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FIFTH ANNUAL REPORT

INTERAGENCY GEOTHERMAL COORDINATING COUNCIL

FY 1980

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MASTER

This is the Fifth Annual Report to the Congress of the Inter-agency Geothermal Coordinating Council (IGCC). This report is mandated by the Geothermal Energy Research, Development, and Demonstration Act of 1974 (PL 93-410). It describes progress during fiscal year 1980 (FY 1980) for the Federal geothermal program.

The Federal geothermal program comprises the efforts of the various Federal agencies that support the development of geothermal resources. These agencies include the Departments of Energy, Interior, Agriculture, Treasury, Commerce, Defense, Housing and Urban Development, and the Environmental Protection Agency. The IGCC is comprised of representatives of these agencies.

Geothermal energy is concentrations of earth's thermal energy stored in sub-surface rocks and fluids which can be tapped by drilling. Hydrothermal, geopressured and hot dry rock are the three principal types of geothermal resource (in order of technological readiness). Much of the hydrothermal energy resource is recoverable with current or near-current technology and could make a significant contribution both to increasing domestic energy supplies and to reducing the United States' dependence on imported oil. Geothermal energy can be used for electric power production, residential and commercial space heating and cooling, industrial process heat, and agricultural applications.

The overall objective of the Federal geothermal program is to perform research which will lead to the development of a technology base that could be used for future development by the private sector, and to remove disincentives which may hinder industrial and commercial development (e.g., increasing the rate of public land leasing). Private industry and State and local governments have the lead role in the direct planning and construction of geothermal energy systems. A close liaison is maintained with them to ensure that Federal actions are those most vital to geothermal development.

The Appendix to this report provides supplementary information about: The organization of the IGCC, the history of U.S. geothermal energy development, leasing of Federal lands, the location of U.S. geothermal resources, status of direct heat feasibility and development projects, and research priorities for geothermal environmental control studies. More details about the Federal geothermal program can be found in "Geothermal Federal Program: Accomplishments - Fiscal Year 1980".

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TABLE 1
FEDERAL FUNDING FOR GEOTHERMAL ENERGY (\$000)*

FISCAL YEAR ORGANIZATION UNIT	ACTUAL 1978	ACTUAL 1979	ACTUAL 1980	ESTIMATED 1981
Department of Agriculture U.S. Forest Service	678	780	750	700
Department of Defense Navy Air Force DOD Total	 542 0 542	 300 0 300	 230 200 430	 930 1,010 1,940
Department of Energy Conservation & Renewable Energy (formerly Resource Applications) Office of Energy Research Environment GLCP (Administrative Expenses) DOE Total	 105,962 2,800 3,896 410 113,068	 152,990 2,100 2,820 0 157,910	 149,870 3,102 1,950 181 155,103	 142,521 3,305 723 193 146,742
Department of the Interior National Park Service Fish & Wildlife Service** Bureau of Land Management Bureau of Mines Bureau of Reclamation USGS, Geothermal Research Program USGS, Geothermal Evaluation & Lease Regulation DOI Total	 200 2,300 550 1,800 10,184 1,854 16,888	 200 2,590 1,050 550 12,043 750 17,183	 13 200 2,550 800 910 860 15,612	 15 70 2,650 400 60 898 12,039
Environmental Protection Agency	670	920	850	1,550
TOTAL FEDERAL GEOTHERMAL PROGRAM BUDGET	131,846	177,093	172,745	162,971

*Operating expenses rounded to nearest thousand.
**Dependent on transfer funds from other agencies.

BUDGET

The total Federal budget for geothermal development has remained fairly constant over the last several years, although there has been a significant reduction in funds for FY 1982. This results from a policy decision to shift more of the responsibility for industrialization to the private sector and to state and local governments. Most notably, Department of Energy (DOE) and U.S. Geological Survey (USGS) budget cuts have occurred in the resource assessment and hydrothermal industrialization activities. Table 1 presents the Federal funding levels for the geothermal program. Table 2 presents the status of the Geothermal Resources Development Fund and loan guarantee authority at the end of FY 1980.

TABLE 2

GEOHERMAL RESOURCES DEVELOPMENT FUND AND GUARANTEE AUTHORITY*

		<u>FY 80</u>
	<u>FUND</u>	<u>AUTHORITY</u>
Unexpended Appropriations, Carried Forward from FY79	\$43,832,277	
New Guarantee Authorization, FY 81		\$150,000,000
FY 80 Guarantee Authorization		350,000,000
Value of Loans Guaranteed		91,048,000
Uncommitted Guarantee Authorization Carried to FY 1981		258,952,000
Uncommitted Guarantee Authorization for FY 1981		408,952,000
Administrative Expenses		
Incurred**(FY 80)	1,043,000	
Guarantee Fees Collected in FY 80	334,490	
Unexpended Appropriation Carried to FY 1981	43,123,767	
Guarantee Fees Collected in FY 1980 and Deposited in GRDF	118,715	

*This financial information is included in the Fifth Annual Report to satisfy the requirements of P.L. 93-410, Section 204(C).

**Contractor and consultant costs necessary to assist in evaluating data submitted with guarantee applications and to assist in monitoring guaranteed projects.

ACCOMPLISHMENTS

FY 1980 was a year of significant accomplishment for the Federal program. Highlights of advances are given below.

LEASING OF FEDERAL LANDS

The DOE/Leasing Policy Development Office established preliminary production goals for energy from leased Federal lands. The goals were intended to help land management agencies in determining leasing programs and schedules and thereby prevent unnecessary delays in leasing that impede geothermal energy development. The goal analysis suggested that (1) leasing of lands with potential merit for electric power production must be increased markedly; and (2) about 500,000 acres per year of Bureau of Land Management (BLM) and United States Forest Service (USFS) administered lands having such potential would have to be leased during 1981-1990 to ensure that enough land is explored to sustain rapid geothermal development through the year 2000.

The number of noncompetitive leases issued by DOI in FY 1980 increased by almost 50 percent from FY 1979. The general status of geothermal leases indicates that Federal geothermal leasing proceeded at a rate of 600,000 acres per year. Although this exceeds the desired rate of leasing (500,000 acres per year) indicated by the DOE/Leasing Policy Development Office's analysis, it is generally recognized that the areas being leased are not necessarily the areas having the highest geothermal potential. DOE initiated a process to aid BLM and USFS in selecting specific areas on which to concentrate their efforts.

By the end of FY 1980 the BLM and the USFS had begun to formulate new streamlined procedures for leasing Federal lands for geothermal exploration. Under the new procedures, lands could be explored prior to the exhaustive environmental assessments required to permit construction of facilities to produce energy. Comprehensive production-related environmental reviews would be conducted if and when the developer determined that a potential for geothermal energy production exists. This new approach to leasing was intended to reduce the backlog of lease applications. The Forest Service issued new guidelines on leasing Federal lands for geothermal exploration during FY 1980.

RESOURCE IDENTIFICATION, ASSESSMENT, AND EXPLORATION

DOE and DOI/USGS continued to collaborate in activities to establish the extent and to identify the location of geothermal resources in the United States. The objectives of the assessment

program have been: (1) to characterize the geological nature of each type of geothermal resource, (2) to estimate locations, distribution, and energy content of geothermal resources in the United States, (3) to evaluate geothermal energy potential in the United States through inventory of the identified portion and prediction of the undiscovered portion of the nation's resources, and (4) to contribute to the confirmation of selected specific geothermal reservoirs. The USGS activities emphasized geothermal resource inventory and assessment work. The DOE activities focused on more detailed study of specific resource areas.

Major accomplishments of the USGS Geothermal Research Program in FY 1980 included:

- An eight-year geologic and geophysical study of the Snake River Plain of Idaho was completed. The region shows considerable promise for the development of low and moderate temperature hydrothermal resources.
- Several geophysical surveys undertaken in the Cascades region produced encouraging results by revealing potential geothermal sources in the western high Cascades.
- Geologic mapping of Medicine Lake volcano in northeastern California was completed. The presence of several rhyolite flows from eruptions within the past 1,200 years and other geological indicators suggest that the volcano may have significant geothermal potential.
- An up-to-date version of the heat-flow map of the United States was prepared. Several new regions of higher than normal heat flow have been identified in the eastern U.S. and many new significant details are apparent in the western U.S.
- The well/spring file from the GEOTHERM database was entered into the General Electric Information Service Network. The file is now available to subscribers of the GE system.
- Experiments with an airborne electromagnetic (AEM) system have shown that many geothermal systems have a near-surface electrical signature. AEM surveys in five KGRAs have shown the usefulness of AEM techniques for exploring for and defining geothermal systems.
- Increasingly encouraging evidence of the utility of the self-potential technique for delineating hydrothermal convective systems was gathered during the year. This

technique has a great deal of promise as a new exploration tool.

DOE sponsored a State-Coupled Program for resource definition. This resulted in cooperative agreements with 22 states to perform state-level resource definition activities, as well as contracts with several institutions that provide geothermal investigations extending over a number of states. A more detailed definition of low and moderate temperature resources was accomplished under this program than is performed by the USGS in its regional surveys. By the end of FY 1980, activities were under way or planned in all 37 states that have manifestations of a geothermal resource. Resource maps have been published for Arizona, Oregon, Nevada, Colorado, Idaho, New Mexico, and Utah.

DOE established the User-Coupled Confirmation Drilling Program in FY 1980 to stimulate the development of low and moderate temperature hydrothermal resources for direct heat applications. Projects selected for funding under this program were scheduled to begin in early 1981. As a precursor to this program, five reservoir confirmation drilling projects were initiated in FY 1980; three in Oregon, one in New York, and one in Delaware.

Analysis of the hydrothermal resource estimates of the USGS was conducted in support of a study by DOE designed to obtain improved estimates of the market potential of geothermal energy. Fifty-three development sites associated with known hydrothermal reservoirs having fluid temperature higher than 150°C are estimated to have a total electric power generation potential of 23,385 MWe for 30 years.

HYDROTHERMAL INDUSTRIALIZATION

DOE's hydrothermal industrialization program consisted of construction and operation of pilot and commercial-scale electric power demonstration facilities, site-specific direct heat feasibility studies and field demonstrations, and legal and regulatory reform and streamlining. Financial and economic incentives for private sector development have also been provided by various Federal agencies.

Hydrothermal industrialization activities conducted in FY 1980 reflected the past Administration's policy to foster geothermal energy development by extensive interaction with potential users. Most of these programs are being brought to completion or reduced markedly in scope in the FY 1981-1982 period. Accomplishments in FY 1980 included:

- DOE supported geothermal commercialization teams in seventeen states, including Alaska, Hawaii, Idaho, Washington, Oregon, California, Arizona, Nevada, Colorado, Montana, New Mexico, North Dakota, South Dakota, Utah, Wyoming, New York, and Delaware. The New York and Delaware state team projects were initiated in FY 1980. These teams conducted activities such as resource area identification, site-specific development analysis, formulation of development plans, and information dissemination.
- Technical consultation was made available on a limited scale to potential industry, community, and utility end-users through four regional technical assistance centers located in Idaho, Maryland, Oregon, and Utah.
- DOE supported the National Conference of State Legislatures (NCSL) to provide research and legal assistance to State legislatures to modify laws to better accommodate and control the production and use of geothermal energy. During FY 1980 NCSL actions led to the consideration of 58 geothermal bills by 12 of the 14 states which sought geothermal advice from NCSL. Major legislation was passed in Alaska, Washington, and Delaware.

DOE supported the design, construction, and operation of test facilities and pilot and commercial-scale electric power plants. Facilities supported in FY 1980 included:

- Cost-Shared 50 MWe Flash-Steam Demonstration Power Plant at Baca Ranch, NM. The final EIS was released in January 1980; plant design was begun and orders for a turbine and other long-lead time procurements were placed; well drilling and flow testing were initiated.
- Cost-Shared 50 MWe Binary Cycle Demonstration Power Plant at Haber, CA. A cooperative agreement between DOE and the utility, San Diego Gas and Electric, was signed in September 1980.
- 5 MWe Binary Cycle Pilot Plant at Raft River, Idaho. Work on construction was completed and the system is being checked out. Additional well tests were begun.
- 3 MWe Wellhead Generator System near Puna, Hawaii. Construction is under way.
- Geothermal Loop Experimental Facility (GLEF), located near Niland, California. The GLEF has established the

feasibility of using flash-steam binary systems for electric power production from high-temperature, high-salinity resources. The facility was decommissioned in FY 80. The data derived from the facility prompted Magma Power Company to agree to construct and operate a 28 MWe (gross) plant on the site.

- Geothermal Component Test Facility (GCTF). The facility, constructed in 1975, 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, California, the GCTF was used by several DOE-sponsored and independent experimenters.

By the end of FY 1980, 42 technical and economic feasibility studies of direct heat applications had been supported by DOE; 34 of these studies have been completed, 11 in FY 1980. A competitive solicitation covering cost-shared industrial applications was issued near the end of FY 1980. This led to the support of eight new studies, four involving direct heat use for ethanol plants.

Twenty-four cost-shared direct heat demonstration projects were underway at the end of FY 1980. The majority of these projects were for space and district heating, while four were directed toward agribusiness, and three involved industrial processing. Ten of these experiments had reached the construction stage and five field experiments were in the reservoir confirmation phase. The following five projects were in operation at the end of FY 1980:

- Haakon, SD - space conditioning for 5 school buildings
- Klamath Falls, OR - space conditioning and hot water for YMCA
- Midland, SD - agricultural uses on ranch
- Truth or Consequences, NM - space conditioning for a hospital
- Pierre, SD - space conditioning for a hospital

The Geothermal Loan Guarantee Program had guaranteed parts of six loans, for five projects, by the end of FY 1980. The guarantees from this program totalled \$136.0 million for projects totalling \$202.7 million in cost. Two projects were approved for loan guarantees of \$94.4 million in FY 1980. Four of these projects will add 258 MWe (gross) to current electric power production. Another project provides 117 billion Btu/year for food processing.

HYDROTHERMAL TECHNOLOGY DEVELOPMENT

The recovery of geothermal energy has been accomplished through the use of an evolving technology. The techniques used by the oil

and gas industry for exploration and reservoir evaluation are being adapted by the geothermal industry to high-temperature, high-salt content environments. Similarly, existing steam and organic-fluid turbines are being adapted to geothermal conditions. The FY 1980 activities of this DOE program were focused on research and development activities that were considered by industry to be too expensive or risky to undertake.

The areas of technology development described below apply primarily to hydrothermal resources, because this resource appears to be the most likely candidate for immediate development. These development efforts have been aimed at reducing the costs of geothermal exploration, resource assessment, and field development; reducing capital costs of geothermal facilities; and improving resource utilization efficiency.

Reservoir Evaluation Technology

The purpose of reservoir evaluation technology, which includes exploration technology, reservoir engineering, and well logging instrumentation and interpretation, is to locate hydrothermal reservoirs more accurately, measure their properties, and predict their behavior. These activities are conducted primarily by USGS and DOE.

Exploration Technology: Exploration technology activities seek to develop more reliable and cost effective techniques for locating and identifying geothermal resources, and especially to improve the success ratio of geothermal exploratory wells. In FY 1980:

- A strategy of exploration for high-temperature hydrothermal systems in the Rocky Mountain Basin and Range Province was developed, based on exploration data that were generated by DOE's Industry-Coupled Program. The strategy features a balance of geological, geochemical, geophysical, hydrological, and drilling activities for locating and confirming high-temperature resources. It can be adapted to the search for lower-temperature resources.
- The use of trace elements as geothermal exploration tools was demonstrated. Analysis of trace elements in drilling chips and bore samples provides valuable information on the location of production zones in drill holes.
- Three-dimensional forward and inverse solutions were developed for interpreting exploration data obtained using resistivity and magnetotelluric techniques. This permits topographic variations, layering, and other structural

features to be introduced into the algorithms, providing for a more meaningful interpretation of the data.

- An automated seismic processor was successfully field tested at The Geysers geothermal field in California. The processor is used to obtain microearthquake data that can be used in identifying and delineating hydrothermal reservoirs.
- Studies were initiated to: (1) Improve or refine geothermometry techniques that are used to estimate the temperature of fluids at depth of geothermal systems, (2) Investigate the use of microearthquakes as a geothermal exploration tool, and (3) Evaluate the effects of water-rock interaction in the evaluation of geothermal reservoir systems.

Reservoir Engineering: Reservoir engineering attempts to develop a basic understanding of the nature of hydrothermal reservoirs, including the distribution of temperature, pressure, porosity, salinity of fluid, and permeability. Numerical models use these factors to predict reservoir production capacity and longevity. In FY 1980:

- A numerical code was developed that simulates transient fluid flow in a fracture propagating through a porous medium. It is applicable to the study and design of hydraulic fracturing experiments.
- A transient, two-phase well-bore simulator was completed for use in calculating transient flow in the bore during pressure buildup tests.
- A two-phased, multidimensional geothermal reservoir simulator was developed. It can be used in solving a variety of problems related to real reservoir behavior, and to provide a better understanding of the physics of two-phase systems.
- Reservoir simulation codes that have been developed by reservoir engineering groups were evaluated and compared to provide greater confidence in these simulators on the part of financial institutions, utilities, and investors who must rely on their use for estimates of reservoir production and longevity.

Well Logging Instrumentation and Interpretation: Logging instrumentation activities have been aimed at upgrading tool capabilities from the present rating of 180°C to 275°C, in order to take in the upper range of geothermal temperatures. DOE log

interpretation activities seek to analyze problems in data interpretation caused by significant differences between hydrocarbon and geothermal wells. Calibration facilities for industrial plants continue to be provided as part of this effort. Projects have been coordinated with industry in an effort to test and evaluate new concepts. A major achievement was realized in FY 1980 with the production of 50 commercial hybrid logging circuits by Teledyne Philbrick, Inc.

Well Drilling and Completion Technology

The purpose of this DOE program has been to provide the technology to reduce the cost of geothermal drilling through improvements in drill bits, downhole motors, and drilling fluids. In FY 1980:

- Further tests were conducted on a continuous chain drill, leading to a design incorporating all Stratapax (polycrystalline diamond) cutters.
- A new, high-temperature drilling mud was developed, and is now used commercially for geothermal drilling in the Imperial Valley of California.
- Further field tests were run to evaluate drill bits with polycrystalline diamond cutters.

Well Stimulation Technology

The DOE geothermal well stimulation program was built upon the technology utilized by the oil and gas industry to increase production from geothermal wells. The program develops specialized geothermal hardware, stimulation treatments, and data analysis methods, and conducts field demonstration experiments at specific sites. In FY 1980:

- Two wells at the Raft River site in Idaho were treated by hydraulic fracture. The analysis of results showed improved flows for one of these moderate-temperature wells.
- In East Mesa, California, two treatments on two different zones in a well were performed. Both levels were hydraulically fractured, with the result that production was more than doubled and overall fluid temperature was increased.

Conversion Technology

The purpose of the DOE conversion technology program was to reduce the cost of generating electricity from geothermal resources. Emphasis has been placed on developing technologies for exploitation of moderate-temperature (150-200°C) hydrothermal reservoirs which are more prevalent than the higher-temperature ones. In FY 1980:

- A 500 kWe binary power system employing a direct contact preheat/boiler was installed and operated at the DOE Geothermal Test Facility (GTF) at Holtville, California. The boiler and associated working fluid recovery and noncondensable gas removal systems have exceeded design performance goals.
- An electric downhole pump designed and built for DOE ran nearly six months at the GTF before failing. The pump was modified several times during the year as design improvements were identified by analysis of failure modes. This project extended previous pump operational life sixfold.
- A large diameter well was drilled and cased for the development and field test of a 4.2 MW "gravity head" binary power plant that could achieve 35 percent better brine utilization than conventional binary systems.
- Several months of unattended continuous operation of a 60 kWe binary power plant provided new data on the reliability of binary systems.
- A 1 MWe total flow wellhead power plant utilizing a helical screw expander was installed and tested at Cerro Prieto, Mexico, under a cooperative program of the International Energy Agency.

Geochemical Engineering and Materials Handling

This program, managed primarily by DOE, focused on fluid handling and materials problems related to geothermal drilling, plant construction, and fluid production and reinjection. Progress in FY 1980 included:

- Projects to develop polymer concrete for pipes and pressure vessels and corrosion-resistant seals for casings, drill pipes, and energy conversion equipment.

- Activities to characterize injected particulate materials, develop and field test injection well maintenance procedures, and evaluate chemicals and scale resistant materials for scale control. Applied development activities in the field and laboratory evaluated hydrodynamic effects as a possible means for mechanically controlling scale formation and removal.
- Improved drill pipe, casings, and cements designed for higher-temperature service were being developed in programs cost-shared by industry and the governments of the Federal Republic of Mexico and Italy.
- Projects to screen, develop, and commercialize bearing, seal, and corrosion-resistant construction materials for down-hole pumps.
- Technology transfer through the formation of a major ASTM committee on geothermal resources and energy. A major Geothermal Engineering and Materials Technology Transfer Conference was scheduled for the fall of FY 1981.
- Geobrines research conducted by the Bureau of Mines studied methods of recovering minerals from geobrines and examined the effects of geobrines on construction materials. Minerals recovery processes under study included a bulk precipitation technique, demonstrated at Niland, California, and a selective sulfide process to recover lead and zinc and other metal values from highly saline geobrines.

Geobrines Desalination

Interior's Water and Power Resources Service continued its program to desalt geothermal brines using heat energy inherent in geothermal fluid to augment water supplies in the Southwest. Field investigations, including a number of shallow test holes and geophysical tests, were completed at several promising sites. The data were to be analyzed for potential geothermal use and to determine whether to continue investigations through more detailed resource assessments.

GEOPRESSURED RESOURCES

The geopressured resource base is unquestionably large, but little is known about the economics of recovering its methane, thermal, and hydraulic energy. Hence, geopressured energy use is viewed as a midterm probability. FY 1980 activities by DOE

concentrated on resource evaluation work and preparation for the testing of geopressured wells:

- Final preparations were made for long-term testing of the geopressured well in Brazoria County, Texas.
- An existing gas well in Louisiana was reworked prior to geopressured aquifer testing, and negotiations were completed for four additional existing oil or gas well tests in the Gulf Coast.
- Two new geopressured drilling projects for designed production wells in Louisiana were started, and a solicitation for proposals was issued for the drilling of four additional geopressured wells in Louisiana and Texas.

HOT DRY ROCK RESOURCES

The hot dry rock resource base is very large, and extensive use of energy from hot dry rock is a long-term possibility. In FY 1980 DOE efforts included:

- Generation of sixty kilowatts of electricity on a continuous basis at the Fenton Hill, New Mexico research installation, demonstrating the technical feasibility of electric power production from hot dry rock resources.
- Completion of the first well of a commercial-scale, 20-50 MWt loop at Fenton Hill. The original thermal loop was expanded from an effective surface area of 8,000 square meters to about 50,000 square meters; the enlarged loop was operated continuously for over 7 months.
- Completion of geological evaluations near Mountain Home, Idaho, and Crisfield, Maryland, as part of an effort to select a second hot dry rock demonstration site.
- Publication of a national thermal gradient map.
- Execution of a cost-shared agreement with the Federal Republic of Germany for participation in the Fenton Hill hot dry rock project, under the auspices of the International Energy Agency.

GEOSCIENCES RESEARCH

The Geosciences Research Program of DOE's Office of Energy Research develops geoscience information of relevance to geothermal

energy exploration and development. Projects in progress during FY 1980 included:

- Seismic research in northern New Mexico. This research analyzed seismic data collected from a network of seismic stations to investigate geodynamics of the rift where several major tectonic regions (Colorado Plateau, Basin and Range, Rio Grande Rift, and Southern Rockies and Great Plains stable area) intersect.
- Seismic velocity variations and attenuation of delineated geothermal reservoirs. Results from field measurement may provide the basis for improved, high-resolution sonic well logging techniques, with particular application to geothermal reservoir evaluation.
- Reservoir dynamics related to geothermal energy development. A study was begun to understand the behavior of reservoir pressure and temperature when a doublet of one production and one injection well is present.
- Thermodynamics of high-temperature brines. Theoretical and experimental studies of solution thermodynamics of strong aqueous aquifers over a wide temperature range were initiated to provide essential information for technical utilization of several geothermal resources.
- Geology and geophysics of magma. This focuses on understanding structures, tectonics, and evaluation of potential geothermal resources and properties of reservoirs with special emphasis on thermal regimes of the Jemez Lineament and the Northern Rio Grande Rift.
- Magma energy research. This project included five research tasks designed to assess the scientific feasibility of extracting energy directly from buried magma sources: (1) magma source location and definition, (2) magma source tapping, (3) magma characterization, (4) magma/material compatibility, and (5) energy extraction.
- Continental Scientific Drilling Program: Thermal Regimes. This effort was aimed at developing an understanding of the heat and mass transfer within and between magma and hydrothermal systems, and the evaluation of hydrothermal magma systems in space and time, through the utilization of drilling to obtain samples and data and to conduct downhole experiments.

ENVIRONMENT

Several accomplishments in the areas of environmental control technology and methodology were achieved during FY 1980. These achievements should help encourage geothermal energy development from the standpoint that fewer environmental impediments exist. Progress in the environmental control area included:

- A technology assessment integrating environmental, health, and socioeconomic impacts of full-scale development of geothermal resources in the Imperial Valley of California was completed by DOE. This study will serve as a basis for understanding liquid-dominated resources in other regions of the country.
- The Pacific Gas and Electric Company (PG&E), under a Cooperative Agreement with DOE and EPA, completed pilot scale tests of an H₂S removal process for geothermal steam developed by the EIC Corporation. A pilot scale field test documented H₂S emissions abatement efficiencies to 99.996 percent and led PG&E to announce that they planned to build a full-scale emissions control plant at their Geysers site.
- The clarifier developed at the DOE-sponsored Geothermal Loop Experimental Facility at Niland, California was turned over to Magma Power, Inc. for their use in controlling solid wastes on a 28 MW geothermal power plant planned at the site.
- A major National Environmental Policy Act (NEPA) compliance activity involved the 50 MWe Geothermal Demonstration Power Plant on the Valles Caldera, New Mexico. The final environmental impact statement (EIS) for this project was prepared, approved and issued. A Record of Decision (ROD) was issued, documenting the decision by DOE to proceed with the project.
- The Environmental Protection Agency (EPA) began revising Prevention of Significant Deterioration (PSD) regulations under the Clean Air Act. Hazardous Waste Disposal and Underground Injection Control regulations were issued under the Resource Conservation and Recovery Act and the Safe Drinking Water Act respectively. EPA continued to evaluate potential regulatory actions with regard to H₂S control, hazardous wastes from geothermal operations, and solid and liquid waste disposal.

FEDERAL USE OF GEOTHERMAL ENERGY

The Department of Defense (DOD) continued to study the feasibility of using geothermal energy at military bases throughout the U.S. and abroad. By the end of FY 1980, DOD had the following geothermal projects in the planning or initiation phase:

- Adak Naval Station, Adak, Alaska - space heating and electric power generation
- China Lake Naval Weapon Center, Coso, CA - electric power generation
- Fallon Naval Air Station, Fallon, NV - electric power generation
- Hill Air Force Base, Utah - space heating
- Keflavik Naval Station, Iceland - space heating; construction is under way
- Norfolk Naval Station, Norfolk, VA - space heating
- Williams Air Force Base, Arizona - space cooling and electric power generation
- Kings Bay, GA - space heating; DOE/DOD-sponsored exploratory well drilled
- MX Weapon System - electric power generation in Nevada and Utah for MX system and its support facilities.

INTERNATIONAL ACTIVITIES

At the end of FY 1980, worldwide installed geothermal electric capacity was 2,475 MWe among 14 countries. There were twelve countries with significant direct use of geothermal energy totalling 8,300 MWt for space conditioning, water heating, agricultural and industrial applications.

DOE was involved with three multilateral cooperative efforts through the International Energy Agency and had bilateral agreements with Italy, Mexico and Japan at the end of FY 1980.

The 1.2 MWe geothermal power system (helical screw expander) developed by DOE began a program of research and development and demonstration of geothermal equipment involving test sites in

Mexico, Italy and New Zealand under an International Energy Agency multilateral agreement.

PROGRAM COORDINATION

The IGCC prepared the first (FY 1981) Federal Geothermal Program Plan, which provides an integrated overview of the geothermal program and activities of the IGCC member agencies. The Plan presented objectives, strategy, and planned activities for geothermal development. It identified inconsistencies in the overall program and made recommendations for improving program effectiveness.

DOE published four issues of the Geothermal Progress Monitor Report. The report was produced by the Geothermal Progress Monitor System, which is designed to collect and compile information about geothermal activities. The report served program management functions for the member agencies of the IGCC.

The report of the IGCC Environmental Controls Panel, entitled "Status of Environmental Controls for Geothermal Energy Development", was prepared. This report assessed the adequacy of existing environmental controls for geothermal energy systems, reviewed ongoing programs to develop environmental controls, and identified controls-related research areas where Federal efforts are appropriate and necessary.

STATE GOVERNMENT ACTIVITIES

Although the primary governmental funding source for geothermal projects has been at the Federal level, state energy offices have provided increased financial and technical assistance support to geothermal energy applications. Many states have helped localities to develop and implement district heating systems, food processing plants, and numerous other projects. FY 1980 saw a significant proliferation of state assistance for resource assessment and other exploratory activities.

State legislative and regulatory bodies have demonstrated a concern about the ramifications of developing hot-water reservoirs, as reflected in many proposed bills and enacted laws defining the nature of geothermal fluids. Issues of mineral rights, water rights, ownership, permitting, and leasing are paramount. Regulations to ensure adequate environmental protection measures are being formulated.

CONCLUSION

The Federal Geothermal Program made significant advances in FY 1980, especially in the areas of making geothermal resources available for development by industry, development of energy extraction and conversion technology, and assessment of the technical/economic feasibility of extracting energy from geopressured, hot dry rock, and magma resources. FY 1980 also saw State and local governments gaining momentum in both the governance and advancement of geothermal energy development.

It is the belief of the IGCC that geothermal energy can be a clean, safe, and economical source of electric power and direct heat. Electric power production from the higher quality hydrothermal resources and direct heat use from the lower quality resources are technologically feasible today. Widespread geothermal power will become increasingly available as research and development yield technologies appropriate for electric power production from moderate temperature fluids, for discovery of new hydrothermal reservoirs, and for economic extraction of energy from geopressured and hot dry rock resources.

APPENDIX TO THE FIFTH ANNUAL REPORT
OF THE INTERAGENCY GEOTHERMAL
COORDINATING COUNCIL

This appendix amplifies several important matters referred to in the body of the report.

THE INTERAGENCY GEOTHERMAL COORDINATING COUNCIL

The Interagency Geothermal Coordinating Council (IGCC) consists of the Federal agencies which participate in the geothermal program. The IGCC is responsible for oversight and coordination of the activities of the Federal geothermal community. That responsibility is spelled out in the Geothermal Research, Development, and Demonstration Act of 1974 (PL 93-410), specifically:

"...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."

At the end of FY 1980, the Council consisted of:

- Assistant Secretary for Resource Applications, Department of Energy (Chairperson)
- Assistant Secretary for Natural Resources and Environment, Department of Agriculture
- Assistant Secretary for Energy and Minerals, Department of the Interior
- Assistant Secretary for Community Planning and Development, Department of Housing and Urban Development
- Assistant Administrator for Research and Development, Environmental Protection Agency
- Assistant Secretary for Economic Policy, Department of the Treasury
- Assistant Secretary for Policy, Department of Commerce

- Assistant Secretary of Defense (Manpower, Reserve Affairs, and Logistics)

Six major staff subgroups assist the Council. The Staff Committee, chaired by a representative of DOE, supports the Council and manages the other groups. The Budget and Planning Working Group coordinates budgets and agency plans for geothermal energy activities. The Institutional Barriers Panel is responsible for assessing legal, environmental, regulatory, and other aspects of Federal, state, and local government policy as they relate to geothermal energy. The Leasing and Permitting Panel has responsibility for reviewing, analyzing, evaluating, and reporting on existing and proposed legislation and regulations relating to the leasing and permitting of geothermal resources and development on public lands. The Environmental Controls Panel assesses the adequacy of existing controls for geothermal energy systems, reviews ongoing programs to develop environmental controls, and identifies areas for increased or reduced Federal support. The Financial/Grants Task Force is responsible for determining what Federal funding programs may be applicable to geothermal development projects, and for delineating the total Federal assistance potentially available to help meet geothermal objectives.

RESOURCES AND DEVELOPMENT

Figure A-1 is a map of the known and potential hydrothermal resources of the United States. The most promising resources are in the West, and many other areas have useful potential.

Selected significant events in the commercial and Federal development of geothermal energy are shown in Table A-1.

LEASING OF FEDERAL LANDS

Table A-2 shows the acreage leased in 1974 through 1980 through competitive leases of Federal lands in Known Geothermal Resource Areas.

Table A-3 shows the cumulative acreage leased in 1976 through 1980 through noncompetitive leases of Federal lands not in known Geothermal Resource Areas. Table A-4 shows the status of all noncompetitive lease applications, by state, as of September 30, 1980.

GEOHERMAL DIRECT HEAT PROJECTS

Table A-5 lists the completed technical and economic feasibility studies of direct heat use of geothermal fluid, conducted as part of the DOE Hydrothermal Commercialization effort. Table A-6 describes the geothermal direct heat application demonstration projects initiated by DOE during the past few years, and their status at the end of FY 1980.

ENVIRONMENTAL CONTROLS RESEARCH NEEDS

The Environmental Controls Panel of the IGCC met frequently in FY 1980 to assess the needs for Federal R&D for environmental controls for geothermal energy systems. The panel reported that current environmental controls are not adequate, and that continued and redirected Federal R&D is necessary if environmental controls are to be adequate by 1985.

The Panel developed extensive recommendations for R&D, funding requirements, timing, and agency responsibilities, in a report, "Environmental Controls Research Strategy for Geothermal Development". The top priorities for R&D identified by the Panel are:

- Hydrogen sulfide (H_2S) emission - H_2S controls for power plants and H_2S steam stacking/well emission controls;
- Non- H_2S gaseous emissions characterization and controls development;
- Solid waste characterization and management evaluation;
- Injection monitoring; and
- Methods for subsidence prevention, prediction, and control.

FIGURE A-1
KNOWN AND POTENTIAL HYDROTHERMAL RESOURCES

TABLE A-1

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

1894	District Heating Is Installed In Boise, Idaho
1900	Hot Water Is Supplied to Homes in Klamath Falls, Oregon
1916	Power Is Generated At Geysers Resort
1927	First Exploratory Geothermal Wells Are Drilled in Imperial Valley, California, by Pioneer Development Company
1959	Small Pilot Plant Is Operated Near Niland, California, on Sinclair No. 1 Well
1960	Commercial Electricity Is Generated From Dry Steam at The Geysers (California)
1970	Geothermal Steam Act Is Passed (PL 91-518)
1972	NSF Became Lead Agency for Federal Geothermal Programs
1973	USGS, AEC, NSF Prepared First Federal Geothermal Program
1974	Geothermal RD&D Act Is Passed (PL 93-410) First Federal Lands Are Leased for Geothermal Development
1975	ERDA Is Formed; Division of Geothermal Energy Is Formed Primarily from NSF, AEC Staff USGS Released First Geothermal Resource Estimates and Inventory
1977	DOE Is Formed; DGE Is Kept Intact
1978	Energy Tax Act Is Passed (PL 95-618) EPA Issued Pollution Control Guidelines for Geothermal Energy Development Successful Hot Dry Rock Experiment Is Conducted (New Mexico) First Geothermal Crop-Drying Plant Began Operations (Nevada)

TABLE A-1 (CONCLUDED)

1979	<p>USGS Released Updated National Geothermal Resource Estimates and Inventory</p> <p>Streamlining Task Force Recommended to IGCC Measures To Speed Federal Leasing.</p> <p>First Geothermal Electricity Is Produced from Federal Lands, at The Geysers (California)</p> <p>World's First Commercial Binary Cycle Plant (10 MWe) Is Built by Industry at East Mesa, California</p>
1980	<p>World's Largest Single Geothermal Power Facility (129 MWe) Generated Electricity at The Geysers, California</p> <p>10 MWe Flash-Steam Plant Is Built by Industry at Brawley, California</p> <p>First Electric Power from a Hot Dry Rock Resource Is Produced at Fenton Hill, New Mexico</p> <p>First Geothermal Ethanol Plant Began Production at La Grande, Oregon, under Private Funding</p> <p>First 5 DOE-Sponsored Field Demonstrations of Direct Heat Applications Became Operational</p> <p>First Deep Geothermal Reservoir Confirmation Well Is Drilled in Atlantic Coastal Plain, near Crisfield, Maryland</p> <p>Crude Oil Windfall Profits Tax Act Is Passed -- Provides Tax Credit Increase for Geothermal Equipment (PL 96-223)</p> <p>Energy Security Act, Containing Title VI, "The Geothermal Energy Act of 1979," Is Passed (PL 96-294)</p>

TABLE A-2

COMPETITIVE LEASING BY STATE, TOTAL ACREAGE LEASED, BY YEAR

STATE	1974	1975	1976	1977	1978	1979	1980 ^a	TOTAL
Nevada	31,499	28,557	60,940	36,663	9,322	21,920	13,407	202,308
Utah	23,400	26,171	26,968	12,788	1,658	-0-	-0-	90,985
New Mexico	-0-	18,476	14,088	48,065	8,767	7,062	-0-	96,458
Oregon	1,347	47,689	19,836	-0-	5,818	-0-	19,523	94,213
California	26,354	10,583	-0-	2,856	4,395	6,958	-0-	51,146
Idaho	-0-	20,963	3,940	6,985	-0-	-0-	-0-	31,888
Colorado	-0-	5,036	-0-	-0-	-0-	-0-	-0-	5,036
Total Acres Leased	82,600	157,475	125,772	107,357	29,960	35,940	32,390	572,034

^aSeptember 30, 1980

TABLE A-3
CUMULATIVE NONCOMPETITIVE LEASE TOTALS, 1976-1980

Year*	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
1980	8,243	4,457	2,111	1,675	2,933,901

*Year ends June 30 until 1979, thereafter September 30. Data for 1980 are for 15 months.

TABLE A-4
NONCOMPETITIVE GEOTHERMAL LEASING, 1980

<u>LEASE APPLICATIONS</u>								
STATE	<u>FILED</u>			<u>INACTIVE</u>			<u>AWAITING ACTION</u>	
	BLM	FS	SUBTOTAL	WITHDRAWN	REJECTED	REFUSED	BLM	FS
Alaska	0	0	0	0	0	0	0	0
Arizona	108	73	181	15	35	8	49	61
California	786	514	1,300	431	307	11	265	262
Colorado	113	83	196	100	17	2	4	23
Idaho	670	375	1,045	279	175	30	188	207
Montana	38	66	104	64	28	0	6	0
Nevada	2,077	77	2,094	676	417	78	151	19
New Mexico	676	42	718	354	87	12	118	19
Oregon	673	620	1,293	270	302	0	88	406
Utah	647	113	760	118	160	23	64	34
Washington	0	376	376	160	70	0	0	144
Wyoming	26	138	164	141	16	0	1	2
Eastern States	0	12	12	0	1	0	0	0
TOTALS	5,814	2,429	8,243	2,678	1,615	164	934	1,177

<u>LEASES ISSUED</u>						
	<u>NUMBER</u>			<u>ACRES</u>		
	BLM	FS	SUBTOTAL	BLM	FS	SUBTOTAL
Alaska	0	0	0	0	0	0
Arizona	12	1	13	19,621	1,920	21,541
California	25	0	24	35,147	0	35,147
Colorado	43	5	50	52,394	10,099	62,493
Idaho	165	1	166	291,385	2,560	293,945
Montana	6	0	6	10,687	0	10,687
Nevada	750	3	753	1,378,225	4,434	1,382,659
New Mexico	128	0	128	231,179	0	231,179
Oregon	202	25	227	317,091	40,154	357,245
Utah	279	12	291	492,038	14,653	506,693
Washington	0	2	2	0	5,120	5,120
Wyoming	0	4	4	0	7,448	7,488
Eastern States	0	11	11	0	19,744	19,744
TOTALS	1,611	64	1,675	2,827,767	106,134	2,933,901

(1) Applications awaiting action for the following reasons:

27	Awaiting KGRA report from USGS	1,069	Awaiting comment of other agencies
5	Preliminary plan of development	31	Lease forwarded for signature
701	Pending preparation of EAR (BLM only)	278	Processing (Adjudication)-BLM

TABLE A-5

COMPLETED TECHNICAL AND ECONOMIC FEASIBILITY STUDIES

PROJECT	LOCATION
<u>District and Institutional Heating</u>	
Mini Core District System	*Glenwood Springs, CO
Municipal Waste Treatment	
Community District System	*Lakeview, OR
District System for 1,000	*Poplar, MT
Planned Homes, Fort Peck	
Indian Reservation	
University of New Mexico	*Albuquerque, NM
Campus System	
District Heating	Mammoth Lakes, CA
District Heating with	Susanville, CA
Possible Augmentation	
Six Rural Alaskan Towns	AK
District Heating for	Alamosa, CO
Baca Grand Community	
Space Heating for Edgemont	Edgemont, SD
School Complex	
District Heating and Cooling	El Centro, CA
System Including	
Industrial Park	
Space Heating	Midland and Philip, SD
Space Heating and	City of Desert Hot Springs, CA
Agribusiness	
District Heating	Boise City, ID
<u>Agribusiness</u>	
Salmon Aquaculture	Alaska
Livestock Controlled	Susanville, CA
Environment	
Agribusiness	Lake, Napa, and Sonoma
	Counties, CA
Greenhouse Corps, Mushroom	Lake County, CA
Culture, Fish Farming,	
and Biogas Generation	
Vertically Integrated Live-	Mountain Home, ID
stock, Meat and Feed	
Processing Facility	
Integrated Feed Lot and	*Vale, OR
Farming Operation Producing	
Methane from Animal Waste	
Control Livestock Production	CA and NV
System	

TABLE A-5 (Continued)

PROJECT	LOCATION
<u>Industrial Process Heat</u>	
Sugar Cane Processing	Puna, HI
Industrial Park	*Pahoa, HI
Wetcorn Milling Plant	*East Mensa, CA
Hosiery Factory	*Las Cruces, NM
Frozen Food Plant	*Salisbury, MD
Sugar Beet and Barley Processing	*San Luis Valley, CO
Food Processing Using Geopressured/Geothermal Resources	Louisiana Geopressured Resources
Holly Beet Sugar Refinery	Imperial Valley, CA
Fertilizer Production, Valley Nitrogen	Heber KGRA Near El Centro, CA
Potato Processing, Onion Dehydration, Alfalfa Drying, Greenhouses, and Sugar Refinery Feasibility	Klamath and Snake River Basin, OR
Refrigeration for Food Processing Including Freeze Drying and Meat Packing	Raft River, ID; Weiser-Crane Creek, ID; Vale, OR; Coos Hot Springs, CA; and Imperial Valley, CA
Industrial Complexes, Including Forest Products, Caustic/Chlorine, and Corn Products	Calistoga, CA; Brawley, CA; Surprise Valley, CA; Lakeview, OR; Vale, OR; Bruneau Granview, ID; Steamboat Springs, NV; Core/Ft. Sulphurdale, UT
Ethanol Production for Automotive Fuel Use	*Raft River, ID
Alfalfa Dehydration Plant	El Centro, CA
Evaluation/Crystallization Industry, Including Tomato Paste Processing, Sugar Beet Refining, and Sodium Chloride Production	Not Site-Specific
Tungsten Ore Mining & Processing	Mons Lake, CA

*Study completed in FY 1980.

TABLE A-6

DIRECT HEAT APPLICATION DEMONSTRATION PROJECTS

State	Operator & Location	Type of Use	Operation First Year	BTU/Yr (Billions)	Project Dev. Phase in FY 80
CA	City of Susanville Susanville, CA	SP	1982	41.0	Reservoir Confirmation
CA	City of El Centro El Centro, CA	SP	1982	7.0	Reservoir Confirmation & Design
CA	Geothermal Power Corp. Kallay Hot Springs, CA	AG	1982	81.9	Environmental Assessment
CA	Aquafarms International Mecca, CA	AG	1981	171.0	Construction
CA	Holly Sugar, Inc. Brawley, CA	IND	1982	144.0	Reservoir Confirmation & Design
CO	Town of Pagosa Springs Pagosa Springs, CO	DH	1982	14.0	Construction
ID	City of Boise Boise, ID	DH	1981	95.0	Environmental Assessment & Design
ID	Ore-Ida Foods Boise, ID	IND	-	-	Project Terminated
ID	Rogers Food, Inc. & Madison County Madison County, ID	SP&IND	-	-	Under Review
MT	Warm Spring State Hosp. Butler, MT	SP	-	6.4	Under Review
NV	Hydro Energy Corp. Reno, NV	SP	1981	0.1	Reservoir Confirmation & Design
NV	Elko Heating Co. Elko, NV	SP	1982	42.0	Reservoir Confirmation & Design
OR	City of Klamath Falls Klamath Falls, OR	DH	1981	35.4	Construction

TABLE A-6 (Continued)

State	Operator & Location	Type of Use	Operation First Year	BTU/Yr (Billions)	Project Dev. Phase in FY 80
OR	Klamath City YMCA Klamath Falls, OR	SP	1980	5.0	Operational
SD	Haakon & Philips Schools Haakon, SD	SP	1980	5.2	Operational
SD	St. Mary's Hospital Pierre, SD	SP	1980	8.4	Operational
SD	Diamond Ring Ranch Midland, SD	AG	1980	5.5	Operational
TX	Torbett-Hutchings-Smith Hospital Marlin, TX	SP	1981	0.1	Construction
TX	Navarro College Corsicana, TX	SP	1981	0.1	Reservoir Confirmation
UT	City of Monroe Monroe, UT	DH	-	-	Under Review
UT	Utah State Prison Salt Lake City, UT	SP	1981	21.0	Reservoir Confirmation
UT	Utah Roses, Inc. Salt Lake City, UT	AG	1981	97.0	Reservoir Confirmation

SP - Space Heating and/or Cooling
 DH - District Heating
 AG - Agribusiness
 IND - Process Heat