state assessment activities, undertaken in concert with USGS. This Federal-state relationship will provide information on low-and moderate-temperature resource areas.

The National Energy Act of 1978 gives impetus to geothermal resource development in general by allowing investment tax credits, expensing of

intangible drilling costs, and a percentage depletion allowance. Specifically, these incentives should stimulate greater financial involvement by industry in exploration for and confirmation of geothermal reservoirs.

Reservoir Definition

USGS Assessment. A comprehensive, multi-year study of the Cascade Mountains of Washington, Oregon, and northern California is under way to determine the character and extent of geothermal resources of the region. It is being conducted by the USGS, state agencies, several universities, and several private firms. Reconnaissance studies have been initiated and will be followed by selection of a few areas for concentrated studies. In a related effort, DOE and USGS are jointly evaluating the resource potential of Mount Hood, Oregon.

Major aspects of a comprehensive, multidisciplinary investigation of the geothermal resource potential of the Snake River Plain region, spanning three years, were completed during FY 79. Results are being compiled into a regional case study.

The USGS has placed added emphasis on assessing geopressed resources by initiating a study of the deeper onshore and offshore portions along the Gulf Coast to characterize their structures, stratigraphic framework, and depositional environments for improved estimates of thermal and methane energy content.

Industry-Coupled Case Study. To accelerate confirmation of geothermal reservoirs with apparent commercial electric potential, the industry-coupled case study program was begun in FY 78. DOE shares exploration and drilling costs with industry, in exchange for public release of data; these data help in finding successful techniques for exploration, well drilling, and completion. In FY 79, nine companies participated. The program was extended to northern Nevada, where 12 candidate sites are being investigated for exploratory drilling in FY 80.

State-Coupled Program. Low- and moderate-temperature resources are being defined in cooperation with nearly all 37 states that have identified resource potential. The effort consists of two phases. Phase 1 analyzes existing geological and geophysical data to establish the size and distribution of hydrothermal resources. Phase 2 assesses target areas in detail and may drill heat flow measurement holes to confirm the existence and nature of the resource. Progress in FY 79:

- The Atlantic Coastal Plain project has delineated several probable reservoir targets as part of Phase 1. Therefore, in FY 80, a number of Phase 2 heat flow holes 1,000 to 2,000 feet deep will be drilled.
- Potential reservoirs have been identified in Arizona, California, Colorado, Idaho, Montana, New Mexico, Oregon, Texas, Utah, Washington, and Wyoming.

- Geothermal resource maps have been published for Oregon, Nevada, and Arizona; maps for Oregon and Montana are in press. Maps for most other states participating in the state-coupled program will be published in FY 80.
- Many data on low- and moderate-temperature hydrothermal resources are being added to the geothermal data file of the USGS, GEOTHERM, which provides the principal data bank for assessing these resources.

Exploratory Drilling for Low- and Moderate-Temperature Reservoir Confirmation

The use of hydrothermal energy for direct heat applications is hampered by the lack of resource knowledge and by the high risks and costs of reservoir confirmation. In addition, no infrastructure exists in the private sector to undertake the development of resources once they are confirmed. A limited exploratory drilling program has been carried out in several regions where there is strong interest in the use of hydrothermal energy for nonelectric purposes but where there is no confirmed resource.

DOE plans a much more aggressive program in FY 81, to be called the User-Coupled Drilling Program. Competitively selected teams composed of a developer and a user will share the cost of surface exploration and drilling to locate and confirm a reservoir that could be commercially developed for direct heat applications identified by the user.

In FY 79:

- A deep test well drilled at Crisfield (Md.) recovered warm water at 4,000 feet, 54°C at a potential flow rate of 325 gallons per minute. One or two more exploratory wells will be drilled in the Atlantic Coastal Plain during FY 80.
- A well was drilled to a depth of 10,500 feet at the Idaho National Engineering Laboratory (INEL). The purpose of the well was to locate moderate- to high-temperature fluids underneath the Snake River Plain, to be used as a source of heat for the chemical processing plant at INEL. The well temperatures registered 150°C but the volume of fluid sufficient to meet plant needs was not found.
- A well was drilled at the Los Alamos Scientific Laboratory in an attempt to provide an alternate energy source for the laboratory. The well was abandoned at 2,300 feet, because of lost circulation.

One or more deep wells will be drilled in the Mount Hood (Ore.) area in FY 80, as a result of a Congressional add-on. Interest has been expressed in the use of hydrothermal energy for district heating in the city of Portland and for space heating of facilities on or near Mount Hood.

The expanding economy of the Pacific Southwest is being maintained at the expense of a diminishing water supply. Current water demands, exceeding the annual renewable supplies, are being met by overdrafts of groundwater reservoirs. To augment the water-short area of the Colorado River Basin, the Water and Power Resources Service's geothermal investigations began in FY 78 to locate new sources of water supply: the geothermal brines are desalted by using the heat energy inherent in the geothermal fluid.

The Water and Power Resources Service (DOI) is conducting reconnaissance-level geothermal investigations throughout the Colorado River Basin, with special emphasis on the Springerville-St. Johns and Clifton areas of Arizona. The service provides drilling capability for heat flow and other geophysical studies being performed by the University of Arizona. Five temperature-gradient holes 500-1,500 feet deep have been drilled this past year in the Springerville area and one 1,000-foot hole was drilled in the Clifton area. Logging of new and existing wells is continuing. Electronic mapping is being done by the University of Arizona. After data are collected, the University will prepare and publish a total geothermal resource report in FY 80.

The Service also drilled five temperature gradient holes 200 feet deep in the Mono Lake area of California during the past year. Water supply studies from geothermal resources will continue through FY 80. Geothermal studies in the Salton Trough area (Cal.) are now limited to literature research and geothermal water supply studies using existing data. This work is expected to be completed in FY 80. A final report describing the desalting program at the East Mesa Geothermal Test site is expected by early FY 80. In the Susanville area, the Service drilled 10 temperature-gradient holes 400-900 feet deep. Only minor work, such as pumping tests and installation of casing in several holes, remains to be done. WPRS will drill eight 150-foot temperature gradient holes in the Litchfield area and may extend one or two holes to 1500 feet during FY 80. A pump test will be run in the deeper hole. Geophysical surveys will continue in both Susanville and Litchfield with a final report due by the end of the year. No funding for geothermal field work in Susanville is scheduled after FY 80.

Resource Assessments on BLM Lands. Under the provisions of the Federal Land Policy Management Act (FLPMA), the Bureau of Land Management is developing recommendations to Congress for certain lands to be designated wilderness areas. These areas should generally be 5,000 contiguous acres or more of roadless lands that have opportunity for primitive and unconfined recreation. After such areas are identified, an interim management policy allowing for assessment of mineral and energy resources will be implemented. A final management policy for BLM lands will be recommended to Congress by 1993.

At present, BLM is identifying and taking inventory of roadless areas, and will complete this task by October 1980. After that, comprehensive resource assessment studies will begin. It is anticipated that roadless tracts containing vital mineral resources will be released for development before 1993.

DOE will take an active role in resource assessment for energy minerals, and will advocate nonwilderness classification of energy-rich lands. Therefore, with support from a national laboratory, the Leasing Policy Development Office (LPDO) of DOE has begun its own resource assessment on BLM's Wilderness Study Areas (WSA).

The Division of Geothermal Resource Management has been working closely with LPDO in planning for the assessment and ranking of geothermal resources on BLM Wilderness Study Areas. WSAs with known or suspected geothermal resources have been identified in a preliminary manner, and criteria for ranking of geothermal resources are under development. Over the next several years, DOE will maintain an active role in the Wilderness Study.

F. LEASING

The Federal leasing program is an important determinant of the rate at which geothermal resources will be developed in the United States. The experience of Federal leasing agencies since the passage of the Geothermal Steam Act has demonstrated how difficult it is to balance rapid resource development, especially in areas of technological uncertainty, against environmental values and sound land management practices.

Regulations implementing Federal leasing took effect in December 1973, and the first leases were issued in 1974. The first commercial production of geothermal energy from Federal lands began in 1979 at the Geysers in California--nearly 20 years after production began there on non-Federal lands.

At the end of FY 79, over 2.8 million acres had been leased: 296 competitive leases on 510,000 and 1,332 noncompetitive leases on 2,315,000 acres (Tables ES-4 and V.7). While this is a substantial acreage, it may not be enough. To achieve the IGCC's goals for the year 2000, an estimated 20-40 million acres will have to be explored by 1990. About half of that will be Federal lands. The requirements for environmental reviews and land-use planning, coupled with limited manpower and budgets, have seriously delayed issuance of leases in Forest Service lands. Furthermore, the issuance of noncompetitive leases has been slow in some states. About 1.3 million acres in Known Geothermal Resources Areas (KGRAs) have not been offered for competitive sale. Tables V.3 through V.8 present detailed breakdowns for competitive and noncompetitive leasing over the past several years.

The U.S. Geological Survey designates certain lands Known Geothermal Resource Areas, based on strong evidence of geothermal resources. To date, 3.38 million acres have been designated KGRA lands, 2.15 million acres (64 percent) of those on Federally administered lands. The Geysers Known Geothermal Resource Area alone has accounted for over \$24 million in high

bonus bids, which is 65 percent of the total bonus bids accepted since the first Federal geothermal sale in 1974. About 35 percent of the KGRA acreage offered for competitive sale has not been bid upon. Almost one-fourth of all leases issued have been relinquished, and a substantial number of leases offered to applicants have been rejected.

The U.S. Geological Survey provides permits and monitors development on leased lands. Of the 1,628 outstanding leases issued since 1974, 129 plans of operations for exploration have been approved, and 192 wells drilled. About 400 exploratory operations have been approved on unleased land. Twenty-five of the on-lease exploratory plans were filed since the passage of the National Energy Act in October 1978; thanks to the tax incentives in this Act.

BLM Leasing

According to industry sources, accelerated leasing of Federal lands may be accomplished by changing some of the BLM's leasing regulations and procedures. In FY 80 BLM plans to focus activity on relieving two major obstacles to Federal leasing. First, regulations will be drafted to allow reissuance of 343 relinquished leases. Second, a new environmental assessment procedure will be implemented to match the level of review with the proposed activity. These two changes, accompanied by a legislative revision of maximum acreage limitation currently being considered by the Congress could very substantially affect the amount of acreage leased.

Believing that the key to direct use development lies in cooperation among state and Federal agencies, local governments, and small businesses, BLM is planning state-specific training and orientation meetings for its field managers, with participation from various state geothermal coordinators on contract to DOE. BLM will issue specific instructions for processing direct use applications in its local field offices. To make the process much easier for the applicant, the instructions will, as much as possible, include state requirements.

USFS Leasing

A letter drafted late in FY 79 by the U.S. Forest Service advised its regional foresters of a reorientation in the policy concerning mineral-related activities. Citing a backlog of several hundred geothermal leases, some pending for several years, the letter states, "Our objective is to eliminate this backlog within 2 years, while keeping current with new applications".

To accomplish this, regional foresters were told that there is no legal reason to withhold action on leasing pending completion of Land Management Plans. This advice is intended to speed up leasing by allowing applications to be processed before completion of Forest Plans under the National Forest Management Act. Further, the regional foresters were advised of plans to establish reasonable time limits for leasing and permitting decisions, to require that applicants be promptly notified of decision schedules, and to make those schedules appealable.

Only about 5 percent of geothermal noncompetitive lease applications for National Forest System lands have led to leases being issued. However, that figure does not indicate the significant efforts of the past two or three years. For example:

- On May 15, 1979, the Regional Forester for the Pacific Northwest Region signed a final Environmental Statement that approved leasing of 192,310 acres in the Gifford Pinchot National Forest in Oregon and denied leases for 107,298 acres. About 100 leases are involved--nearly 10 percent of the Forest Service's total backlog of pending applications.
- The Island Park Geothermal area, west of the Yellowstone National Park, has nearly 130 pending lease applications, or about 13 percent of the total backlog. In cooperation with the BLM, FS issued a draft environmental statement in March 1979, which discussed a number of leasing alternatives; the final environmental statement was in preparation at the end of the fiscal year. There is considerable controversy over possible effects on Yellowstone National Park, and even if FS consents to lease National Forest System lands, the Department of the Interior may refuse to issue the leases.

With regard to competitive leasing, about 12 percent of those KGRAs wholly or partly on National Forest System lands have been offered for sale. Some offered KGRAs have not received any bids. The majority of the KGRAs have not been proposed for leasing by BLM because of apparent lack of industry interest. Only a few KGRAs are considered to have potential for electric generation. Two of these, West Yellowstone KGRA and Island Park Competitive KGRA, are covered in the draft environmental statement discussed above. The Mono Long Valley KGRA of California has been the object of considerable interest from the geothermal industry; the Forest Service is now in the final stages of prelease review, and a sale has tentatively been scheduled for early 1980.

Based on recommendations of the IGCC's Streamlining Task Force, a pilot test of staged leasing using a (conditional development) stipulation was approved for use in Oregon and Washington State National Forests. A successful outcome will encourage staged leasing elsewhere on Forest Service lands. Staged leasing derives from the idea that to perform a full-scale environmental review of possible development before any leasing begins is often to waste both money and time, and cannot meet the intent of the National Environmental Policy Act (NEPA), since the location, type, and scale of development are unknown. As set up in the Forest Service test areas, lease issuance will be based primarily on environmental review of exploration. If the lessee discovers a commercially viable resource and presents a plan of development, a comprehensive environmental review of that plan will be conducted before development can begin.

Essentially, this process is already in effect. The value of the stipulation is primarily to serve notice of the process and thereby provide a clear rationale for not attempting to fully address development in the pre-lease review.

Table V.3
COMPETITIVE LEASING BY STATE
TOTAL ACREAGE LEASED, BY YEAR

STATE	1974	1975	1976	1977	1978	*1979	Total
Nevada	28,338	29,197	60,944	36,663	9,322	24,298	188,763
Utah	23,391	26,171	26,968	12,788	1,658	-0-	90,977
New Mexico	-0-	18,476	14,088	48,066	8,767	7,062	96,461
Oregon	1,374	47,689	19,836	-0-	5,818	-0-	74,691
California	26,007	10,583	-0-	2,856	4,395	6,958	50,802
Idaho	-0-	20,963	3,940	6,985	-0-	-0-	31,889
Colorado	-0-	5,036	-0-	-0-	-0-	-0-	5,036
Total acres leased (by year)	79,110	158,115	125,776	107,358	29,960	*38,318	*538,619

*September 1979.

Table V.4

TOTAL HIGH BONUS BIDS BY STATE AND YEAR (IN DOLLARS)

State	1974	1975	1976	1977	1978	1979	Total
Cal.	8,614,912	134,532	-0-	780,451	16,016,169	1,368,191	\$ 26,914,257
Utah	877,188	2,705,618	96,688	668,825	33,862	-0-	4,382,184
Nev.	1,030,172	392,160	757,991	451,984	480,893	657,469	3,770,671
N. Mex.	-0-	359,682	54,901	1,089,213	72,639	240,631	1,817,070
Ore.	13,831	296,798	140,251	-0-	86,531	-0-	537,462
Ida.	-0-	153,470	27,006	30,452	-0-	-0-	221,929
Colo.	-0-	13,577	-0-	-0-	-0-	-0-	13,577
Total	10,536,103	4,055,837	1,076,837	3,020,925	16,690,094	2,266,291	37,657,150

Table V.5

DISTRIBUTION OF COMPETITIVE LEASE SALES BY STATE AND YEAR

	CY 1974	1975	1976	1977	1978	*1979	Total
Western Region:							
Nevada.....	2	3	7	3	1	1	17
California.....	3	1	0	1	2	1	8
Oregon.....	1	5	3	1	2	0	12
Idaho.....	0	2	2	1	0	0	5
Arizona.....	0	1	0	0	0	0	1
Subtotal.....	6	12	12	6	5	2	43
Central Region:							
New Mexico.....	0	1	2	3	1	1	8
Utah.....	1	2	1	1	1	0	6
Colorado.....	0	1	0	1	0	0	2
Montana.....	0	0	0	1	0	1	2
Subtotal.....	1	4	3	6	2	2	18
Total.....	7	16	15	12	7	4	61

*(September 1979)

Table V.6

CUMULATIVE NONCOMPETITIVE LEASE TOTALS, 1976-1979

Year (June 30)	Filings	Withdrawn, Rejected, & Refused	Awaiting Action	Leases Issued	Acreage Leased
1976	5,432	2,734	2,012	656	1,141,980
1977	6,043	3,232	1,831	904	1,500,005
1978	6,655	3,673	1,806	1,117	1,930,163
1979	7,315	4,027	1,956	1,332	2,314,670

Table V. 7
NONCOMPETITIVE GEOTHERMAL LEASING, 1979

STATE	APPLICATIONS							LEASES						
	FILED			INACTIVE			AWAITING ACTION		ISSUED			ACRES		
	BLM	FS	SUBTOTAL	WITHDRAWN	REJECTED	REFUSED	BLM	FS	BLM	FS	SUBTOTAL	BLM	FS	SUBTOTAL
Alaska	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arizona	64	67	131	7	35	8	13	55	12	1	13	19,621	1,920	21,541
California	730	460	1190	389	303	0	245	233	20	0	20	32,584	0	32,584
Colorado	113	83	196	100	17	2	6	38	42	1	43	49,565	680	50,245
Idaho	649	332	981	270	175	30	164	176	165	1	166	291,385	2,560	293,945
Montana	38	66	104	54	26	0	18	0	6	0	6	10,687	0	10,687
Nevada	1655	13	1668	542	356	78	165	0	524	3	527	981,184	4,434	985,618
New Mexico	629	42	671	337	83	10	109	19	113	0	113	194,318	0	194,318
Oregon	638	526	1164	243	295	0	134	351	118	26	144	161,041	43,437	204,478
Utah	584	108	692	172	149	22	31	33	274	11	285	480,551	13,513	494,064
Washington	0	342	342	105	61	0	0	176	0	0	0	0	0	0
Wyoming	26	138	164	141	16	0	1	2	0	4	4	0	7,448	7,448
East'n. States	0	12	12	0	1	0	0	0	0	11	11	0	19,744	19,744
TOTALS	5,126	2,189	7,315	2,360	1,517	150	886	1,083	1,274	58	1,332	2,220,936	93,736	2,314,672

(1) Applications awaiting action for the following reasons:

- 34 Awaiting KGRA report from USGS
- 1 Pre-lease plan of development
- 597 Pending preparation of EAR (BLM only)
- 1004 Awaiting comment of other agencies
- 30 Lease forwarded for signature
- 290 Processing (Adjudication) -- BLM

Table V. 8
NONCOMPETITIVE GEOTHERMAL LEASING
APPLICATIONS AWAITING ACTION

STATE	AWAITING KGRA REPORT FROM USGS	AWAITING PRE- LEASE PLAN OF DEV. FROM APPLICANT	PENDING PREP OF EAR (BLM ONLY)	AWAITING COMMENT OF OTHER AGENCIES		LEASE FORWARDED FOR SIGNATURE BY APPLICANT	PROCESSING (ADJUDICATION) BLM	TOTALS
				Other	FS			
Alaska								
Arizona			13		55			68
California			230	11	233		4	478
Colorado					28		6	34
Idaho	3		130		173		34	340
Montana			8		10			18
Nevada	26		9		14	15	101	165
New Mexico	5		65		29	8	21	128
Oregon			134		340	6	2	482
Utah		1	7	4	33	1	18	64
Washington					72		104	176
Wyoming			1		2			3
Eastern States								
SUBTOTAL	34	1	597	15	989	30	290	1,956

The Forest Service intends that with increased emphasis on mineral activities, lease processing will be accelerated, and subsequently the entire geothermal program on National Forest Service Lands.

G. ENVIRONMENT

The Federal environmental program includes acquisition of baseline data, monitoring, and research related to air and water quality, ecology, noise, subsidence and seismicity, health effects and socioeconomic problems; regional and site specific assessments of the environmental, health, and socioeconomic impacts of the development of geothermal resources; development and assessment of environmental control technologies; and the promulgation of regulations to protect the environment from the adverse effects of exploiting geothermal resources.

The DOE, EPA, and DOI have been the principal supporters of the environmental program, with DOE sponsoring most of the research activities. DOE and EPA have increased their funding for cooperative projects over the past few years.

Environmental Studies and Control Technology

Assessment. In FY 79, DOE and EPA continued to prepare environmental assessments and develop control technologies begun in previous years.

The Geothermal Environmental Overview Project (GEOP) sponsored by DOE is a major effort to identify and assess current information of potential environmental concerns in those Known Geothermal Resources Areas having a high probability of commercial development. Preliminary assessment reports issued in FY 79 included The Geysers-Calistoga area, and the Texas-Louisiana Gulf Coast. Assessments were initiated at Hawaii, Oregon, New Mexico, and northern Nevada, and are continuing for Mono-Long Valley, Raft River, and Roosevelt Hot Springs.

Other developments include:

- The GEOP's preliminary assessment of the Geysers-Calistoga KGRA, which pointed to potential socioeconomic problems. As a result DOE initiated a study of socioeconomic impacts resulting from geothermal expansion in this region. This study will be completed in FY 80.
- An extensive field measurements program to establish a baseline for future development in the Imperial Valley, (and to serve as a knowledge base for other studies), which has been completed. Data are being formatted for access by potential users, and analyses are available.
- A technology assessment integrating the environmental, economic, and social impacts of full-scale development of geothermal resources in the

Imperial Valley has been completed by DOE and will be published in FY 80.

- Continued preparation of programmatic environmental assessments and site specific Environmental Impact Statements (EIS) for DOE's development activities. The most significant of these was the EIS for the joint DOE-Industry 50 MWe powerplant development at Baca Ranch in New Mexico, published in January 1980.
- A subsurface environmental assessment by EPA for four geothermal systems: Imperial Valley (Cal.); The Geysers (Cal.); Klamath Falls (Ore.) and Valles Caldera (N.M.). As part of that project, a groundwater monitoring methodology was developed and its demonstration initiated.
- Initiation of a major program of specific and generic environmental studies using the 50 MWe hydrothermal demonstration project at Baca Ranch (N.M.).
- Data gathering by DOE and EPA on chemical and physical characteristics of geothermal fluids, including both liquids and gases, at existing and potential development sites.

H₂S Emissions. DOE has compiled all available information on H₂S control technologies applicable to geothermal emissions, including information gathered in recent applications, both new and retrofitted.

EPA initiated a project to examine the concept of electrochemical H₂S oxidation. If successful, this concept offers several advantages, not the least of which is that the only raw material operational requirement is electricity, ideal for power plant application.

DOE and EPA jointly initiated a project to develop UOP's sulfox process to remove H₂S while producing a usable by-product (sulfur) rather than creating solid waste or other disposal problems.

A demonstration of the EIC process, a prototype system to scrub 100,000 pounds of raw steam per hour, began at The Geysers. The initial results are very encouraging. Supported by DOE, EPA, and Pacific Gas & Electric Co., this system offers the opportunity to remove H₂S during steam stacking when the plant is shut down.

Subsidence and Seismicity. USGS requires baseline monitoring of subsidence at geothermal projects on leased Federal lands, and can shut down plants on evidence of seismicity. The Coastal Zone Management Act administered by the Department of Commerce contains a subsidence provision as well.

DOE continued its subsidence research, establishing the Geothermal Subsidence Research Program with the objectives of characterizing,

measuring, predicting and mitigating subsidence. This year, DOE completed an assessment of the environmental and economic effects of subsidence and prepared a manual of guidelines for monitoring surface displacements. Projects to assess mathematical subsidence models, to study the compressibility of reservoir cores, and to study the compaction properties of reservoir materials were continued. Case histories of subsidence were prepared for Long Beach, California, and Wairakei, New Zealand. Analytical models were developed for comparison with observed data. Near-future projects will include a detailed case history for Chocolate Bayou (Tex.), a subsurface risk assessment, and an assessment of potential indirect measurement techniques.

A major program to understand, predict, and mitigate induced seismic activity from geothermal development is in progress by USGS and DOE. A study to evaluate the effectiveness of current seismic control techniques has begun and is due in FY 80. Monitoring nets were emplaced in northern Nevada, at Roosevelt Hot Springs (Utah), and at The Geysers Field in California to detect and measure induced seismicity.

Liquid and Solid Waste Treatment and Disposal. Liquid waste treatment and disposal have not received great attention to date. It has been assumed that subsurface injection would provide reservoir conservation, subsidence prevention, and pollution control. DOE and the Department of Interior continue to experiment with methods and materials that reduce the potential for corrosion failure and for plugging of injection systems by chemical precipitation. DOE continues to investigate the need to treat Imperial Valley geothermal fluids and methods to dispose of solid waste residuals. EPA intends to begin an assessment of the overall geothermal solid waste problem in FY 80.

Other activities include

- A project initiated by EPA and the U.S. Fish and Wildlife Service in FY 79 to determine the feasibility of using spent geothermal fluids to create or enhance waterfowl wetlands. DOE is also examining surface uses at its Raft River (Ida.) test site.
- A project completed by EPA to develop a methodology for determining the ground water contamination potential of fluid releases at any point in the geothermal conversion system. Other EPA projects completed in FY 79 estimated the costs of pollution control technologies and examined the need for surface containment of potential brine spills.
- Plans by EPA to initiate broad-scale environmental assessments of spent fluid injection and of ocean disposal, the latter applying particularly to the Gulf Coast geopressured area.

Noise. DOE began the study of geothermal noise and state-of-the-art abatement measures. The project will address both general and site-specific problems. Although noise in geothermal operations can be intense, it appears to be controllable and therefore will not seriously constrain geothermal development. A report will be available in FY 80.

Table V.9

ENVIRONMENTAL AND CONSERVATION LAWS AFFECTING GEOTHERMAL DEVELOPMENT

Geothermal Steam Act of 1970

National Environmental Policy Act of 1969

Federal Water Pollution Control Act, as Amended

Clean Air Act, as Amended

Resource Conservation and Recovery Act

Safe Drinking Water Act

Federal Land Policy and Management Act of 1976

National Forest Management Act of 1976

Endangered Species Act of 1973

National Historic Preservation Act of 1966

Noise Control Act of 1972

Coastal Zone Management Act of 1972

Wild and Scenic Rivers Management Act

Wilderness Act and other Conservation Statutes

The Marine Protection Research and Sanctuaries Act

Environmental Policy and Regulatory Development

Table V.9 lists the current laws affecting geothermal development. Hazardous waste guidelines and regulations were proposed December 18, 1978 (40CFR Part 250) by EPA under the Resource Conservation and Recovery Act. Under the criteria in these regulations, geothermal drilling wastes and brine treatment residuals would probably be classified as hazardous (toxic) wastes. Congress is considering amendments to the Resource Conservation and Recovery Act that would include the temporary exemption of geothermal solid wastes from regulation as hazardous wastes, at least until studies are made of their character, control methods, and control costs.

Regulations for state underground injection programs were repropoed April 20, 1979 (40CFR Part 146) under the Safe Drinking Water Act. The regulations as repropoed would allow states to exclude groundwater aquifers as drinking water sources on the basis that they produce geothermal energy. Thus, injection could be allowed to these aquifers whether or not they otherwise met the criteria as drinking water sources. The proposed regulations now divide injection into five classes; geothermal injection wells are included in Class III, special process injection wells. Each class has specific requirements for construction, abandonment, operating, monitoring, and reporting. Of particular significance are the proposed monitoring requirements which include at least five monitoring wells at each injection site.

Both the hazardous waste and the injection regulations will be intensively reviewed and revised before their final promulgation.

The Prevention of Significant Deterioration (PSD) provisions of the Clean Air Act as amended have significant implications for geothermal energy development, with respect to hydrogen sulfide (H_2S) emissions. The PSD regulation amendment, proposed September 5, 1979, indicate that each permit application will be reviewed and that wherever emissions of a criterion pollutant total 250 tons per year or more, best available control technology will be required. Where the actual emissions, whether raw or controlled, are less than 250 tons per year, the PSD requirements will not be applied, although, of course, the state ambient air quality standards must still be met. The proposed regulations recognize court decisions that would, in effect, exclude geothermal operations from PSD requirements since they are not major sources of criteria pollutants. H_2S is not a criterion pollutant, but the resulting sulfur oxide would have fallen under PSD.

The Environmental Protection Agency intends to update its "Pollution Control Guidance for Geothermal Energy Development" during FY 81. The revised document is likely to define three separate categories of geothermal development--hydrothermal, geopressured, and hot dry rock--with the possibility of somewhat different guidance for each.

Environmental Status of Geothermal Loan Guaranty Program Projects

DOE issued an Environmental Assessment of the exploratory phase and full field development for California-Utah (CU1) project at South Brawley,

Imperial County, California. A Notice of Intent to write an Environmental Impact Statement for full field development and power plant construction was published in the Federal Register in December 1978.

For the Westmorland Project in the Imperial Valley (Cal.), involving development of geothermal resources on privately owned leased land, DOE issued an Environmental Assessment in May 1979. This EA asserted that there are no major environmental problems associated with the project's exploratory phases. An Environmental Impact Statement will be prepared before power plant construction and operation.

On June 12, 1979, DOE's Assistant Secretary for Environment issued a finding of no significant environmental impact for Republic Geothermal's project at East Mesa, Imperial Valley, California. Hence, an Environmental Impact Statement will not be required by DOE for the 48 MWe power plant.

In June 1979, DOE, the Department of Interior, State of Utah officials, and leaseholders met to discuss Federal/state environmental requirements for power plant sitings in the Roosevelt Hot Springs (Utah) geothermal area. Further meetings were held to prepare an interagency Memorandum of Understanding, and to prepare an implementation plan and schedule for environmental assessments. DOE will be involved only if the resource developer and power plant owners choose to finance those projects through the Geothermal Loan Guaranty Program.

H. POLICY DEVELOPMENT

The President, in his April 1977 energy message, directed the Departments of Interior and Agriculture to streamline their procedures for leases and environmental reviews of geothermal resources. An interagency Streamlining Task Force was formed and conducted a number of public workshops and meetings to identify problems and concerns surrounding geothermal development. The report of the Streamlining Task Force was transmitted to the IGCC for consideration. The IGCC approved 16 of the 19 recommendations contained in the report, and directed the Institutional Barriers Panel to work toward implementing those recommendations. (Recommendations 12 and 16, and part of recommendation 7 of that report were not approved). Table V.10 presents these recommendations and the actions taken.

During the meetings of the Streamlining Task Force, the acreage limit was the problem most cited as a barrier to exploration and development, and an increase was uniformly supported by industry, state government, and environmental and public interest groups. In an informal survey conducted in support of the Task Force, of 40 percent of companies who had terminated Federal leases, all but one company identified the acreage limit as a major problem and a primary reason for lease relinquishment.

Legislation

The Energy Tax Act of 1978 provided substantial tax incentives for geothermal energy, including depletion allowances of 15-22 percent,

Table V.10

STATUS REPORT
STREAMLINING TASK FORCE RECOMMENDATIONS

RECOMMENDATION	ACTION
1. Establish a permanent task group to review and make recommendations to review DOI/DOA/DOE Geothermal Regulations and Special Lease Stipulation Policy.	Establishment of Leasing and Permitting Committee (L&PC) was recommended and members have been named. This committee would interrelate strongly with designated agency field coordinator (recommendation 4) and report to IGCC. Field coordinators have not been appointed.
2. Compile a comprehensive handbook of regulations with flow diagrams.	None as yet; suggest this be a high-priority L&PC task.
3. Initiate a training and education program for Federal Field Managers with management responsibility in the geothermal program.	BLM workshop proposal deleted from Annual Work Plan by the meeting and workshop committee. Will try again next year.
4. Establish coordinators, modify agreements, and improve coordination among and with Federal, state, and local government agencies.	None.
5. Increase program priority for and management commitment to geothermal development.	Would be accomplished incidental to implementation of other recommendations. However, the deleted workshops were integral part.
6. Require a response within 30 days for noncompetitive lease applications and indicate anticipated actions and time requirements.	Has been stalled because of legislative proposals.
7. Require a 30-day time limitation on post-lease response to permit applications and allow Lease extension and rental suspension commensurate with agency delay.	Second part was remanded by IGCC; first part is in process of implementation.

Table V.10

**STATUS REPORT
STREAMLINING TASK FORCE RECOMMENDATIONS
(Continued)**

RECOMMENDATION	ACTION
8. Revise Geothermal Lease Form.	Suggested revision has been made—needs to be typed and distributed for review by DOE solicitor.
9. Modify BLM nationwide-statewide Geothermal Resources Exploration Bond Form so as to be acceptable to all surface management agencies.	Modified in revision of lease form—to be reviewed.
10. Modify Proposed Power Plant Siting regulations to clarify readjustment of rentals.	None.
11. Review and revise KGRA Designation Criteria.	Included in a legislative proposal.
12. Subject to normal adjudication, issue a noncompetitive lease unless the area is in a KGRA at the time of application.	Remanded for further study. However, it is included in a legislative proposal.
13. Provide, as an alternative, leases based upon separate environmental assessment of exploration and development phases.	Stipulations approved for Forest Service implementation; letter sent to Region Six of the Forest Service on July 6, and immediately sent to forest supervisors for use.
14. Use generalized, areawide environmental assessment through the land management planning process in pre-lease review and detailed site-specific studies only for post-lease actions.	As recognized by the task force, this procedure varies by states. It was recommended to provide emphasis. There have been no changes.
15. Expedite the wilderness/roadless review process and prioritize study areas where geothermal potential is high.	Areas of known energy potential will receive priority.

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11-11-11

GEOHERMAL ENERGY OMNIBUS LEGISLATION: COMPARISON OF BILLS
as of September 30, 1979

	<u>ISSUE</u>	<u>CHURCH</u>	<u>MCCLURE</u>	<u>ADMINISTRATION</u>
I.	<u>Loan Guaranties and Other Subsidies</u>			
	- 90% guaranties for municipals and cooperatives	x	x	no
	- 90% guaranties for small business		x	no
	- Reservoir insurance and reinsurance			no
	- Direct 90% forgiveable loan-feasibility studies		x	x
	- Direct forgiveable loans--exploratory drilling	x		grants
	- Direct 75% loans--construction		x	no
	- SBA, HUD, REA, FmHa use of GLGP		x	use existing authority
	- 4-month time limit on GLGP processing		x	9 month
	- Duplicative NEPA reviews prohibited		x	
	- Expedited procedures for nonelectric GLGP applications		x	
II.	<u>Geothermal Steam Act</u>			
	<u>A. Competitive/Noncompetitive Leasing</u>			
	- Increase acreage limit to 51,200	Couple with Also 248,000 oil and acre overall gas limits limit		x
	- Exempt developed acreage	x	x	producing
	- KGRA definition--discoveries only	x		(substantial geological criteria) competitive interest
<hr/>				
Legend: Church - position taken in S. 1388/H.R. 5187				
McClure - position taken in S. 1330/H.R. 4471				
Administration - position taken, with OMB clearance, by Administration				
no - opposed				
x - in agreement				
blank - no position taken				

Table V.11

GEOHERMAL ENERGY OMNIBUS LEGISLATION: COMPARISON OF BILLS
(Continued)

<u>ISSUE</u>	<u>CHURCH</u>	<u>MCCLURE</u>	<u>ADMINISTRATION</u>
- KGRA definition-electric only	x	60MWe	criteria for nonelectric
- Noncompetitive applications exempt from KGRA designation	public notice procedure	x	x
- Declassification of unbid KGRA lands	x	also if unleased 12 months after designation	x
B. <u>Procedural Streamlining</u>			
- Conditioned leasing	includes NSO lease	x	x
- Time limits	x	very stringent goals	x
C. <u>Other</u>			
- Free use permits	x	x	x
- Federal use authorized	x	x	x
- Authority to negotiate lease		permits	
- Elimination of "steam" references	x	x	x
- Clarification of authority for withdrawn and acquired lands	x	study	x
- Diligence requirements	x		modified
- Alternative bidding procedures	x		x
- Relief from 10-year readjustment authority	x		x
- Production goals		x	x
- Interagency Leasing Committee		x	

Table V.11

GEOHERMAL ENERGY OMNIBUS LEGISLATION: COMPARISON OF BILLS
(Continued)

<u>ISSUE</u>	<u>CHURCH</u>	<u>MCCLURE</u>	<u>ADMINISTRATION</u>
C. <u>Other</u> (Continued)			
- Requires implementation of STF recommendations (handbook, field coordinators, training program, budget coordination, interagency agreements coordination with states, permanent task force)		x	
- Inclusion of geothermal in land use plans		x	expanded
- "Raw land value" a rental basis		x	provided by regulation
III. <u>Tax Amendments</u>			
- 10% Investment tax credit for utilities until 1990		x	no
- Elimination of minimum tax on intangible drilling cost (IDC) deduction		x	no
- IDCs for injection wells		x	not needed
IV. <u>Fuel Use Act</u>			
- Exemption from geopressured methane			(done by regulation)
V. <u>Public Utility Regulatory Policy Act</u>			
- Geothermal included in small power producer category		x	x
- Increase 30 MWe regulatory exemptions		x	80 MWe
VI. <u>National Energy Conservation Policy Act</u>			
- Federal Buildings Program		x	x
- HUD, FmHA mortgage limit extension			x

Table V.11

**GEOHERMAL ENERGY OMNIBUS LEGISLATION: COMPARISON OF BILLS
(Concluded)**

<u>ISSUE</u>	<u>CHURCH</u>	<u>MCCLURE</u>	<u>ADMINISTRATION</u>
VI. <u>National Energy Conservation Policy Act (Continued)</u>			
- Schools and hospitals program		x	x
- Secondary financing and loan insurance (GNMA)			x
VIII <u>Priority Geothermal Project Act</u>			
- Procedures for certification and NEPA exemption		x	
- Automatic qualification for publicly owned utility nonelectric projects and for power plants greater than 10 MWe		x	

intangible drilling cost deductions, a 10 percent business investment tax credit, and credits for residential applications of geothermal energy.

These actions at the Federal level were supplemented by state actions such as California's definition of geothermal energy as a preferred energy source and reduction of its geothermal power plant siting time to 12 months, and the formation by the Pacific states of geothermal development coordinating councils to foster rapid geothermal growth. Notwithstanding the gains made from these actions, other legislative remedies are needed to bring geothermal energy into a competitive position.

In FY 79 four bills were introduced on Capitol Hill: S. 1338, introduced by Sen. Church (D-Idaho) and its companion H.R. 5187, introduced by Reps. Udall (D-Arizona) and Santini (D-Nevada); and S. 1330 introduced by Sen. McClure (R-Idaho), and its companion bill H.R. 4471, sponsored by Rep. Symms (R-Idaho). In addition, several changes to geothermal tax credits are proposed in the Windfall Profits Tax legislation now before Congress, and extensive amendments to the 1970 Steam Act are proposed in other pending legislation.

In its review of the recommendations from the Streamlining Task Force, the IBP presented an Omnibus bill to the IGCC incorporating those suggestions. The work of the IBP became the basis for several of the bills listed above. Table V.11 presents the original position of the IBP and the major provisions of these bills. The Administration is reviewing its position. In September 1978, the Institutional Barriers Panel, in a report to the IGCC, discussed various regulations affecting geothermal energy development, and suggested certain approaches to be used in writing new regulations and changes to be made in existing regulations.

The IBP is also reviewing manpower training needs and will recommend specific actions to the IGCC. The National Conference of State Legislatures, under a grant from DOE, is conducting a study of state laws and regulations affecting geothermal development, and regularly conducts workshops for state legislators and authorities. The major feature of the NCSL project activities is direct technical assistance to state legislatures. This generally means a four-phase process consisting of project introduction/resource overview; state-specific issues identification; analysis of policy options; and legislative recommendations, including draft legislation. Background materials are available, and efforts are coordinated with state regulatory agencies and private as well as public developers. In addition, NCSL provides tracking of state geothermal legislation, advises DOE geothermal contractors, and participates with the geothermal operations research effort.

Other issues being examined by the IBP include questions of royalty payments and tax exemptions. The requirement for royalty payments is hampering nonelectric development, particularly where no sale of the resource occurs. Both DOE and USGS are reviewing for residential tax exemptions are in question. The IRS issued draft regulations on May 23, 1979 proposing a minimum of 60°C for a resource to qualify. DOE has recommended 18°C; these regulations are under review and discussion.

Table V.12

SUMMARY: GEOTHERMAL LOAN GUARANTY APPLICATIONS*

CATEGORY	NUMBER	AMOUNT (\$M)
<hr/>		
I. Applications Received		
A. Approved	4	\$43.4
B. Under Evaluation	4	\$104.2
II. Applications Currently Being Prepared	8	\$429.9 (Estimated)
<hr/>		
TOTAL:	20	\$577.5 (Estimated)

*Figures are current as of February 1980.

Table V.13

STATUS OF GEOTHERMAL LOAN GUARANTIES MADE TO DATE*

BORROWER	LENDER	GUARANTY	PROJECT	LOCATION	RESULTS
Republic Geothermal, Inc.	Bank of America	\$ 9,017,000	Resource exploration and testing	East Mesa, California	Drilled 4 reinjection and 7 production wells. Temperature 160-168° C at wellhead when pumped. USGS agrees that project can produce 64 MW for 25 years.
Westmorland Geothermal Associates	Bank of America	\$29,100,000	Resource exploration, testing, and full field development	Westmorland, Imperial County, California	Guaranty recently awarded: exploration beginning.
Geothermal Food Processors, Inc.	Georgia State State Teachers Retirement System	\$ 3,500,000	Process heat to dry agricultural products	Brady Hot Springs, Nevada	Plant operational and running at 88-100% of capacity. Drying contracts sufficient to repay debt. Back-up well flow affecting production well.
CU-I	Bank of Montreal (California)	\$ 1,800,000	Resource exploration and testing	Brawley, Imperial County, California	One production well drilled to 14,000 feet, wellhead temperature of 232°C. salinity of over 269,000 ppm.

*Figures are current as of February 1980.

Table V.14

LOAN GUARANTY PROJECTS UNDER EVALUATION*

PROJECT	TYPE	<u>\$ millions</u>	
		COST	GUARANTY
1. CU-I South Brawley, Cal.	Electric - Field Development	\$ 78.8	\$ 49.4
2. NCPA, The Geysers	Power Plant	\$ 56.2	\$ 47.1
3. Oregon Trail Mushrooms Vale, Ore.	Mushroom Plant	\$ 6.2	\$ 4.7
4. R&R Energies, Inc. Cove Fort, Utah	Ethanol Plant	\$ 4.0	\$ 3.0

*Figures are current as of February 1980

Table V.15

LOAN GUARANTY APPLICATIONS BEING PREPARED*

APPLICATION	LOCATION	AMOUNT
1. 25 MWe Power Plant	Puna, Hawaii	\$ 50.0 Million
2. 55 MWe Power Plant	Roosevelt Hot Springs, Utah	\$ 16.0 Million
3. Field Development	The Geysers, Cal.	\$ 18.7 Million
4. 50 MWe Power Plant	Heber, Cal.	\$ 50.0 Million
5. Gasohol Projects	Various locations	\$ 38.9 Million
6. Ethanol Projects	Various locations	\$ 19.4 Million
7. Agricultural Project	Brady Hot Springs, Nev.	\$ 1.5 Million
8. 2 District Heat Projects	Various locations	\$ 1.2 Million
9. Field Development	East Mesa, Cal.	\$ 66.0 Million
10. 64 MWe Power Plant	East Mesa, Cal.	\$ 87.0 Million
11. Field Development and 66 MWe Power Plant	The Geysers, Cal.	\$ 48.7 Million
12. Sulphur Processing Plant	Cove Fort, Utah	\$ 4.0 Million
13. Field Development and Power Plant	Coso, Cal.	\$ 28.5 Million
	TOTAL	\$429.9 Million (Estimated)

*Figures are current as of February 1980.

L GEOTHERMAL LOAN GUARANTY PROGRAM

On January 5, 1979, DOE published its proposed regulations for GLGP for comment from interested parties. (44FR 1568.) The proposed regulations incorporated GLGP amendments in P.L. 95-238, which in summary:

- Pledge the full faith and credit of the United States to the payment of these guarantees
- Allow DOE to borrow funds from the Department of the Treasury, if balances in the Geothermal Resources Development Fund are insufficient to carry out guaranty and other responsibilities
- Authorize DOE to help the borrower pay the loan principal
- Allow DOE to complete and operate a plant acquired through default
- Limit loans to \$100 million per project and to \$200 million per qualified borrower
- Clarify the scope of direct heat projects
- Limit to 1 percent the guaranty fee to be imposed annually on the outstanding guaranteed debt, and permit fee collection to be deposited in the Geothermal Resources Development Fund
- Authorize DOE to reimburse qualified public agencies and Indian tribes for a portion of the interest when a holder of the debt guaranteed under this regulation is required to include that income under Chapter 1 of the Internal Revenue Code
- Authorize certain forms of community impact for loans over \$50 million.

In response to the request for comment, DOE received 12 replies, many of which were accepted. In addition, DOE's staff review of the proposed regulations produced a number of changes.

In July, several amendments to PL 93-410 were proposed by DOE and Senators Church and McClure. These amendments would increase the amounts of DOE's guaranty on loans to small businesses, municipalities and cooperatives; establish a time limit on DOE's processing of loan guaranty applications; and clarify certain provisions and authorities contained in PL 95-238.

In FY 79, four loans were approved:

- Republic Geothermal, Inc., obtained a guaranty of \$9 million from the Bank of America for resource

exploration and testing in East Mesa, California. Four reinjection and seven production wells were drilled. Temperatures of 160°C were obtained at the wellhead. It is estimated that 64 MW can be produced from this project for 25 years. Republic plans to submit guaranty applications for follow-on loans for full field development and power plant construction within the near future.

- Westmorland Geothermal Associates was awarded \$29.1 million by Bank of America to explore, test, and develop the resource in Westmorland (Imperial County, California). This guaranty was approved June 22; a site for drilling has not yet been chosen. Among the issues to be resolved are whether a viable resource can be found, whether a power plant can be built at acceptable terms, and whether Westmorland can find a customer.
- Geothermal Food Processor, Inc., borrowed \$3.5 million from the Georgia State Teachers Retirement System, with Bankers Trust as the trustee under a refinancing of the original \$2.8 million note with Nevada National Bank (\$200,000 remains in an escrow account). Geothermal heat is being used in a food-drying project at Brady Hot Springs, Nevada. The plant, now operating at 88-100 percent of capacity, has netted drying contracts sufficient to repay its debt. It has successfully completed its first full season of operation. Additional food processing contracts are being sought to enhance plant utilization.
- California-Utah (CU1) borrowed \$1.8 million from the Bank of Montreal (California) for resource exploration and testing in Brawley (Imperial County, California). One production well was drilled to 14,000 feet with a wellhead temperature of 232°C and a salinity of over 269,000 ppm. Whether the technology exists to permit use of such a highly saline resource, and whether handling costs will be deemed reasonable, remains to be determined. Meanwhile, DOE's San Francisco office is evaluating a loan guaranty application for a follow-on contract for full field development, in the amount of \$49.4 million.

Tables V.12 through V.15 summarize the status of all loan guaranty applications.

J. PLANNING

Facilitated by its Budget and Planning Working Group, the principal planning efforts of IGCC in 1979 were to establish a National Progress Monitor, a computerized Project Management System, a coordinated interagency budget, and lease planning.

The Department of Energy has the lead in establishing the National Progress Monitor, a system for collecting information about geothermal activities directly from state and Federal agencies, state geothermal teams, and research institutes. The information will be sent to a national center where it will be collated and published in periodic progress reports. The first report was scheduled for publication early in FY 80. The IGCC's Annual Report to Congress will be based in large part on the Monitor's files

The Project Management System, when fully implemented, will analyze national plans and programs by examining the impact of each geothermal project on each site. Power-on-line schedules will be developed for each site, to check and balance national goals and to provide a basis for determining the nature and level of activity for Federal agencies.

An integrated budget of all Federal agencies involved in geothermal development was prepared and forwarded to OMB early in the development of the FY 81 budget. This document allows each agency to compare its program levels and to anticipate work loads due to other agency's activities.

For lease planning, the Department of Energy has lead responsibility for establishing geothermal production goals on Federal lands. Using these goals, the Bureau of Land Management, USGS, and the Forest Service will develop a leasing schedule that can meet these goals. A report on the production goals and a coordination meeting are scheduled for FY 80.

The Budget and Planning Working Group will continue to take the lead in national geothermal planning.

In addition to the national level planning, state level planning was accomplished in cooperation with state governments. Fifteen states, mostly in the western United States received planning contracts or grants. State fact books that described the resources and status of geothermal development in the state were prepared and general plans for the state were developed. In some states more detailed plans were developed for selected areas and for specific sites. The site specific plans include identification of principal decision in the development process and a development schedule.

Economic Studies

Economic studies provide basic information to determine the potential for geothermal energy compared with other energy sources. They also provide information to guide the geothermal program. Two studies updated resource availability curves, showing that significant amounts of geothermal energy for electricity or direct use are available at costs competitive with conventional sources.

A study was completed on the decision process for geothermal field developers. Results showed that large energy firms are not interested in reservoirs with small capacity because the potential profits are too small. Small firms, on the other hand, are only interested in small projects where large amounts of equity are not at risk. Thus, the commercialization program has to be very diversified to meet the needs of the different types of developers.

A study of market potential was completed for some of the western states. In these studies, each demand center (city or town) within a reasonable distance of a geothermal resource was analyzed to determine the amount of energy demand that could be supplied by geothermal energy at a cost competitive with conventional sources. In 60 cities geothermal district heating would provide lower cost heat than conventional sources.

The economic studies were used to locate those industries that are expected to grow significantly over the next two decades and that could use geothermal energy. These will be the industries most likely to build new plants near geothermal resources to obtain an economical and reliable energy supply, and will form the key targets for development planning teams.

According to net energy calculations for all geothermal energy forms, i.e., hydrothermal, geopressured, and hot dry rock, the useful energy obtained greatly exceeds the useful energy expended.

A study of the potential for geothermal energy as a supply of economically competitive electricity for the aluminum industry revealed that at current aluminum prices, transmission of electricity from one of the most promising sites (Roosevelt Hot Springs) to existing aluminum plants in the Northwest was economically competitive. Additional sites and the location of new plants at geothermal sites would be economically feasible only if aluminum prices increase.

Simple cost accounting models were developed for electric and direct heat use to allow rapid analysis of proposed economic incentives, and many of the economic incentives proposed for geothermal energy legislation were analyzed.

Ten Standard Federal Regions

Region

States

1	Conn, Maine, Mass, NH, RI, Vt
2	NJ, NY, Puerto Rico, Virgin Islands
3	Del, DC, Md, Pa, Va, W Va
4	Ala, Fla, Ga, Ky, Miss, NC, SC, Tenn
5	Ill, Ind, Mich, Minn, Ohio, Wis
6	Ark, La, NM, Okla, Tex
7	Iowa, Kan, Mo, Neb
8	Colo, Mont, ND, SD, Utah, Wyo
9	Ariz, Calif, Guam, Hawaii, Nev, Trust Territory of the Pacific Islands
10	Alaska, Idaho, Ore, Wash

CHAPTER VI. REGIONS, STATES AND LOCAL GOVERNMENTS, AND INDIAN TRIBES

A. REGIONS I, II, III, IV, V, AND VII

Both hydrothermal and hot dry rock geothermal prospects have been identified by Federal programs for selected geological provinces in more than half of the eastern United States. Regional scenarios have determined existing and potential markets for moderate-temperature hydrothermal resources, broadly for the eastern Gulf Coastal Plain states, and in detail for the mid-Atlantic Coastal Plain states.

Activity in the eastern United States has been primarily Federal to date; however, regional, state, and private programs are beginning. State-coupled programs exist in Delaware, Mississippi, Alabama, Nebraska, Kansas, and New York. To set the stage for orderly development and application of the hydrothermal resources under the Atlantic Coastal Plain, the individual states must consider the legal aspects of ownership, insurance, permitting, access, reservoir management, etc.

The state of Maryland passed a Geothermal Resources Act in 1978, but has yet to issue the attendant rules and regulations. Further, no user has yet applied to force a determination of ownership left ambiguous by the current law.

Maryland

The state of Maryland developed and passed a Geothermal Act in 1978 and is currently drafting implementing rules and regulations under the Water Resources Division of the Department of Natural Resources. A format for a State Site Prospectus for development of geothermal energy has been developed and the state plans to complete the Site Prospectus as data become available. A team to coordinate state geothermal activities and draft the state prospectus is in the process of formulation.

The Campbell Soup Company of Salisbury, together with the consulting engineering company of Burns and Roe, will evaluate geothermal energy for its frozen dinner plant in Salisbury, Maryland.

The private sector has expressed interest in:

- Geothermal vaporization of Liquefied Natural Gas delivered at Cove Point, Maryland, prior to delivery to gas pipelines (The operating company is the Columbia Gas Company.)
- Geothermal space heating of the rebuilt downtown of Salisbury, Maryland

- Geothermal space heating of schools and hospitals under energy conservation grants in Wicomico, Somerset, and Worcester Counties
- Mariculture of oysters and clams in a mixture of geothermal and Chesapeake Bay water by the University of Maryland and the Ceda Corporation.

Delaware

The Delaware legislature and energy committee are in the process of drafting a geothermal law. They have held workshops with the National Conference of State Legislatures (NCSL) and interested parties in the state.

The town of Lewes, Delaware, is considering the use of geothermal energy for space conditioning of schools and hospital; heating sea water for shellfish production at the University of Delaware Marine Culture Laboratory; the recovery of chemicals from the geothermal fluid, and use as process water in a fish processing industry.

Virginia

The state of Virginia has been conducting workshops with NCSL to evaluate the present legal and regulatory framework within the state in reference to the development of geothermal energy.

A generic State Site Prospectus has been developed and a state geothermal development team is being formed to add more details as data become available.

Pennsylvania

There are individual expressions of interest in geothermal heating in Pennsylvania. In New Hope, Pennsylvania, a residential home builder is exploring the region for higher than normal temperature, modest depth, ground water for water to water heat pumps for space conditioning. In Scranton, Pennsylvania, a developer is evaluating the use of water in flooded mines with heat pumps to space condition a shopping center.

New York

Discussions with the town of Auburn, New York, are in process to assess the potential of geothermal energy and its application in the area.

Vermont

The town of Bellows Falls, Vermont, is assessing the potential of using glacial fill along the Connecticut River near the center of town as a storage median for warm river water, to be used in the winter with heat pumps to heat sections of downtown.

Alabama

The Tuscaloosa Formation, which underlies much of southern Alabama, has been used for years as a source of hot water for balneology. At Cottonwood, Alabama, there was a health spa for many years, and near Dothan, Alabama, at the Olympia Spa the waters are used as a recreation facility. The Tuscaloosa is at modest depth 3000 feet with modest temperatures (51°C).

B. REGIONS VI AND VIII

A market penetration analysis, showing near and far term potential in each of the ten states in these regions found that geothermal penetration is most likely in the residential and commercial sectors, and considerably less likely in the industrial sector.

Colorado

Colorado has undertaken extensive outreach programming and has uncovered several candidates for community and industrial project applications of hydrothermal resources. Coury and Associates, Inc., has been awarded a \$248,000 grant by the Four Corners Regional Commission for a comprehensive evaluation of geothermal resources and applications in the San Luis Valley of Colorado.

Montana

The Montana Department of Natural Resources and Conservation mapped potential geothermal use, showing population distribution, resource location, and agricultural areas where processing facilities might be built. The Department also is seeking 10-to-1 matching funds totaling \$220,000 for a resource assessment program in six valleys of Montana. The proposed projects would be conducted by the Montana School of Mines.

New Mexico

The New Mexico Energy and Minerals Department has awarded a \$37,000 grant to Coupland, Moran & Associates to start a drilling program at Jemez Springs, which will assess the low-temperature geothermal potential for district heating system. If successful, the activity will be expanded to assess the resource for agribusiness applications—e.g., a sawmill for timber production. The Department also has authorized \$45,000 to assist development of geothermal space heating of a hosiery company at Las Cruces.

The New Mexico Research and Development Committee awarded \$21,000 to a geothermally heated greenhouse in Silver City and \$40,000 to a Taos County project demonstrating use of geothermal spring waters for year-round crop production in a solar-assisted greenhouse.

Truth or Consequences is attempting to develop a plan for the retrofit of city buildings for geothermal space heating.

The New Mexico Energy Institute published "The Geothermal Option," a one-time publication containing technical information on geothermal resources and applications.

North Dakota

The State resource team has begun a program of resource assessment as part of the Western States Cooperative Program.

South Dakota

The city of Lemmon is moving aggressively to use the Madison aquifer's geothermal waters for residential, commercial, and industrial applications. The first well drilling found 82°C water at a depth of about 6,000 feet.

Utah

McCullough has announced an agreement for a partnership with Roosevelt Hot Springs Geothermal, Inc., and has applied to drill wells in the area.

The Utah Geological Mineral and Survey has a new publication on Geothermal Waters of Utah.

Wyoming

The Wyoming State Coupled Resource Assessment Contract has been signed with the Wyoming Geological Survey.

Commercial ventures and site specific development plan for a gasohol plant in Cody area: the Wyoming resource assessment team drilled six temperature gradient holes 500-700 feet deep in late FY 79. Private parties developing the plant are prepared to drill well holes this summer. Recent field data indicates water temperatures of 77°-93°C—16 degrees higher than previously thought. A Cincinnati engineering firm is conducting preliminary engineering feasibility studies for a gasohol plant. A corporation has formed to develop and operate the plant, at a projected cost of \$50 million.

C. REGION IX

Arizona

In the state government, primary emphasis is currently on testing the resource. The New Mexico Bureau of Geology and Mineral Technology conducted a resistivity survey in Safford, and conducted thermal gradient, geologic field work, and geochemical sampling statewide. The University of Arizona, University of Texas at El Paso, and New Mexico State University surveyed electrical resistivity and active and passive seismic studies in the San Bernardino Valley, Clifton, and Springerville-St. Johns. The New Mexico Bureau of Mines is doing thermal gradient and heat flow work statewide.

The Arizona Solar Energy Research Commission has signed a contract with Arizona State University for the performance of the Rocky Mountain Basin and Range Region State Geothermal Planning Project under funding received from New Mexico Energy Institute and the Four Corners Regional Commission.

A favorable feasibility study by EG&G Idaho examining the technical and economical aspects of developing an approximate 177°C geothermal resource for space cooling facilities at Williams Air Force Base has been completed.

The final version of the Arizona Geothermal Resource Map has been completed by the Arizona Bureau of Geology and Mineral Technology. The map is being forwarded to NOAA for publication.

Three geothermal facilities are in operation today: Hooker Hot Springs health spa, hot baths in Safford and Buckhorn Hot Springs, and the Arizona State University conference center at Castle Hot Springs. Whitewing Ranch, near Hyder, is studying the feasibility of space heating, cooling, and greenhouse adaptation. In Phoenix, an electronics firm is estimating the cost of space cooling, and in Tucson, IBM is considering space cooling of its plant.

Private sector programs embrace both exploration and commercialization. Since 1973, industries have drilled several test wells in Maricopa County, Pinal County, Kingman, and Bagdad.

Future state projects may include

- space heating or cooling at Chandler, Tucson, and Phoenix
- salt production and water desalinization at Yuma
- copper solution mining at Morenci
- integrated citrus processing, peak electrical power, and desalinization at Hyder
- upgrading of water quality, water heating and electrical power at Springerville-St. Johns, and Alpine
- electrical power at Clifton
- a 50 MW powerplant in Clifton
- a 700 MW plant in the San Bernardino Valley.

California

California serves as a model for other states where extensive geothermal resources offer the promise of commercialization. Both electric and direct use applications have been operating for some time now, and plans for more are actively being developed.

The California Energy Commission has completed a market survey for direct heat potential, and is sponsoring a geological mapping project in Susanville. The State Lands Commission is surveying all regulations affecting direct use. These two bodies together are completing a study of regulations for drilling low-temperature geothermal wells. In an attempt to speed commercialization, the California legislature streamlined the permitting process for exploratory drilling, and the Public Utility Commission required that geothermally produced electricity be wheeled through major utility transmission lines, even if the utilities are not customers.

Private sector development is taking place all over the state, almost all for electricity production. Phillips Petroleum is drilling temperature gradient holes at The Geysers, and is planning to drill at Mono Lake. Phillips is also doing extensive exploration studies near West Mesa and Chocolate Mountain and in San Bernardino county. Occidental Geothermal is drilling temperature gradient holes in the Glamis KGRA and at East Mesa, and is conducting a seismic survey and test drilling in Lake and Sonoma counties. Aminoil, USA has just completed its exploration of the Knoxville KGRA, and AMAX Exploration is working in the Mount St. Helens area. A magnetotelluric survey is being conducted in Surprise Valley by Geotronix, Inc.

More than 200 wells have been drilled at The Geysers, with generating capacity in excess of 663 MWe. An additional 320 MWe generating capacity is due on line at The Geysers in 1980; 1,200 MWe more are planned by 1987. A notice of intent has been approved for PG&E's Unit 16 at The Geysers. Specifically, Pacific Gas and Electric's (PG&E) Unit 13 (135 MWe) will come on line in 1980, and construction has been approved for Unit 17 (110 MWe).

In the Imperial Valley, 10 MWe is now coming on line, and an additional 425 MWe is expected by 1985. A total of 1,000 MWe is planned for 1990. The 10 MWe is a binary unit built by Magma Power and San Diego Gas and Electric at East Mesa. Southern California Edison and Union Oil are developing a 10 MWe single flash pilot plant at Brawley to expand to 100 MWe and are planning a 10 MWe powerplant at Salton Sea. With Chevron, SCE has a 50 MWe unit in the final design stage, due on line in 1982.

The Northern California Power Authority is awaiting final approval for construction of two 55 MWe plants in Sonoma County, and has filed a notice of intent for a 66 MWe unit in Lake County. The California Department of Water Resources is awaiting certification approval for a 55 MWe unit at Bottle Rock. The Sacramento Municipal Utility District and Aminoil are considering a 50 MWe unit in 1984 and a 55 MWe unit in the late 1980s. The city of Burbank is considering a hybrid geothermal/coal-fired powerplant in Rose Valley.

Direct Heat. At Honey Lake, greenhouses are being geothermally heated. The Latter Day Saints Church in Susanville is heated by geothermal energy; Calaquia, Inc. uses geothermal direct heat in fish farming and alfalfa field irrigation at Paso Robles.

The city of Middletown is considering the use of bleed steam from one of the wells at The Geysers* to heat the water, the swimming pool, and the greenhouse at Verdant Vales School.

The use of a 32°C developed spring is being considered for aquaculture at the Fort Bidwell Indian reservation. Basic Foods of Vacaville may relocate a food dehydration plant so that geothermal fluids can be used. An integrated livestock production system at Wendell-Amedee is in process by CLR Consortium and the University of Nevada.

Geoproductions, Inc. is conducting a geophysical study of an alfalfa pelletizing operation planned with Lassen College Foundation and Skakless Foundation at Wendell-Amedee. Susanville now heats its municipal swimming pool geothermally.

Hawaii

The University of Hawaii is studying three sites for exploration for high-temperature resources: Puna and Kailua-Kona on Hawaii, and Lahaina on Maui. The University of Hawaii Geophysics Institute is currently doing geothermal assessment on the island of Hawaii, and will expand its assessments to Maui and Oahu.

The private sector has undertaken exploration and made some tentative commitments. Geothermal Exploration and Development Company drilled exploratory holes at Puna, and announced plans to develop the entire 10,000 acre field there. If GEDC is successful, Kaiser Aluminum will build a plant that will use a 100 MW powerplant, leading to 300 MW capacity in the mid-1980s. Water Resources International, Inc. is drilling a step-cut well near Kailua-Kona.

Idaho

Site-specific development planning for the City of Boise's geothermal space heating project has guided city engineers in their procurement of hardware. Institutional, legal, and planning activities undertaken by the state of Idaho have convinced Idaho legislators to authorize municipalities to issue revenue bonds for geothermal district heating. Also, the Idaho Office of Energy and Governor Evans have introduced a bill to the Idaho House of Representatives to empower cities to issue revenue bonds for district heating with geothermal energy. A second bill declaring space heating a beneficial use passed the legislature.

A Raft River Geoscience Review was conducted April 16 and 17 in Pocatello, for representatives of the Federal and state governments, universities and national labs, and geoscience industries. Participants reviewed geoscience details and decisions since the inception of the Raft River Project and discussed technical exchanges and comments on future direction of Raft River programs.

Three agribusinesses in Idaho have shown interest in gasohol plants using geothermal energy.

*The well supplies steam for electric generation at the Geysers.

Nevada

Nevada already has several commercial direct heat applications. Forty wells have been developed in Reno for space conditioning and recreational use. Golconda, Caliente, and Steamboat are using geothermal space heating. Spas at Carson City and Steamboat are geothermal, and a firehouse at Gabbs is being geothermally heated. Wabuska Hot Springs has a commercial aquaculture facility. The Bureau of Mines and Geology is studying thermal waters. Preliminary designs and economic analyses are being carried out for retrofitting the Grover C. Dils Medical Center in Caliente, for district heating systems in Caliente, and for the Newlands Green Valley Estates in Fernley. A domestic hot water system for the Las Vegas Hilton Hotel is being designed and evaluated. The Reno Moana swimming pool is being considered for geothermal heating.

A well at Rye Patch achieved 171°C water at 1800 feet; the well is reported to be capable of driving a 7 MWe generator.

The developers of a prospective geothermal alcohol production plant in Crescent Valley are applying to the Four Corners Regional Commission for partial funding of the project.

A \$125,000 study is evaluating overall energy requirements, including alternative energy sources, of the MX missile system base facility in Nevada. A peak demand electrical requirement of 200 MW is likely to be supplied by a tie-in to an existing electrical bridge system, with an independent backup power system, which could be geothermal.

The state of Nevada has

- projected electrical development at Beowawe, Carson Sink, Deak Horse Wells, Cordero Mercury Mine, Darroughe's Hot Springs, Desert Peak, Dixie Hot Springs, Dyke Hot Springs, Fish Lake Valley, Hot Sulphur Springs, Humboldt Wells, Leach Hot Springs, McFairlane's, the Needles Rock, Rye Patch, San Emidio Desert, Soda Lake, Steamboat Springs, Wabuska Hot Springs, Sulphur Hot Springs, Warm Springs, and Brady Hot Springs.
- projected direct heat application at Steamboat Springs, Wabuska Hot Springs, Battle Mountain, Elko Hot Springs, Golconda, Sarcobatus Flat, Sodaville Springs, Brady Hot Springs and Caliente.

D. REGION X

Oregon

Oregonians have been reaping the benefits of geothermal energy use since the turn of the century. The Klamath Falls area of southern Oregon is a notable example, and has the most widespread use of direct geothermal application in the United States. The Oregon Institute of Technology campus in Klamath Falls represents one of the largest applications of geothermal space heating. Approximately 400 shallow-depth wells provide

heat to about 500 structures: residences, schools, businesses, industrial facilities, and swimming pools. Geothermal energy is now being consumed in Oregon at an average annual rate of approximately 16 MW, which is equivalent to 83,000 barrels of oil per year.

Both geothermal exploration and development are at an all-time high in Oregon. Five drill rigs are drilling temperature gradient wells in the Cascades and work is progressing on two DOE-funded demonstration projects. Oregon released a new map of thermal springs. A contract was signed and awarded on July 3 to the Oregon Department of Geology and Mineral Industries for geothermal assessment in the state of Oregon under the state co-op program.

Exploration, primarily temperature gradient holes, is taking place at the Mount Hood area, Lakeview, the Central Cascades, north Klamath County, Vale, Hot Lake, Malheur County, Lake County, Harney County, and LaGrande.

Existing Uses of Geothermal Energy. In Klamath Falls, geothermal resources are widely used for space heating and domestic hot water in private, public, and commercial buildings; milk pasteurization; pavement deicing; pool heating; agriculture facilities; accelerated curing of concrete; and greenhouse heating. In Lakeview, commercial greenhouses, residential space heating, pool heating, and worm farming all use geothermal energy. In Vale, greenhouses and residential space heating is accomplished by geothermal resources. Greenhouses, pools and hog-raising compounds in Cove are geothermal. Ontario, Hot Lake, and Haines all have geothermal space heating; the latter has greenhouses as well. Numerous spas and pools around the state are geothermally heated.

Oregon Trail Development in Vale is establishing a mushroom-growing facility that will use geothermal energy as a heat source. Hot Lake Resort near LaGrande is renovating and expanding an existing geothermal system for space heating.

Interest Expressed for Future Exploration and Development. In Nyssa, a food processor building a new facility is actively interested in using geothermal energy. Potato growers in Klamath Falls and La Grande, both of which have hot water resources, are pursuing alcohol production facilities using geothermal as a heat source. Timberline Lodge at Mt. Hood would like to use a geo-heating system in the existing lodge and in the planned day lodge. A commercial greenhouse operation is planning to relocate their facilities to the Klamath Hills area to use geothermal energy for heating. J.A. Albertson Ranch near Nyssa is conducting a feasibility study of using hot water for a feedlot operation and methane production. The cities of Oakridge, Lakeview, and Vale are interested in developing district heating systems and geothermal industrial parks. LaGrande and Eastern Oregon State College are interested in geothermal utilization for space heating.

Leasing. The primary areas of interest from an industry perspective, based on resource viability and available end use applications are the Cascade region from Mt. Hood south to the Belknap-Foley area and the Alvord Valley. Other areas of high interest include Newberry Crater and Vale.

It is important to note that, despite the level of current resource use, the potential for geothermal energy use in Oregon has barely been tapped.

Washington

Interest in geothermal energy in Washington began in the early 1970s and reached a high point in 1971 with the First Northwest Conference on Geothermal Power, in Olympia.

This initial surge was followed by considerable interest by industry; 238 lease applications for 492,000 acres were filed with BLM. Since then interest has waned, and many of the lease applications have been withdrawn. Only Amax Exploration, Inc., is known to have done exploratory heat-flow drilling in the state; Burlington Northern has maintained a low-profile program to assess the geothermal potential of company-owned properties in Washington. To date, no Federal geothermal leases have been issued in Washington.

The Division of Geology and Earth Resources has been assessing the geothermal potential of the state since 1972. As part of this assessment work, the Division has attempted to sample and do detailed geochemical analyses of all known thermal and mineral springs in the state. These geochemical data have been used to estimate reservoir temperatures for each spring system sampled.

In addition, the Division has supported or cooperated in (1) measuring thermal gradients and heat flows in mineral exploration drill holes and water well; (2) compiling existing geologic maps and conducting detailed reconnaissance geologic mapping in the southern Cascades; (3) assessing the use of ground noise measurements as a geothermal exploration tool; (4) publishing reports on the locations of earthquake hypocenters; (5) producing an aero-magnetic map of a large part of the southern Cascades; (6) publishing a gravity map of the state; and (7) sponsoring a project designed to measure gravity in the Indian Heaven areas. The Division intends to continue the geochemical assessment of the thermal and mineral springs in the state, while emphasizing those springs in the Cascades. The Division will also become increasingly involved in geological and geophysical assessment of Mount St. Helens, which is expected to continue for the next 3-5 years.

Of the known thermal and mineral springs in the state, 7 spring systems exhibit Na-K-Ca temperatures of over 100°C: Mount Baker Hot Springs, Sulphur Hot Springs, Kennedy Hot Springs, Garland Mineral Springs, Ohanapecosh Hot Springs, Gamma Hot Springs, and Summit Creek Mineral Springs (Soda Springs). None of these spring systems exhibits a significant flow; however, all have a definite spatial relationship to the strato-volcanoes.

The granting of Federal leases should serve as a catalyst in generating renewed interest in the geothermal potential of the state by industry. A renewed interest and commitment in the state by industry in conjunction with the accelerated assessment program conducted by the U.S.

Geological Survey and the Washington Division of Geology and Earth Resources is expected to result in the assessment and development of the state's geothermal resources, but remains dependent upon the adequate funding by the state and Federal agencies involved.

Alaska

The Alaskan state government has recently become involved in geothermal development. The State Division of Energy and Power Development has been working in conjunction with the Department of Fish and Game to utilize the geothermal resources on Bell Island for salmon hatcheries. The state legislature last year considered nearly \$1 million worth of appropriations for development of its geothermal energy resources by road building, drilling, and an agricultural experiment station at Pilgrim Hot Springs on the Seward Peninsula. The Legislature appropriated \$245,000 for a geothermal demonstration at Pilgrim.

It is obvious that Alaska has tremendous geothermal resources. The 104 hot spring locations and 88 volcanoes have the potential to provide a large amount of energy for the state. Local gradient and hot dry rock applications appear to have a future in Alaska as well. To date, no Federal or state geothermal leases have been issued in Alaska.

At Pilgrim Hot Springs, the State of Alaska plans to drill an exploratory well, if funding can be arranged to be used for an agricultural experiment station. If, in fact, the 180°C temperature is encountered, then a 4 MWe powerplant will be developed to come on-line in 1989. This would meet the expected electrical energy needs of the Nome area in that year.

In the case of Clear Creek Hot Springs, it has been calculated that the surface flow of that spring could produce 20-30 kw of binary electrical power, as well as space heat for up to 30 homes; it will take until 1989 to get this energy on-line.

Umnak Island has one of the best physical resources of those likely to be developed in the state. The presence of superheated water has raised a lot of speculation about the electrical potential of the KGRA there; 50 megawatts of electrical power will come on line in 1990 for metals processing.

Aquaculture/agriculture applications planned by the Aleutian Pribiloff Native Corporation will exceed 5×10^{10} Btu's annually by 1985. This will replace 380,000 gallons of fuel.

The new state capital in Willow will require 1.6×10^{12} Btu's for space heating by 1994, according to Capital Site Plans. Ninety percent of this amount, or 1.44×10^{12} Btu's, is targeted for on-line geothermal. This would be developed in increments from 1983-1994. Four separate events of somewhat equal magnitude are portrayed on the scenario.

The Klawasi geothermal project will put another 25 MW of electrical power on line by the year 2003. Other uses around the state, including those at Tegakee Springs, Baranof and Bell Island projects should add another 1×10^9 Btu's per year of geothermal utilization by the year 1987.

E. INDIAN TRIBES

Many tribes are interested in and some are pursuing the development of geothermal resource utilization as a contributor to the economies of their reservations. Many of the potential geothermal-resource-using tribes have a low economic base with high government subsidies. While most geothermal resource opportunities have not been fully explored, there is substantial reason to believe that tribes can develop their own local resources.

At Fort Hall Reservation, near Pocatello (Idaho), low to medium temperature well sites surround the reservation. The tribal council has passed resolutions to pursue geothermal development on the reservation. In one possible application, geothermal fluids could be used to distill alcohol from potatoes grown on the reservation. This alcohol will then be used to make gasohol that will be sold in the newly operating tribal gasoline station. The tribe is ready to start exploration.

The Fort Peck tribal research department has recently received a grant from DOE to begin resource exploration, identification of institutional barriers, and preliminary heating system design for a geothermal heating district system on the Reservation. If a decision is made to develop the resource, a new town with 250 Indian housing authority units may be located near the well sites.

Moapa reservation is located in the southern portion of Nevada. The tribe has received development dollars from Economic Development Administration (EDA-DOC) of over \$500,000. Costs to continue the greenhouse operation require high amounts of energy dollars to heat the four acres of structures. A geothermal development project would cut overhead heating costs of the structures and make the project competitive.

The Baca Ranch is a joint venture of DOE, Union Oil and Public Service Company of New Mexico to build a 50 MWe geothermal power plant. The area is bounded on three sides by Indian pueblos and reservations. Tribes could provide labor during the construction phase, which would lower the high unemployment rate on the neighboring reservations.

Geothermal Heat Exchangers

CONVENTIONAL SHELL AND TUBE
HEAT EXCHANGER

ADVANCED TECHNOLOGY DIRECT
CONTACT HEAT EXCHANGER

CHAPTER VII. PRIVATE INDUSTRY

The private sector has played the major role in the development of geothermal energy. The largest geothermal project in the world, The Geysers, was initiated and developed to its current status by the private sector. The government, primarily since 1970, with the passage of the Geothermal Steam Act, has attempted to accelerate the development of the geothermal industry by providing access to resources on public lands (leasing) and by removing technical, economic, and institutional barriers. However, the development of a significant geothermal industry in this country and the production and use of significant amounts of geothermal energy rests with the private sector.

Initially the geothermal industry was organized around the exploration, development, and use of geothermal energy for the production of electricity. Recently the industry has changed its focus as direct use and development of low-to moderate-temperature resources have become more important.

The industry is composed of four very diverse groups: major energy companies, companies organized for the express purpose of developing geothermal energy (geothermal companies), engineering companies, and users. A more detailed breakdown on types of companies involved is presented in Table VII.1.

Energy Companies. Most of the energy companies are involved in the development of geothermal energy, in one form or another, as an extension of their general mission as energy suppliers. The major objective of the energy companies is the production of steam for electrical power. Currently, they show little interest in direct heat applications, primarily because of the small size of most of these activities. Energy companies have been among the most active in acquiring resources on Federal land by competitive bidding. The major energy companies have also been active in exploring and developing the resource. They have not been very involved in energy conversion (power plants) or energy use.

Geothermal Companies. The companies have usually been formed for the express purpose of developing geothermal energy. In general, they are small--but some have developed affiliations with very large energy companies. Their current role ranges from exploration support to the production of steam and ultimately to the production of electricity. They often promote joint action between energy companies as operators and utilities as users.

Engineering Companies. These companies are generally small, special purpose engineering companies that pioneer certain plant design concepts or components thereof, but are often large architectural and engineering firms that design and build geothermal plants in the same manner as other energy generating plants. These companies see themselves as the technical bridge between the developer/operator and the final user of the geothermal energy resource. Although they prefer to limit their role to design and construction, they often find themselves marketing geothermal energy to

Table VII. 1

TYPES OF COMPANIES INVOLVED WITH GEOTHERMAL INDUSTRY

TYPE	APPROXIMATE NUMBER
Large Energy Companies	5
Small Energy Companies	10
Geothermal Companies	5
Engineering Companies	5
Utility Companies	15
Direct Heat Users	200
Municipalities	10
Trade Associations	2
Drilling Companies	5
Financial Institutions	5
Promoters/Developers of Direct Heat Applications	10

the user (most frequently utilities) and even underwriting the project risk.

Users. There are two main groups of users: electricity producers and nonelectric users. For electricity, the principal firms involved are a small group of utilities in the western states and, to a lesser extent, some companies, known as geothermal companies, are specially organized for the development of geothermal energy. The latter acquire leases, undertake exploratory activities, and develop the geothermal resources and, in some cases, produce electricity and sell it to utilities for distribution. Other electric users include municipalities that intend to develop geothermal for public use and some large industrial users of electricity that own or lease land containing geothermal resources and are evaluating those resources as possible alternative means for generating electricity to meet their needs.

The principal nonelectric users are firms wanting to obtain access to geothermal energy, small resource owners seeking ways to develop or sell the resource, and engineering companies or companies formed as general promoters/developers to put together complete development packages.

Some owners or leaseholders of land containing geothermal resources have sufficient capital and incentive to explore the areas of geothermal potential themselves. This exploratory effort is often the first phase of an overall development program by the owner; at other times, exploration is undertaken to determine the resource's worth for later sale or leasing to developers.

Owners lacking the resources for exploration invite developers to join them in joint ventures, sell their holdings to the developers in direct sales, or maintain their holdings as future investments.

Other than the individual development of small, private holdings, most direct heat applications have resulted from the efforts of intermediaries or general promoters. In some cases, the promoters are engineering companies that have undertaken management of the resources' development programs and the engineering of their applications; in other cases, the promoters have taken their efforts a step further and included in their roles as promoters the securing of venture capital as well. In addition, new companies have been formed for the express purpose of developing overall programs for the resource owners; and these companies will develop complete financial packages--including the securing of venture capital--as part of the program's integration.

During the past year, striking advances have been made toward the application of hydrothermal resources. One firm, Magma Energy, has completed the construction of a 10 MWe plant in Southern California. This plant, which was in operation early in 1980, is the first U.S. plant to generate electricity from a hot water resource, and the first geothermal plant in the world of any substantial size to utilize a binary process. Two other 10 MWe plants will be completed in California in 1980. The development of The Geysers has grown to 663 MWe and may reach 1,000 MWe in 1981.

Union Oil, in a joint activity with Southern California Edison, and Magma with San Diego Gas and Electric, have announced intentions to proceed with two 50 MWe power plants at Niland, California. Chevron and Southern California Edison plan a plant at Heber; California's Department of Water Resources intends to build a hybrid geothermal/wood-waste plant at Honey Lake; and Sierra Pacific is considering plans to build a power plant in northern Nevada. These, their expansions, and other planned projects will bring the expected hydrothermal power on-line (exclusive of The Geysers) to over 350 megawatts by the end of 1982 and 650 megawatts by 1984. The Department of Energy is involved in funding about half of these plants. California is projecting 1,100 megawatts from the Imperial Valley alone by 1986, which, together with a total of 1,900 megawatts planned for The Geysers, will total 3,000 megawatts. Thus, prospects appear favorable for the achievement of a 1985 goal of 3-4 GW of electric generating capacity from geothermal resources.

Geothermal Field Developers

The period from 1975 through 1978 has shown essentially no growth in the rate of geothermal drilling (Table VII.2). There has been very little drilling in areas outside of proven reservoirs where economic feasibility has already been demonstrated to industry (Table VII.2). California's Imperial Valley and The Geysers have accounted for 65-75 percent of all the geothermal drilling in the western United States. No more than 19 major wells were drilled outside of The Geysers or the Imperial Valley in any year through 1978.

Early evidence suggests that the rate of geothermal drilling increased somewhat in 1979. At least 80 and perhaps upward of 100 wells were spudded. This may reflect a significant impact of the improved financial incentives for geothermal development provided in the 1978 National Energy Act.

The Insurance Company of North America announced in September 1979 that it is prepared to issue reservoir insurance. The policy would cover both the field developer and user, during both development and operating periods. This policy is expected to boost the interest of private developers in assessment, drilling, and development.

Table VII.2

GEOTHERMAL DRILLING ACTIVITIES

CLASSIFICATION	1975	1976	1977	1978	1979
PRODUCIBLE	37	39	25	30	30
SUSPENDED	2	8	17	15	6
ABANDONED	7	5	5	4	11
INJECTION	0	0	3	5	0
OBSERVATION	0	13	2	4	8
UNKNOWN	0	0	0	0	25
TOTAL	46	65	52	58	80

Sources: 1975-1978 estimates are from Geothermal Energy Magazine Annual Drilling Summaries.

1979 estimates are from the Geothermal Progress Monitor Drilling file. These include 9 wells for which spud dates but no completion date or footage were reported by 2/15/80.

Table VII.3

SUMMARY OF GEOTHERMAL DRILLING BY STATES
IN THE WESTERN U.S., 1975-1978*

STATE	1975	1976	1977	1978
CALIFORNIA				
Imperial Valley	10	16	8	13
Geysers	24	30	32	27
Other	0	2	1	1
HAWAII	1	--	--	2
IDAHO	2	4	3	5
NEW MEXICO	2	--	1	1
NEVADA	6	6	3	4
OREGON	1	1	--	2
UTAH	6	6	4	3
TOTAL	52	65	52	58

*From Geothermal Energy Magazine Geothermal Drilling Summaries.

• APPENDIX A

ORGANIZATION OF THE IGCC

ORGANIZATION OF IGCC

The responsibility of the IGCC, in accordance with the provisions and intent of PL 93-410, is to

...coordinate those Federal plans, activities, and policies which are related to or impact on geothermal energy, including ancillary activities of agencies not represented in the Council membership...The Council, through the Chairman, may make recommendations to the appropriate agencies and the President with regard to alternative policies or actions considered necessary or desirable to expedite the development and utilization of geothermal energy resources.

Figure A.1 shows the organizational structure and membership of the IGCC. The Council, chaired by an assistant Secretary of the Department of Energy, has responsibility for coordinating the total Federal program in geothermal energy. The Staff Committee, chaired by a representative of DOE, formulates Federal geothermal program plans and directs the activities of the Budget and Planning Work Group (BPWG), the Resource Panel (RP), the Research and Technology Panel (RTP), and the Institutional Barriers Panel (IBP). The nine agency members of the Staff committee are appointed by the Council and represents suborganizations of those Federal agencies on the Council itself.

The Budget and Planning Work Group (BPWG) formulates "long range geothermal energy utilization goals and a comprehensive program of Federal activities and initiatives and associated budget requirements to meet these goals"; coordinates the programs and budgets (related to geothermal energy) of other Federal agencies; prepares the IGCC Annual Report; brings to the attention of the Council relevant programmatic and policy issues relating to Federal coordination; and "monitor(s) and report(s) to the Council on the progress of the Federal program and the response of the non-Federal sector toward achieving the goals". The BPWG is chaired by a representative of DOE, and comprises representatives of each of the council agencies.

The Resource Panel coordinated Federal activities in geothermal resource assessment and assists in developing geothermal resources through the Federal leasing program. Chaired by a representative of the Department of the Interior, this panel was abolished in August 1979.

The Research and Technology Panel promoted effective exchange of information within the U.S. geothermal energy community regarding "Federal research, development, and demonstration programs for geothermal exploration, resource assessment, energy and other product utilization, environmental effects and control technology, and basic and applied research related to geothermal energy". The Panel was chaired by a representative of the Department of Energy, and was abolished in August 1979.

Figure A.1

ORGANIZATIONAL STRUCTURE OF IGCC

LEGEND

ASEV-Office of Assistant Secretary,
Environment
ASPE-Office of Assistant Secretary,
Policy and Evaluation
ASRA-Office of Assistant Secretary,
Resource Application
BES-Basic Energy Sciences
BLM-Bureau of Land Management
BOM-Bureau of Mines
CEQ-Council of Environmental Quality
COMMERCE-Department of Commerce
DGE-Division of Geothermal Energy
DOD-Department of Defense
DOE-Department of Energy
DOI-Department of Interior
EIA-Energy Information Administration
EPA-Environmental Protection Agency
FERC-Federal Energy Regulatory Commission

FWS-Fish and Wildlife Service
GSFC-Goddard Space Flight Center
HUD-Housing and Urban Development
NASA-National Aeronautics and Space
Administration
NFEC-Naval Facilities Engineering
Command
NSF-National Science Foundation
OEP-Office of Energy Policy
OER-Office of Energy Research
OR&D-Office of Research and Development
OWRT-Office of Water Research and
Technology
TREASURY-Department of the Treasury
USDA-Department of Agriculture
USFS-United States Forest Service
USGS-United States Geological Survey
WPRS-Water and Power Resources Service

*Denotes chairing function

MEMBERSHIP OF IGCC AND ITS COMPONENTS

AS OF

OCTOBER 1, 1979

IGCC

STAFF COMMITTEE

BUDGET AND PLANNING WORKING GROUP

INSTITUTIONAL BARRIER PANEL

RESEARCH AND TECHNOLOGY PANEL

RESOURCE PANEL

LEASING AND PERMITTING PANEL

August, 1979

INTERAGENCY GEOTHERMAL COORDINATING COUNCIL

Chairman:

Honorable George S. McIsaac
Assistant Secretary Resource Applications
Department of Energy

Honorable Daniel H. Brill
Assistant Secretary for Economic Policy
Department of the Treasury

Honorable M. Rupert Cutler
Assistant Secretary for Conservation, Research and Education
Department of Agriculture

Honorable Joan M. Davenport
Assistant Secretary for Energy and Minerals
Department of the Interior

Honorable Stephen J. Gage
Assistant Administrator for Research and Development
Environmental Protection Agency

Dr. Walter L. Gillespie
Deputy Assistant Director for Science Education
National Science Foundation

Honorable Donna E. Shalala
Assistant Secretary for Policy Development and Research
Department of Housing and Urban Development

Honorable Jerry J. Jasinowsky
Assistant Secretary for Policy
Department of Commerce

Honorable Robert B. Pirie, Jr.
Assistant Secretary of Defense (Manpower, Reserve Affairs and Logistics)
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Staff:

Helen Krupovich
Division of Geothermal Resource Management
Resource Applications
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MINUTES OF MEETINGS OF IGCC AND COMPONENTS

FISCAL YEAR 1979

1944-1945

1946-1947

1948-1949

1950-1951

1952-1953

1954-1955

1956-1957

1958-1959

INTERAGENCY GEOTHERMAL COORDINATING COUNCIL

MEETING OF JANUARY 18, 1979

The IGCC met and discussed the following issues:

- Expansion of the IGCC to include DOC, DOD and HUD, in order to bring in other agencies dealing with geothermal development. Agreed, letters sent to each agency.
- Streamlining Task Force - presented its report and recommendations. IGCC approved several and instructed IBP to prepare letters to the responsible agencies citing recommendations and urging prompt implementation. Several other recommendations remanded back to the Task Force for reconsideration. IGCC agreed to make the report of the Task Force available to the Administration, Congress, and the public.
- Institutional Barriers Panel - presented recommendations of what ought to be included in a Geothermal Energy Omnibus bill.
- Budget & Planning Working Group - presented the Draft Third Annual Report of the IGCC for review. (The report was subsequently approved and submitted to Congress in March 1979.)
- Resource Panel - noted that the USGS had completed its update of national geothermal resources, which would be available at the end of January (Circular 790).

MEETING OF AUGUST 28, 1979

The IGCC met and discussed the following items:

- Expansion of the IGCC
- Budget & Planning Working Group - reported work on the following:
 - Fourth Annual Report started
 - Progress Monitoring System established
 - Project Management System under way
 - Leasing needs being reviewed
 - Joint budget proposal under development.
- Institutional Barriers Panel - no formal recommendations were presented. A status report of the bills before Congress was made. Several of IBP's recommendations have been incorporated as amendments. IBP is examining several IRS tax provisions.
- Streamlining Task Force - the recommendations of the Task Force were approved (see Chapter V). The IGCC moved to establish a permanent leasing committee to deal with the issues identified by the Task Force.

- Resources Panel - most of the work of the Panel has been covered by the resource analysis recently released by USGS, Circular 790. Thus, this panel was also abolished.
- Environmental Control Technology Panel - the IGCC established this panel to deal with issues concerning environmental impacts of geothermal development, and to make recommendations to mitigate adverse environmental impacts.

STAFF COMMITTEE

MEETING OF OCTOBER 12, 1978

The Staff Committee met to consider and review:

- Addition of DOC, DOD, and HUD to the IGCC
- BPWG Report - interagency budget coordination, leasing schedules, annual report, and the project management system.
- IBP Report - status of NEA provisions, EPA regulations, Omnibus Bill, recommendations, Forest Service RARE II review, and BLM wilderness review.
- Resource Panel - membership being reconstituted, national assessment plan being drafted
- Research & Technology Panel - reviewed advances in drilling technology, reviewing EPA Pollution Control Guidance report.

MEETING OF JANUARY 9, 1979

The Committee discussed the reorganization of DOE, and received the following reports:

- BPWG - updating site-specific development schedules; reviewing draft Third Annual Report.
- Streamlining Task Force - presented final report. The Committee agreed to forward the report to the IGCC and directed the IBP to prepare an implementation plan for the recommendations.
- IBP - reviewed legislative amendments to the NEA, tax provisions, and progress on the Omnibus Bill.
- Resource Panel - described the upcoming USGS resource assessment (Circular 790).

MEETING OF FEBRUARY 26, 1979

The Committee received the following status reports:

- BPWG - will review NEA for impact on agency geothermal budgets; Third Annual Report nearing completion.
- IBP - presented progress report on Streamlining Task Force recommendations; letters sent to appropriate agencies.
- Leasing & Permitting Panel - the Committee recommended permanent establishment of this panel to review regulations affecting geothermal development.

Staff Committee - 2

MEETING OF AUGUST 10, 1979

The Committee discussed the following:

- DOD indicated willingness to join IGCC
- BPWG Report - coordinated budget plans were delayed by OMB's schedule; the National Progress Monitor should be expanded from DOE to include all agencies of the IGCC; the Project Management System is being developed to assist in long-term planning.
- IBP - agencies have received the IGCC Omnibus recommendations, and some have been incorporated into legislation now before Congress.
- Research & Technology Panel - reviewed agency programs in geothermal research.

MEETING OF SEPTEMBER 20, 1979

The Committee reviewed the following items:

- DOC, HUD still considering membership in the IGCC. NSF is no longer a member, but will continue to act in an advisory capacity.
- IBP - presented a status report of Omnibus legislation.
- Resource Panel, Research & Technology Panel - recommended they be abolished.
- Leasing & Permitting Panel - the Committee agreed to establish a permanent panel.
- Environmental Control Technology Panel - the Committee was asked by the IGCC to establish such a panel; discussed makeup of this new panel.

BUDGET & PLANNING WORKING GROUP

MEETING OF DECEMBER 19, 1978

The BPWG met to review:

- The Third Annual Report to Congress - in the final draft stages
- Activity Network - used to estimate what is achievable in the near term and make sure research programs are timely.

MEETING OF APRIL 27 & 30, 1979

The BPWG met and discussed:

- Joint Federal Geothermal Budget - a coordinated geothermal agency budget to clarify scope of the geothermal program and clarify agency responsibility.
- National Progress Monitor - a mechanism with which DOE plans to monitor and report all activity germane to the commercialization of geothermal energy.
- Project Management System - a system designed to serve as a basis for long-range planning, and to review site-specific developments.
- Fourth Annual Report to Congress - new format and emphasis proposed and discussed.
- Leasing coordination - a priority list of geothermal sites to be leased in order to meet IGCC goals being developed by BPWG.
- National Plan - an integrated national plan for geothermal development being developed by BPWG.

MEETING OF AUGUST 13 & 14, 1979

The BPWG met to review progress on the issues from the previous meeting:

- Joint Budget - unable to put together for FY 80; requests highly disaggregated.
- Project Management System - under review and development in DOE
- Fourth Annual Report - discussed organization of report and changes in strategy, national geothermal plan, utilization estimates, resource development, drilling activity, and mid- and long-term plans.

INSTITUTIONAL BARRIERS PANEL

MEETING OF JANUARY 4, 1979

The Panel discussed the following amendments to legislation:

- Geothermal Energy Omnibus Bill
 - Agency membership in IGCC
 - leasing authority
 - phased environmental review (omitted by IBP).
- Steam Act Amendments
 - exploration of wilderness study areas
 - abolishment of KGRA designations
 - leasing of private lands
 - limitations on lease readjustment terms
- Tax Proposals
 - 10 percent investment tax credits for public utility property
 - 7-year moratorium on investment tax credit paybacks
 - inclusion of injection well as eligible for intangible drilling cost deductions
 - elimination of minimum tax on intangible drilling costs
- Public Utility Regulatory Policy Act
 - expanded size of small power producer
 - inclusion of geothermal in the renewable resource category
 - expanded wheeling and interconnection authority
 - rolled-in pricing for geopressured methane
- National Energy Conservation Policy Act
 - inclusion of explicit references to geothermal

MEETING OF FEBRUARY 13, 1979

The Panel conducted the following business:

- Discussed the recommendations of the Streamlining Task Force
- Established means by which to implement those recommendations
- Reviewed status of previous Panel recommendations
- Began legislative drafting of recommendations to the Omnibus Bill
- Discussed site-specific geothermal developments and problems

MEETING OF AUGUST 2, 1979

The Panel met to review its ongoing work. No action items were scheduled. The Panel received a new report from EPA on environmental regulations, including injection requirements, Resource Conservation Recovery Act, Safe Drinking Water Act, and PSD developments under the Clean Air Act Amendments.

RESEARCH & TECHNOLOGY PANEL

MEETING OF MARCH 27, 1979

The Research and Technology Panel met to review agency research and technology programs and to discuss the need for interagency coordination. Representatives from the agencies presented summaries of their program activities.

NAVY

The Dept. of Navy has the lead in DOD for geothermal development programs, of which China Lake is the primary research project. The Navy recognizes a need to become involved in DOE programs of reservoir analysis.

EPA

EPA is concerned with environmental degradation and protection in geothermal development. Research includes:

- characterization of ecological effects (Roosevelt Hot Springs)
- establishment of environmental monitoring methodology
- development of control technology for pollutants emitted from geothermal plants.

NSF

NSF conducts no energy research programs, but does support basic and applied research, which may or may not be specific to geothermal resources and their development.

WATER AND POWER RESOURCES SERVICE, INTERIOR

WPRS is a water development organization. Its main geothermal program research includes:

- desalting geothermal brines
- use of geothermal fluid to supplement water supplies in southern California and the lower Colorado River region.

USGS

The research of USGS focuses on:

- thermodynamic research on minerals
- aqueous constituents to geologic field investigations

BUREAU OF MINES

Major areas of investigation are:

- mineral recovery
- examination of construction materials (corrosion resistance).

Reviewing the major programs of these agencies, the Panel determined that there was very little overlap in research efforts. About 95 percent of the technology research now being done is in DOE, which should eliminate duplication. The Panel's efforts could thus be to provide direction to the work of DOE through the IGCC. The Panel considered coordinating or possibly combining with the Resource Panel. Subsequently, both panels were abolished by the IGCC.

RESOURCE PANEL

MEETING OF JANUARY 9, 1979

The Resource Panel met to consider:

- Whether the original charge of the Resource Panel is still appropriate
- Whether the original document establishing the Panel should be revised
- What the focus of Panel activities should be.

The Panel then reviewed the 1976 Federal Plan for Resource Assessment, the major product of the Panel. The Federal Plan described the goal, objectives, and elements of the Federal program for geothermal resource assessment and provided useful input into the Budget and Planning Working Group for preparation and analysis of detailed resource development scenarios. It also established priorities for general studies needed to characterize geothermal systems, and recommended a balance between program elements along these guidelines:

geothermal systems	50%
exploration & assessment technology	30%
Geothermal resource inventory	20%

The Panel also established a report on "Proprietary Technical Data in the Federal Geothermal Energy Program", which recommended:

- a universal indexing system
- procedures
- data inventory.

The final recommendations of the Panel include:

- analysis of FY 79 and FY 80 program expenditures
- review of the 1976 Federal Plan
- coordination of assessment activities related to Wilderness and RARE II areas.

APPENDIX B

INTERNATIONAL AGREEMENTS

MULTILATERAL AGREEMENTS

<u>AGREEMENT</u>	<u>PARTICIPATING COUNTRIES</u>	<u>FY 79 STATUS</u>	<u>FUTURE ACTIVITIES</u>
International Energy Agency (IEA)	Federal Republic of Germany, Japan, Sweden, Switzerland, United Kingdom, United States	<u>Man-made Geothermal Energy Systems (MAGES) Project:</u> Final Report issued after successful completion of first phase of the project to evaluate HDR techniques and equipment.	A meeting to approve Final Report and discuss funding for the second phase of the project is planned for FY 80.
	Italy, Mexico, New Zealand	<u>Small Geothermal Power Plants:</u> Meetings of Mexico, Italy, New Zealand, United States held for information/technical exchange.	
	Federal Republic of Germany, United States	U.S.-FRG agreement for participation at Los Alamos Scientific Laboratory hot dry rock project signed 9/79.	
NATO-CCMS Geothermal Energy Pilot Study	Canada, Federal Republic of Germany, France, Greece, Iceland, Italy, Netherlands, New Zealand, Sweden, Switzerland, United Kingdom, United States	A follow-up conference on the Geothermal Energy Pilot Study for FY 80 is being planned. The conference will review developments in the area of (1) Computerized International - Geothermal Information Systems; (2) Direct use of geothermal energy in Canada, France, and Iceland; (3) Geothermal Fluid Injection Studies in New Zealand and Reservoir Engineering Studies at Cerro Prieto; (4) International testing of a wellhead generator unit and the Turkish experience on small power plants; (5) Status of HDR developments in Europe and the United States.	Conference to review recent international geothermal developments will be held in Paris in July 1980.

Table B.2

BILATERAL AGREEMENTS

<u>AGREEMENT</u>	<u>FY 79 STATUS</u>	<u>FUTURE ACTIVITIES</u>
U.S.-Italy (ENEL)	<p><u>Stimulation of Hydrothermal Areas:</u> Exchanges of information on well stimulation techniques and selection of wells for possible stimulation have been completed.</p> <p><u>Utilization of Hot Brines:</u> Continue exchanges of information on brine technology, materials, and geochemistry were carried out in FY 79.</p> <p><u>Reservoir Assessment and Engineering:</u> Computer model of production, injection and application of models to Lardarello has been completed.</p> <p><u>Deep Drilling:</u> Exchange of information on drilling problems of deep test hole (targeted for depth of 5 km) at Sesso field, SW of Lardarello, including drill mud technology and high temperature cements.</p>	<p>Italian scientists will observe stimulation activities at The Geysers in FY 80.</p> <p>Proposed expansion of activities will cover studies on thermodynamic equilibria and solubility reaction in brines, production test of Cesano brines and design, construction, and operation of multiple-use plant for power production and potash recovery in Italy.</p> <p>Proposed activities include investigations on helium prospecting for geothermal fields, use of radon as reservoir indicator, fracture exploration to locate highly permeable zones and continue modeling for reservoir engineering.</p> <p>Exchange of information will continue.</p>

Table B.2 (Cont.)

BILATERAL AGREEMENTS

<u>AGREEMENT</u>	<u>FY 79 STATUS</u>	<u>FUTURE ACTIVITIES</u>
U.S.-Italy	<p><u>Environmental Control Technology:</u> U.S. provided equipment for monitoring radon and H₂S emissions in the vicinity of Lardarello. Exchanges of information on methods of H₂S control continued. Italian scientists visited The Geysers H₂S pilot project in August 1979. In addition, 3 areas, Torre Alfina, Latera, and Cesano have been instrumented for seismic studies.</p>	Exchange of information will continue.
U.S.-Japan	<p><u>1980 Workshop:</u> United States made a proposal in April 1979 for a workshop in FY 80 to review all work completed to date under the Italian Agreement.</p> <p>A U.S.-Japan Geothermal Coordinating Committee was established in June 1979 to facilitate cooperation and exchange of information on geothermal energy. Future cooperative activities under the original "implementing agreement" will continue under the auspices of a recently concluded umbrella agreement on energy research and related fields. Negotiations are also under way for Japanese participation in LASL hot dry rock project.</p>	Exchange of information will continue.
U.S.-Mexico	<p>Bilingual proceedings of the First Symposium on the Cerro Prieto field were published in FY 79. Cooperative instrumentation and monitoring of geophysical, hydrological characteristics of Cerro Prieto field continued. Several proposals to extend the scope of the U.S.-Mexican Agreement to cover other geothermal fields are being considered.</p>	A Second Symposium on cooperative activities at Cerro Prieto field was held in October 1979.

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APPENDIX C

METHOD USED TO SET NATIONAL HYDROTHERMAL ELECTRIC GOALS

METHOD USED TO SET NATIONAL HYDROTHERMAL ELECTRIC GOALS

Hydrothermal electric goals were reevaluated in 1979 to reflect the updated resource information in USGS Circular 790. The following discussion describes the approach to setting goals suggested by the MITRE Corporation and adopted by the IGCC Budget and Planning Working Group. The approach considers a number of factors, including site-specific power economics and potential development impediments. Results for 1980-2020 are shown in Table C-4 at the end of this section.

For this approach, 50 of the 53 hot water sites with estimated subsurface temperatures 150°C were selected as high-potential geothermal resource development prospects, on the basis of data provided in USGS Circular 790.* Table C.1 defines the prospect areas and provides pertinent data on the reservoir characteristics in terms of electrical generation capacity.

The main parameters governing the prospect development schedule are

- Size of initial geothermal power plant (50 MWe)
- Size of all additional power plants (100 MWe)
- Year in which the first plant is economically competitive
- Interplant lead time (the time between two consecutive power plants).

A deterministic site development scenario was then scheduled following the stepwise procedure depicted in Figure C.1. The required input data included:

- The list of identified prospects
- Reservoir characteristics
- Planning horizon or time span covered by scenario
- A list of prospect development impediments and associated time delays (an example is given in Table C.2)
- A list of known planned start dates for some prospects
- Competitive unit energy costs for each site, relative to competitive energy costs
- Development decision parameters

* Yellowstone, Steaming Flats, and Gamma Hot Springs were omitted because they are in National Parks or Wilderness Areas. The Geysers were also omitted because it is a vapor-dominated rather than a hot-water hydrothermal resource; it is, however, included later.

Figure C.1

SCENARIO GENERATION PROCEDURE

Table C.1
POTENTIAL PROSPECTS DATA

STATE	SITE	30-YEAR CAPACITY (MW)	COMPETITIVE RATE MILLS/KWH
Alas.	Bailey Bay Hot Springs	26	83
	Geyser Bight	136	81
	Hot Springs	27	81
Ariz.	Power Ranches, Inc., Wells	23	96
Cal.	Border	31	117
	Brawley	650	44
	Clear Lake Volcanic Field Area	900	55
	Coso	650	34
	East Mesa	350	42
	Heber	650	46
	Mono-Long Valley	2,100	32
	Morgan Springs - Growler	110	43
	Randsburg Area	80	45
	Salton Sea	3,400	33
	Surprise Valley	1,490	77
	Sulfur Bank Mine (Hot Bolata)	75	53
	Westmorland	1,710	56

(See Table D.2 for capacities and costs at other sites.)

Table C.2

EXAMPLES OF SITE IMPEDIMENTS AND ASSOCIATED DELAY TIME

SITE	POSTULATED FIRST POLICY DATE		LEASING STATUS	ENVIRONMENTAL STATUS	EXPLORATORY DRILLING AND RESERVOIR CHARACTERISTICS	COMMENTS	FEDERAL ACTION REQUIRED TO PREVENT LATE POL
	DGE POSTULATED	EARLIEST PROBABLE DELAY YEARS					
Mono-Long Valley, Cal.	1985	1981	392,000 acres of Federal land in the KGRA mostly F.S. BLM offered 7 tracts, but only 3 tracts totaling 5,000 acres were leased. Two of the 3 tracts are tied up in litigation over Grand- father Rights.	The F.S. can- not lease land until environmental work is com- pleted. expected com- pletion in November 1978. Envi- ronmental opposition is likely.	Several shallow (1,000 ft) wells have been drilled. Envi- ronmental and Grandfather Rights are causing delays.	Delays longer than one year seem likely due to Grand- father Rights and environ- mental issues.	Immediate resolution of Grand- father Rights issue and immedi- ate comple- tion of Environmen- tal Study with public approval both seem highly unlikely.

- Scenario starting year
- First plant size in MWE (50 MWe)
- Interplant lead time (3 years)
- Additional unit size (100 MWe)

A variety of decision parameters (including plant size and interplant lead time) were considered before settling on 50 MW for the first plant, 100 MW for following plants, and a 3-year interplant lead time. Table 3 presents some typical results of the sensitivity of the outcome to the selected decision parameters. The relative escalation of competitive energy costs was assumed to be 5 percent per year.

Under the 3-year plan, 50/100 MW assumption, most of the capacity described for the known high- and moderate- temperature hot water resources in USGS Circular 790 is brought on line by the year 2000. If all these resources are developed, and no new resource (beyond that in Circular 790) is discovered, the final cumulative technically feasible power on line from hot water hydrothermal resources is limited to 17,200 MWe. The amount that is estimated to be economical is 15,825 MWe (see Table C.4). To get beyond this figure, it was assumed that the following net discoveries would be made: 1981-1990, an amount equal to the currently known resource (about 17,000 MWe); 1991-2000, an additional 75 percent of the currently known resource (about 12,900 MWe); 2001-2010, an additional 50 percent of the currently known resource (about 8,500 MWe). The sum of these discoveries amounts to about 55 percent of the Circular 790 estimate of (undiscovered) hot water hydrothermal resource.

Additional new discoveries of vapor-dominated hydrothermal resources were assumed to be discovered by 1990, in amount roughly equivalent to that estimated for The Geysers, California, field.

The results of the exercise are shown in Table C.4. These were reviewed by the Budget and Planning Working Group of the IGCC in October 1979, and deemed to be reasonable, except that the 1985 estimate of 4,000 MWe was reduced to 3,000 MWe. This was done because there appear to be no active development plans for some of the sites that apparently could be competitive by 1985.

Table C.3

SUMMARY OF SENSITIVITY ANALYSES: CUMULATIVE POWER
ON-LINE IN 1990 (EXCLUDING THE GEYSERS)*

OPTIONS CONSIDERED		YEAR OF FIRST PLANT ON-LINE		
		1979	1981	1983
Interplant Time	Size of First/Following Plants	MWe Power on Line		
5 years	50/100 MW	5100	3850	2650
3 years	50/100 MW	6450	6150	5150
5 years	100/200 MW	10200	7700	5300
3 years	100/200 MW	12900	12300	10300

*Based on 27 sites from USGS Circular 726.

Table C.4

RESULTS OF GOAL SETTING FOR HYDROTHERMAL ELECTRIC: CUMULATIVE MW INSTALLED

Year	<u>HOT WATER SITES</u>					<u>VAPOR-DOMINATED SITES</u>			
	<u>Discovery Period</u>				<u>Hot Water</u> Total	<u>Geysers</u>	<u>Other Sites</u>	<u>Vapor</u> Total	Total
	To 1980	1981-1990	1991-2000	2001-2010					
1975	2,116				2,116	1,964		1,964	4,080
1990	4,655				4,655	2,614		2,614	7,269
1995	7,939	3,979			11,920	2,614	300	2,914	14,834
2000	10,515	7,715			18,200	2,614	1,000	3,614	21,814
2005	12,918	9,698	3,651		26,327	2,614	1,800	4,414	30,741
2010	14,375	12,505	6,379		33,259	2,614	2,500	5,114	48,373
2015	15,225	14,105	7,429	2,434	39,193	2,614	2,500	5,114	44,307
2020	15,825	14,755	9,379	4,253	44,212	2,614	2,500	5,114	49,326

APPENDIX D

ASSUMPTIONS FOR HYDROTHERMAL COST CURVES

 

ASSUMPTIONS FOR HYDROTHERMAL COST CURVES

A. ELECTRIC SYSTEM COSTS

The hydrothermal electric system cost curve (Figure II.5 in Chapter II of this report) was derived from estimates of the cost of electricity generated at 50 U.S. hot water hydrothermal sites. The cost estimates were developed by applying the MITRE Corporation's GELCOM cost of electric power model to the high and moderate temperature sites (150°C) described in USGS Circular 790, but deleting Yellowstone, Steaming Flats, and Gamma Hot Springs. The results are a predicted leveled busbar cost of electricity as well as other financial estimates for each site. These costs are leveled over an assumed life of 30 years for the generating plant.

To take into account the total impact of the current Federal Division of Geothermal Energy Hydrothermal Support Branch technology R&D programs, the model assumed a power-on-line year of 1990 for a 50 MWe plant at each site, calculated a busbar cost assuming certain magnitudes of cost-reducing impacts of R&D, and then deflated the busbar costs back to 1978 values. Most impacts of the R&D program should be felt by 1985, and fully commercialized by 1990.

The curves (Figure II.5) present the busbar cost of the sites on the vertical axis and the cumulative potential electric capacity of known sites on the lower horizontal axis. The sites were plotted in ascending order of their busbar cost. The upper horizontal axis is the cumulative potential electric capacity of known plus inferred resources and is based on USGS estimates. This axis assumes that the inferred will be developed at costs and quantities proportional to those of the known sites.

The financial assumptions used as input to the cost of power model are shown in Table D.1.

The field and plant cost estimates used assumes that installation and operation proceed with no problems, and with no elaborate environmental controls. Exploration costs are not included, since these can be very high for a first plant and relatively low for additional plants at the same site. These assumptions imply that the cost of power from the first plant at each site could be significantly higher (perhaps even double) than that shown in the curves.

The estimated busbar costs as well as capital and O&M costs are given in Table D.2 for each of the 50 sites considered. The site potential generating capacity for 30 years is taken from estimates in USGS Circular 790.

B. HYDROTHERMAL DIRECT USE COSTS

Based on the sites listed in USGS Circular 790 for hot water hydrothermal systems 90-150°C, Battelle Pacific Northwest Laboratories

Table D.1

**FINANCIAL ASSUMPTIONS FOR HYDROTHERMAL
ELECTRIC COST ESTIMATES**

PRODUCER FINANCIAL ASSUMPTIONS

Debt Fraction:	0.30
Annual Interest Rate on Debt (Fraction):	0.08
Required Rate of Return on Equity (Fraction):	0.20
Property Tax Rate (Fraction):	0.20
Revenue Tax Rate or Royalty (Fraction):	0.10
Effective Total Income Tax Rate (Fraction):	0.50
Effective Investment Tax Credit (Fraction):	0.12
Escalation Factor for O&M Costs:	0.05
Escalation Factor for Energy Costs:	0.05
Escalation Factor for Capital Costs:	0.05
Life Span of Production Wells (Years):	15.00
Life Span on Injection Wells (Years):	15.00
Life Span of Producer Plant (Years):	20.00
Start-Up Cost Multiplier:	1.08
Well-Expensing Allowance:	0.06
Percentage Depletion Rate:	0.15
General Inflation Rate:	0.05

UTILITY FINANCIAL ASSUMPTIONS

Debt Fraction:	0.50
Annual Interest Rate on Debt (Fraction):	0.08
Required Rate of Return on Equity (Fraction):	0.12
Property Tax Rate (Fraction):	0.02
Revenue Tax Rate or Royalty (Fraction):	0.00
Effective Total Income Tax Rate (Fraction):	0.50
Effective Investment Tax Credit (Fraction):	0.12
Escalation Factor for O&M Costs:	0.05
Escalation Factor for Energy Costs:	0.05
Escalation Factor for Capital Costs:	0.05
Life Span of Utility Plant (Years):	30.00
Ultimate Capacity Factor:	0.80
Start-Up Cost Multiplier:	1.04

Table D.2

COST ESTIMATES FOR U.S. HOT WATER HYDROTHERMAL ELECTRIC SITES (150°C)*

STATE	SITE	SITE POTENTIAL MWe FOR 30 YRS	PRODUCER COSTS**		UTILITY COSTS**		BUSBAR COST MILLS/kWh***
			CAPITAL \$M	O&M \$/YR	CAPITAL \$M	O&M \$/YR	
Alas.	Bailey Bay Hot Springs	26	80.9	1.8	38.3	1.3	83
	Geyser Bight	136	77.9	1.8	38.2	1.3	81
	Hot Springs Cove	27	77.9	1.8	38.2	1.3	91
Ariz.	Power Ranches, Inc., Wells	23	98.0	2.1	38.2	1.3	96
Cal.	Border	31	96.4	4.2	41.7	1.6	117
	Brawley	640	17.3	1.5	38.8	1.5	44
	Clear Lake Volcanic Field	900	45.6	1.1	37.0	1.3	55
	Coso	650	26.5	0.5	28.7	0.8	34
	East Mesa	360	27.9	0.7	37.3	1.3	42
	Heber	650	32.0	0.8	37.6	1.3	46
	Mono-Long Valley	2100	24.5	0.4	27.9	0.8	32
	Morgan Springs-Growler	116	38.6	0.7	29.1	0.8	43
	Randsburg Area	84	45.1	1.1	37.8	1.3	45
	Salton Sea	3400	7.6	0.9	38.1	1.5	33
	Surprise Valley	1490	71.1	1.6	39.0	1.4	77
Colo.	Sulfur Bank Mine	75	42.8	1.0	36.9	1.3	53
	Westmorland	1710	43.3	1.5	29.1	0.9	56
	Paradise	24	97.4	4.4	42.1	1.6	120

*Does not include The Geysers, Yellowstone, Steaming Flats or Gamma Hot Springs.

**Based on a 50 MWe power plant in 1978 \$.

***Price in current dollars for 1978-2008 time frame.

Table D.2 (Cont.)

COST ESTIMATES FOR U.S. HYDROTHERMAL ELECTRIC SITES*

STATE	SITE	SITE POTENTIAL MWe FOR 30 YRS	PRODUCER COSTS**		UTILITY COSTS**		BUSBAR COST MILLS/kWh***
			CAPITAL \$M	O&M \$M/YR	CAPITAL \$M	O&M \$M/YR	
N.M.	Valles Caldera	2700	19.3	0.4	24.4	0.7	26
Ore.	Alvord Hot Springs	49	79.5	1.8	37.4	1.3	81
	Crump's Hot Springs	61	70.0	1.6	38.0	1.3	75
	Hot (Borax) Lake Area	91	45.3	1.1	37.0	1.3	55
	Mickey Hot Springs	160	46.3	0.8	30.9	0.9	50
	Neal Hot Springs	36	71.0	1.6	37.1	1.3	76
	Newberry Caldera	740	47.2	0.9	27.6	0.8	49
	Trout Creek Area	24	144.2	3.0	38.8	1.4	131
	Vale Hot Springs	870	46.8	1.2	38.6	1.4	58
Utah	Cove Fort-Sulphurdale	330	71.7	1.6	38.0	1.3	76
	Roosevelt Hot Springs	970	11.9	0.2	24.8	0.7	21

*Does not include The Geysers, Yellowstone, Steaming Flats, or Gamma Hot Springs.

**Based on a 50 MWe power plant in 1978 \$.

***Price in current dollars for 1978-2008 time frame.

Table D.2 (Cont.)

COST ESTIMATES FOR U.S. HYDROTHERMAL ELECTRIC SITES*

STATE	SITE	SITE POTENTIAL MWe FOR 30 YRS	PRODUCER COSTS**		UTILITY COSTS**		BUSBAR COST MILLS/kWh***
			CAPITAL \$M	O&M \$/YR	CAPITAL \$M	O&M \$/YR	
Haw.	Kamaili Homestead	210	19.3	0.4	24.4	0.7	26
	Puna (Kapoho Reservoir)	41	39.0	0.7	24.3	0.7	41
Ida.	Big Creek Hot Springs	26	80.9	1.8	38.3	1.3	83
	Crane Creek-Cove Creek	340	45.5	1.1	37.8	1.3	56
Nev.	Baltazor Hot Springs	46	88.2	2.0	38.6	1.4	89
	Beowave Hot Springs	127	32.9	0.6	27.7	0.8	38
	Brady Hot Springs	156	95.7	2.3	48.8	1.4	102
	Desert Peak Area	750	37.6	0.7	28.6	0.8	42
	Fernley Area	33	52.7	1.2	37.3	1.3	61
	Great Boiling Springs	32	48.8	1.2	37.5	1.3	58
	Hot Sulphur Springs	27	53.7	1.3	38.2	1.3	62
	Humboldt House	47	28.1	0.5	29.1	0.8	36
	Kyle Hot Springs	97	72.3	1.6	38.5	1.4	77
	Leach Hot Springs	77	106.5	2.3	38.3	1.3	102
	Lee Hot Springs	28	105.9	2.3	38.1	1.3	101
	Pinto Hot Springs	90	62.5	1.4	37.7	1.3	69
	San Emedio Desert Area	28	72.3	1.6	38.1	1.3	76
	Soda Lake Area	146	62.4	1.5	38.6	1.4	70
	Steamboat Springs	350	29.0	0.7	31.8	0.9	39
	Stillwater Area	450	83.8	1.9	38.5	1.4	85
	Sulfur Hot Springs	74	57.5	1.3	37.5	1.3	65

*Does not include The Geysers, Yellowstone, Steaming Flats, or Gamma Hot Springs.

**Based on a 50 MWe power plant in 1978 \$.

***Price in current dollars for 1978-2008 time frame.

(PNL) developed resource availability curves for nonelectric geothermal applications (see Figure II.6 in Chapter II); these curves are reported in "Near Term Geothermal Energy Supply Curves and the Impacts of Technology", (Battelle, PNL, September 1978).

Cost refers to the delivery of energy to the door of the user: a residence, a commercial business, or an industrial concern. Costs are based on private financing as described in PNL's previous reports. These costs reflect the efficiency of utilization, which should be taken into account to compare with the costs of competing energy resources. For example, the efficiency of utilization for space heating with oil is between 50 and 70 percent, but the efficiency of utilization for space heating with geothermal is nearly 100 percent.

Because costs for direct applications are sensitive to transport distance, the curves assume that 1/6 of the energy would be used at each of the 6 distances from the wellhead: 0 miles, 10 miles, 20 miles, 30 miles, 40 miles, and 50 miles.

The costs reflect current technology and today's prices. They do not assume any reductions for future technology improvements. That is, this energy is estimated to be deliverable today under PNL's assumptions at the costs indicated.

These estimates differ with calculation of beneficial heat made by the USGS in Table 6 of Circular 790, where it was assumed that 24 percent of the wellhead thermal energy could actually be used. The amount of usable energy is a function of both the resource temperature and the particular end use. PNL's calculations show that 24 percent is a reasonable estimate of the usable energy for process heating. However, 64 percent of the wellhead thermal energy is usable (on the average) for space heating, depending upon the resource temperature. A reject temperature of 38°C is assumed for space heating and a reject temperature of 100°C for process heating. (This implies that only the resource above 100°C would be used for process heating.) PNL also assumed a heat loss of 20 percent in the transmission piping and heat exchangers.

For earlier resource availability curves, PNL had assumed that all resources that were not previously shown in the old USGS Circular 726 were found in reservoirs with the following characteristics: depth to top of reservoir--1.0 km, and depth to bottom of reservoir--3.0 km. However, Circular 790 assumes the following reservoir characteristics: depth to top of reservoir--1.5 km, and depth to bottom of reservoir--3.0 km.

This caused PNL to increase its drilling depth estimate by 0.25 km since it is assumed that wells are drilled to the midpoint of the reservoir. The drilling cost estimates were revised for this increased drilling depth, which caused a slight increase in production costs from some previously released curves.