**Third Annual Report
Geothermal Energy
Research Development
& Demonstration Program**

Interagency Geothermal Coordinating Council

Member Agencies

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PREFACE

This is the third annual report on the Federal Geothermal Energy Program, and was prepared by the Interagency Geothermal Coordinating Council (IGCC), chaired by the Assistant Secretary of Energy Technology, Department of Energy. Geothermal energy development was significantly advanced during FY 1978, and this report presents the major accomplishments of the Federal Program and some private-sector accomplishments during FY 1978. (October 1, 1977 - September 30, 1978)

John M. Deutch, Chairman

Interagency Geothermal
Coordinating Council

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GEOTHERMAL ENERGY AT THE GEYSERS

Courtesy of Pacific Gas and Electric Company

EXECUTIVE SUMMARY

The objectives of the Federal Geothermal Energy Program are to define the resource, to develop economically viable and environmentally acceptable utilization technology, and to reduce institutional barriers in order to make geothermal energy competitive with available alternative energy resources. The strategy of the Federal program is to accelerate the commercial development of hydrothermal resources through the 1980s, to stimulate initial development of geopressured resources by the mid-1980s, and to promote initial development of hot dry rock resources by the year 2000. To accomplish this, the Federal government will have to demonstrate the desirability of developing geothermal resources, particularly in terms of economic viability and environmental acceptability. In FY 1978, the IGCC and its member agencies took enormous strides in that direction.

Significant progress has been made in establishing a legal and institutional framework that will encourage rapid, orderly development of geothermal resources.

- The passage of the National Energy Act dramatically improved the financial attractiveness of investment in geothermal resource development and utilization projects.
- Modifications to the loan guaranty program enacted in February 1978 in PL 95-238 enhanced the effectiveness of that program and made it more attractive to lenders as well as borrowers.
- A Streamlining Task Force, meeting several times over the course of the year, developed a set of proposals to streamline Federal geothermal leasing and environmental procedures; recommendations will be prepared for implementation by member IGCC agencies and a report will be made available in 1979.
- The Institutional Barriers Panel recommended other changes to reduce impediments to geothermal development; several of these already have been implemented.

The Bureau of Land Management (BLM) offered over 200,000 acres of Federal land (administered by BLM and the U.S. Forest Service) for competitive lease in FY 1978. Approximately 60,000 acres were leased, for over \$1 million. Tentative schedules have been established for both competitive and noncompetitive lease offerings in FY 1979. More than 30 areas will be offered for lease throughout the year.

The U.S. Geological Survey reassessed the geothermal resources of the United States, updating and refining the 1975 national assessment; this new assessment has been published as USGS Circular 790.

To date, the DOE Geothermal Loan Guaranty Program (GLGP) has received 12 applications for loan guaranties in hydrothermal development. Three have been processed and a fourth is near completion. It is expected that tax measures included in the National Energy Act will stimulate participation in geothermal development by additional investors. In FY 1978, the GLGP received a loan guaranty application from the Northern California Power Agency (a consortium of 13 communities) to construct a 110 MWe power plant, scheduled for completion in 1982. In FY 1979, the GLGP expects to approve loan guaranties in the amount of \$82.1 million. A loan guaranty application for construction of a 50 MWe power plant at Roosevelt Hot Springs, Utah, is anticipated, and six applications for loans amounting to \$115 million also are expected.

At East Mesa, California, Imperial Magma Power Company's construction of a 10 MWe pilot plant neared completion. The binary-cycle plant is expected to begin operation in mid-FY 1979. Financed entirely by the private sector, the plant should enable Imperial Magma to carry out reservoir testing, and to demonstrate a patented process for energy extraction. If technically and economically successful, the pilot plant should lead to larger plants at East Mesa, and will encourage Magma to lease other low-temperature resource sites.

At The Geysers (Cal.), completion of four 110 MWE units in late FY 1979 will bring PG&E's total capacity at The Geysers to 900 MW.

At Puna, Hawaii, development is proceeding faster than anticipated, and the IGCC-postulated generating capacity of 20 MWe may be achieved earlier than 1985. Progress has been hastened by the initiation of a DOE/state/county/industry cost-shared effort that should demonstrate the commercial viability of utilizing the very high temperature (around 365°C) hydrothermal reservoir recently defined at the Puna site.

At Valles Caldera, N.M., preliminary work on the DOE/industry cost-shared 50 MWe geothermal demonstration plant will be completed in FY 1979.

With regard to other field activities:

- Comprehensive tests of the thermal loop were completed at the jointly funded industry/DOE Geothermal Loop Experimental Facility (GLEF) near Niland, California. High salinity brine was successfully used and reinjected.
- The first evaluation of the role of wellhead generators was begun by the Hawaii Geothermal Project Development Group, a project jointly funded by the public and private sectors. Preliminary designs of a 5 MWe wellhead generator were completed.
- Well drilling and detailed engineering designs were completed for the Raft River, Idaho, Thermal Loop Facility. Construction continued on the first 40 MWt thermal loop.

- The Los Alamos Scientific Laboratory hot dry rock thermal loop operated for 2-1/2 months, and first steps were taken toward developing a 40-50 MWt energy extraction loop at Fenton Hill, N.M.

The broad objective of technology development is to bring the technologies required for geothermal development to a point of readiness for practical application.

In FY 1978:

- Data from the Cerro Prieto, Mexico, geothermal field were used to improve reservoir confirmation techniques that will be used in Imperial Valley, California.
- The first field application of the diamond chain drill bit, capable of high penetration rates, was undertaken.
- The helical screw expander--a rugged, easily transportable wellhead generator system--was tested on a geothermal well in Utah.
- A 500 kW direct-contact binary-cycle heat exchanger and power conversion system, the forerunner of a system that may be used in 50 MW power plants, was designed, built, and tested.
- Designs were completed for a new wellhead generator system (thermal siphon binary-cycle) intended to be useful in generating electric power more efficiently and economically.
- A pilot scale steam scrubbing process tested at The Geysers (Cal.) is capable of removing up to 95 percent of hydrogen sulfide from geothermal fluids.
- EPA announced guidelines for monitoring environmental impacts of geothermal development (to be published early in FY 1979).
- USGS significantly aided assessment methodology by improving a geothermometer used to estimate subsurface temperatures in geothermal systems.

Development in the Pacific Region stayed generally on schedule. In the Rocky Mountain Basin and Range Region and the Gulf Coast Region, resource assessment and early development brought encouraging results. In the Eastern United States, where the resource is as yet unconfirmed, assessment and exploration continued: a DOE thermal-gradient drilling program to identify areas of unusually high subsurface temperature laid the groundwork for the first deep test well in the Atlantic Coastal Plain. Direct heat applications of geothermal fluids are expected to grow rapidly as a result of DOE/State reservoir confirmations and nonelectric demonstrations. The table below summarizes the IGCC-postulated electric power on line by region during the the 1980s.

In FY 1979, efforts will continue to be directed toward mitigating institutional barriers that are important in shaping future geothermal development.

Technology development will continue, and efforts will be made to show that, using present-day technology, electric power derived from high temperature hydrothermal resources is economically competitive with present alternative energy sources. Advanced technology being developed is expected to show that power from moderate-temperature hydrothermal resources can be competitive in the near future.

TABLE ES-1

POSTULATED GEOTHERMAL ELECTRIC POWER ON LINE, BY REGIONS, 1983-1990*
Cumulative Commercial-Scale Generating Capacity (MWe)**

	Pre-1983	1983	1984	1985	1986	1987	1988	1989	1990
REGION I (California, Hawaii, Alaska, Oregon, Washington)	1,680	1,990	2,210	2,790	3,065	3,690	4,390	4,940	5,940
REGION II (Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Wyoming)	--	200	200	300	600	800	1,300	1,350	2,350
ix REGION III (Louisiana, Texas)	--	--	--	--	25	325	425	525	1,025
U.S. Total***	1,680	2,190	2,410	3,090	3,690	4,815	6,115	6,815	9,315

*The postulated generating capacities are based on current knowledge of the geothermal resources in the Regions. Figures are intended for planning purposes only and do not imply any commitment on the part of the Federal government to develop these sites.

**Pilot plants and test facilities have not been included in these totals.

***Region IV, the Eastern States, has not been included in this table because the Region's geothermal resources are postulated to undergo only direct thermal utilization.

THE GEYSERS: Largest Single Unit in Operation

Courtesy of Pacific Gas and Electric Company

I. INTRODUCTION

Geothermal resources are underground sources of heat stored in rock and fluids. These resources can be tapped by drilling, and the heated fluids brought to the surface for generation of electricity or for direct thermal utilization.

- Hydrothermal resources consist of water and steam trapped in fractured rocks or sediments. A specific hydrothermal system is classified as hot-water or vapor-dominated (steam), according to the principal state of the subsurface fluid. Hydrothermal resources are utilized currently for electric production and direct thermal applications.
- Geopressured resources consist of water and dissolved methane at moderately high temperatures, but at pressures higher than normal in sedimentary formations, principally along the U.S. Gulf Coast. The Gulf Coast geopressured resources are believed to be quite large, and there are indications of similar geopressured formations in sedimentary basins elsewhere in the United States. Commercial-scale utilization of the heat, pressure, and methane contained in these resources is expected to begin in the late 1980s.
- Hot dry rock resources consist of hot rocks at accessible depths that are relatively unfractured and contain little or no water. To extract usable power, these resources require fracturing for the introduction and circulation of a heat transfer fluid. Commercial-scale utilization of hot dry rock resources is expected to begin in the 1990s.

To develop geothermal resources most quickly and efficiently, it is necessary to coordinate the efforts of a wide variety of Federal, State, and local government organizations, industry, consumer and environmental groups, and private citizens.

A. The Interagency Geothermal Coordinating Council

Congress established the Geothermal Energy Coordination and Management Project with Public Law 93-410,* enacted on September 3, 1974. The Project was authorized to

*See Appendix A for a history of PL 93-410 and other geothermal legislation.

- coordinate and manage national geothermal energy RD & 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 designates certain functions to be carried out by specific agencies, e.g., NASA, Department of the Interior, National Science Foundation, Department of the Treasury. One of its major foci is the initiation of activities through "the appropriate Federal agencies in cooperation with non-Federal entities." Figure 1 depicts the U.S. Geothermal Energy Community. It is composed of Federal and non-Federal organizations involved in the development of commercial utilization of geothermal energy. The Federal responsibilities and programs are divided among a number of agencies. The activities of these agencies are coordinated through the Interagency Geothermal Coordinating Council (IGCC), formally established by a Charter adopted in November 1977.

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.

Figure 2 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, is responsible for formulating Federal geothermal program plans and for directing 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 six agency members of the Staff Committee are appointed by the Council and represent sub-organizations of those Federal agencies on the Council itself.*

*Lists of members, by name, can be found in Appendix B.

*Some subdivisions of DOI, NSF, and USDA serve primary functions, while other subdivisions of these agencies serve secondary functions. Thus, the parent agencies appear in both primary and secondary categories. See Figure 2.

**Representatives of the non-Federal sector serve on the Advisory Committee on Geothermal Energy.

***NASA was a member of the IGCC, but has resigned.

Figure 1

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
BOR-Bureau of Reclamation
CEQ-Council of Environmental Quality
COMMERCE-Department of Commerce
DOD-Department of Defense
DGE-Division of Geothermal Energy
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
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

*Denotes Chairing function

Figure 2

The Budget and Planning Working Group (BPWG) 1) formulates "long-range geothermal energy utilization goals and a comprehensive program of Federal activities and initiatives and associated budget requirements to meet these goals," 2) coordinates the programs and budgets (related to geothermal energy) of other Federal agencies, 3) prepares the IGCC Annual Report, 4) brings to the attention of the Council relevant programmatic and policy issues relating to Federal coordination, and 5) "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 also includes representatives from the Department of the Interior, the Department of Agriculture, the Environmental Protection Agency, and the National Science Foundation.

The Resource Panel is responsible for coordinating Federal activities in geothermal resource assessment and assists in developing geothermal resources through the Federal leasing program. The Panel is chaired by a representative of the Department of the Interior.

The Research and Technology Panel promotes 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 is chaired by a representative of the Department of Energy.

The Institutional Barriers Panel recommends changes in laws, governmental policy and procedures that impede the development of geothermal energy. The Panel is chaired by a representative of the Department of Energy.

The IGCC brings together all the Federal agencies that encourage private industry to develop geothermal resources, and serves as an effective means for exchanging information among government agencies and for formulating Federal policy measures. It develops detailed Federal program plans and goals, and defines actions and policies to be followed by Federal agencies to accomplish these goals.

To promote coordination of activities of non-Federal organizations and to involve this sector at the Federal and regional levels adequately, an Advisory Committee on Geothermal Energy was formed in 1976. The Committee provides advice to the Federal sector on the "status of social, legal, technological, and institutional problems that inhibit the private sector from exploiting the nation's vast reserves of geothermal energy." Membership includes representatives from private industry, utilities, organizations conducting research in geothermal energy, environmental groups, consumer interest groups, state and local government agencies, and academia.

B. Organization of the IGCC Report

This report describes the activities of Federal, state, and local governments in stimulating commercial development of geothermally derived electric generation and direct thermal use. These various elements work

together to maximize economically attractive geothermal development in an environmentally and socially acceptable manner.

This report covers the following topics:

1. An estimate of the geothermal resource in the United States.
2. The national utilization estimates for development of geothermal resources.
3. The Federal strategy and program for development of geothermal resources.
4. The progress and accomplishments of the program in FY 1978.
5. Progress, accomplishments, and plans for geothermal development at regional and site-specific levels.
6. Major Federal initiatives anticipated in FY 1979.*

*Initiatives are those activities required to achieve power-on-line goals in a timely manner.

II. GEOTHERMAL RESOURCE POTENTIAL IN THE UNITED STATES

This section describes the current estimated potential of geothermal resources in the United States, based on the 1978 national resource assessment recently concluded by the U.S. Geological Survey.

Geothermal resource assessment uses 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. Because it is regional or national in scope, resource assessment is used by industry and government in developing long-term policy and strategies, but should not be used to establish specific reserve figures for short-term investment and marketing decisions.

The first systematic effort to estimate the geothermal resources of the entire United States was published as USGS Circular 726, "Assessment of Geothermal Resources of the United States--1975." This study used the data available in early 1975 to estimate the quantity of geothermal energy. Since Circular 726 was issued, an accelerated interest in the use of geothermal energy has led to increases in data from exploration, technology development, and direct utilization. USGS re-evaluated the geothermal resources in the United States in the light of data available in June 1978, and published the new resource assessment as USGS Circular 790, "Assessment of Geothermal Resources of the United States--1978."

A. Differences in Content of Circular 726 and Circular 790

Circular 790 both adds to and refines the information found in Circular 726. With regard to new material:

- Circular 790 describes areas favorable for the discovery and development of low-temperature (less than 90°C) geothermal waters from depths less than 1 km. This is the first time that such a nationwide evaluation has been attempted.
- Circular 790 substantially expands the scope of the geopressured-geothermal assessment, by evaluating the northern Gulf of Mexico Basin's continental shelf and the Cretaceous deposits on land. Circular 726 analyzed data from 250 wells; Circular 790 analyzes data from over 3000 wells. The updated assessment also calculates the methane likely to be found in solution in geopressured-geothermal waters.

In assessing hydrothermal convection systems with reservoir temperatures of 90°C or more, Circular 790 made four basic refinements, by

- revising reservoir volumes and temperatures, based on new data and improved chemical geothermometers,
- using statistical methods in calculating thermal energies of identified systems,

- tabulating energy recoverability based on the concept of "available work," and
- estimating the undiscovered accessible resource base by geologic region.

B. Differences in Estimates of Circular 726 and Circular 790

In several regards, Circular 790 improves the estimates made in Circular 726, but fundamentally Circular 790's findings confirm the basic rationale and conclusions of Circular 726. The principal findings of Circular 790 are summarized in Table A.

In terms of the accessible resource base* in the United States, all geothermal energy is found in either regional conductive environments or young igneous systems. Included in the geothermal energy of these two broad types of environments is the thermal energy of water, hot rocks, and magma. The water may be contained in hydrothermal systems, or in geopressured or hydrostatic zones of sedimentary basins, or may be dispersed through large volumes of rock. None of the energy represented by these very large numbers can be considered as a resource without specifying the technical and economic assumptions used, and no universal recovery factors can be applied to the figures as a whole. Therefore, thermal energy calculated in Circular 790 (to depths of 10 km, for both regional conductive environments and young igneous systems) represents upper limits to the amount of energy from which resource values must be calculated. These values are derived from the physical parameters of systems to be developed, from the methods for recovery and use of energy, and from the basic economic factors that determine the course of development.

Most geothermal development scenarios consider primarily that part of the accessible resource base concentrated in hydrothermal convective systems. Circular 790 presents a detailed inventory of the energy in hydrothermal convective systems with temperatures greater than 90°C, to a depth of 3 km. Significant changes from Circular 726 result largely from use of improved chemical geothermometers and include

- a decrease of 24 percent in the number of identified systems above 90°C;
- a greater preponderance of intermediate temperature (90°-150°C) systems over high-temperature (above 150°C) systems; and
- a decrease in the size of several of the largest systems inventoried (based on additional drill hole data as well as chemical geothermometers).

Statistical uncertainties involved in estimating thermal energy are included in Circular 790 as well.

*Defined as geothermal energy in the ground above a specified reference temperature to a specified depth.

TABLE A. 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 36,000 ^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 8,000	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 ^e	410,000 ^e	11,000 6,000	96,000 57,000	107,000 63,000				270 ^f -2800 ^g 158 ^f -1640 ^g		
Other geopressured basins					46,000 ^h						

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

b. Equations on p. 85 and 91 of Diment and others (1975) (assuming an exponential decrease of heat production with depth) give 11,700,000 x 10¹⁸ 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 km² using the "basic calculation" of Diment and others (1975) and the thermal parameters listed for the coastal plain on their table 13. The result is then increased by approximately 18 percent to give a figure comparable to their "best estimates."

d. Does not include 1290 x 10¹⁸ J in National Parks (mainly Yellowstone).

e. Calculated for an area of 310,000 km² 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 Circular 790.

**10¹⁸ J ≈ 1 quad.

Circular 790 analyzes the probable size of the undiscovered resource base in more detail, taking account of differing geologic characteristics from region to region. Nevertheless, for each region the estimates of undiscovered energy are taken as a fraction of the energy in identifying systems in that region; the tally, therefore, is necessarily lower, just as the inventory of energy in identified systems is lower.

The total identified and undiscovered accessible resource base for all hydrothermal convection systems to a depth of 3 km* is now estimated to be lower, by a factor of about 20 percent, than the Circular 726 estimate. This reflects the high inherent uncertainty in assessing the resource base for any mineral or fuel resource. Hydrothermal resources greater than or equal to 90°C, calculated from the accessible resource base by an analysis of recoverability, are also 20 percent lower than in Circular 726.

Circular 790 estimates energy for utilization from the calculated resource value by first assuming that geothermal energy above 150°C will be converted for utilization as electricity, and that lower temperature energy will be utilized as beneficial heat. For identified systems above 150°C, energy recoverability is calculated and utilization factors for electrical conversion applied. For undiscovered systems, two limiting models are applied to yield estimates of the relative distribution of temperatures above and below 150°C; a calculation gives ranges of energy recoverable as electricity or as beneficial heat. These figures cannot be compared directly to those of Circular 726, because the higher value for electricity could occur only with the lower value for beneficial heat and vice versa.

Circular 790 also considers the problem of assessing the resource base for energy potentially extractable by proposed hot dry rock energy extraction technology, but concludes that it is not possible to make such an assessment with the information now available. Suggestions for the kinds of research needed for a meaningful assessment are made.

Low-temperature geothermal waters (less than 90°C) were not considered in Circular 726, but are discussed in Circular 790. Sufficient data are not available, however, to calculate quantitative energy estimates for these low-temperature waters, owing to differences in formats, thoroughness, and reliability of the many data sets and to the paucity of reliable data over wide areas.** Circular 790 considers the geologic and hydrologic factors favorable to development of such waters, delimits areas having greatest potential for their occurrence at depths less than 1 km, and suggests how, with better data, an assessment might be made in the future.

In assessing geopressured zones, Circular 726 was limited to the shallower (Tertiary) deposits of the onshore area. Circular 790 essentially completes the inventory of the northern Gulf of Mexico Basin's accessible geopressured

*Outside the national parks.

**A more elaborate collation of data in individual states is being carried out by the Western States Cooperative Direct Heat Geothermal Program of DOE's Division of Geothermal Energy.

resource base. Geopressured zones of all sedimentary rocks in the basin, both onshore and offshore, are inventoried to a depth of 6.86 km (the depth of existing well control). The total identified thermal energy in the fluid resource base of both sandstone and shale is estimated. In addition, the updated assessment calculates the amount of methane dissolved in the geopressured zone waters, assuming saturation of the waters with methane. Circular 726's recovery models were then applied to the new resource base estimates to derive a range of resource values at the wellhead.

C. Estimates of Energy for Utilization

A set of three tables (B, C, and D), based on Circular 790 estimates and additional calculations, has been prepared by the USGS to replace a table titled "Estimated Recoverable Heat from Geothermal Resources" included in previous IGCC, DOE, and ERDA documents, even though the table actually showed energy in quads utilized as electricity or beneficial heat.

Tables B and C can be found in Appendix C. Table B shows the categories of geothermal energy for which resource estimates can actually be made (hydrothermal convection and geopressured systems). Table C illustrates the type of calculation that could be made for the energy that might be put to use through the hot dry rock extraction technique. Table D of this section summarizes the energy for utilization as represented in Tables B and C. It must be reiterated here that many unknown geological parameters have been estimated, and many factors have been assumed arbitrarily (although the assumptions do not seem unreasonable). A range of values has been calculated for each category of geothermal energy represented, to illustrate how varying the assumptions used might affect the calculations. The values do not, however, represent the total range of reasonable assumptions that might be made.

Table D indicates a range of about 710-3400 quads of geothermal energy for utilization (both electric and direct thermal).^{*} This range exists because of a variety of assumptions for energy recoverability and utilization. This estimate is based on a more complete data base than Circular 726's, but a number of deficiencies remain. Like any large-scale resource assessment, this latest assessment will require future revision.

^{*}It must be pointed out, however, that not all of the calculations for these figures are based on actual resource estimates; some have been calculated for the purpose of this report from resource base values using arbitrary assumptions for recoverability and utilization.

TABLE D. Calculated energy for utilization*

(Values rounded upward or downward where necessary to retain significant figure in totals)

CATEGORY OF GEOTHERMAL ENERGY	ENERGY FOR UTILIZATION** (in 10 ¹⁸ Joules, ≈ 1 Quad)		
<hr/>			
<u>Hydrothermal Convection</u>			
>150°C	142 (1.5+20+120)	-	90*** (1.5+20+68)
90°-150°C	230 (42+184)	-	350 (42+310)
	<hr/>		
Total Hydrothermal	370	-	440
 <u>Geopressured</u>			
Thermal	31 (22+9)	-	320 (220+96)
Methane	79	-	820
	<hr/>		
Total Geopressured	110	-	1140
 <u>Hot Dry Rock</u>			
Hot Igneous Systems	75 (8+67)	-	590 (59+526)
Regional Conductive Environments	152	-	1190
	<hr/>		
Total Hot Dry Rock	230	-	1780
<hr/>			
TOTAL (Rounded)	710	-	3400

*Summarized from Tables B and C, in Appendix C (figures in parentheses), as totals of identified plus undiscovered and evaluated plus unevaluated resources.

**These figures represent a range of values for each category, because of a variety of assumptions used for energy recoverability and utilization.

***The lower figure of 90 should be used for systems >150°C if the higher figure of 350 is used for systems 90-150°C, and vice versa.

III. NATIONAL GEOTHERMAL UTILIZATION ESTIMATES

Table I presents the IGCC's estimates of the achievable commercial utilization of geothermal resources in the United States. These estimates incorporate knowledge of existing and planned geothermal development, and are based on the quantity of exploitable geothermal resources in the United States. Achievement of these estimates will require a major national effort, primarily by the private sector, but supported by local, state, and Federal governments.

Each of these estimates includes direct heat applications and heat used to generate electricity, as well as geopressured derived power, as categorized in Table 1. While the estimates incorporate knowledge of existing and planned geothermal development, they do not otherwise consider the relative cost of geothermal versus other energy forms, nor the potential impact of changing environmental regulations. In other words, the estimates provide a basis for framing Federal, state, and local policies and measures necessary to bring about increased use of geothermal energy.

Table 1

NATIONAL GEOTHERMAL UTILIZATION ESTIMATES
FOR GEOTHERMALLY DERIVED POWER^a

	<u>1985</u>	<u>2000</u>	<u>2020</u>
Electric Capacity (MW)	3,000-4,000 ^b	20,000-40,000	70,000-140,000
Electrical Applications (Equiv. fossil fuel energy in quads/year) ^d	.2-.3 ^c	1.5-3.0 ^c	5.0-10.0 ^c
Direct thermal Applications (quads/year)	.1-.2	.5-2.0	6.0-8.0
Geopressured Methane (quads/year)	0-.02	2.0-4.0	5.0-10.0
TOTAL (quads/year)	.3-.5	4.0-9.0	16.0-28.0

^aThese data are derived from USGS Circular 726, issued in 1975, and represent no change from last year's estimates. After the release of USGS Circular 790 (expected in January 1979), these estimates will be revised to conform to the new data.

^bBased on utilization of reservoirs with temperatures of approximately 180°C or greater.

^cBased on an assumed capacity factor between 0.65 and 0.85, and an efficiency equivalent of fossil fuel plants of 0.3 to 0.4.

^d1 Quad = 1.0×10^{15} BTU. 1 Quad per year = approximately 0.5 million barrels of crude oil per day.

FIELD DEVELOPMENT DRILLING

Courtesy of Union Oil of California

IV. THE FEDERAL GEOTHERMAL DEVELOPMENT STRATEGY AND PROGRAM

A. Objectives

It is provisionally projected that by the year 2020 the equivalent of between 8 and 14 million barrels of crude oil per day would be saved by maximizing geothermal utilization.

The Federal geothermal energy program assists and encourages the private sector to develop the geothermal energy potential of the United States in order to reduce dependence on imported petroleum products and scarce domestic fuel supplies. Specifically, the program objectives are to develop economically viable and environmentally acceptable technology, and to reduce institutional barriers and thereby help make geothermal energy competitive with available alternate energy resources. The IGCC furthers these objectives by coordinating those Federal plans, activities, and policies related to development of geothermal energy.

B. Program Strategy

The Federal geothermal energy program focuses on describing the geothermal resources of the United States, reducing uncertainty about their recoverability, and stimulating the commercial development of geothermal resources. In order to accomplish this:

- The program helps to better define the available resource on both regional and site-specific levels. Definition of the resource is carried out both by the Federal government and by private organizations.
- The program is intended to stimulate commercial development of hydrothermal resources through the 1980s by the following activities: (a) an RD&D program to reduce technological and environmental risks and costs, (b) loan guarantees and other incentives to stimulate the flow of equity capital and to reduce lenders' risks, (c) policy measures to reduce institutional uncertainties, and (d) execution of Federal regulatory functions in a timely manner.
- The program includes measures to stimulate initial development of geopressured resources by the mid-1980s, and to encourage continued growth thereafter. This development is accomplished through a program to confirm the resource and through incentives included within the National Energy Act.

- The program aims to accelerate initial development of the potentially large hot dry rock resource, and to prepare for rapid development around the year 2000, when the geothermal industry has matured. Current emphasis is placed on research and development of advanced technology and a basic geoscience research program.

C. The Federal Program

The Federal program consists of the following interrelated activities:

- Coordinating national planning efforts between government and private organizations to achieve the national utilization goals for geothermal energy
- Identifying specific public initiatives required to achieve the national goals for utilization of geothermal energy in the time frame of the Federal program
- Coordinating Federal policy activities to create the most favorable climate for commercial geothermal development
- Conducting a research, development, and demonstration program
- Promoting international cooperation through multinational geothermal agreements.

Over the past three years, the Federal approach has shifted from a program of many relatively independent research and development projects providing the basic technology for energy extraction and utilization, to a mission-oriented program aimed at accelerating the commercial utilization of actual geothermal reservoirs. The mission-oriented program includes planning, implementation, and monitoring of the time-phased, interrelated activities needed to produce electricity and to utilize commercial quantities of heat directly from geothermal reservoirs without adversely affecting the environment.

The Federal government works closely with state and local governments, industry, municipal authorities, and environmental and other public interest groups to identify the public and private initiatives that will most effectively encourage investment in geothermal energy and promote public acceptance of its development and use. Annually updated geothermal development plans provide a basis for government decisions about its financial and manpower allocations.

The amount of commercially useful energy available for specific sites has been estimated in potential geothermal areas. These estimates were derived from geothermal development plans that assessed industry activity and outlined the technological and institutional initiatives needed at the Federal, state, and local levels to make additional geothermal energy forms competitive and acceptable. If these initiatives are taken and combined with the projected potential contribution of new discoveries, these plans yield the estimate of achievable levels of geothermal energy in the United States.

The mission-oriented approach to planning, implementation, progress monitoring, and overall coordination and management was adopted to place primary emphasis on achieving environmentally acceptable use of economically attractive geothermal energy resources as soon as possible.

Table 2 presents estimated Federal funding over time for the development of geothermal resources. Table 3 contains detailed information on funding and guaranty authority under the geothermal loan guaranty program.

Table 2

ESTIMATED FEDERAL FUNDING FOR
THE DEVELOPMENT OF GEOTHERMAL RESOURCES
(IN \$ THOUSANDS)*

	<u>Actual FY 1977</u>	<u>Actual FY 1978</u>	<u>Est. FY 1979</u>	<u>Requested FY 1980</u>
Department of Agriculture (USDA)				
U.S. Forest Service	40	678	775	750
Department of the Interior (DOI)				
Fish and Wildlife Service	200	200	200	200
Bureau of Land Management	2,500	2,300	2,600	2,600
Bureau of Mines	528	550	650	650
Bureau of Reclamation	1,420	1,080	1,250	900
Geological Survey	11,831	13,828	15,375	13,400
DOI TOTAL	16,479	17,953	20,075	17,750
Environmental Protection Agency (EPA)				
Office of Research & Development	600	670	650	650
National Science Foundation (NSF)	220	175	70	70
Department of Energy (DOE)				
Office of the Assistant Secretary for Energy Technology	51,554	104,582	143,114	126,800
Office of the Assistant Secretary for Resource Applications	---	---	9,686	9,000
Office of Energy Research	1,235	1,400	1,920	2,225
Office of the Assistant Secretary for Environment	3,840	3,910	4,025	4,000
Geothermal Resources Development Fund and Guaranty Authority (Administrative Expenses)	380	410	1,000	1,000
DOE TOTAL	57,209	110,302	160,145	143,025
TOTAL FEDERAL GEOTHERMAL PROGRAM BUDGET	74,508	129,100	180,940	161,495

*Operating Expenses rounded to the
nearest thousand.

Table 3

GEOHERMAL RESOURCES DEVELOPMENT FUND AND GUARANTY AUTHORITY*

	FY 1978	
	<u>Fund</u>	<u>Authority</u>
Unexpended Appropriations, carried forward from FY 1977	\$ 29,620,244	\$
Guaranty Authorization, carried forward from FY 1977	15,000,000	190,970,000
Total Value of Loans Authorized for Guaranty		100,000,000
Value of Loans Guaranteed		<u>4,653,800</u>
Guaranty Authorization Carried to FY 1979		<u>286,316,200</u>
Administrative Expenses Incurred**	<u>409,981</u>	
Unexpended Appropriation Carried to FY 1979	<u>44,210,263</u>	
User Charge Collections in FY 1978 deposited in miscellaneous receipts	104,842	

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

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

RAFT RIVER 5 MEGAWATT BINARY POWER CYCLE FACILITY

- 1 TURBINE-GENERATOR
- 2 CONDENSER
- 3 CONDENSATE STORAGE TANK
- 4 HIGH PRESSURE BOILER
- 5 HIGH PRESSURE PREHEATER
- 6 LOW PRESSURE BOILER
- 7 LOW PRESSURE PREHEATER
- 8 ISOBUTANE FEED PUMPS
- 9 GEOTHERMAL FLUID PUMPS
- 10 GEOTHERMAL SUPPLY LINE
- 11 GEOTHERMAL INJECTION LINE
- 12 COOLING TOWER

V. FEDERAL PROGRESS AND ACHIEVEMENTS FY 1978

Introduction

Progress at the Federal level in 1978 was substantial and moved the Federal program further toward achieving the goal of bringing geothermally derived power on line at the earliest possible date. Regional cooperative planning, institutional research, loan guaranties, and tax policy are advanced through the activities of DOE and the Department of the Treasury. Federal geothermal land leasing is accomplished by the Department of the Interior's Bureau of Land Management (BLM) with the assistance of the U.S. Geological Survey (USGS), and the U.S. Forest Service (USFS) on Federal lands administered by the U.S. Department of Agriculture. The bulk of Federal research and development is carried out by DOE and by agencies of DOI, especially the USGS, the Bureau of Mines, and the Bureau of Reclamation. Environmental research, monitoring, and policy development is the primary responsibility of the Environmental Protection Agency (EPA), as well as DOI's USGS and Fish and Wildlife Service (FWS), and DOE. The Geothermal Loan Guaranty Program initiated by ERDA in 1976 has been continued by DOE.

The near- to mid-term approach to the commercialization of geothermal resources blends regional and site-specific planning, mitigation of institutional and legal barriers, reservoir assessment and confirmation activities, demonstrations, loan guaranties, and supporting R&D.

A. Interagency Coordination and Management

The mechanisms developed by IGCC for interagency and international coordination and management continued to evolve in 1978. The approach to coordinated planning for the national effort is based on collective site-specific planning, with direct participation of Federal agency field offices, state and local governments, geothermal energy-related industries (both producers and users), and community interest groups. Commercialization planning formulates aggressive development scenarios for specific development sites, and identifies the Federal and non-Federal, policy, administrative, and R&D initiatives that must be properly timed to achieve the national geothermal development goals. A sample site-specific development plan is given in Appendix D.

The working groups and panels of the IGCC provide forums for discussions of Federal incentives and barriers affecting the development scenarios created by site-specific planning. Federal barriers and alternative development approaches formulated in the site-specific development plans are subsequently addressed at the agency headquarters level through the IGCC. A summary of the major decisions and recommendations of the IGCC during FY 1978 is presented in Appendix E.

The initiatives that fall within the purview of the Federal government form the basis for the Federal program for geothermal energy development and are coordinated through the IGCC. This approach provides for coordination of activities not only within the Federal sector, but with the non-Federal sector at state, local, and community levels as well. In addition, input to development plans is obtained from the private and public sectors through the Advisory Committee on Geothermal Energy. A summary of this committee's minutes is presented in Appendix E.

The Budget and Planning Working Group (BPWG) of the IGCC held three meetings in FY 1978, which brought member agencies up to date on each other's activities and laid groundwork for coordination and implementation of plans developed in FY 1977. Progress made within the Federal program is being monitored, along with the success of non-Federal entities in achieving site-specific targets for geothermal energy utilization. Progress monitoring identifies events early in development processes, thereby allowing enough time for corrective measures and program redirection. Prospect-specific plans have been developed for each major geothermal site, and include a delineation of work-load requirements for each participating agency and activity. Through the Institutional Barriers Panels of the IGCC, existing and pending legislation have been examined in terms of the possible impact on geothermal development.

In support of the BPWG, DOE and DOI are developing a computerized program management system to facilitate monitoring of progress in geothermal energy development. Activities, relationships, resource requirements, and goals defining the program are being used to construct an activity network and data base for the system. This network will be used to record progress, project future status, and relate R&D and commercialization activities to program goals. In addition, in FY 1978 DOE completed a major study of commercialization strategy for hydrothermal electric and direct heat applications. This study described the barriers to commercialization and identified various Federal actions most important in eliminating these barriers on a priority basis.

Geothermal energy resource developments are proceeding in several foreign countries in which initial development pre-dates U.S. development. International coordination provides for exchange of information and participation in joint studies and development projects. Cooperative activities between the United States and other nations are expected to enhance the nation's ability to develop and demonstrate a wide range of energy options and may contribute to the development of markets for U.S. geothermal technology.

An implementation agreement for a 15-month cooperative study of Manmade Geothermal Energy Systems (hot dry rock) was signed by the Federal Republic of Germany, Sweden, Switzerland, United Kingdom, and the United States in FY 1978. The Federal Republic of Germany was chosen as the Operating Agency for this project, and the planning phase is near completion.

Under the U.S.-Italian Bilateral Agreement, well selection for hydrothermal field stimulation tests was completed through exchanges of information and site visits. Data collection and evaluation for reservoir modeling efforts at Larderello, Radicondoli, and Bagnore are on schedule. Collaborative efforts in the environmental research area are proceeding as planned, and actual H₂S monitoring activities will be initiated after an air-quality and meteorological monitoring network for the Larderello field is established.

An Implementing Arrangement between the United States Department of Energy and the Agency for Industrial Science and Technology of Japan was signed in FY 1978. Areas of cooperation include development and evaluation of 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 Symposium on the Cerro Prieto (Mexico) Geothermal Field, held in FY 1978, reported on the results of geophysical studies, reservoir engineering, and injection studies conducted under the U.S.-Mexico Agreement. Appendix F presents a status summary of multilateral/bilateral agreements and activities.

B. Policy Development

FY 1978 saw major progress in establishing a legal and institutional framework that will encourage rapid, orderly development of geothermal resources. The passage of the National Energy Act significantly improves the financial attractiveness of investment in geothermal resource development and utilization projects, and assists in resolving certain other problems as well. Modifications to the loan guaranty program enacted in February 1978 in P.L. 95-238 enhance the utility of that program to a variety of potential users. A Streamlining Task Force developed a set of proposals to streamline the Federal geothermal leasing and environmental procedures; many of these recommendations will be implemented in 1979. The Institutional Barriers Panel has made several recommendations regarding leases, tax policy, wheeling and interconnection, environmental procedures and regulations, and other policy matters, and several of these have already been or are being implemented.

The National Energy Act eliminates what has been the principal deterrent to investment in geothermal resource development projects--uncertain tax treatment. The NEA explicitly authorizes intangible drilling cost deductions and a percentage depletion allowance for geothermal resources, and also 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 FERC certain powers to order wheeling and interconnection for geothermal plants, and to exempt from public utility regulation geothermal plants that qualify as cogenerators or small power producers. These provisions have resulted for the first time in substantial attention in the financial community to investment in geothermal projects. The result should be an almost immediate increase in exploration and development activity. A detailed summary of the provisions of the NEA relating to geothermal energy may be found in Appendix H.

Amendments to the loan guaranty program are described in the next section. While this program has been little used to date, the low level of activity has stemmed partially from the tax situation. Increased activity and interest is expected in response to these amendments and the NEA.

The Streamlining Task Force was established in response to a commitment in the President's National Energy Plan (announced April 20, 1977), that the Departments of Interior and Agriculture would streamline their leasing and environmental procedures to reduce unnecessary barriers to development of geothermal resources. The Task Force has conducted an in-depth study of present procedures and a series of public meetings to obtain suggestions and comments. The Task Force report, released in January 1979, includes a comprehensive set of legislative, regulatory, and administrative remedies that are expected to improve the system substantially when implemented.

The Institutional Barriers Panel (IBP) of the IGCC, in its report of September 13, 1978, made recommendations dealing with the following issues:

- Underground injection regulations under the Safe Drinking Water Act
- No-surface-occupancy leases
- Wheeling and interconnection authority
- The relationship of geothermal energy to the provisions of the Federal Power Act and the Public Utility Holding Company Act
- Tax policy for intangible drilling costs
- Geothermal percentage depletion allowances
- Investment tax credits
- Production tax credits for geopressured methane

Table 4 describes the status of action as of September 30, 1978, on the recommendations of the Panel in its three reports to the Council, most of which pertain to Federal land management.

RARE II, the second roadless area resource evaluation, is now completed. Its publication is expected to allow accelerated U.S. Forest Service leasing activity. More than 15 million acres will be designated wilderness areas, but over 36 million acres have been classified nonwilderness areas, with nearly 11 million acres awaiting further study before final classification.

Table 4

STATUS OF ACTIONS RECOMMENDED BY THE INSTITUTIONAL BARRIERS PANEL

Date Recommended	Agency Assigned	DESCRIPTION OF RECOMMENDED ACTION	STATUS
June 1976	Treasury	1. Legislation amending internal revenue code to allow R&D expensing for exploration expenses.	NEA includes intangible drilling cost allowance. This recommendation no longer appropriate.
June 1976	FPC (FERC)	2. Issue guidelines to state PUCs to provide incentives for geothermal use.	FPC concluded such guidelines not needed at present. Status being monitored.
June 1976	ERDA (DOE)	3. Conduct workshops to coordinate inter-governmental environmental reviews.	California Permitting Project initiated.
June 1976	EPA	4. Develop geothermal environmental guidelines.	Completed
June 1976	USGS	5. Expand USGS Resource Assessment Program.	Completed
June 1976	BLM	6. Reduce competitive interest KGRA to area overlapped. (Revised to provide for reclassification of unbid competitive interest KGRAs after two unsuccessful sales.)	Draft regulations in coordination in DOI. (Solicitor's office)
June 1976	BLM	7. Provide for deferred bonus payments and recoupment for development work.	Deferred bonus regulation in coordination in DOI. Recoupment not included.
June 1976	BLM	8. Legislation to increase per-state acreage limit to 51,200 acres.	Draft legislation in coordination in DOI. (Assistant Secretary for Land and Water)

Table 4 (Cont.)

STATUS OF ACTIONS RECOMMENDED BY THE INSTITUTIONAL BARRIERS PANEL

Date Recommended	Agency Assigned	DESCRIPTION OF RECOMMENDED ACTION	STATUS
June 1976	BLM	9. Provide utility first option in the event of termination of leases.	To be handled in lease terms.
June 1976	BLM	10. Amend Steam Act regulations to define when steam is "produced" for purposes of 10-year readjustment term.	Draft regulations. Released for comment.
June 1976	BLM	11. Revise Steam Act regulation to allow leases of less than 640 acres for small-scale nonelectric uses, or to fill out contiguous block.	Draft regulations. Released for comments.
June 1976	BLM	12. Amend regulations on work requirements to enable aggregation and lesser requirements for small scale nonelectric uses.	Released for comment.
December 1976	BLM	13. Allow no-surface-occupancy (NSO) leases, and periodically review lease issuance status to suggest remedial action.	NSO policy letter issued to field offices March 1977. Streamlining Task Force reviewing status of all applications and KGRAs.
December 1976	USGS	14. Establish interagency task force to reduce drilling permit processing time.	Streamlining Task Force established.
December 1976	USGS	15. Modify regulations to allow lessee to conduct casual use operations with NOI procedure.	Regulation published for comment.

Table 4 (Cont.)

STATUS OF ACTIONS RECOMMENDED BY THE INSTITUTIONAL BARRIERS PANEL

Date Recommended	Agency Assigned	DESCRIPTION OF RECOMMENDED ACTION	STATUS
New	EPA	16. Revise Draft Reinjection Regulations under Safe Drinking Water Act to include geothermal aquifers in exemption for aquifers producing oil or minerals.	New
New	BLM	17. Issue letter to noncompetitive lease applicants advising them of availability of no-surface-occupancy leases.	New
New	DOE	18. Legislation modifying wheeling and inter-connection authority to allow such orders for entities producing electricity from site-dependent resources.	New
New	DOE	19. Include geothermal generation in "small generator" category, exempted from FPA and PUHCA and eligible for wheeling orders.	New
New	DOE/Treasury	20. Legislation eliminating minimum tax on geothermal intangible drilling costs in excess of income from geothermal property.	New
New	DOE/Treasury	21. Support Senate version of geothermal percentage depletion allowance.	New
New	DOE/Treasury	22. Support Senate version of 10 percent investment tax credit.	New
New	DOE/Treasury	23. Propose legislation authorizing investment tax credit for use of geothermal in new facilities.	New

Table 4 (Cont.)

STATUS OF ACTIONS RECOMMENDED BY THE INSTITUTIONAL BARRIERS PANEL

Date Recommended	Agency Assigned	DESCRIPTION OF RECOMMENDED ACTION	STATUS
New	DOE/Treasury	24. Support geopressured methane production tax credit in Senate bill.	New
New	DOE/DOI	25. Propose legislation conveying title to Boise Barracks tract to City of Boise, or expedite competitive sale.	New

C. Technology Development

The broad objective of technology development is to bring the technologies required for geothermal development to a point of readiness for commercial application. Work in this area is focused on reducing costs of geothermal exploration, assessment, and field development; reducing capital costs of electricity-generating facilities; improving resource utilization efficiency; and reducing the technical risks in all aspects of geothermal fluid handling (production, utilization, disposal) in the near future.

The USGS, DOE, and EPA conduct research, development, and demonstration (RD&D) explicitly directed towards geothermal development. The USGS Geothermal Research Program emphasizes resource assessment--characterization of resource types, regional and national estimates, assessment methodology, and exploration techniques. In DOE, Division of Geothermal Energy programs concentrate on reservoir confirmation, exploration methodology, and techniques for energy extraction, production, and utilization, while Office of Energy Research programs stress physical research in the geosciences and materials sciences. EPA programs assess environmental impacts of potential surface ground water contamination by hazardous substances found in geothermal fluids, and develop guidelines for monitoring this contamination. In short, the Federal program attempts to make geothermal development economically attractive while avoiding any significant degradation of the environment. This program is designed to complement private sector activities and will affect both the rate and the ultimate magnitude of geothermal development.

Resource assessment and reservoir confirmation technology. Typically, resource assessment of a geothermal prospect is followed by exploration and reservoir confirmation by drilling. The success of geothermal exploration, including drilling, may be increased by developing tools and techniques to locate and define subsurface resources in the quickest and most cost-effective way. Improved resource assessment, exploration, and confirmation techniques aim to reduce 1) uncertainties concerning the characteristics of geothermal resources, 2) the number of wells required to define a prospect, 3) geothermal field development costs, and 4) demand for drilling rigs.

The FY 1978 accomplishments include the following:

- To advance the methods of locating geothermal resources, a portable SQUID (Superconducting Quantum Interference Device) has been developed, and is used in the field to detect geothermal reservoirs by measuring the propagation of electromagnetic waves through geologic formations. Seismic methods for determining the structure of geothermal energy regions have been used in interpreting data collected at the Kilauea Iki volcano in Hawaii, and the hot dry rock geothermal site in Fenton, New Mexico.

- USGS significantly improved the methodology for assessing hydrothermal resources by development of a correction for the sodium-potassium-calcium (Na-K-Ca) geothermometer for high concentrations of magnesium. This geothermometer has been widely used to estimate subsurface temperatures in geothermal systems; the correction will result in more accurate temperature estimates, in areas with high concentrations of magnesium. In addition, a method for dating young volcanic rocks based on thermoluminescence was demonstrated. This method fills a gap in the techniques for dating the ages of young volcanic rocks, and should therefore be useful in more specifically locating potential hot dry rock areas as well as in locating hydrothermal systems.
- USGS led the development of two equations that are major advances in geopressured resource assessment methodology. The first is a generalized equation used to identify composition of brine-methane solutions in geopressured zones under varying conditions of temperature and pressure. The second equation gives the solubility of methane in geopressured fluids (as a function of temperature, pressure, and salinity).
- DOE sponsored research to develop advanced interpretive techniques in applying deep electric prospecting methods for delineating geothermal reservoirs.
- A USGS study of heat flow techniques for geothermal exploration better defined the usefulness of shallow (approximately 1 meter depth) measurements. Results showed that this rapid technique can be used where lateral variations in temperature are large, and where near-surface heat flow is much larger than normal.
- Reservoir confirmation technology made use of a DOE study, analyzing reservoir data from the Cerro Prieto geothermal field in Mexico, to improve reservoir modeling capabilities for the Imperial Valley geothermal fields in California.
- In Brazoria County, Texas, concurrent field and laboratory measurements of permeability and formation compaction were used to develop methods for mapping optimum geopressured reservoir locations and to determine possible subsidence effects.

Well drilling and completion technology. DOE is developing technology in two main areas. First, to reduce costs and minimize environmental risks in severe downhole environments common to geothermal reservoirs, work focuses on rotary drill bits, downhole drill motors, and drilling fluids. Improved drill bits and downhole motors could bring about a 25 percent reduction in the cost of geothermal drilling by 1982; a new drilling system could bring about a 50 percent reduction by 1986. Second, to improve well completion

techniques and associated equipment, materials research focuses on cementing compounds and elastomers for seals, packers, logging cables, and blowout preventers.

Among the achievements of FY 1978:

- The first field application of the diamond chain drill bit capable of high penetration rates was undertaken.
- Several improved Compax diamond bits (Stratapax) incorporating manmade diamonds were tested, and plans completed for field tests.
- Field tests of the first improved seal/bearing assembly for downhole drill motors used in geothermal applications were initiated.
- The American Petroleum Institute and the American Society for Testing Materials established standards for testing cements used in geothermal well completions and heat-resistant elastomeric seals used in blowout preventers and packers.

Energy extraction and conversion technology. Extraction technology aims to increase production from geothermal wells by the use of downhole pumps and well stimulation techniques. The process of producing and disposing of geothermal fluids accounts for 50 to 75 percent of the total cost of geothermal power. Increasing well productivity by 50 to 100 percent, at nominal increase in cost, could reduce power costs by almost 30 percent. DOE has emphasized the development of high-temperature downhole pumps, near-borehole chemical treatment, and hydraulic and explosive fracturing techniques. In FY 1978, major DOE efforts involved the laboratory test of steam and electric downhole pumps and the completion of preliminary analysis of borehole treatment techniques.

Technological advances in the areas of advanced heat exchanger and advanced energy conversion systems also will bring about a significant reduction in the cost of geothermal power. Using the same quantity of moderate-temperature geothermal fluid, binary-cycle power plants could produce 20 percent more power than flash-steam plants. Advanced binary systems employing direct-contact heat exchangers are expected to have even greater geothermal fluid utilization efficiency while simultaneously reducing plant capital costs by 20 percent. DOE efforts in conversion technology cover 1) the testing of prime movers such as the helical screw expander, 2) the development of binary cycle systems, and 3) the design of improved waste heat reinjection systems to reduce cooling water requirements for geothermal plants. Significant accomplishments in FY 1978:

- The 1 MWe helical screw expander, a rugged, easily transportable wellhead generator system, was field tested in Utah. Test results offer industry the prospect of an early return on investment from wells

drilled during field development. This means that income can be obtained during the extended initial testing phase of reservoir development.

- The design and fabrication of a 500 kW direct-contact binary-cycle heat exchanger and power conversion system was completed. The system, now undergoing laboratory testing, will provide the basic engineering design data and operating experience to design and build commercial-scale modules up to 50 MW in size.
- Designs for a heat exchanger, a turbogenerator, and a downhole brine pump subsystem for a thermal siphon binary-cycle wellhead generator system were initiated.
- The fluted tube condenser component test, which began in FY 1977 at the East Mesa test facility, was expanded to a full field test of a fluted tube and shell condenser unit.

Geochemical engineering and materials. Utilization of geothermal fluids requires the production, handling, and disposal of large quantities of brines. Since the chemistry of brines is to a large extent site-specific, the solution of geochemical problems requires a detailed design to balance technical and economic subsystems for each potential site.

Geochemical engineering efforts by DOE cover two areas of interest: fluid chemistry and materials. Fluid chemistry R&D for water use, fluid control, and process modeling is aimed at improved geothermal fluid management and disposal procedures. Materials research develops new high-temperature materials for geothermal well completion, and less expensive construction materials for geothermal power plants. In FY 1978, field tests were conducted on polymer concrete pipes and power plant materials to find alternative corrosion-resistant materials that are cost-effective for some applications. Other tests provided essential corrosion and scaling information for large facilities such as those at Niland, California; Raft River, Idaho; and East Mesa, California.

Environmental control studies and technology. Projects in environmental control techniques, principally the reduction of atmospheric pollutants to acceptable levels and the disposal of geothermal fluids, were pursued in FY 1978.

To facilitate hydrogen sulfide removal, DOE directed major effort at the copper sulfate (CuSO_4) steam-scrubbing process and the fluid oxidation process. In a steam-scrubbing process test at The Geysers, up to 95 percent removal of H_2S has been achieved by mixing a copper sulfate salt solution with H_2S to form a copper sulfide precipitate. A prototype system to scrub 100,000 pounds per hour of steam is under construction at The Geysers (Cal.) and testing will begin in Spring 1979. Comparable success has been achieved in laboratory testing of an oxidation process for H_2S removal in which oxygen is injected directly into the geothermal fluid; field tests have been initiated at a site in the Imperial Valley of California. EPA expects to support investigation of electrochemical oxidation of H_2S in water.

Subsidence research seeks to distinguish between naturally occurring subsidence and subsidence possibly caused by geothermal operations, and to develop a means for operating a geothermal field that will prevent or minimize adverse effects of subsidence. FY 1978 DOE tasks included measurement of subsidence and subsidence effects; development of a theory of subsidence to describe the physical processes that cause subsidence; study of geologic response to external perturbations, such as the removal of geothermal fluids, mathematical modeling of subsidence and related phenomena; and subsidence control, for example by reinjection of spent fluids.

Other ongoing efforts include R&D for fluid disposal, induced seismicity control, and noise control; environmental monitoring; support of criteria, guidelines, and standards development and EIA/EIS preparations; research to develop data bases for guidelines and standards for other geothermal activities; and environmental monitoring of increased field activities. FY 1978 accomplishments include the following:

- Environmental control monitoring was initiated in support of the geopressured test well in Brazoria County, Texas and other DOE geothermal field facilities.
- The Environmental Development Plan (EDP), entitled "Geothermal Energy Systems," September 1977, was updated and expanded in scope. The plan is a guide for planning and managing environmental health and safety activities required by DOE's geothermal program, including identification of EH&S issues, plans for solutions, and milestones for environmental impact assessments and statements.
- State-of-the-art reports were completed for liquid waste disposal systems and gaseous waste disposal. These studies identify and assess controls for use with existing and planned environmental standards, and cover airborne emissions, water pollution, blowouts, subsidence, and induced seismicity, noise, heat stress, and sampling and analysis procedures.

Three groups of Environmental Protection Agency's Office of Research and Development have programs of relevance to geothermal development: the Environmental Monitoring and Support Laboratory at Las Vegas, Nev., identifies pollutants, pathways to underground water environment, and ecological hazards associated with long-term operating facilities. Chief among pollutants from geothermal energy sources are heavy metals (Mn, Ni, Zn, As, Sr, Hg, and Pb). The Office of Health and Ecological Effects characterizes the health and ecological effects of these pollutants. Since these pollutants may originate from other sources, the program is not considered to be solely geothermal work. The Industrial Environmental Research Laboratory runs a program to assess and develop pollution control technology, including geothermal pollutant control.

In FY 1978, EPA published or prepared the following reports: 1) Geothermal Environmental Impact Assessment (three volumes) covering baseline geotechnical data subsurface environmental assessment for four geothermal areas, and groundwater monitoring guidelines for geothermal development; 2) Known Geothermal Resource Areas of the Region VIII States; 3) Geothermal

Resource Utilization, Waste Disposal, and Regulatory Constraints--A Decision Maker's Handbook; 4) Proceedings of the First and Second Workshops on Sampling Geothermal Effluents; 5) Survey of Environmental Regulations Applying to Geothermal Exploration; and 6) Pollution Control Guidance for Geothermal Energy Development.

EPA will announce its guidelines for monitoring environmental impacts of geothermal development early in FY 1979. Working with the Bureau of Reclamation, USGS, BLM, its own regional office, and private industries and consultants, EPA is developing a systems approach to monitor impacts at any development and conversion facility using geothermal resources.

In FY 1978, the Industrial Environmental Research Laboratory also

- sponsored a project to examine costs of pollution control in geothermal development.
- sponsored projects in pollution control technologies, including injection.
- with DOI's Fish and Wildlife Service, initiated a feasibility study directed toward using geothermal effluents for the creation or enhancement of waterfowl wetlands. By the end of FY 1979, the sponsoring agencies will be ready to begin site-specific projects.
- studied air emissions by measuring gas at wellheads on six sites, including two at East Mesa, one at Raft River. Negotiations are being conducted to expand tests to Desert Peak, Nev., Valles Caldera, N.M., and Roosevelt Hot Springs, Utah. Begun in May 1978, the studies will continue 15 months.
- began sampling and analyzing water chemistry at 121 sites in geothermal manifestations to characterize the pollutants in water.
- began developing a method to predict possible groundwater contamination resulting from development of geothermal resources.

D. Institutional Support

DOE geothermal loan guaranty program. Twelve applications for loan guaranties in hydrothermal development have been submitted to DOE. Three have been processed and a fourth is near completion; a number of companies are now preparing applications. It is expected that tax measures included in the National Energy Act will stimulate participation by investors interested in providing equity necessary to obtain a guaranteed loan.

The time required for the review process has inhibited use of the loan guaranty program, especially by smaller direct thermal developers. DOE has undergone a high degree of learning in processing the first four applications, and is optimistic about reducing the time required to process new loan guaranty applications. Current goals are to complete processing in no more than four months on the average and six months at the outside.

In PL 95-238, Title V, amendments to the loan guaranty authority provided for in PL 93-410 enhance the effectiveness of the program in several ways. PL 95-238 raises the loan guaranty limits to \$100 million per electric project, \$50 million per nonelectric project, and \$200 million per borrower, with authority to exceed these limits, provided Congress is given 30 days' notice. The amendments include authority to guarantee 75 percent of the cost of an entire facility that is located at a geothermal resource for the purpose of utilizing geothermal energy, or that is economically dependent on the geothermal reservoir. DOE was authorized to make interest-differential payments to State or local government authorities and to Indian tribes so that these groups could obtain guaranties on development bonds or other obligations whose interest payments are not exempt from Federal income taxes. Several other improvements such as authority to issue guaranties supported by the full faith and credit of the United States, and to provide assistance in making payments on principal as well as interest, will make the program more attractive to lenders.

A coordinated environmental evaluation procedure is being established for loan guaranties to projects on Federal land. The Institutional Barriers Panel will examine the need for such evaluations in light of the environmental reviews done prior to leasing and permitting exploration and development on Federal lands.

Two loans totaling \$4.6 million were guaranteed by DOE and one commitment for a guaranty of up to \$30 million was issued in FY 1978. Three other applications for guarantees totaling \$82.1 million are pending and final determination by DOE is expected in FY 1979.

Economic studies and incentives. Among the studies undertaken by IGCC member agencies in FY 1978:

- DOE sponsored a conference on levelized busbar costing methodologies in June; proceedings of that conference will be published in FY 1979.
- In a companion report scheduled for publication in FY 1979, DOE examined 16 organizations active in hydrothermal development to attempt to derive a uniform system for estimating geothermal electric power costs.

- According to a DOE study, the cost of controlling hydrogen sulfide emissions at a site similar to The Geysers varies from 1.2 mills per kWh to 2.4 mills per kWh, depending on the abatement level desired.

Several new engineering and economic studies of direct uses of geothermal heat were performed, and a number of field experiments for direct uses, selected from responses to the Program Opportunity Notice issued in FY 1977, are under way. Operations research studies identified additional candidates for direct-use demonstration projects, and another Program Opportunity Notice directed to the development needs of various regions was issued.

In support of a DOE Hydrothermal Commercialization Task Force Study, the market readiness of hydrothermal resources was analyzed. This analysis followed the current IGCC site-specific planning approach in which programs are based on the best available information about individual prospects.

Life-cycle electricity busbar cost estimates were calculated for 34 candidate hydrothermal sites and compared with estimates for coal, nuclear, and oil/gas-fired power plants. The impact of advanced technology and the National Energy Act incentives on the cost of geothermal power is illustrated in the cost-supply curves (Appendix G).

In general, the higher temperature hydrothermal resources (250°C) will be more competitive than the cooler resources (around 200°C or less) for generating baseload electricity in the Pacific and Rocky Mountain Census Regions. If the competition is oil-fired steam, as it is in Hawaii and may be in California, hydrothermal resources may be competitive at 190°C using present technology, or even at 160°C with tax incentives* plus advanced technology.** With regard to nuclear plants, a resource of about 230°C using present technology would be competitive, and tax incentives and advanced technology could make 210°C resources competitive with nuclear plants. A resource of around 210°C using present technology could be competitive with coal-fired plants, whereas tax incentives coupled with advanced technology could render resources of about 190°C competitive with coal-fired plants.

DOE contracts for nonelectric engineering and economic studies were issued for

- sugar cane processing, using fluids with the characteristics of those from the Hawaii Project Well A (HFP-A).
- a multiple-use district in El Centro, California, using the Heber KGRA hydrothermal resource.

*Expensing of intangible drilling costs, investment tax credit, and depletion allowances.

**Beginning in 1980, the outputs of R&D sponsored by the Federal Geothermal Program are expected to enhance the economic competitiveness of geothermal electricity. Reductions in the cost of fluid (through lower well costs, longer well life, and increased flow rate) and increased efficiency of resource utilization could result in a significant drop in the busbar cost of electricity.

- a multiple-use space and water heating and cooling system for the city of Susanville, California.
- an integrated heating facility for livestock and feed production at Mountain Home, Idaho.
- a multiple-use heating district in the Baca Grande Development (San Luis Valley, Colorado).
- space heating the Edgemont (S.D.) school complex, using geothermal fluids from the Madison aquifer.

In the area of direct thermal field experiments and demonstrations, DOE issued Program Opportunity Notices and awarded contracts for the following projects:

- Monroe City, Utah--to develop heating system on a known hydrothermal system.
- Haakon School District, S.D.--to heat a school building at Philip, S.D., with geothermal energy from the Madison Formation.
- Douglas School System, S.D.--to heat a school building, using water from the Madison aquifer.
- Ore-Ida Foods, Boise, Idaho--to develop a system using geothermal energy to dry onions at an existing food processing plant in Ontario, Oregon.
- St. Mary's Hospital, Pierre, S.D.--to provide supplemental heat for a hospital and extend the system to provide heat to a nearby shopping plaza.
- South Dakota School of Mines and Technology, Rapid City, S.D.--to use geothermal energy for (1) space heating farm buildings, (2) drying grain, and (3) providing warm water for stock during the winter, near Midland, S.D.
- City of Klamath Falls, Oregon--to design, construct, and initiate operation of a geothermal space heating district in the central business district of Klamath Falls, Oregon. This will be a city-owned and operated system, initially serving 14 government buildings, with subsequent expansion to 115 private commercial buildings.
- Torbett-Hutchings-Smith Memorial Hospital, Harlin, Texas--to augment the space and water heating systems of a hospital.

The National Science Foundation has no specifically identified program for geothermal training. However, geothermal activity support for FY 1978 under generic programs included \$175,000 for 25 energy-related graduate traineeships.

E. Resource Assessment, Exploration, and Confirmation

Resource assessment. In FY 1978, the United States Geological Survey reassessed the geothermal resources of the United States, updating and refining the 1975 national assessment. Changes include new calculations of statistical uncertainty of estimates of reservoir thermal energy for hydrothermal convection systems over 90°C, a more comprehensive analysis of energy recoverability (including an explicit statement of "available work"), and estimates for lower temperature (less than 90°C) resources. For a discussion of major changes from the 1975 assessment, please see Section II, above.

GEO THERM, the geothermal data file of the USGS, was updated with many new records of warm springs and well data; it is now fully operational and was used in preparing both the intermediate- to high-temperature hydrothermal and the low-temperature portions of the 1978 national assessment of geothermal resources.

USGS tests of a recently developed downhole geothermal fluid sampler at The Geysers retrieved a water sample from a 6000-foot well. This was the first time that a fluid sample was obtained from within a vapor-dominated system. In other studies of vapor-dominated systems, a mathematical model describing some of the physical processes of such a reservoir was modified to include radial flow of steam for the first time. This model subsequently was used to evaluate transient pressure drawdown and recovery behavior during a simulated production period.

Chemical and isotope analyses of water and steam samples from Cerro Prieto, Mexico, geothermal wells were used comprehensively for the first time in a hot-water system to evaluate entrance of cooler water from shallow aquifers into the production zone.

To assist the assessment of hot dry rock resources, mapping the distribution of young volcanoes less than 17 million years old in Utah-Colorado and Arizona-New Mexico was carried out and presented on two color maps at a scale of 1:1,000,000.

Geologic and geophysical study of the Snake River Plain of Idaho, including temperature measurements in slim shallow holes, was a major effort in FY 1978 and will be concluded in FY 1979. This activity, conducted principally by the USGS but aided by several universities and other DOE-funded activities, has as its objective a conceptual model to better understand the background heat flow and type of geothermal anomalies of the region. In addition to specially drilled heat flow holes, available wells are logged for temperature measurements. Heat flow data have been recorded in over 450 holes. Two to three deep holes (to 1,000m) are also included as part of the DOE/USGS regional study to obtain information about the thermal regime at greater depths.

Exploration. An analytical model, based on surface heat flow and downhole temperature measurements, has been developed to help locate and define the shape of magma bodies.

Seismic velocity measurements across the southern Rio Grande rift indicate a region of high alteration at a depth of 20 kilometers, which has been interpreted as a magma layer. Seismic studies of the source regions of the Hawaiian volcanoes give useful information of the frequency and volumes with which shallow magma chambers are being refilled.

An insulated high-temperature drill stem has been developed for penetrating the Kilauea Lava Lake. A long-tube heat exchanger has also been developed to study the heat transfer rates and mechanisms in the Kilauea Lava Lake.

Reservoir confirmation. In the eastern radiogenic program, a DOE thermal gradient drilling program located heat sources for potential warm-water reservoirs in the Atlantic Coastal Plain. The DOE western states cooperative program expanded the state-coupled program for confirmation of low- and moderate-temperature resources for direct heat application to include cooperation with 28 states.

A major effort to confirm high-temperature reservoirs, in cost-shared exploration drilling with industry, included three new prospects in the Northern Basin and Range Province (northern Nevada, southeastern Oregon, southern Idaho).

In addition, resource definition studies produced maps of the Wilcox and Vicksburg geological formations in Texas and completed the delineation of five optimum geopressured reservoirs in the Miocene sands in Louisiana.

Intermediate depth drilling programs were combined with geophysical studies at targeted sites for deep exploratory drilling in FY 1979 at two major study areas: the Snake River Plain, Idaho, and the Mt. Hood region, Oregon.

Table 5 shows FY 1978 commercial drilling activities in the western United States, by area and by developer. While this table may not be inclusive of all drilling activities, it is indicative of the level of effort occurring during the reporting period.

F. Resource Acquisition and Leasing

Geothermal resources on Federal lands are developed by private operators under a DOI lease program. Federal lands classified as occurring in Known Geothermal Resource Areas (KGRAs) are leased by competitive bids at lease sales conducted by the Bureau of Land Management. BLM leases Federal lands outside of KGRAs to the first qualified applicant. The USGS evaluates geothermal resources on lands leased by competitive procedures.

The first leases for geothermal development were issued early in 1974 after the competitive offering of 8755 acres in The Geysers KGRA, California. A total of approximately 1.2 million acres have been offered for lease through competitive bidding, including some tracts that were classified as a KGRA because of indications of competitive interest where two or more applicants

Table 5

COMMERCIAL DRILLING ACTIVITY, FY 1978

<u>Operator</u>	<u>Well Designation</u>	<u>Status & Date</u>	<u>Type</u>	<u>Field</u>	<u>State</u>
Phillips Petro.	E. Brawley Strat Test 2	Drilling 11/18/78	Exploratory	East Mesa	California
Phillips Petro.	E. Brawley Strat Test 3	Drilling 11/18/78	Exploratory	East Mesa	California
Union	Clay Pit 1	Drilling 10/28/78	Exploratory	Mono-Long Valley	California
Union	Mammoth 1	Drilling 10/28/78	Geothermal Dev.	Mono-Long Valley	California
Natomas Co.	Davies-State 5206-1	Drilling 9/2/78	Geothermal Dev.	Geysers	California
McCulloch Geoth.	Hot Mineral 1-15	Drilling 7/15/78	Exploratory	Salton Sea	California
McCulloch Geoth.	Hot Mineral 2-15	Drilling 7/15/78	Exploratory	Salton Sea	California
Union	Slater 1	Drilling 7/1/78	Exploratory	Imperial County	California
Chevron	Brandt 1	Drilling 6/3/78	Exploratory	Imperial County	California
Aminoil	Thorne 7	Drilling 4/29/78	Geothermal Dev.	Geysers-Calistoga	California
Thermogenics	Klau Mines K-1	Drilling 4/1/78	Geothermal Dev	Geysers-Calistoga	California
Aminoil	Aidlin 3	Drilling 3/25/78	Geothermal Dev.	Geysers-Calistoga	California
Union	Curry 1	Drilling 3/25/78	Geothermal Dev.	Geysers-Calistoga	California
Phillips Petro.	K-1	Drilling 3/25/78	Observation	Geysers-Calistoga	California
Phillips Petro.	K-2	Drilling 3/25/78	Observation	Geysers-Calistoga	California
Phillips Petro.	K-3	Drilling 3/25/78	Observation	Geysers-Calistoga	California
Phillips Petro.	K-4	Drilling 3/25/78	Observation	Geysers-Calistoga	California
Phillips Petro.	K-5	Drilling 3/25/78	Observation	Geysers-Calistoga	California
Phillips Petro.	K-6	Drilling 3/25/78	Observation	Geysers-Calistoga	California
Phillips Petro.	K-7	Drilling 3/25/78	Observation	Geysers-Calistoga	California
Phillips Petro.	K-8	Drilling 3/25/78	Observation	Geysers-Calistoga	California
Phillips Petro.	K-9	Drilling 3/25/78	Observation	Geysers-Calistoga	California
Phillips Petro.	K-10	Drilling 3/25/78	Observation	Geysers-Calistoga	California

Table 5 (Cont.)

<u>Operator</u>	<u>Well Designation</u>	<u>Status & Date</u>	<u>Type</u>	<u>Field</u>	<u>State</u>
Thermogenics	65	Drilling 3/25/78	Observation	Geysers-Calistoga	California
Chevron	Orita C-131	Drilling 3/18/78	Exploration	Imperial County	California
Union	Angeli 1	Drilling 3/18/78	Geothermal Dev.	Geysers-Calistoga	California
Phillips	E. Brawley Strat Test 1-A	Drilling 3/11/78	Exploratory	Imperial County	California
Sunedco	C. H. Stocks 1-A	Susp. 8/3/78 - 9/2/78			Idaho
Chevron	Silver Lake	Susp. 12/29/77 - 2/2/78			Nevada
N. W. Natural Gas	Old Maid Flats		Geothermal Test		Oregon
Sunedco		12/8/78		Dixie Valley	Nevada
Union	Veysey	Spud 8/25/78	Semi-Exploratory	Brawley	California
Aminoil	Ca 956	Spud 11/15/78		Geysers-Calistoga	California
McCulloch Geoth.	Mercer 1-28	Spud 7/11/78	Exploratory	Brawley	California
Magma Power	7 48A-7	Spud 10/30/78		East Mesa	California
Union	Occidental Federal 1	Spud 10/4/78	Semi-Exploratory	Geysers-Calistoga	California
Amax	Amax	Spud 8/4/78	Exploratory	Middletown	California
Repub. Geoth.	58-30	Spud 7/9/78		East Mesa	California
Union	Sinclair	Spud 10/22/78		Salton Sea	California

SOURCE: U.S. Geological Survey.

filed lease offers for the same lands. A total of 474,553 acres were leased through the competitive bidding process, accounting for \$19.1 million in bonuses.

Leases issued without competitive bidding for lands not within a known geothermal resources area or for which no competitive interest has been shown total, to date, 1190 and cover 2.1 million acres. of which 71,128 acres are situated within the national forests; the remainder is under the jurisdiction of the Bureau of Land Management.

A total of 217,865 acres was offered for competitive lease in FY 1978. No bids were received on 158,647 acres. The remaining 59,218 acres were leased for \$1,067,515.01. States where competitive geothermal leases were issued in FY 1978 include California, Arizona, Colorado, Idaho, Montana, Nevada, and New Mexico.

The number and acreage of the leases issued are shown in Appendix I.

G. Field Development and Production Drilling

Recompletions of two abandoned wells in Louisiana were initiated by DOE to enlarge the geopressured resource data base and to provide for production tests. One was completed, and three others will be completed in FY 1979. The first well designed especially to test a geopressured aquifer was initiated in Brazoria County, Texas. Production tests are planned to test flow rates as high as 40,000 barrels per day for up to two years. Plans were laid to drill four more designed wells in Louisiana and Texas. The Brazoria well and other well data will be used with reservoir computer models to estimate long-term productivity from the aquifers.

H. Plant/Facility Construction and Testing

The DOE objective for facility construction and testing is to provide a means for demonstrating that the generation of electric power from hydrothermal resources is technically feasible, economically sound, and environmentally acceptable.

The specific objectives of the demonstration program are as follows:

1. To operate by the end of FY 1982 a commercial-scale plant capable of generating electricity from a superheated water hydrothermal resource.
2. To demonstrate with high confidence by 1983 that a particular low-to-moderate salinity geothermal reservoir can provide an adequate supply of hot water for the extended operation of such a plant.

3. To demonstrate by 1985 the acceptability of environmental impacts associated with the construction and operation of such a plant.
4. To demonstrate by 1985 the production of electric power from such a plant at a commercially competitive cost.

Over 60 resource areas likely to contain liquid-dominated, low-to-moderate salinity geothermal reservoirs have been identified in the western United States. Many of these areas will be candidates for geothermal electric plants if the first and subsequent demonstration plants convince industry of the technical practicality, economic viability, and environmental acceptability of geothermal electric systems.

In FY 1977, 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 (nominal 50 MWe) electric power plant. Funds were appropriated in FY 1978 and a PON issued to encourage respondents to identify suitable sites, energy conversion systems, and cost-sharing arrangements. Proposals were received and evaluated; a contract is being negotiated for the construction and operation of the demonstration plant at Valles Caldera, N.M.

Although the unique dry steam geothermal resource at The Geysers (California) has produced electricity for years, no hot-water geothermal resource has yet produced commercial electric power in the United States. The principal impediments to such development include uncertainties about the long-term productive capacities of reservoirs, disposal of spent fluids, corrosion and scaling, possible land surface subsidence, environmental impacts, and of course economics, including reservoir and plant maintenance costs. The Valles Caldera demonstration plant will reduce the risks to potential investors by providing technical data and financial operating experience for a commercial-scale enterprise.

A joint DOE-EPRI program was implemented in FY 1978 to develop conceptual designs and cost estimates of power plants at those prospects in California expected to have power on line by 1985. Data from this program will identify and quantify the specific, prospect-related research and development required to remove technical impediments and to reduce the cost of electricity from the geothermal energy available at each prospect.

Comprehensive tests of the thermal loop were completed at the jointly funded industry/DOE Geothermal Loop Experimental Facility (GLEF) near Niland, California. The facility uses a flashed-to-binary energy conversion cycle with the hypersaline brines of the reservoir. Based on very favorable results obtained during operation of GLEF, a study was conducted to see how the cycle could be exploited and the development of commercial power generation advanced, for example, by passing scrubbed steam from flashing units directly to a steam turbine generator unit.

The first evaluation of the role of wellhead generators was initiated in a jointly funded effort with the Hawaii Geothermal Project Development Group, which includes the State of Hawaii, the county of Hawaii, the University of Hawaii, the Hawaiian Electric Company, and DOE. Conceptual and preliminary designs of a 5 MWe wellhead generator were completed.

Component and subsystem testing at the Geothermal Component Test Facility in East Mesa, California, continued through FY 1978, to accommodate DOE and industry requirements.

Well-drilling and detailed engineering designs have been completed for the Raft River Thermal Loop Facility at Malta, Idaho. The Loop Facility will test integrated energy conversion systems specifically for moderate-temperature hydrothermal reservoirs. Construction of the first 40 MWt (5 MWe equivalent) thermal loop using currently available technology continued through FY 1978. Designs for turbine generators and procurement of hardware marked the beginning of conversion of the facility to a pilot electric plant.

The Los Alamos Scientific Laboratory hot dry rock thermal loop operated for 2-1/2 months to assess the long-term stability of the heat extraction rate, to determine the geothermal effects and to evaluate fluid loss, and to determine energy input requirements. First steps were taken toward developing a Phase 2 (40-50 MWt) energy extraction loop at the Fenton Hill Site, in New Mexico.

VI. REGIONAL PROGRESS FY 1978

Introduction

For the purposes of discussing regional accomplishments, the United States has been divided as shown in Figure 3, so that roughly equivalent levels of activity are expected to occur in each region. The Pacific Region and the Rocky Mountain Basin and Range Region contain mostly hydrothermal convective resources, while the Gulf Coast Region contains geopressured resources and the Eastern Region contains low-temperature resources of various types.

A. Region I - Pacific Region (California, Hawaii, Oregon, Washington, Alaska)

Resource characteristics. Region I geothermal resources are primarily of the hydrothermal convective type. Hot water resources are predominant in the region, but a large vapor-dominated resource exists at The Geysers, California and another, possibly, at Mount Lassen. Hot dry rock resources exist in Hawaii and other areas. The geothermal energy of Region I could supply a substantial amount of the energy needs of the five states. IGCC postulates that more than 80 percent of the geothermal electric power produced in the United States by 1985 will come from this region. USGS Circular 726 identified 131 hydrothermal sources distributed throughout the region.* In 32 of these systems the reservoir temperatures were estimated to be above 150°C. The potential electrical power production of the high-temperature systems was estimated to exceed 20,000 MWe.

Geothermal development goals. Table 6 shows the geothermal electric power on line postulated by the IGCC for Region I. As can be seen from the table, extensive generation of electricity is expected in this region.

Progress and accomplishments. A substantial amount of Federal land has been leased in the region and numerous shallow and deep wells have been drilled. Additional geophysical and geological studies were initiated in FY 1978 to better define the geothermal resources of the region.

On National Forest System lands, many leasing decisions are being delayed pending completion of land management plans as directed by the National Forest Management Act of 1976. Several plans are in progress, and geothermal areas in which great interest has been expressed are receiving preferential treatment. All National Forest land management plans are due for completion by 1983.

*References are made to Circular 726 rather than 790 at several places in Section VI because Circular 790 data have just been published and have not yet been incorporated into regional analyses.

Figure 3. Geothermal Energy Operations Research Regional Boundaries

Regional boundaries based on rough estimates of near future development activities as deduced by DOE from the USGS Circular 726, Assessment of Geothermal Resources of the United States - 1975.

Table 6

GEOTHERMAL ELECTRIC SCENARIOS POSTULATED BY THE IGCC
FOR PLANNING PURPOSES* -- REGION I

Generating Capacity Installed Each Year (MWe)

	<u>Pre- 1983</u>	<u>1983</u>	<u>1984</u>	<u>1985</u>	<u>1986</u>	<u>1987</u>	<u>1988</u>	<u>1989</u>	<u>1990</u>	<u>1990- 2020</u>	<u>Total</u>
Alvord, OR	--	--	--	--	--	50	--	--	50	200	300
Baker Hot Springs, WA	--	--	--	--	--	--	--	--	50	--	50
Brawley, CA**	--	50	--	50	--	100	100	100	100	500	1,000
Coso Hot Springs, CA	--	--	--	50	50	50	150	150	150	--	600
East Mesa, CA**	--	--	--	50	--	--	50	--	--	--	100
Geysers, CA (hot water)	--	--	--	100	100	100	100	100	100	400	1,000
Geysers, CA (steam)	1,680	160	220	110	--	--	--	--	--	--	2,170
Glass Mt., CA	--	--	--	--	--	--	--	--	50	--	50
Heber, CA	--	50	--	50	--	100	100	--	--	700	1,000
Lassen, CA	--	--	--	--	--	50	--	--	50	--	100
Mono-Long Valley, CA	--	--	--	50	--	100	--	--	100	--	250
Mount Hood, OR	--	--	--	--	--	--	--	--	50	--	50
Puna, HI	--	--	--	20	--	--	--	--	50	850	920
Salton Sea, CA	--	50	--	100	75	75	100	100	100	1,400	2,000
Surprise Valley, CA	--	--	--	--	50	--	50	100	100	1,700	2,000
Vale Hot Springs, OR	--	--	--	--	--	--	50	--	50	700	800
Total Installed Power On Line	1,680	1,990	2,210	2,790	3,065	3,690	4,390	4,940	5,940	12,390	12,390

*The selection of sites and the postulated generating capacities are based on current knowledge of the geothermal resources in the region. The scenario is intended for planning purposes only and does not imply any commitment on the part of the Federal government to development at these sites. Generating capacity estimates in Table 1 (p. 14) for the years after 1985 assume development of additional sites.

**The IGCC postulates that a 10 MWe pilot plant will be completed at East Mesa in 1978 and at Brawley in 1979.

Figure 4. Region I Sites in the IGCC Geothermal Electric Scenario

Exploration and assessment of the vapor-dominated resource at The Geysers continued through FY 1978. Additionally, construction began on four new power plant units expected to ultimately contribute an additional 406 MWe. The IGCC postulated that by 1985, more than 1,500 MWe of steam power will be generated. However, it appears unlikely that a hot water resource will be developed at this site until the extent of the steam resource is known (all the land is leased) and it is established that production from a hot-water reservoir will not jeopardize production from the vapor-dominated reservoir. Therefore, the IGCC-postulated production of 100 MWe from a liquid-dominated resource by 1985 may be delayed.

In July, 1977, the Northern California Power Agency and the Shell Oil Company announced plans to construct a 110 MWe plant at The Geysers, to be completed in late 1980. The Pacific Gas and Electric Company continued to construct power plants throughout FY 1978. Table 7 summarizes postulated steam-electric development in California through 1986.

The major obstacle to continued development at The Geysers has been the odor of H₂S emissions. Public concern over the odors from existing geothermal plants was a prime element in the county's decision to delay permits for construction of power plants between 1972 and 1976, and may threaten the renewal of variance permits for older operating plants.

At East Mesa, California, Imperial Magma Power Company's construction of a 10 MWe pilot plant continued in 1978. The geothermal resource at East Mesa already has been extensively developed, but is being used now only for experiments. The Bureau of Reclamation completed its desalting and reservoir evaluation tests, and in July 1978 turned over site operations, including the GCTF Test Site, to DOE. The IGCC-postulated production of 50 MWe by 1985 may require that additional Federal land be leased by 1981.

Other resource areas where geothermal development is occurring as anticipated by the IGCC include Heber, Salton Sea, Coso, and Brawley, California. Areas where resources are being assessed include Vale, Oregon, Baker Hot Springs, Washington, and Surprise Valley, California. Development of four other prospects may be delayed due to environmental concerns: Lassen and Glass Mountain, California, and Alvord and Vale, Oregon.

Direct heat use of geothermal fluids is occurring in several locations in the Region, particularly at Klamath Falls, Oregon, and Susanville, California.

The Hawaiian Geothermal Development Group has completed preliminary design of a 3-5 MWe wellhead generator system and has formulated plans for its installation and operation at a site near Puna, Hawaii. This DOE/state/county/industry cost-shared effort is expected to produce electric power in FY 1979 and subsequently demonstrate the commercial viability of generating electric power from the very high-temperature (around 365°C) hydrothermal reservoir recently defined at the Puna site. Development has progressed so well at the site that the IGCC-postulated generating capacity of 20 MWe may be achieved earlier than 1985.

Table 7

GEOTHERMAL STEAM-ELECTRIC INSTALLED CAPACITY

Date	Site	Developer	MWe
1/78	Geysers	PG&E	502
10/78	Geysers #12	PG&E	608
12/78	Geysers #15	PG&E	663
6/79	Geysers #14	PG&E	773
10/79	Geysers #13	PG&E	908
6/80	Unsited	Imp. Irrig. Dist.	958
12/80	Geysers	NCPA	1,068
10/81	Geysers #16	PG&E	1,178
10/81	Geysers #17	PG&E	1,288
4/83	Unsited	Cal. St. Dept. of H ₂ O Res.	1,343
6/83	Unsited	Imp. Irrig. Dist.	1,393
8/83	Geysers #18	PG&E	1,503
9/83	Geysers #19	PG&E	1,613
1/84	Unsited	Cal. St. Dept. of H ₂ O Res.	1,668
6/84	Geysers #20	PG&E	1,778
6/84	Geysers #21	PG&E	1,888
6/86	Unsited	Imp. Irrig. Dist.	1,938
6/86	Unsited	PG&E	2,048
6/86	Unsited	SCE	2,098
6/86	Unsited	SCE	2,148

SOURCE: Additions to Generating Capacity, 1978-87, for the Contiguous United States, DOE/ERA-0020, September 15, 1978.

B. Region II-Rocky Mountain Basin and Range Region
(Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, North Dakota,
South Dakota, Utah, Wyoming)

Resource characteristics. Region II geothermal resources include a number of high-temperature hydrothermal convective resources, and a larger number of low-to-moderate temperature hydrothermal convective resources. One hot dry rock resource has been confirmed in the Jemez Mountains adjacent to Valles Caldera.

Relatively little is known about Region II resource characteristics, and the majority of potential reservoirs may lack any surface expression. Principal efforts, therefore, are directed at the following:

1. Industry-coupled case studies involving exploratory drilling in the region, to begin in FY 1979 and continue through the end of FY 1982. These efforts, along with independent industry activities, may confirm the reservoirs needed to reach the 1985 goals by mid-FY 1980.
2. State-coupled reservoir confirmation projects for direct heat utilization.
3. Initial resource inventory resulting in state-by-state low-to-moderate resource maps, to be completed by mid-FY 1980.
4. Regional heat flow mapping and lava flow dating, to begin in FY 1980. Both heat flow anomalies and indications of recent volcanic activity will help to locate hidden resources in the region.

Two areas in the region have both the quality and quantity of resources needed for electrical power generation: Roosevelt Hot Springs, Utah, and Valles Caldera, New Mexico. Numerous other excellent prospects exist, but drilling has not been intensive or extensive enough to prove reservoir capacity for power generation.

Geothermal development goals. Extensive geothermal electric production in Region II is expected. The first commercial-scale electric production is postulated at four sites in 1983. Direct thermal uses in Region II also may be substantial.

Table 8 shows the IGCC-postulated electric generation potential for Region II.

Progress and accomplishments. Using areal geology, geophysics surveys, paleomagnetic dating and regional heat flow study, USGS systematically investigated the geothermal potential of the Snake River Plain of southern Idaho. The investigation resulted in plans for development of various prospects, and identification of initiatives required to stimulate commercial development.

Figure 5. Region II Sites in the IGCC Geothermal Electric Scenario

Table 8

GEOTHERMAL ELECTRIC SCENARIOS POSTULATED BY THE IGCC
FOR PLANNING PURPOSES* -- REGION II

Generating Capacity Installed Each Year (MWe)										
	Pre- 1983	1983	1984	1985	1986	1987	1988	1989	1990	1990- 2020
										Total
Brady Hot Springs, NV	--	50	--	--	50	--	100	--	100	700
Beowawe, NV	--	50	--	--	50	--	50	--	100	750
Bruneau-Grandview, ID	--	--	--	--	--	50	--	--	100	3,000
Chandler, AZ	--	--	--	--	50	--	--	--	100	80
Cove Fort-Sulphurdale, UT	--	--	--	50	--	50	--	50	50	1,300
Leach, NV	--	--	--	--	--	50	--	--	50	1,400
Raft River ID	--	--	--	--	--	--	50	--	50	700
Roosevelt Hot Springs, UT	--	50	--	--	50	--	50	--	100	750
Safford, AZ	--	--	--	--	--	50	--	--	--	50
Steamboat Springs, NV	--	--	--	50	--	--	50	--	100	--
Thermo, UT	--	--	--	--	--	--	50	--	--	450
Valles Caldera, NM	--	50	--	--	100	--	100	--	100	1,150
Weiser-Crane Creek, ID	--	--	--	--	--	--	50	--	100	850
West Yellowstone, MT	--	--	--	--	--	--	--	--	50	--
Total Installed Power On Line	0	200	200	300	600	800	1,300	1,350	2,350	13,530

*The selection of sites and the postulated generating capacities are based on current knowledge of the geothermal resources in the region. The scenario is intended for planning purposes only and does not imply any commitment on the part of the Federal government to development at these sites. Generating capacity estimates in Table 1 (p. 14) for the years after 1985 assume development of additional sites.

A number of EISs were completed within the State of Arizona in FY 1978. In addition, some leasing and exploration has occurred in the state, but much of the area that has potential for geothermal activity may not be exploitable, due to the environmentally sensitive nature of most of the resource areas.

In Colorado, the San Luis Valley may have potential for direct geothermal fluid use in agriculture. Other areas have potential for direct-use space heating. The Colorado Geological Survey is optimistic about the geothermal potential of the state, but none of the four KGRAs in the state appear to have electric potential.

A number of geothermal development activities in Idaho occurred in FY 1978. In particular, construction began on the first 40 MWt loop at Raft River, and the Agriculture Health Laboratory completed its first season using geothermal heat, with a 50-percent reduction in heating costs. The Idaho Department of Agriculture building, under construction in Boise, will be heated with geothermal fluids. A new ten-story office building also under construction in Boise is designed for geothermal heating and will be retrofitted when the geothermal fluids are delivered. The city of Cascade is designing its new high school to use geothermal heat. Significant progress is anticipated in retrofitting the Boise downtown heating system to use geothermal fluids now that Congress has deeded the resource land to the city.

Space heat projects using geothermal fluids are also underway at Warm Springs State Hospital and the White Sulphur Springs Bank in Montana.

Three sites in Nevada have electric potential: Beowawe, Brady Hot Springs, and Leach. However, a delay of up to three years in bringing power on line at Beowawe is now anticipated. At Brady Hot Springs, development is progressing adequately to meet the IGCC-postulated production of 50 MWe by 1983, and possibly 150 MWe by 1985. At Leach, geophysical evaluation has now been completed. While this evaluation indicates a significant geothermal resource, the potential for electric power production appears limited. Three other sites appear to have electric potential: Desert Peak, Humboldt House, and Dixie Valley.

A number of other areas in Nevada are potentially exploitable, but exploration cannot begin until the completion of Environmental Impact Statements. Areas where EISs are pending include: Soldier Meadow, Trego, Gerlack, Double Hot Springs, and Fly Ranch.

In New Mexico, geothermal development is occurring as postulated at the Valles Caldera, DOE-Union 50 MWe demonstration plant, to be operational in 1983. There is major industry interest in this area and definite potential for near-term electric development. Similarly, at Roosevelt Hot Springs, Utah, negotiations are underway between Utah Power and Light and Phillips Petroleum for the construction of a 52 MWe power plant.

There is evidence of a significant geothermal resource in South Dakota. The Madison limestone, an aquifer containing considerable quantities of water with temperatures ranging up to 80°C, underlies most of the

western half of the State at relatively shallow depths. The Madison is used now for space heating.

The temperature and widespread availability of hot water make the Madison a significant source of energy for additional commercial and residential space heating and other low-temperature energy uses. DOE has completed an initial development scenario and has revised and updated a cost model for geothermal space heating. Plans for reservoir engineering, begun in FY 1978, will continue in FY 1979. The USGS cooperates by extending its study of water in the Madison Formation in southeastern Wyoming to South Dakota.

C. Region III - Gulf Coast
(Louisiana and Texas)

Resource characteristics. Region III's geopressured-geothermal resources consist of three forms of energy: thermal, dissolved methane, and hydraulic pressure. The geopressured resources occur both onshore and offshore from the Gulf Coast of Texas and Louisiana. Estimates in USGS Circular 726 indicate that the potentially recoverable thermal energy of these reservoirs could exceed 38,000 megawatt-centuries, and that the energy of the dissolved methane could be several times greater.

The characteristics of the geopressured aquifers as reservoirs have not been examined adequately, even though thousands of oil and gas wells have penetrated the geopressured formations. Heretofore, economic considerations demanded that only "free gas" (rather than dissolved natural gas) reservoirs be produced from these formations; drilling and testing of these "overpressured zones" involved hazard and expense.

Geothermal development goals. Commercial-scale utilization of the geopressured resources is not expected before the mid-1980s.

The shallower geopressured reservoirs are suitable for methane production, but the deeper, higher temperature reservoirs must be exploited for "total energy recovery" (i.e., methane recovery, production of electrical power from pressure, and direct heat from fluids) to be economical.

Program plans are being formulated by industry and state and local government agencies to bring geopressured-geothermal resources on-line in a planned and time-phased manner. These plans include resource development scenarios for each of the identified optimum geopressured prospects. The prospect-specific analyses include preliminary technical and economic considerations. Because of large uncertainties, the program goals, as shown in Table 9, show a large range of potential energy derived from these resources. Table 10 shows the geopressured hydrothermal electric power on line postulated by the IGCC for Region III.

Progress and accomplishments. Resource assessment and confirmation continued in FY 1978. The U.S. Fish and Wildlife Service (USFWS) issued its final report on ecological implications of geopressured development. The DGE inventory and case study of direct thermal use of geopressured resources by industry in Louisiana was completed. Four tests of existing wells in

Figure 6. Region III Sites in the IGCC Geothermal Electric Scenario

Region III were performed. The USGS published papers concerning the geochemistry of geopressured waters from oil and gas fields in coastal Texas and Louisiana. Detailed chemical analysis of these waters show that the salinity of water in the geopressured zones can vary widely, from about 10,000 to 270,000 mg per liter dissolved solids.

Table 9

GEOPRESSURED-GEOTHERMAL UTILIZATION ESTIMATES

	<u>1985</u>	<u>2000</u>
Electric Power Capacity (MW)	10-20	500-2500
Electric Power Fossil Equivalent (Quads/Year)	.0007-.0014	.036-.18
Nonelectric Application	*	*
Geopressured Methane (Quads/Year)	0.0-0.02	2-4
Total Energy (Quads/Year)	0.0-0.02	2.04-4.18

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

The Wilcox and Vicksburg formations of Texas were mapped. Optimum well sites in reservoirs of Miocene sands in Louisiana were delineated. USGS conducted geological and hydrologic studies to assess the deeper on-shore and off-shore geopressured resources. Regional resource assessment conducted by Louisiana State University and Louisiana Geological Survey have identified 63 candidate geopressured reservoirs, and 5 top prospects have been selected.

A first well designed to test geopressured aquifers was started in Brazoria County, Texas. The well is expected to produce 40,000 barrels of fluid per day. Within the Brazoria Fairway, the Austin Bayou Prospect was selected for confirmation drilling and long-term testing, which began in July 1978. An EIA has been prepared for the Brazoria County Test Well.

TABLE 10
GEOHERMAL ELECTRIC SCENARIOS POSTULATED BY THE IGCC
FOR PLANNING PURPOSES* -- REGION III

Generating Capacity Installed Each Year (MW _e)											
	<u>Pre- 1983</u>	<u>1983</u>	<u>1984</u>	<u>1985</u>	<u>1986</u>	<u>1987</u>	<u>1988</u>	<u>1989</u>	<u>1990</u>	<u>1990- 2020</u>	<u>Total</u>
Acadia Parish, LA	--	--	--	--	--	50	--	--	50	250	350
Brazoria, TX	--	--	--	--	25	--	100	100	200	1800	2225
Calcasieu Parish, LA	--	--	--	--	--	50	--	--	50	250	350
Cameron Parish, LA	--	--	--	--	--	50	--	--	50	400	500
Corpus Christi, TX	--	--	--	--	--	50	--	--	50	1550	1650
Kenedy County, TX	--	--	--	--	--	50	--	--	50	200	300
Matagorda County, TX	<u>--</u>	<u>--</u>	<u>--</u>	<u>--</u>	<u>--</u>	<u>50</u>	<u>--</u>	<u>--</u>	<u>50</u>	<u>400</u>	<u>500</u>
Cumulative Total					25	325	425	525	1025	5875	

* The selection of sites and the postulated generating capacities are based on current knowledge of the geothermal resources in the region. The scenario is intended for planning purposes only and does not imply any commitment on the part of the Federal government to development at these sites. The generating capacity estimates in Table 1 (page 14) for the years after 1985 assume development of additional sites.

Figure 7. Region IV. Potential Hydrothermal Geothermal Resources

D. Region IV - Eastern United States

Resource characteristics. The Eastern Hydrothermal Region includes all of the United States east of the Rocky Mountains except those parts of Texas and Louisiana with geopressed resources. The IGCC's goal is to bring about the commercial application of the Region's geothermal resources to its energy markets in the near to middle term. Resource temperature limitations suggest that these resources are usable principally as direct heat for industrial and agricultural processing and for space conditioning rather than for the generation of electricity.

The geothermal resources in Region IV may be grouped into six types:

1. Aquifers containing radiogenic heat from granitic rocks beneath the Atlantic Coastal Plain
2. Hot oil-field brines produced with oil and gas from sedimentary basins
3. Hot, relatively fresh groundwater produced from aquifers of regional extent
4. Hot water emanating from fault zones as a result of apparent leakage from greater depths
5. Hot dry rock in regions of abnormal gradient resulting from radiogenic heat
6. Normal geothermal gradient resources.

Prospects exist in more than half of its states. The Gulf Coast area may contain extensive hydrothermal resources in a deep, structurally controlled abnormal heat gradient associated with a major fault zone. The existence of this zone was suggested by data derived from oil and gas wells. It appears unlikely that there will be adequate Federal resources to support early, simultaneous, and vigorous efforts to assess all the prospects and their associated markets. Planning therefore has established criteria (e.g., resource temperature, environmental impact, proximity to market) to evaluate the early power-on-line potential of each resource type, and to rank the region's resource types accordingly.

Geothermal development goals. A specific set of objectives has been postulated for the region: the use of .01-.025 quads per year of geothermal energy by 1985, and 0.25-1.0 quads per year by 2000. Because of inadequate knowledge about resource size, character, and capacity, and about the corresponding energy markets, only a few scenarios for geothermal development in the region have been prepared. Consequently, the objectives will be revised as more data are acquired. The initial objectives are ambitious. If they are met, geothermal energy development in the Eastern United States will begin by the mid-1980s and will have a truly significant impact on the nation's energy supply by the end of the century.

Figure 8. Potential Geothermal Resource Areas in the Atlantic Coastal Plain Region

In Texas, direct thermal use of the fluids from the abnormal-gradient fault zone, north of the geopressured zone, may begin in the mid-1980s. The zone underlies many major cities, including San Antonio and Dallas, that could use the geothermal resource for space heating.

The strategy for achieving these objectives responds to the need for knowledge about resources and their energy markets, and to the expectation of low to moderate resource temperatures. The first step is to examine the region's resources in general and specific prospects in particular. Where significant energy markets appear to be located near promising prospects, those markets will be analyzed as the prospects are assessed. Individual prospects will be ranked by apparent size of the resource and the time needed for its commercial development. The second step is to develop a commercialization plan for each prospect.

Progress and accomplishments. In the eastern United States, a DOE project is assessing the amount of geothermal fluid in deeply buried aquifers that overlie plutonic rocks. Detailed energy market analyses in promising areas of the Atlantic Coastal Plain were completed. Early in FY 1979 a site for the first deep test well on the Atlantic Coastal Plain will be selected by analyzing thermal gradients determined from many shallow holes drilled to obtain these data.

The Eastern Gulf Coastal Plain offers promise of high-temperature geothermal resources consisting of both hydrothermal and geopressured resources and possibly methane. In FY 1978 a development scenario was prepared for the area, outlining and phasing the steps required to explore, assess, and develop the resource.

A development scenario for geothermal energy use in Arkansas was completed and published in FY 1978. The resource is expected to be of moderate- to low-temperature hydrothermal fluids usable for direct heat.

FLASH STEAM GEOTHERMAL POWER

VII. FEDERAL PROGRAM PLANS FOR FY 1979

Many activities planned for FY 1979 continue activities under way in FY 1978 and therefore are not repeated here. Private sector plans are not discussed here, because companies often consider their plans to be proprietary in nature. The following discussion deals entirely with future government activities, based in part on needs expressed by the private sector to achieve the national geothermal utilization estimates.

Reorganization within the Department of Energy specifically involving the Division of Geothermal Energy will influence intra- and inter-agency geothermal development policies significantly. The Division of Geothermal Energy has been subdivided, separating technology research operations from planning operations, to focus more sharply on commercialization strategy. To that end, a new unit, the office of the Geothermal Resource Manager, was created under the Assistant Secretary for Resource Applications. The program thrust of this unit is directed toward Marketing (which includes the Loan Guaranty Program), and Planning and Analysis (where increasing attention will be devoted to institutional and legislative issues).

The technology development responsibilities remain under the Assistant Secretary for Energy Technology. Strong attention will continue to be directed to identifying resources, developing technology, increasing reliability, and reducing costs of development.

A. Interagency Coordination and Management

Coordination between the Federal government agencies working in the area of geothermal leasing and development will be improved primarily by implementing recommendations of the Streamlining Task Force. In addition, coordination at the field level will be increased to insure that development projects are phased in an appropriate manner; and attention will be given to scheduling meetings in a way that lessens the burden on participating Federal agencies.

Planning activities to update existing development plans for specific prospects will continue in FY 1979.

Regional development scenarios for both electric and direct heat applications will be aggregated; the magnitude and schedule for achievable national utilization estimates will be evaluated, and potential benefits over conventional energy sources will be explored. In addition, Federal alternatives for administrative, policy, and RD&D initiatives identified through regional planning activities will be evaluated and assigned priorities for implementation as part of the Federal geothermal program. Finally, recommendations for resource allocation or schedule adjustments necessary to

maintain a time-phased interagency program plan in FY 1979 and beyond will be reviewed and acted upon by the IGCC through its Budget and Planning Working Group and Staff Committee.

B. Policy Development

Efforts in FY 1979 will continue to be based on the premise that institutional factors are more critical in expediting geothermal development than technological factors. Agencies involved will use policy initiatives and administrative procedures in attempts to break down institutional barriers. As in the past, initiatives and administrative procedures to be considered include positive incentives for investments in geothermal activities.

A continuing review of newly proposed legislation and regulations affecting geothermal energy will be established in FY 1979. Environmental, tax, land policy, and other potentially limiting policies will be monitored and appropriate IGCC response proposed.

The work of the Institutional Barriers Panel will continue in FY 1979; review and publication of the IBP Streamlining Task Force report will occur in the first quarter of FY 1979.

At the state level, legislatures will be assisted by the National Conference of State Legislators in reviewing existing legislation and regulations and in promoting changes to accommodate geothermal resource development.

FY 1979 plans also include support of economic and policy research: economic assessments of technical, administrative, and policy options; net energy analyses; and studies of permitting, regulatory, legal, taxation, and other institutional issues for hydrothermal, geopressured, and hot dry rock resources.

C. Technology Development

Projects started in prior years to develop geothermal drill bits, fluidized bed and direct-contact heat exchangers, the "thermal siphon" binary system, and well stimulation projects will be continued in FY 1979. These projects will progress from concept evaluation toward hardware development and precommercial demonstration. Field experiments to identify site-specific geothermal fluid handling problems will be initiated. The thermal siphon binary system will be carried through final design and selection of the test site. Fabrication of the heat exchanger, turbogenerator, and downhole brine pump for the system will be initiated.

A 500 kW direct-contact power conversion system built in FY 1978 underwent long-term (2000 hour) reliability testing at East Mesa, Cal., a high-temperature facility (170°C). In FY 1979, similar testing will be carried out at the moderate temperature facility (148°C) of Raft River, Idaho. Data

from these tests will be used to design a 5 MWe pilot power plant. In the reservoir stimulation program, low permeability reservoirs will be selected for at least one hydraulic fracturing experiment to increase productivity. Research and development projects will continue to develop geothermal fluid-handling technology and specific materials for application in drilling and heat transfer.

A heat transfer test jointly funded by the Electric Power Research Institute and the Department of Energy is planned for early FY 1979. This will provide performance data upon which industry can base designs of efficient heat exchangers for binary systems in commercial-size geothermal power plants.

In general, the USGS geothermal research program will place less emphasis on developing new resource assessment and exploration instrumentation and techniques, and more emphasis on applying recently developed technology to the study of geothermal systems. For example, passive seismic systems will help define the seismic characteristics of geothermal systems. In the past subsidence studies have largely been data-gathering efforts; in the future these studies will be focused on data interpretation and modeling in order to better understand and predict subsidence processes.

Resource assessment methodology will be improved by expanding studies of "fossil" geothermal systems such as the Creede hydrothermal vein system in Colorado and similar systems in the Western Cascades. These studies have a primary impact on estimating the lifetime of geothermal resources, and also contribute to the location of hidden geothermal systems--those systems that are active today but do not contain readily observable surface manifestations.

Environmental research and development in FY 1979 will include continued development of alternative technologies for hydrogen sulfide control, leading to commercial demonstrations in FY 1979 and FY 1980; continued research begun in FY 1978 on brine disposal, subsidence-induced seismicity, and noise control; research to develop data bases for guidelines and standards for other geothermal activities; and environmental monitoring.

D. Institutional Support

Loans in the amount of \$82.1 million are expected to be guaranteed in FY 1979. A loan guaranty for the construction of a 50 MWe power plant at Roosevelt Hot Springs, Utah, is expected to be submitted and completed. Two more loans will be processed and completed in late FY 1979. Six guaranty applications for loans in the amount of \$115 million are expected by DOE in FY 1979. The processing time and costs for loan guaranties will be reduced to make the program more effective. Amendments and proposed regulations to PL 93-410 were published for public comment in January 1979. Final regulations implementing the amendments will be issued in FY 1979.

Quantitative economic analyses of potential market penetration by geothermal electric and direct-use applications will be continued by DOE in FY 1979. In addition, active market development projects will be expanded to include five or six major industrial process heat user sectors, including food processing, the aluminum industry, mining companies, and the chemical

industry. These projects will involve corporate energy decisionmakers in evaluating geothermal resource use in their plants and in identifying technical and policy measures to make use more attractive.

Program opportunity notices issued in FY 1978 for direct-heat field experiments yielded 15 proposals selected for evaluation. Negotiations are under way, and awards should be made in FY 1979. Proposed sites are located in Oregon, California, Idaho, Nevada, Utah, Montana, Colorado, and Texas.

With regard to technology transfer and information dissemination activities in FY 1979, DOE will continue to maintain the Geothermal Resource Information Documentation (GRID) system, will publish reports, and will initiate a public awareness program for geothermal development.

Although the National Science Foundation budget for FY 1979 includes no specific request for funds to support geothermal projects, three to five postdoctoral fellowships in the amount of \$42,000 to \$70,000 are likely to be awarded to individuals engaged in geothermal studies.

E. Resource Assessment, Exploration, and Confirmation

DOE will increase efforts for reservoir confirmation and new prospect identification in cooperation with industry. It is anticipated that six of the new prospects necessary to meet 1985 electric power generation goals will be identified in FY 1979, through expansion of the industry-coupled program in which industry and DOE share costs of drilling new high-temperature prospects.

The planned support in FY 1979 to identify new prospects will allow corfirmation drilling at two prospects now being studied and will begin reservoir definition studies at a new site. Deep exploratory wells will be drilled in the Mt. Hood area of Oregon and in previously unexplored portions of the Snake River Plain in Idaho.

FY 1979 also will see support of a program leading to a determination by 1985 of the technical and economic feasibility of hot dry rock as a significant new energy source. Two new experiments will be initiated to define resource characteristics in different geologic settings and to evaluate alternate extraction concepts. Exploration holes will be drilled in as many as four prospects with perhaps one in the eastern United States. The existing resource assessment activity will be expanded and development of exploration, drilling and logging technology specifically for HDR will be accelerated to meet program goals.

The USGS geothermal research program will place increased emphasis on assessing geopressured zones of the Gulf Coast. A study of the offshore and deeper onshore portions of these zones will characterize their structures, stratigraphic framework, and depositional environments to better identify thermal and methane energy content. Hydro-dynamic modeling of these zones will also begin in FY 1979, to define flow processes within these zones.

Other resource assessment activities of USGS will shift from geologic and geophysical investigation of the San Francisco volcanic field in Arizona, and of the Snake River Plain in Idaho (to be completed in FY 1979), to a major multidisciplinary study of the Cascade Mountains of Washington, Oregon and northern California. The new study seeks to better understand the magnitude and nature of these geothermal resources, and will be coordinated with related geophysical, geological, and hydrological investigations by several universities and with DOE. A reconnaissance study first will be made of the entire Cascade Range and a few areas then will be selected for concentrated effort.

Site-specific studies by the USGS and DOE associated with the Raft River geothermal area (which led to the siting of several successful geothermal wells), will be brought to a conclusion in FY 1979. These studies have included geologic, geophysical, and hydrologic investigations of the Raft River area as well as reservoir studies of the geothermal system.

The Bureau of Reclamation will continue its investigations in producing fresh water supplies from geothermal resources in southern California and Arizona. A number of 500-foot exploratory holes will be drilled at several prospective locations and more detailed exploration will be undertaken if initial hole data are favorable. Drilling of observation wells and other geophysical work will continue in the Susanville, California, area.

F. Resource Acquisition and Leasing

In view of the time involved in developing environmental assessment records, tentative leasing schedules have been established for both KGRA and non-KGRA lands. The leasing schedule for fiscal year 1979 is as follows:

COMPETITIVE LEASE SCHEDULE, FY 1979

October	Alvord Desert, Oregon
October	The Geysers, California
December	Marysville, Boulder Hot Springs, Montana
December	Meadow Hatton and various reoffers, Utah
February	Mono-Long Valley, California
April	East Mesa, California
April	West Yellowstone, Montana
May	The Geysers, California
June	Pinto Hot Springs, Stillwater, Monte Neva, Salt Wells Basin, Nevada
June	Beckworth Peak, California
September	Belknap-Foley Hot Springs, Oregon
September	Gillard Hot Springs, Arizona

NONCOMPETITIVE GEOTHERMAL LEASE SCHEDULE, FY 1979

Arizona	Burro Creek, San Bernardino Valley
California	East Mesa
Montana	West Yellowstone
New Mexico	Ojo Caliente, Lightning Dock, Radium Springs, Socorro Peak
Oregon/ Washington	Northern Malheur area, Glass Butte area, South Pueblo Mountain area, Goose Valley area, Mount Hood National Forest, Freeman National Forest, Deschutes National Forest, Willamette National Forest
Utah	360 acres of stockraising homestead lands.

G. Field Development and Production Drilling

DOE plans for FY 1979 include more extensive well-flow tests and sample analyses to increase the reservoir data base for a number of selected area, geographically dispersed over the Gulf Coast geopressured region, with three wells planned for drilling in FY 1979. The data will be added to that from the two abandoned wells reopened in FY 1978. Each successful production well is expected to produce about three-quarter billion cubic feet of natural gas per year, and the three wells together may yield as much as two billion cubic feet of gas per year by the end of FY 1979. Further production wells in optimum reservoir areas such as Brazoria County, Texas, may be grouped to provide a four-well system to supply a pilot power plant and methane extraction facility, which could be constructed and put in operation by about FY 1982.

H. Plant Facility Construction and Testing

Four units under construction at The Geysers, California, with a projected total capacity of 406 MW are due for completion late in FY 1979. At East Mesa, California, a 10 MWe plant is under construction by Republic Geothermal, and will near completion in FY 1979.

Results of the DOE study of alternative energy conversion systems for use with Salton Sea geothermal brines, to be completed in early FY 1979, may indicate the desirability of upgrading the Geothermal Loop Experimental Facility (GLEF) at Niland, California, to a pilot electric power plant. If a go-ahead decision is made in FY 1979, DOE plans to order a turbine generator and to begin structural and system design modifications for the GLEF.

The final design for the wellhead generator jointly funded with the Hawaii Geothermal Development Group will be completed, with fabrication and installation in FY 1979. During operation, electric power will be distributed by the Hawaiian Electric Company. Production tests of the existing well, together with tests made on other wells expected to be drilled for resource assessment, will permit estimation of the size and productivity of the reservoir for further commercial development.

At the Raft River project, DOE plans to complete construction of the first 40 Mwt thermal loop facility and to install a 5 MWe turbine generator. Component and system checkout will be initiated in FY 1979 with operation scheduled to start in FY 1980.

Design work and associated environmental assessments for the DOE/industry cost-shared 50 MWe liquid-dominated geothermal demonstration plant will be completed in FY 1979. Orders for additional long-lead-time components will be placed, and the drilling of production and injection wells will commence. Construction of the surface piping systems will also begin before the end of the fiscal year. This plant will be completed and operating no later than FY 1982.

BOISE SPACE HEATING PROJECT

Appendix A

BRIEF HISTORY OF GEOTHERMAL LEGISLATION

SUMMARY OF LEGISLATIVE HISTORY

During the late 1960s, growing national concern over diminishing conventional energy resources led to demands that new, cleaner sources, such as solar energy and geothermal energy, be developed. In response to this mandate, the 91st Congress enacted the Geothermal Steam Act of 1970.

The Geothermal Steam Act of 1970 (PL 91-581) stipulated that

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

With the expectation of the wiser use of national resources in the future, the Act also states,

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

and

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

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

As the need for even more rapid development of geothermal energy technologies as well as resources became evident, the Congress enacted the Geothermal Energy Research, Development, and Demonstration Act of 1974

(PL 93-410), which affirmed the potential benefits to the Nation of geothermal energy development and defined the major components of a coordinated Federal program to realize these benefits, saying,

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

The Act continues,

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

concluding,

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

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

The wide range of the functions and activities named in PL 93-410 and other energy legislation, and the importance of their success to the Nation, led the Congress to promulgate the Energy Reorganization Act of

1974, which established the Energy Research and Development Administration (ERDA). The responsibilities of the new agency included

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

Responding to the urgency of the Nation's energy challenge, the Congress further classified and enlarged the scope of ERDA's responsibilities in the Federal Nonnuclear Energy Research and Development Act of 1974 (PL 93-577), which emphasized that "proper priority" must be given "to developing new nonnuclear energy options to serve national needs, conserve vital resources, and protect the environment." Besides reiterating the high priority to be given to energy conservation and the importance of taking the environmental and social consequences of proposed programs into account, the Act required that ERDA submit a comprehensive program plan

each year to the Congress. It repeated the directive of PL 93-410 that commercial demonstrations of geothermal energy technologies and environmental control systems be accelerated; called for joint Federal/industry experiments, demonstration plants, and corporations, along with other forms of Federal assistance; and required the promulgation of "regulations establishing procedures for submission of proposals to (ERDA) for the purposes of this Act."

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

Among the major aims of this latest Act are

- to achieve . . . effective management of energy functions . . . and to promote maximum possible energy conservation measures . . .
- to provide for a mechanism through which a coordinated national energy policy can be formulated and implemented . . .
- to place major emphasis on the development and commercial use of solar, geothermal, recycling and other technologies utilizing renewable energy resources.

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

Appendix B

MEMBERS OF THE INTERAGENCY GEOTHERMAL
COORDINATING COUNCIL AND ITS PANELS

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Appendix C

TABLES DERIVED FROM USGS CIRCULAR 790

TABLES DERIVED FROM USGS CIRCULAR 790

Table B shows categories of geothermal energy for which resource estimates can actually be made, tabulating resources in hydrothermal convection systems and in the geopressured zones of sedimentary basins. Also shown are values of energy for utilization calculated from resource figures. All of these values are taken directly from USGS Circular 790, except that

- energy calculated in Circular 790 as electricity in units of megawatts-electric for 30 years is given here in units of 10^{18} joules;
- geopressured resources outside the northern Gulf of Mexico Basin are calculated from the estimated accessible fluid resource base assuming the same average recoverability factors as for the Gulf region; and
- methane is postulated for use as beneficial heat, with a utilization efficiency of 50 percent.

Table C illustrates the type of calculation that could be made for the energy put to use through the hot dry rock extraction technique. Because "hot dry rock" is not a geologically defined concept, but rather a specific proposed energy-recovery method, it is not possible, given present knowledge, to estimate "resources" of hot dry rock. At present, the geological and resource parameters of systems to which this method may be applied have not been specifically defined. The figures shown in Table C were calculated from resource base data of Circulars 726 and 790. They are intended as illustration only; therefore the calculations used a variety of arbitrary assumptions. The logic used to develop these figures is outlined below.

The primary assumptions used are (1) that the hot dry rock extraction method will be shown to be technically and economically feasible, and (2) that extracted energy will be utilized to generate electricity, requiring a rock temperature of 150°C or greater. Energy is calculated for both regional conductive environments and hot igneous systems, and for two depth intervals, 0-3 km and 3-7 km (based on the assumptions that the basic geological properties of the earth's crust differ between the upper few kilometers and the deeper regions and that wells drilled for energy production generally go no deeper than 7 km).

As discussed in Circular 790, any large volume of the earth's crust may be expected to contain some parts with permeability low enough to allow application of the hot dry rock method; some parts with permeability too high to allow this extraction method, but too low to allow production of natural geothermal fluids; some parts permeable enough to produce natural

TABLE B. Calculated resources and energy for utilization from hydrothermal and geopressured geothermal systems. Based upon USGS Circular 790 (in 10^{18} joules, ≈ 1 quad).

CATEGORY OF GEOTHERMAL ENERGY	RESOURCES ¹		ENERGY FOR UTILIZATION ²	
	IDENTIFIED (excluding national parks)	UNDISCOVERED	IDENTIFIED (excluding national parks)	UNDISCOVERED
<u>Hydrothermal Convection</u> ³				
Vapor Dominated	9.3 ± 4.5	} $700^4 - 1230^5$	1.5 ± 0.7	} $68^4 - 120^5$
Hot Water:				
High Temperature ($>150^\circ\text{C}$)	210 ± 30		20 ± 3	
Intermediate Temperature ($90-150^\circ\text{C}$)	176 ± 55		42 ± 13	
<u>Geopressured</u>				
Thermal	$270^6 - 2800^7$	$116^{6,8} - 1200^{7,8}$	$22^{6,9} - 220^{7,9}$	$9^{6,8,9} - 96^{7,8,9}$
Methane ¹²	$158^6 - 1640^7$	----- ¹⁰	$79^{6,11} - 820^{7,11}$	----- ¹⁰

¹ Thermal energy recoverable at the wellhead.

² Electrical energy is calculated in Circular 790 for systems $>150^\circ\text{C}$ in units of megawatts for 30 years, based upon calculation of available work and utilization factors discussed in the circular; these numbers are here expressed in units of 10^{18} joules. Beneficial heat is calculated in Circular 790 for systems $<150^\circ\text{C}$ with a utilization factor of 24%.

³ Does not include low-temperature thermal waters ($\leq 90^\circ\text{C}$) although they do represent a significant source of energy for utilization.

⁴ Assuming that average volumes of high-temperature undiscovered systems are equal to the average volumes of intermediate-temperature undiscovered systems and that only systems above 150°C will be used to produce electrical energy. If the lower figure is used for systems $>150^\circ\text{C}$, then the higher figure for systems $90-150^\circ\text{C}$ should be used in considering the total undiscovered hydrothermal resources above 90°C and vice versa.

⁵ Assuming that average volumes of high-temperature undiscovered systems are higher than those of intermediate-temperature undiscovered systems as described by an empirical logarithmic equation discussed in USGS Circular 790 and that only systems above 150°C will be used to produce electrical energy.

⁶ Assuming recovery by a model that minimizes pressure reduction and surface subsidence (plan 3 of USGS Circular 726).

⁷ Assuming recovery by a model that allows pressure reduction to hydrostatic levels and may result in maximum subsidence (plan 2 of USGS Circular 726).

⁸ Assuming the same average recovery factors as for the northern Gulf of Mexico Basin.

⁹ Assuming that energy is utilized by generation of electricity at a conversion efficiency of 8%, as discussed in Circular 790.

¹⁰ Methane resources not estimated for geopressured basins outside northern Gulf of Mexico Basin.

¹¹ Assuming that methane is used for heating with a 50% utilization efficiency.

¹² Assuming saturation of waters with methane.

TABLE C. Illustration of a calculation of energy for utilization as electricity using the proposed hot dry rock extraction method. Calculated from resource base data of USGS Circulars 726 and 790 using arbitrary geologic, technological, and economic assumptions as explained in text (in 10^{18} joules, ≈ 1 quad).

DEPTH REGION	REGIONAL CONDUCTIVE ENVIRONMENTS	HOT IGNEOUS SYSTEMS	
		Evaluated ¹	Unevaluated
0 - 3 km	0 ²	.8 - 6.3	7.2 - 56
3 - 7 km	152 - 1190 ³	6.8 - 53	60 - 470
Totals		7.6 - 59.3	67.2 - 526
(Rounded)		(8 - 59)	(67 - 526)

¹Systems for which an energy value is calculated in Circular 790.

²None of the temperatures represented by the three average temperature-gradient curves used in Circular 790 are $\geq 150^\circ\text{C}$ at depths less than 7 km.

³Temperatures represented only by the Basin and Range type of temperature-gradient curve of Circular 790 are $\geq 150^\circ\text{C}$ at depths less than 7 km. Regions assumed in Circular 726 to have heat flow of this type include the Basin and Range province, the Rocky Mountains, the Columbia Plateaus, the Cascade Range, the San Andreas fault zone, the state of Hawaii, and one-half the state of Alaska. These areas aggregate to 28 percent of the total surface area of the United States. From the average temperature-gradient curve for Basin and Range type areas, temperatures $\geq 150^\circ\text{C}$ are assumed to exist only below 4.5 km. Calculation of the geothermal resource base from 4.5 to 7 km in areas of Basin and Range type according to the method of Diment and others in Circular 726 gives a value of $3,800,000 \times 10^{18}$ joules. Energy for utilization was calculated from this value, as shown below. This calculation is illustrative of how each of the figures in this table was calculated.

$$\begin{array}{rcl}
 3,800,000 \times 10^{18} \text{ J} & & \text{(accessible resource base, 4.5-7 km)} \\
 \hline
 \times .25 & & \text{(proportion of area assumed suitable} \\
 950,000 \times 10^{18} & & \text{for energy development)} \\
 \hline
 \times .10 & & \text{(proportion of volume assumed to have} \\
 95,000 \times 10^{18} & & \text{permeability low enough for method)} \\
 \swarrow \quad \searrow & & \\
 \begin{array}{rcl}
 \times .02 & & \\
 \hline
 1,900 \times 10^{18} & & \\
 \hline
 \times .08 & & \\
 \hline
 152 \times 10^{18} \text{ J} & &
 \end{array}
 & \begin{array}{rcl}
 \times .125 & & \text{(assumed recoverability} \\
 \hline
 11,875 \times 10^{18} & & \text{factors)} \\
 \hline
 \times .10 & & \text{(assumed electrical con-} \\
 \hline
 1,188 \times 10^{18} \text{ J} & & \text{version factors)}
 \end{array}
 \end{array}$$

fluids, but at uneconomic rates; and some parts permeable enough for commercial hydrothermal production. Permeability limits of these various parts, or the proportions of these parts in any particular area, are not known. Therefore, it is arbitrarily assumed that 5 percent of the upper 3 km, and 10 percent of the region from 3-7 km, have sufficiently low permeability for hot dry rock energy extraction.

The actual distributions of temperatures with depth over large regions of the United States are not known. Therefore, it is assumed that regional conductive environments are characterized by one of three types of heat flow and that temperatures at any particular depth in any area are given by the average temperature-gradient curves for that region. (See Circular 790, Figure 27.)

Values for regional conductive environments pose a special problem in this calculation, for it seems necessary to include a factor, in addition to a minimum temperature of 150°C and sufficiently low permeability, to allow the hot dry rock method to operate. In those areas of the U.S. where temperatures of 150°C or higher are inferred to exist above 7 km, it does not seem feasible to place enough wells to extract all hypothetically recoverable heat. It is therefore here assumed that such energy-extraction operations would be feasible in only 25 percent of the region having sufficiently high temperature and low permeability.

The accessible geothermal resource base for hot igneous systems is calculated in Circular 790 for the entire depth interval from 0 to 10 km. It is not known what proportion of that thermal energy lies between 0 and 3 km and what proportion lies between 3 and 7 km; therefore, it is assumed here that thermal energy in hot igneous systems is distributed with depth proportionally to the distribution of energy in the same depth ranges in regional conductive environments. As calculated in Circular 790, 10 percent of the geothermal resource base of regional conductive environments to 10 km is present in the 0-3 km range and 42 percent in the 3-7 km range.

To calculate the energy for electric utilization that might be made available from hot dry rock technology, two additional factors must be applied: the percentage of heat that might be extracted from depth to a wellhead, and the conversion of that thermal energy to electricity. Because neither factor can be rigorously evaluated using available data, two sets of calculations are made for each type of geologic environment and each depth range considered. One is based on Circular 726's reasoning that the fraction of energy obtainable at the surface by the hot dry rock method would likely be half the value for hydrothermal systems. Since the latter is estimated to be 25 percent, recoverability for hot dry rock is assumed to be 12.5 percent. This corresponds to one of the two recoverability factors assumed but not explained in Table I-2 of the ERDA Definition Report.* Both sets of calculations made here therefore follow the two sets of assumptions used in that table and similar later tables. They are

*ERDA-86, 1975.

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- a recoverability factor of 12.5 percent and a conversion efficiency of 10 percent, and
- a recoverability factor of 2 percent and a conversion efficiency of 8 percent.

The first of these assumptions more nearly corresponds to the values discussed in Circular 726.

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Appendix D

SAMPLE SITE-SPECIFIC DEVELOPMENT PLAN

SAMPLE SITE-SPECIFIC DEVELOPMENT PLAN

The site-specific development plans that follow provide examples of when and how hydrothermal resources will be brought on line and serve to illustrate the planning activity in progress. Examples include the development of a high-temperature resource for electric power generation at Cove Fort, Utah (see Figures 1-3); the application of new technology for electric generation with a moderate-temperature resource at Stillwater/Soda Lake, Nevada (see Figures 4-6); the development of the moderate-temperature resource in the Vale-Weiser-Ontario area (Oregon and Idaho) for direct applications (see Figures 7-8); and the progressive spread of these applications across the Snake River Plain (see Figures 9-11).

A cooperative effort between the private sector and the local, state, and Federal governments is needed for development to proceed in a timely manner. The scenarios indicate the required Federal, state, and local activities that must take place for development to proceed. In addition, the Department of Energy initiatives, which are designed to encourage the involvement of the private sector during the early stages of hydrothermal commercialization when the risk is comparatively high, are depicted in the prospect commercialization scenarios.

The site-specific development plans presented herein have been developed with the assumption that the hydrothermal energy resource will enjoy equitable tax treatment as provided in the National Energy Act.

Cove Fort Prospect Commercialization Scenario

Cove Fort is a known geothermal resource area (KGRA) in the southwestern quadrant of Utah. There are no surface springs at Cove Fort, but the surface is characterized by active gas seeps and thermally altered areas.

Drilling began at Cove Fort in the summer of 1976. Union Oil drilled an 1100 foot well. This well was plagued with drilling difficulties and eventually caved in. There was no further drilling activity until late in 1977 when Union Oil, utilizing a cost-sharing program with the Department of Energy (Industry-Coupled Program), drilled a second well deeper than the first. This well was also very difficult to drill and was not a commercial producer; however, evidence of high-temperature fluid was found and a third well currently is being drilled with a fourth well planned. The second, third, and fourth wells are being drilled as a part of the DOE's Industry-Coupled Program.

Several miles farther north, Hunt Energy Corporation is drilling an exploratory well on private lands. A transmission line will be required for a unit at the Hunt site. It is assumed that the 46 kV and 138 kV lines near the Union wells have the capacity to handle the first unit at that site.

For purposes of this prospect commercialization scenario, it is assumed that drilling in both areas will lead to production of a commercial high-temperature resource.

Stillwater/Soda Lake Prospect Commercialization Scenario

The Stillwater/Soda Lake KGRA is located about 60 miles east of Reno, Nevada. Exploratory wells indicate that a 165°C hydrothermal resource exists at approximately 7500 feet.

Design of the first commercial electric power unit for this site is not expected until the feasibility of utilizing binary technology for moderate-temperature resources is demonstrated by Raft River Loop 1. By the time design starts for the second unit, results from Raft River Loop 2 should be available. This loop will demonstrate the economic feasibility of utilizing advanced binary technology for moderate-temperature resources.

Direct Applications Prospect Commercialization Scenario

The commercialization scenario for direct applications development is best illustrated using both an application and resource spreadout technique. Most direct application units are relatively small when compared to the step-by-step development of a field for electric power, but initially an exponential type of growth can be postulated for both the types of application and the number of resources. The initial commercialization pattern depicted herein was initiated by a Program Research and Development Announcement (PRDA) engineering and economic analysis which in turn was followed by the submittal and acceptance of a field demonstration Program Opportunity Notice (PON) cost-sharing proposal. Following the initial success of reservoir confirmation and proof of operating principle, further development is anticipated in two directions, other applications will be initiated within the resource area of the original field, as shown for the Vale-Weiser-Ontario prospect, and competing processors will either develop the resource at existing facility sites where resources and sites coexist, or tend to move to known resources to develop new facilities, as shown for the Snake River Plain prospect.

This scenario is illustrative of the anticipated two-pronged commercialization process.

Figure D.1. Cove Fort High Temperature Electric Prospect Commercialization Scenario.

DOE Initiatives

- ① DOE/Industry cost sharing for drilling exploratory wells (Industry Coupled Program)
- ② Economic study funded under DOE Program Research and Development Announcement (PRDA)
- ③ DOE/Industry cost sharing of preliminary design by means of the Program Opportunity Notice (PON)
- ④ Loan guaranties for drilling and/or for construction

Required Federal Activities

- Ⓐ Leasing of federal lands by Bureau of Land Management
- Ⓑ Surface management of national forest lands by Forest Service including environmental assessment and concurrence in leasing and permitting
- Ⓒ Permitting for surface exploration, drilling and plant siting on federal lands by the Conservation Division of the U.S. Geological Survey
- Ⓓ EIS/EIA wildlife evaluation by the Fish And Wildlife Service, Department of Interior
- Ⓔ Certify air discharge permit, issue water discharge and solid waste disposal permits review of EIS by Environmental Protection Agency

Required State and Local Activities

- Ⓐ Lease of state lands and special use permits for surface disturbance by the Division of State Lands
- Ⓑ Well permits, reservoir test approval, appropriation of water by the Division of Water Rights
- Ⓒ Construction plan review and permit, discharge permit certification, waste disposal permit approval by the Bureau of Water Quality
- Ⓓ Construction plan review and approval and discharge permit by the Bureau of Air Quality
- Ⓔ Land zoning by the County Planning Commission
- Ⓕ Business license by the County clerk
- Ⓖ Building inspection and health code enforcement by the County Commission

Figure D.2. Legend for Cove Fort Scenario.

Figure D.3. Cove Fort Projected Power-On-Line.

Figure D.4. Stillwater/Soda Lake Moderate Temperature Electric Prospect Commercialization Scenario.

DOE Initiatives

- ① DOE/Industry cost sharing for drilling exploratory wells (industry coupled program)
- ② Economic evaluation funded under DOE Program Research and Development Announcement (PRDA)
- ③ DOE/Industry cost sharing of preliminary design by means of the Program Opportunity Notice (PON)
- ④ Loan guaranties for drilling and/or for construction
- ⑤ Demonstrate feasibility of moderate temperature binary technology
- ⑥ Demonstrate economic feasibility of using advanced binary technology for moderate temperature resources

Required Federal Activities

- Ⓐ Leasing of Federal Lands by Bureau of Land Management
- Ⓑ Permitting for surface exploration, drilling and plant siting on Federal Lands by the Conservation Division of the U.S. Geological Survey
- Ⓒ EIS/EIA wildlife evaluation by the Fish And Wildlife Service, Department of Interior
- Ⓓ Certify air discharge permit, issue water discharge and solid waste disposal permits, review of EIS by Environmental Protection Agency

Required State and Local Activities

- Ⓐ Well permits, reservoir test approval and appropriation of water by the Nevada State Engineer
- Ⓑ Siting authority, construction plan review and permits, and discharge permits by the Nevada Public Service Commission.
- Ⓒ Land zoning by the County Clerk
- Ⓓ Land zoning by the County Planning Commission
- Ⓔ Building inspection and health code enforcement by the County Commission

Figure D.5. Legend for Stillwater/Soda Lake Scenario.

Figure D.6. Stillwater/Soda Lake Projected Power-On-Line.

Figure D.7. Vale-Weiser-Ontario Prospect Commercialization Scenario for Direct Applications.

Figure D.8. Vale-Weiser-Ontario Projected Power-On-Line

Figure D.9. Snake River Plain Commercialization Scenario for Direct Applications

DOE INITIATIVES

- ① User assistance, provided by DOE (INEL) to determine feasibility of using resource for proposed application
- ② DOE/Industry cost sharing provided by the Program Opportunity Notice (PON) Program
- ③ Loan guaranty for construction
- ④ DOE/Industry cost sharing or exploratory wells provided by the state coupled program
- ⑤ As part of the resource assessment for the Snake River Plain, a joint DOE/USGS deep well will be drilled starting in August, 1978.

Figure D.10. Legend for Snake River Plain Scenario

Figure D.11. Snake River Plain Projected Power-On-Line

Appendix E

SUMMARIES OF MEETINGS HELD IN FY 1978

- 1) Advisory Committee on Geothermal Energy, February 7, 1978
- 2) Interagency Geothermal Coordinating Council, March 14, 1978
- 3) Advisory Committee on Geothermal Energy, September 12, 1978.
- 4) Institutional Barriers Panel, Year-End Summary
- 5) Resource Panel, Year-End Summary

Minutes of the Fourth Meeting of the Advisory Committee on Geothermal Energy,
Los Angeles, California, February 7, 1978.

The following key issues were discussed:

1. The need to reduce overlap and sequential permitting for geothermal licensing procedures through the establishment of a joint Federal-state task force was emphasized.
2. Question was raised of comprehensiveness of land planning with respect to geothermal exploitation: should geothermal planning include a view of total land and resource usage, or should planning be focused essentially on geothermal problems?
3. The usefulness of information coming from the Raft River Project was questioned in relation to its \$10 million cost.
4. It was generally agreed that investigations should proceed for determining what the threshold temperature is for economic viability of geothermal resources for electric power at Raft River.
5. It was observed that the Division of Geothermal Energy should generate authoritative, critical, scholarly reviews of important subjects; e.g., power conversion cycles, two-phase flow, heat transfer, hydrothermal water chemistry, reservoir mechanics, etc.
6. There is need to define the scope and direction of a demonstration program so that it is not competitive with private industry's efforts that are being encouraged.

The Committee approved the resolutions and recommendations as follows:

1. The Technology Utilization Subcommittee recommendation (made last August and accepted by the Committee as a whole) that the Federal Government participate in at least two demonstration plants was sent back to the Subcommittee for review and restudy. The Subcommittee was directed to come back to the Committee with a newly stated recommendation concerning the demonstration program.
2. The Geopressure Subcommittee recommended that the Department of Energy be encouraged to communicate with the U.S. Geological Survey in order to incorporate information contained in the Survey's data bank into DOE studies on seismicity.

3. The Legal and Institutional Subcommittee declared that the subject of geothermal resources ownership is paramount in connection with the orderly development of geothermal energy. It was agreed that each of the members would promptly supply the Chairman with written thoughts about ownership problems, and that this would lead to Subcommittee recommendations to the full Committee.
4. The Committee voted to accept the recommendation that the Division of Geothermal Energy support the concept of concern for regional and area impact in leasing procedures, and support appropriate procedures to define and preserve archaeological and native American historical and cultural values.

Summary of Actions taken by Interagency Geothermal Coordinating Council,
March 17, 1978 Meeting.

The IGCC heard a report on the status of the FY 1978 DOE authorization Bill. With respect to IGCC, the bill's amendments

- formally add the Department of Treasury, USDA, and EPA to the IGCC
- give IGCC authority to recommend regulations as well as legislation
- give IGCC authority to recommend in areas of tax and environmental policy.

With respect to loan guaranties, the amendments

- increase limits per loan and per borrower
- bring program in line with other Federal loan guaranty programs
- extend authority for interest differential payments to municipal utilities or other bodies issuing tax-exempt obligations
- clarify relationship between demonstration and loan guaranties.

New loan guaranty regulations, required by this legislation, were in preparation.

Council members approved a draft letter from Acting Chairman Bresee to Governor Brown (Cal.) identifying Reid Stone (USGS) as IGCC representative to the California Federal-state-local permitting coordination effort, and pledging assistance to IGCC agencies in continuing coordination efforts.

In addition, the Council:

Approved minutes of November 15, 1977 IGCC meeting.

Received the report of the Geothermal Federal Buildings Program, an information effort to identify specific locations at which particular Federal facilities could utilize geothermal resources.

Received a progress report on DOE leasing and permitting regulations in response to 1976 IGCC recommendations. IGCC attempted to resolve problems of coordination between DOE and DOI.

Received draft of annual report to Congress from Budget Planning and Working Group.

Received report of Institutional Barriers Panel.

Received report of Research and Technology Panel on status of draft Environmental Guidelines that EPA had produced. It was agreed that a special meeting of the Advisory Committee on Geothermal Energy would be held to review the document before final issuance.

Received report of Resource Panel on status of updated National Assessment of Geothermal Resources. There was some discussion of the importance of clarifying the definition of geopressured resources in this report because of their impact on price regulation and tax issues. It was agreed that a working group would be set up between the IBP and the Resources Panel to address the issue of definition of geopressured resources.

Received report of Advisory Committee on Geothermal Energy.

Executive Summary of the Fifth Meeting of the Advisory Committee on Geothermal Energy, Washington, D.C., September 12, 1978.

Nominees for Committee membership were introduced: Mr. David Bedford, Dr. John Costain, Ms. Suzanne Reed, Dr. Stanley Ward, Dr. George Vranesh.

The draft Executive Summary of the Fourth meeting of the Advisory Committee on Geothermal Energy held in Los Angeles, California, February 7, 1978 was unanimously adopted.

Dr. Bennett Miller commented on future direction of geothermal program (move to commercialization). He voiced the Department of Energy's commitment to guard against fragmentation of the process of development, communication and program coordination, to continue to work closely with the Advisory Committee, and not to de-emphasize technology R&D.

Mr. Ben Holt, Chairman of the Technology Utilization Subcommittee, moved that in the future, current Congressional budget requests be furnished prior to meetings. This was unanimously carried. Mr. R. A. Black agreed to make this available.

Technology Utilization Subcommittee - Report and recommendations:

- Approval of both phases of the Raft River Project.
- Build a second plant as part of the demonstration program, emphasizing commercial viability.
- Ranking of various programs for DOE priorities and budget allocations. In descending order: binary cycle demonstration plant; direct utilization program; direct contact heat exchange program; Raft River program; wellhead generator program.

This report and the recommendations unanimously accepted by the full Committee.

Geopressure Subcommittee - Report and recommendations:

- Recommended that DOE staff study institutional constraints prohibitive to private sector involvement and report at next meeting.
- In terms of advising DOE of its future direction, it recommended that one well per fairway be drilled.
- Moved that DOE resolve to emphasize the thermal content of geopressured fluids but not to the exclusion of the commercial importance of gas content (methane).

- In considering "Wells of Opportunity" program, recommended reduction of flow rate time constraints to encourage oil companies to make short-term water chemistry and gas content data available to DOE.
- Appointed members as task force to contact private industry sector for views of the resource and incentives for commercialization.
- Recommended that DOE make no changes in current plans for pilot plants, as they felt the money has been well spent thus far.

This report and the recommendations were unanimously adopted by the full Committee.

Legal and Institutional Barrier Subcommittee - Report and recommendations:

- Recommended that the Institutional Barrier Panel advise the Interagency Geothermal Coordinating Council of the ambiguities and technical corrections to the National Energy Act.
- Recommended approval of the Institutional Barrier Panel's recommendations to the Interagency Geothermal Coordinating Council.
- Recommended approval of the Streamlining Task Force's recommendations to the IGCC, with the following changes and reservations:
 - ° Item #5 - expand to more clearly specify time constraints on permitting action.
 - ° Item #9 - include "finalize study criteria and procedures to include a geothermal inventory."
 - ° Item #16 - committee members had reservations but were unable to reach a conclusion and final action was deferred.
- Recommended development of a set of terms, conditions and standards for the exploratory phase of geothermal development on Federal lands (to replace the present case-by-case review for exploratory activities).
- Recommended the Committee establish a special subcommittee to work with the Institutional Barrier Panel of the IGCC to provide recommendations for matters to be included in future legislation.

The full Committee unanimously adopted this report and the recommendations.

Resource Subcommittee - Report and recommendations:

- Reviewed the logging instrumentation program favorably and recommended review by DOE of possible need for additional manpower and money.
- Reviewed the scaling and materials program, agreeing that better cements, elastomers and injection techniques were important, but recommended better focus to the program.
- Recommended review of drilling, reservoir stimulation and resource assessment at the next meeting.

The report was accepted unanimously by the full Committee.

Institutional Barriers Panel, Year-End Summary

During FY 1978 the Institutional Barriers Panel to the IGCC identified several institutional barriers to geothermal development and devised solutions to several of the problem areas.

Underground Injection Regulations

Problem: The EPA draft Underground Injection Regulations under the Safe Drinking Water Act allow states to exclude from the "potential drinking water" aquifer classification aquifers producing oil or minerals. While some states treat geothermal as a mineral, in many the issue is unresolved. Resulting uncertainties could lead to delays of five or more years while regulations are developed and lengthy litigation is probable in some states.

Recommendation: Section 146.05(d) of the regulations should be modified to read: "Is mineral, oil, or geothermal producing."

No-Surface-Occupancy Leases

Problem: There has been little interest in such leases to date, impeding development on adjacent non-Federal lands in many areas. The problem stems from lack of public awareness of availability of such leases and lack of precise policy regarding the circumstances under which such leases should be issued or denied. This has lead many field offices to consider such leases optional.

Recommendation: Department of the Interior - Bureau of Land Management should: notify all noncompetitive lease applicants that no-surface-occupancy leases can be requested, develop precise policy regarding issuance, and promulgate this policy to the field offices.

Inadequate Wheeling and Interconnection Authority

Problem: Under present provisions of the NEA, FERC is authorized to order interconnection and wheeling only to qualified cogeneration and jurisdictional electric utilities. Thus industrial users must either relocate, build their own power lines or gain access to existing transmission lines. Small producers and industrial users are effectively precluded from developing many geothermal reservoirs in which larger utilities are not interested.

Recommendation: The Department of Energy - Policy and Evaluation should define a category of site-dependent generation and authorize FERC to issue wheeling and interconnection orders on application of any person, company, state, or Federal agency which produces electric energy from such resources, provided these orders are necessary and in the public interest.

Exemption from Federal Power Act and Public Utility Holding Company Act

Problem: The NEA does not include geothermal resources in the class of small producers exempt from these acts. Development is hampered due to uncertainty about approved rates and costs of geothermal power.

Recommendation: The Department of Energy - Policy and Evaluation should add geothermal resources to the list of small generator sources.

Minimum Tax on Intangible Drilling Costs

Problem: The minimum tax provision under the NEA will severely limit investment by noncorporate taxpayers in geothermal resource application as there are very few, if any, geothermal independents with income from geothermal property. This will result in industry concentration and limit the formation of independent operators.

Recommendation: The minimum tax on geothermal intangible drilling costs should be eliminated.

Geothermal Percentage Depletion Allowance

Problem: At present there is no depletion allowance for geothermal resources and, under the House version of this bill, the situation will not change. Because major oil companies, in effect, do not have percentage depletion for oil and gas development, geothermal development, from a tax standpoint, is on a par with oil and gas. Small operators do have a depletion allowance for oil and gas and they are thus a more advantageous target for development. Furthermore, there is a reluctance to invest in risky geothermal projects.

Recommendation: The Department of Energy and Treasury Department should support the Senate version of the geothermal percentage depletion allowance.

Turbine Limitation on Investment Tax Credit

Problem: The House version of the NEA excludes turbines and generators from the scope of the 10 percent additional investment tax credit for alternative energy property. This unnecessarily restricts the credit and reduces utility enthusiasm for geothermal resources.

Recommendation: The Department of Energy and Treasury Department should support the Senate version of the investment tax credit.

Investment Tax Credit for Geothermal Equipment in New Facilities

Problem: Because the NEA investment tax credit provisions apply only to installation of equipment in existing facilities, the use of geothermal resources will be lower than could otherwise be achieved.

Recommendation: Future geothermal energy legislation should include a temporary additional 10 percent investment tax credit for geothermal equipment in new structures, as well as for existing structures.*

Production Tax Credit for Geopressured Methane

Problem: Industry perception of the cost of geopressure methane is that it will be too great to allow a rate of return commensurate with the risks involved in exploration and production. Without economic incentives, industry involvement in exploration and testing of the viability of geopressured methane is unlikely for several years.

Recommendation: Support the Senate provision in the Conference Committee.

Legislation Deeding Boise Barracks Tract to City of Boise

Problem: The City of Boise wishes to proceed with development of what would be the first major geothermal hot water system in the United States on a tract known as Boise Barracks. The leases have not been issued, and a decision has been made to designate the tract a KGRA, requiring competitive bidding and thus further delay. Boise already owns much of the surface rights, and the expenses of administration of this small isolated tract will exceed the government royalties from it. If the rights to that tract cannot be resolved within the next few months, Boise intends to use an alternative resource, which DOE geologists believe will not support the proposed system and will at best be 25 percent more costly. This will result in a high-visibility failure or high-cost project and, as such, would severely impair the Federal program for nonelectric geothermal use.

Recommendation: Submit legislation deeding the tract to Boise. In the event such legislation is not enacted, BLM should proceed as soon as possible with issuance of a noncompetitive or a competitive lease sale.**

The Panel will continue work on several other problem areas during FY 1979.

Future geothermal energy legislation should include minor improvements and corrections to the tax measures in the NEA, streamlining measures for the Federal leasing and permitting program, improvements to the loan guaranty program, and other measures to provide for a legal and regulatory framework amenable to extensive development of geothermal resources.

The Panel will undertake an examination of the status of onshore geopressured resources.

*Resolved by NEA as enacted.

**Legislation enacted during 1978.

The Streamlining Task Force will assess the adequacy of agency budgets for leasing and permitting if the tax legislation results as expected in an increase in activity.

The Panel will examine the need for an environmental review on loan guarantees where the project is on Federal land, in light of the several environmental reviews performed prior to leasing and prior to issuing permits for exploration and development.

The Panel will assess the impact of the dedication of geopressured methane wells to the interstate markets and a comprehensive review of institutional barriers to geopressured development will be initiated.

Alternate forms of assistance for transmission capacity installation will be examined, as the use of Federal capacity may help in some areas but, like wheeling and interconnection, cannot help at many sites.

The recommendation that FERC develop rate policies has been tabled for many months. With plants now likely in the near future in California, Utah, New Mexico, and Nevada, this issue will be reexamined.

The Panel will evaluate possible program designs for insurance or indemnities against losses from premature reservoir failure or decline. It may include recommendations in this area for inclusion in future legislation.

The Panel will examine several alternative financial incentives for geothermal heat distribution systems for inclusion in future legislation.

Resource Panel, Year-End Summary

Early in FY 1978, the Resource Panel began an implementation plan for the strategy outlined in its Federal Plan for Geothermal Resource Assessment (January 1977). This report describes the goal, objectives, and program elements of the Federal geothermal resource assessment program, and outlines a strategy for program implementation. The implementation plan will define the Federal budget and work schedule necessary to help resource assessment support other elements of the Federal RD&D program.

During the remainder of FY 1978, the Resource Panel identified resource assessment program elements in USGS and DOE/DGE projects and compared several years of funding levels for these projects with the recommendations in the Federal plan.

In addition, the Panel recommended future funding levels and described time schedules for accomplishing the principal resource assessment projects. The latter task will depend in large part on the findings of Circular 790.

F.1

Appendix F

INTERNATIONAL AGREEMENTS

Multilateral Agreements

PARTICIPATING COUNTRIES	FY 1978 STATUS	REFERENCES	FUTURE ACTIVITIES
International Energy Agency Federal Republic of Germany, Sweden, Switzerland, United Kingdom, United States	<u>Man-made Geothermal Energy Systems (MAGES) Project:</u> An implementation agreement was signed on October 6, 1977. Germany was designated as the operating agent. Phase I of the project consists of a 15-month effort to review hot dry rock concepts, drilling technology, and future development of systems and/or components. Work on the MAGES project commenced in June 1978.		Phase II of the project, if approved, would involve testing of a system defined during Phase I, laboratory and modelling studies, and hardware development.
	<u>Low Enthalpy Geothermal Sources for Nonelectric Use:</u> Member countries responded to a U.S. offer to make available two versions of a fluidized bed heat exchanger for testing by IEA. A delegation from several IEA countries, and Mexico (non-IEA) has visited the Raft River Idaho site to see the prototypes in operation. Italy expressed an interest in testing an exchanger at Milano.		A draft Implementation Agreement for a Program of Research, Development and Demonstration of Geothermal Equipment, which would cover cooperative activities for both the fluidized bed heat exchanger and the helical screw expander, is being circulated among interested countries for comment.
	<u>Small Geothermal Power Plants:</u> The U.S. delegation offered in 1977 to make available a prototype helical screw expander unit for cooperative testing by IEA member countries. The HSE is built by Hydrothermal Power Company, Ltd. of Los Angeles. An IEA delegation observed testing of the prototype unit in May 1978 at Roosevelt Hot Springs, Utah. IEA/DOE has received requests for testing of HSE from Italy, Mexico and New Zealand.		See note above. Initial testing of the helical screw expander will probably be conducted in Mexico and Italy. Tests in New Zealand are scheduled for 1981.

PARTICIPATING COUNTRIES

NATO-CCMS Geothermal
Pilot Study,
Canada, Federal Republic
of Germany, France,
Greece, Iceland, Italy,
the Netherlands, New
Zealand, Sweden,
Switzerland, United
Kingdom, United States

FY 1978 STATUS

A Final Report on the Geothermal Pilot Study, entitled "Creating an International Geothermal Community" was completed in June 1978. The report was reviewed by a panel of international experts along with three other CCMS energy studies (conservation, solar and automotive propulsion systems) at a workshop hosted by the Government of Italy in July, 1978. The pilot study submitted the following recommendations: (1) Continue international exchange of information under the aegis of the U.S.-Italian bilateral agreement for computerized information systems. (2) Continue international cooperation in reservoir studies, brine reinjection and subsidence under the U.S.-Mexican bilateral agreement, which is open to participation by other countries. (3) Continue cooperation in the area of small-scale geothermal power plants including multination testing of the helical screw expander. (4) Develop a cooperative international R/D program in hot dry rock technology under the auspices of the International Energy Agency.

REFERENCES

See CCMS GPS Reports
App. A-4 1-7.

FUTURE ACTIVITIES

An integrated presentation of all four CCMS energy studies, focusing on conservation and development of suitable energy technologies, will be made at the Fall CCMS Plenary in October, 1978. A conference in 1980 to review the status of international geothermal development is planned as a follow-up effort.

Bilateral Agreements

PARTICIPATING COUNTRIES	FY 1978 STATUS	REFERENCE	FUTURE ACTIVITIES
U.S.-Iceland	U.S. and Icelandic correspondents were appointed for exchange of information on liquid fluidized bed heat exchanges.		The agreement is presently inactive and will probably terminate in November, 1978
U.S.-Italy (ENEL)	<p><u>Stimulation of Hydrothermal Areas.</u> Data collection and site selection for well-testing at Cesano, Italy and The Geysers have been completed.</p> <p><u>Reservoir Physics and Engineering:</u> Data collection and evaluation for reservoir modelling efforts at Lardarello, Radincondoli, and Bagnore are on schedule and have been reported to the geothermal community at large. A computer model (SHAFT 78) on the effects of geofluid reinjection into a vapor-dominated systems (Serrazzano and Castelnuovo) zone of the Larderello field has been developed. A cooperative program of numerical studies to further refine SHAFT is proposed.</p> <p><u>Environment Control Technology:</u> Exchange of information is continuing on environmental monitoring at Larderello and The Geysers.</p> <p><u>Seismic Studies.</u> Negotiations are underway to develop a comparative study of seismic activities associated with geothermal development at Larderello and The Geysers.</p>	<p>See U.S.-Italy (ENEL) Reports, Appendix A-4 7-14.</p>	<p>Well-testing will be initiated in FY 1979.</p> <p>Continued development of numerical models is under discussion.</p> <p>Actual collection of H₂S data at Larderello will proceed after an air-monitoring and a meteorological network has been set up. The feasibility of using the CuSO₄ scrubbing system for H₂S at Larderello will be investigated.</p> <p>Final agreement is expected to be reached in early FY 1979. Field monitoring and data collection will commence once specific task assignments have been finalized.</p>

PARTICIPATING COUNTRIES	FY 1978 STATUS	REFERENCE	FUTURE ACTIVITIES
U.S.-Italy (CNR/ENEL)	Data tapes on Geothermics, the Italian journal on geothermal energy were received by ORNL and returned to CNR for compatible computer re-formatting. The U.S. has established new informational contacts with India, Japan, and Peru.	See Reports on Computerized Information Systems, Appendix A-4, 15, 16, 17	Continuing exchange of information.
U.S.-Japan	<p>An "Implementing Arrangement Between the United States Department of Energy and the Agency of Industrial Science and Technology of Japan in the Field of Geothermal Energy Applications was concluded on June 15, 1978 under the U.S.-Japan Bilateral Agreement for Energy R&D. Areas of mutual interest include: Development and evaluation of geothermal resource data; new techniques for resources assessment; new drilling and fracturing techniques; volcanic studies; transportation of steam and hot water for non-power uses; evaluation of reservoir life; and environmental studies.</p> <p>Japanese interest in geothermal cooperation was also expressed by Prime Minister Fukuda of Japan during his visit to the U.S. in April 1978 as part of the "Fukuda Initiatives."</p>		A Joint Coordinating Committee will be set up in the near future to define the scope of work.

PARTICIPATING
COUNTRIES

FY 1978 STATUS

REFERENCE

FUTURE ACTIVITIES

U.S.-Mexico

Collection and analysis of field data for geophysical and reservoir engineering studies have been completed on schedule. Results of field work on the structure, hydrodynamics, and chemistry of the Cerro Prieto geothermal field was shared with the U.S. Geothermal community at the First Symposium on the Cerro Prieto field held in San Diego, California in September 1978.

See Reports on Cerro Prieto Field, Appendix A-4.

The emphasis of work in FY 79 will be to develop an understanding of the dynamic model of the Cerro Prieto field and how it is recharged, e.g., how the geothermal reservoir interfaces with regional aquifers.

U.S.-U.S.S.R.

U.S.-U.S.S.R. cooperation in geothermal energy is under review.

Multilateral/Bilateral Activities

PARTICIPATING COUNTRIES	FY 1978 STATUS	REFERENCES	FUTURE ACTIVITIES
International Energy Development Program (IEDP)	During FY 78, DGE provided technical support to the U.S. IEDP for assessment of the geothermal potential in Egypt and Peru as part of an overall energy assessment effort under bilateral energy assistance agreements with these governments.		
U.S.-Federal Republic of Germany	The U.S. and F.R.G. has reached general agreement on participation of German scientists in the Los Alamos Scientific Laboratory (LASL) hot dry rock program. It is proposed that F.R.G. make a 25 percent contribution to the LASL budget up to \$3 M.		An implementation agreement will be drafted in the near future.
U.S.-New Zealand	Partially as a result of Vice President Mondale's visit to New Zealand in May 1978, there has been renewed interest in geothermal cooperation with the United States.		A team of U.S. geothermal experts have been invited to visit New Zealand in early 1979

G.1

Appendix G

COST-SUPPLY CURVES FOR CANDIDATE HYDROTHERMAL SITES

COST-SUPPLY CURVES FOR CANDIDATE HYDROTHERMAL SITES

Life cycle electricity busbar cost estimates are illustrated for candidate geothermal hydrothermal sites in the cost-supply curves, Figure G.1 (current technology, and current technology plus NEA incentives) and Figure G.2 (advanced technology plus NEA incentives). Competitive electric busbar costs for coal, nuclear and oil are also shown in these figures.

The geothermal costs have been calculated using a computer-based model. This model calculates plant costs based on resource temperature and salinity by interpolating between six generic plant designs (three flash and three binary) at different temperatures. Field costs calculations are based on resource depth, overlying rock type, and numbers of production and injection wells required. The present value (in the start-up year) of all costs associated with the plant is calculated, and the levelized busbar cost is obtained as that value which will give a revenue stream equal in present value to the costs. The levelized busbar cost is assumed to be constant in constant dollars over the life of the plant. The data base supporting these calculations was assembled in late 1976. Detailed descriptions of model and data are given in DGE/4014-3.

Costs of competing sources of energy (i.e., nuclear, coal and oil-fired generating plants) have been calculated based on the study guideline assumptions for capital and O&M costs and financial parameters. The computational methodology used to obtain levelized busbar costs was the same as that employed for the geothermal plants, to ensure comparability of results.

1,000 MW_e of Reservoir Capacity [The Geysers (Steam) and Geopressed Zones Excluded]

Figure G.1. Market/Economic Readiness of Geothermal Hydrothermal:
Impact of NEA on Projected Costs

1,000 MWe of Reservoir Capacity [The Geysers (Steam) and Geopressed Zones Excluded]

Figure G.2. Market/Economic Readiness of Geothermal Hydrothermal:
Impact of NEA Plus Improved Technology on Projected Costs

H.1

Appendix H

SUMMARY OF NATIONAL ENERGY ACT

THE NATIONAL ENERGY ACT

The National Energy Act (NEA) is a broad-ranging measure intended to establish a national energy policy to reduce energy fuel imports, encourage conservation of depleting resources, and increase and accelerate the utilization of renewable resources and of the large national reserves of coal. The five parts of the Act include measures designed to stimulate exploration for and development of geothermal resources.

In particular, tax treatment of the sort traditionally available for other energy resources is provided for by explicitly authorizing a percentage depletion allowance and intangible drilling cost deductions. Geopressured methane is freed from price regulation. Tax credits are provided for geothermal equipment for business and residential applications.

These and other provisions of the Act resolve some of the major factors that have slowed development of geothermal resources, but adequate incentives for utility and industrial applications are not included.

The Council is presently seeking suggestions and recommendations for approaches. The objective will be permanent elimination or minimization of regulatory and legal barriers, and temporary incentives to stimulate early demonstration of the many feasible applications of geothermal resources to a wide variety of uses.

Intangible drilling costs and depletion allowance. The NEA resolves at last a major problem that has severely inhibited geothermal resource exploration for many years. The Act authorizes deduction of intangible drilling costs for geothermal wells on the same basis as for oil and gas. In addition a percentage depletion allowance is permitted without the requirement for demonstrating actual depletability of the resource. The rate for geothermal resources is set at 22 percent, but declines to 15 percent by 1984 on the same schedule as for small oil and gas producers.

The depletion allowance for geopressured methane is set at 10 percent, and is allowable only for wells whose drilling begins after September 30, 1978 and before January 1, 1984. Wells drilled after that date would be treated as normal gas wells. A well producing both geopressured methane and hot water would be allowed a 10 percent depletion allowance for income from methane (until 1984) and 15-22 percent depletion allowance for income from the hot water. There is no limit on the quantity of geothermal resource production on which percentage depletion can be taken.

For tax purposes, a geothermal deposit is defined as "a geothermal reservoir consisting of natural heat which is stored in rocks or in an aqueous liquid or vapor (whether or not under pressure)."

Residential energy credit. A residential energy tax credit is allowed for a homeowner or a member of a cooperative housing association installing "property which, when installed in connection with a dwelling, transmits or uses...energy derived from geothermal deposits...for the purpose of heating or cooling such dwelling or providing hot water for use within such dwelling...." The credit is 30 percent for the first \$2,000, and 20 percent of the next \$8,000, for a total maximum of \$2,200. The residence must be the taxpayer's principal residence, and the credit is available for expenditures between April 20, 1977 and December 31, 1985. The amount of the credit is limited to the taxpayer's tax liability, but the unused credit can be carried forward up until 1987.

The equipment must be original use equipment, and must have a reasonably expected life of five years or more. The equipment must meet any performance and quality standards specified by Treasury in consultation with DOE and HUD. This basis in the equipment is reduced by the amount of the credit.

Business investment credit. The Bill provides for a business investment credit of 10 percent, in addition to the normal investment tax credit, for "alternative energy property," including "equipment used to produce, distribute or use energy derived from a geothermal deposit, but only, in the case of electricity generated by geothermal power, up to (but not including) the transmission stage." This credit is not allowed for public utility property, defined in part as "property used in the furnishing or sale of...electrical energy,...water...or steam...." The credit is only 5 percent if the property is financed by tax-exempt industrial development bonds. This credit is available for equipment whose construction is completed between October 1, 1978 and December 31, 1982. The equipment must be depreciable and must have at least a 3-year lifetime. The credit also applies to "equipment for producing natural gas from geopressured brine."

The equipment must conform to standards required to be developed by the Department of Energy (DOE), once they are developed. The credit is not refundable. It can apply to 100 percent of tax liability. Agricultural uses qualify for the credit, as well as other business uses.

Conversion incentives. The NEA provides additional incentives to convert from oil and gas to geothermal resource utilization. Equipment which uses oil or gas is ineligible for the base investment tax credit, and accelerated depreciation is permitted for oil and gas using equipment which is scheduled for early retirement.

More direct measures to encourage or mandate conversion are included. New power plants and major fuel-burning installations which are boilers, with a design heat rate capacity of 100 million Btu/hr. or more, are prohibited from using petroleum or natural gas. Existing power plants may not use natural gas after January 1, 1990, and DOE may prohibit use of oil or gas in new non-boiler installations and in existing power plants or major fuel-burning installations which are coal-capable.

Various temporary and permanent exemptions can be obtained based on unavailability of coal or other fuels (including geothermal) at a price competitive with imported oil, on environmental limitations, or on site limitations. Note that it is not sufficient in seeking an exemption to show that domestic oil or gas is cheaper--one must show that the cost of coal or other fuels exceeds the cost of imported oil. These provisions effectively require power plants and other facilities to demonstrate unavailability of geothermal resources as well as coal or other alternatives as a condition to continued use of oil or gas.

A utility seeking an exemption must demonstrate the unavailability of alternative sites as well as alternate fuels. It is noteworthy that the procedures for exemption orders require public notice and opportunity for comment by interested parties, including resource developers anxious to sell geothermal steam to a utility seeking such an exemption.

Synthetic gas from coal is not considered gas for the purposes of conversion orders. A user can also trade in synthetic gas purchased elsewhere for gas at his point of use, provided the Btu content is equivalent or better. Geopressured methane is not accorded this exemption, however.

Deregulation of geopressured methane. The NEA provides that within one year of enactment, methane produced from geopressured brine is not subject to price regulation. The cost of such "high-cost" gas is incremental, rather than rolled-in. That is, the cost must be borne by industrial customers, rather than averaged out over all consumers. Rolled-in pricing would open up a larger market for geopressured methane, if the Act could be amended to allow it.

Interconnection and wheeling. The NEA authorizes the Federal Energy Commission (FERC) to issue orders for interconnection; sale, exchange, or other coordination; and the expansion of transmission capacity at the request of a small power producer, cogenerator or electric utility. FERC must find to issue such an order that it will encourage conservation of energy or capital, will optimize the efficiency of use of facilities, or will improve the reliability of an electric utility system.

Small power producers are defined as persons not primarily engaged in the generation or sale of electricity who are producing electrical power from, among other sources, "renewable resources," from a site with no more than 80 megawatts of capacity. It is not clear that geothermal resources are included in "renewable resources."

A cogeneration facility is one that produces electricity and steam or other forms of useful energy (including methane). A geothermal facility producing power and using heat for industrial, heating or agricultural purposes would qualify.

Utilities (but not small power producers or cogenerators) can also seek wheeling orders from FERC. For a wheeling order, FERC must find that the order will conserve a significant amount of energy, promote the effectiveness of facilities and resources, or improve the reliability of an

electric utility system. Wheeling cannot be ordered if it would replace power being provided by the utility owning the transmission facility under a contract, or under a rate schedule on file with FERC.

FERC is authorized to exempt small power producers and cogenerators with less than 30 megawatts of capacity from the Federal Power Act and the Federal Public Utility Holding Company Act.

I.1

Appendix I

STATUS OF GEOTHERMAL LEASING, FY 1978

 

SITE-SPECIFIC PROGRESS

Arizona

The Clifton KGRA contains 480 acres, all of which is Federally owned. This acreage was offered for lease as a single tract but attracted no bids.

California

The East Mesa KGRA contains 38,365 acres, 87% of which is Federally owned. Two sales were held for the East Mesa tracts, resulting in leases for 11,770 acres (6 leases).

The Geysers-Calistoga KGRA contains 376,030 acres. Three sales have been held, resulting in leases for 11,611 acres (16 leases).

The Lake City-Surprise Valley KGRA contains 72,940 acres. One sale was held with 10,584 acres being leased (4 leases).

The Mono-Long Valley KGRA contains 460,256 acres. The one sale resulted in leases for 5,483 acres (3 leases).

The Wendel-Amedee KGRA contains 17,932 acres. One sale offering five tracts resulted in a single lease of 1205 acres.

Colorado

The Alamosa KGRA contains 6,761 acres. Two lease offerings did not attract any bids.

Mineral Hot Springs is a KGRA of 5,765 acres at which two lease sales resulted in a lease for 2,484 acres.

The Poncha KGRA contains 3,200 acres. One lease offering resulted in a single lease of 916 acres.

The Valley View Hot Springs KGRA contains 5,099 acres. Two lease sales resulted in a single lease of 1,636 acres.

Idaho

The Bruneau KGRA contains 5,120 acres. A single lease sale resulted in two leases for a total of 2,600 acres.

Idaho (continued)

The Castle Creek KGRA contains 79,722 acres. Out of two lease sales leases were issued for 20,924 acres (9 leases).

The Crane Creek KGRA contains 4,342 acres. Only one sale has been held, resulting in a lease for 1,381 acres.

The Mountain Home KGRA contains 9,520 acres. Out of three lease sales, a total of 6,986 acres have been leased (3 leases).

The Raft River KGRA contains 30,209 acres. As the result of two lease offerings, only 1883 acres were leased (1 lease).

Montana

The Boulder Hot Springs KGRA contains 6,343 acres. The lease sale did not attract any bids.

Nevada

The Baltazor KGRA contains 5,617 acres. One lease sale has been held resulting in leases for 5,537 acres (3 leases).

The Beowawe KGRA contains 33,224 acres. As the result of three lease sales, leases were issued for 13,766 acres (6 leases).

The Brady-Hazen KGRA contains 98,508 acres. Four sales have been held resulting in leases for 37,686 acres (20 leases).

The Colado KGRA contains 640 acres which was leased at the second offering (1 lease).

The Darrough Hot Springs KGRA contains 8,363 acres. Two lease sales attracted no bids.

The Dixie Valley KGRA contains 38,348 acres. As the result of two lease offerings, leases issued for 30,491 acres (14 leases).

The Fly Ranch KGRA contains 20,759 acres. Four lease sales have been held, resulting in leases for 10,790 acres (5 leases).

The Gerlach KGRA contains 26,326 acres. As the result of two sales 14,175 acres were leased (7 leases).

The Hot Springs Point KGRA and San Emidio Desert KGRA contain 8,549 and 7,678 acres, respectively. Three sales resulted in leases for 6,313 acres (3 leases).

Nevada (continued)

The Kyle Hot Springs KGRA contains 2,561 acres, of which 2,401 acres have been leased (1 lease).

The Leach Hot Springs contains 12,846 acres of which 12,246 acres have been leased (5 leases).

The Monte Neva Hot Springs KGRA contains 10,302 acres. The single lease offering attracted no bids.

The Pinto Hot Springs KGRA contains 8,015 acres. The single lease offering attracted no bids.

The Ruby Valley KGRA contains 5,743 acres. Two lease offerings resulted in leases for 4,023 acres (2 leases).

The Rye Patch KGRA contains 801 acres, all of which has been leased (1 lease).

The Salt Wells Basin KGRA contains 19,232 acres. The single lease offering of 18,577 acres attracted no bids.

The Silver Peak KGRA contains 5,117 acres. Two lease offerings resulted in a lease for 2,547 acres.

The Steamboat Springs KGRA contains 8,911 acres. The single lease offering resulted in a lease for 1,548 acres.

The Stillwater-Soda Lake KGRA contains 225,260 acres. As the result of three lease offerings only 13,259 acres were leased; the remaining 33,597 acres offered attracted no bids (6 leases).

The Wabuska KGRA contains 11,520 acres. The single lease sale resulted in leases for 5,640 acres (3 leases).

The Warm Springs KGRA contains 3,812 acres. The single lease sale resulted in a lease for 1,312 acres.

The Wilson Hot Springs KGRA contains 1,294 acres, all of which has been leased (1 lease).

New Mexico

The Baca Location No. 1 KGRA contains 168,761 acres. As the result of three lease sales 25,625 acres were leased. An additional 15,077 acres offered for lease attracted no bids (16 leases).

New Mexico (continued)

The Kilbourne Hole KGRA contains 25,134 acres. Two lease offerings resulted in leases for 21,034 acres (12 leases).

The Lightning Dock KGRA contains 23,552 acres. As the result of four lease offerings 19,047 acres have been leased (10 leases).

The Radium Springs KGRA contains 9,813 acres and two lease sales resulted in leases for 6,714 acres (8 leases).

The San Ysidro KGRA contains 1,915 acres. Two lease offerings attracted no bids.

The Socorro Peak KGRA contains 89,716 acres. As the result of two lease offerings 14,415 acres were leased. The additional 27,310 acres offered attracted no bids (9 leases).

Oregon

The Alvord Hot Springs KGRA contains 176,835 acres. The single lease sale resulted in leases for 12,643 acres (6 leases).

The single sale of tracts at Borox Lake resulted in leases for 17,808 acres (8 leases).

The Burns Butte KGRA contains 640 acres. This acreage was offered with additional competitive interest KGRA lands for a total of 4,868 acres but attracted no bids.

The Crump Geyser KGRA contains 85,633 acres. At three lease sales 14,343 acres were leased, but an additional 22,756 acres attracted no bids (7 leases).

The Klamath Falls KGRA contains 50,300 acres. As the result of three lease offers, 1,907 acres have been leased (6 leases).

The single sale of tracts at the Mickey Hot Springs resulted in leases for 15,000 acres (6 leases).

The Summer Lake Hot Springs KGRA contains 13,631 acres. Two lease sales resulted in leases for 7,521 acres (4 leases).

The Vale Hot Springs KGRA contains 22,998 acres. As the result of three lease offerings, 13,921 acres were leased (7 leases).

Utah

The Cove Fort-Sulphurdale KGRA contains 24,074 acres. As the result of three lease offerings, 25,100 acres were leased (12 leases).

The Crater Springs KGRA contains 17,321 acres. The single lease sale resulted in leases for 15,001 acres (6 leases).

The Lund KGRA contains 3,840 acres, of which 3,360 acres have been leased (2 leases).

The Monroe-Joseph KGRA contains 16,364 acres. Three lease sales resulted in leases for 7,187 acres (4 leases).

The Newcastle KGRA contains 2,636 acres, of which 1,831 acres have been leased (1 lease).

The Roosevelt Hot Springs KGRA contains 29,791 acres. Two lease sales resulted in leases for 23,319 acres (13 leases).

The Thermo Hot Springs KGRA contains 26,019 acres. As the result of three lease sales, 13,450 acres were leased (10 leases).

NONCOMPETITIVE GEOTHERMAL LEASES
ISSUED 1975-1978

<u>STATE</u>	<u>YEAR</u>	<u>LAND ADMINISTERED BY</u>	<u>NUMBER OF LEASES</u>	<u>ACREAGE LEASED</u>
ARIZONA	1975	BLM	4	5,228
	1975	FS	1	1,920
<u>Subtotal</u>			<u>5</u>	<u>7,148</u>
CALIFORNIA	1975	BLM	3	3,197
	1976	BLM	7	13,887
	1978	BLM	8	12,315
<u>Subtotal</u>			<u>18</u>	<u>29,393</u>
COLORADO	1975	BLM	24	24,810
	1976	BLM	10	12,291
	1977	BLM	8	12,464
	1976	FS	1	680
<u>Subtotal</u>			<u>43</u>	<u>50,245</u>
EASTERN STATES	1975	0	0	0
	1976	FS	11	19,744
<u>Subtotal</u>			<u>11</u>	<u>19,744</u>
IDAHO	1975	BLM	55	94,012
	1976	BLM	19	25,313
	1977	BLM	45	83,890
	1978	BLM	51	98,363
	1976	FS	1	2,560
<u>Subtotal</u>			<u>171</u>	<u>304,138</u>
MONTANA	1976	BLM	6	10,687
<u>Subtotal</u>			<u>6</u>	<u>10,687</u>
NEVADA	1975	BLM	217	387,767.63
	1976	BLM	151	250,086.06
	1977	BLM	63	111,534.95
	1978	BLM	39	77,345.54
BLM Subtotal			470	826,734.18
	1975	FS	2	2,649.21
	1976	FS	1	1,984.33
FS Subtotal			3	4,633.54
<u>Subtotal (both)</u>			<u>473</u>	<u>831,367.72</u>
NEW MEXICO	1975	BLM	47	103,569.94
	1976	BLM	24	26,893.40
	1977	BLM	17	24,958.52
	1978	0	0	0.00
<u>Subtotal</u>			<u>88</u>	<u>155,421.86</u>

NONCOMPETITIVE GEOTHERMAL LEASES ISSUED 1975-1978 (cont.)

<u>STATE</u>	<u>YEAR</u>	<u>LAND ADMINISTERED BY</u>	<u>NUMBER OF LEASES</u>	<u>ACREAGE LEASED</u>
OREGON	1975	BLM	6	7,667.26
	1976	BLM	53	70,467.75
	1977	BLM	43	62,112.21
	1978	BLM	16	23,274.78
	BLM Subtotal		118	163,522.00
	1975	0	0	0.00
	1976	0	0	0.00
	1977	FS	3	5,709.09
	1978	FS	7	16,628.44
	FS Subtotal		10	22,337.53
	Subtotal (both)		128	185,859.53
UTAH	1975	BLM	76	130,250
	1976	BLM	94	169,611
	1977	BLM	39	68,087
	1978	BLM	24	32,982
	BLM Subtotal		233	400,930
	1975	FS	11	15,708
	1976	FS	2	2,838
	1977	0	0	0
	1978	FS	1	707
	FS Subtotal		14	19,253
	Subtotal (both)		247	420,183
WASHINGTON	0	0	0	0

TOTAL OF SUBTOTALS OF 11 STATES

ARIZONA	5	7,148
CALIFORNIA	18	29,393
COLORADO	43	50,245
EASTERN STATES	11	19,744
IDAHO	171	304,138
MONTANA	6	10,687
NEVADA	473	831,367.72
NEW MEXICO	88	155,421.86
OREGON	128	185,859.53
UTAH	247	420,183
WASHINGTON	0	0.00
TOTAL (BLM & FS)	1,190	2,014,187.11
TOTAL (FS Only)	41	71,128.07
TOTAL (BLM Only)	1,149	1,943,059.04

COMPETITIVE GEOTHERMAL LEASE SALES

State	Sale Date	No of Tracts	Total Acreage Offered	Acreage Leased	Acreage with No Bids
Arizona	1-28-75	1	780	0	780
Subtotal		1	780	0	780
California	1-22-74	33	52,639	22,662	29,977
	5-29-74	2	786	786	0
	6-4-74	9	20,959	2,560	18,399
	6-23-75	16	34,591	10,584	24,007
	9-14-77	3	2,937	2,857	80
	9-21-78	5	2,669	1,205	1,464
Subtotal		68	114,581	40,654	73,927
Colorado	5-20-75	8	11,271	5,036	6,235
	4-15-77	5	6,235	0	6,235
Subtotal		13	17,506	5,036	12,470
Idaho	6-23-76	5	9,043	1,381	7,662
	11-17-76	2	4,001	0	4,001
	11-17-77	11	21,020	5,103	15,917
	11-3-75	9	20,924	18,364	2,560
	6-19-75	5	7,676	2,600	5,076
	Subtotal		32	62,664	27,448
Montana	1-18-77	1	1,608	0	1,608
Subtotal		1	1,608	0	1,608
Nevada	9-11-74	8	12,608	4,174	8,434
	12-18-74	15	30,147	21,603	8,544
	4-8-75	7	14,479	8,751	5,728
	6-26-75	21	47,157	13,266	33,891
	9-23-75	7	12,916	7,188	5,728
	1-20-76	17	33,524	10,106	23,418
	3-3-76	16	35,192	1,294	33,898
	4-20-76	19	45,642	17,340	28,302
	6-15-76	27	52,098	13,698	38,400
	8-18-76	8	12,047	3,220	8,827
	10-19-76	6	12,886	12,886	0
	12-14-76	4	8,204	2,400	5,804
	5-17-77	5	9,287	1,312	7,975
	7-19-77	13	21,235	14,254	6,981
	12-13-77	22	49,314	14,117	35,197
	9-26-78	29	58,828	9,322	48,442
Subtotal		224	455,564	154,931	300,633
New Mexico	5-15-75	12	24,278	18,477	5,801
	10-27-76	11	11,423	5,065	6,358
	5-18-76	6	13,371	9,023	4,348
	5-25-77	17	29,375	18,050	11,325
	9-20-77	12	17,968	11,197	6,771
	11-29-77	19	34,654	18,820	15,834
	9-19-78	18	25,533	8,768	16,765
Subtotal		95	156,602	89,400	67,202
Oregon	5-22-75	14	30,348	7,520	22,828
	6-31-75	18	35,974	9,462	26,512
	9-25-75	6	12,574	7,046	5,528
	6-27-74	1	1,347	1,347	0
	9-23-76	4	7,521	4,674	2,847
	12-9-76	28	37,934	13,255	24,679
	5-13-76	15	4,954	1,907	3,047
	6-9-77	1	640	0	640
	7-27-78	29	28,351	0	28,351
	5-29-75	14	26,938	12,643	14,295
	6-5-75	16	35,605	11,019	24,586
Subtotal		146	222,186	68,873	153,313

COMPETITIVE GEOTHERMAL LEASE SALES (cont.)

State	Sale Date	No of Tracts	Total Acreage Offered	Acreage Leased	Acreage with No Bids
Utah	7-30-74	12	23,932	23,932	0
	3-5-75	10	21,059	19,410	1,649
	6-12-75	18	30,368	6,762	23,606
	2-3-76	18	36,956	26,969	9,987
	9-27-77	9	16,308	11,138	5,170
Subtotal		67	128,618	88,211	40,407
TOTAL OF THE SUBTOTALS FOR ALL NINE STATES					
Arizona		1	780	0	780
California		68	114,581	40,654	73,927
Colorado		13	17,506	5,036	12,470
Idaho		32	62,664	27,448	35,216
Montana		1	1,608	0	1,608
Nevada		224	455,564	154,931	300,633
New Mexico		95	156,602	89,400	67,202
Oregon		146	222,186	68,873	153,313
Utah		67	128,618	88,211	40,407
TOTALS		647	1,160,109	474,553	685,556