First Annual Report

MASTER

Geothermal
Energy Research, Development
& Demonstration Program

APRIL 1977

Energy Research & Development
Administration

Division of Geothermal Energy
Washington, D.C. 20545

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LEGEND

- * Developed Geothermal Field
- Areas Undergoing Evaluation for Development
- ▲ Deep Exploratory Drill Hole, 1968-75
- Drilling as Part of Research Program
- Utilization of Low-Enthalpy Fluids

Source: James B. Koenig, et al, "Exploration and Development of Geothermal Resources in the United States," Second United Nations Symposium for the Development and Utilization of Geothermal Resources, San Francisco, May 1975.

GEOHERMAL EXPLORATION IN THE UNITED STATES

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PREFACE

This is the first annual report on the Federal Geothermal Research, Development, and Demonstration Program (Federal Program). Subsequent to the creation of the Energy Research and Development Administration (ERDA), the Administrator established the interagency Geothermal Advisory Council, later renamed the Interagency Geothermal Coordinating Council (IGCC), under the chairmanship of the Assistant Administrator for Solar, Geothermal, and Advanced Energy Systems. The IGCC serves as the successor to the Geothermal Energy Coordination and Management Project (the Project), which was established by P.L. 93-410, the Geothermal Research, Development, and Demonstration Act of 1974. The functions of the Project were transferred to ERDA, which became the lead agency for the Federal Program under the terms of P.L. 93-438, the Energy Reorganization Act of 1974, and P.L. 93-577, the Federal Nonnuclear Energy Research, Development, and Demonstration Act of 1974.

This report on the achievements and progress of the Federal Program was prepared under the auspices of ERDA with the assistance and concurrence of the IGCC. It covers activities under the Federal Program during the period from July 1, 1975, through September 30, 1976, (FY 1976 and the Transition Quarter), and it outlines plans and proposals for the future. It serves to update the "Geothermal Energy Research, Development, and Demonstration Program Definition Report"

(ERDA-86, October, 1975), which was initiated by the Project and completed by ERDA. The present report also contains a brief descriptive sampling of representative activities in industry, and to a lesser extent in academia. If geothermal energy is to make a significant contribution to the achievement of enunciated national energy goals, then the "National" geothermal program must include significant components from state and local governments and from universities, as well as the major contribution from industry.

The Executive Summary, rather than being simply an abbreviated abstract of the report, highlights, ERDA's evolving program strategy and plans. The primary emphasis of the program is being changed, from a concentration on RD&D to provide a set of technologically viable options, to increased emphasis on stimulating greater utilization of geothermal resources in an environmentally and socially acceptable manner. This requires a coordinated, multiagency effort to reduce resource uncertainties, technological risks, and institutional barriers, many of which are not within ERDA's authority. Measures for effecting or expediting management and coordination, both within and outside the Federal sector, have thus become essential components of ERDA's lead agency responsibilities, and are also summarized.

James C. Bresee, Director
Division of Geothermal Energy

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EXECUTIVE SUMMARY

FEDERAL GEOTHERMAL RESEARCH, DEVELOPMENT,
AND DEMONSTRATION PROGRAM

The Goal

The goal of the Federal Program is to stimulate commercial development of geothermal energy as an economic, reliable, and environmentally acceptable energy source.

The Resource: Its Nature and Current Status of Development

There are three principal types of geothermal energy resources of interest for the period through the year 2000. In increasing order of estimated magnitude, they are convective hydrothermal, geopressured hydrothermal, and hot dry rock resources.

The convective hydrothermal resource consists of high temperature, vapor-dominated ("dry steam") reservoirs, or liquid-dominated ("superheated water") reservoirs, at both moderate and high temperatures.

The only known vapor-dominated hydrothermal reservoir in the United States (outside the National Parks) has been under commercial development at The Geysers, in California, for some 15 years. Its present electrical power generating capacity is about 500 megawatts (MWe), and its estimated ultimate capacity about 2500 MWe. Because its commercial feasibility has already been demonstrated, no major role

for the Federal Government is required to complete the exploitation of this resource, other than the reduction of certain environmental or institutional problems common to many geothermal resources.

Liquid-dominated reservoirs are located principally in the western United States (see map inside front cover), with temperatures generally tending to be low in the northwest and high in the central and southwestern areas. The latter have attracted a significant amount of interest, but as yet industrial efforts are small compared to what will be required to make a significant contribution in that region. Similar high-temperature, liquid-dominated hydrothermal reservoirs are being developed commercially in Mexico, New Zealand, Italy, Iceland, the Soviet Union, Turkey, El Salvador, and Japan, where environmental, economic, or other constraints are less stringent than those in the United States. Nonetheless, practical experience gained from some of these developments offers opportunities for international cooperation in the development of geothermal energy.

The geopressured hydrothermal resource comprises water and dissolved methane at moderately high temperatures, with a wide range of salinities, but at pressures much higher than the normal hydrostatic head. In the United States, it is located primarily in deep sedimentary formations along the Gulf Coast. The total resource, including the methane, is believed to be large on the basis of geological information obtained from petroleum operations. Nevertheless, because of technological and economic

uncertainties concerning reservoir producibility and longevity, geopressured systems have not, to date, attracted much commercial activity.

Hot dry rock resources consist of hot rocks at accessible depths that contain little or no water, therefore requiring the introduction and circulation of a heat transfer fluid, such as water, in order to extract usable power, because heat transfer by conduction is much too slow. Technologies must be developed to fracture the rocks in order to establish a large heat exchange surface and to circulate the fluid. For this reason, hot dry rock systems have attracted essentially no commercial interest in the United States, even though they are believed to constitute the largest and widely distributed geothermal resource base at accessible depths in the geologically active areas of the western third of the country.

Impediments to Commercial Development

The level of current commercial activity in geothermal energy development is low primarily because costs, technical and economic risks, environmental uncertainties, and institutional barriers are too great to be compatible with normal private sector investment practices.

The technology in current use is largely adapted from that of the oil industry and is often not well suited to the very different geologic environments of geothermal resources. There are major technological problems and uncertainties associated with resource exploration and assessment, with energy extraction and utilization, and with the potential environmental impacts of geothermal energy.

The determination of reservoir location and size, and of fluid producibility is difficult, time consuming, and costly. Surface exploration methods are deficient, so that exploratory drilling is too often unsuccessful. Borehole instruments for subsurface exploration and reservoir assessment are unsatisfactory or unavailable for use at high temperatures, and reservoir engineering capabilities are often inadequate for satisfactory predictions of reservoir hydrodynamic and life-time characteristics without extensive reservoir testing. Extended production tests are necessary prerequisites to decisions on further investments for extraction and utilization.

Many problems exist in energy extraction and utilization. Deep drilling at high temperatures or in hard rock is expensive. High-temperature, high-salinity fluids cause severe scaling and corrosion. Energy conversion technology suitable at high temperatures cannot be used to generate electric power economically from moderate-temperature resources; and satisfactory performance at a commercial scale of binary-fluid, hybrid, or more advanced "total flow" systems, has not been demonstrated.

With respect to the protection of health, safety, and the environment, the potential magnitude of the problems has yet to be fully assessed, and Federal or consensus guidelines have yet to be established. The technologies to control noxious gas emissions, toxic effluents in waste fluids, seismicity, and subsidence are being developed but have not been demonstrated on a full commercial scale.

Program Strategy

To reduce these impediments to commercialization, the geothermal development strategy comprises two major components: the reduction of technological and institutional uncertainties to a risk level compatible with normal private sector investment practices, and the encouragement of commercial development of geothermal energy resources for both electric and non-electric applications by means of demonstration projects and loan guaranties.

National and regional operations research systems analyses clearly indicated that the initial focus of the Federal program should be on the assessment and development of liquid-dominated hydrothermal resources in the West, in order to establish confidence in geothermal energy as a viable energy option at the earliest possible time. This will not only provide greater early utilization of geothermal energy, but, more significantly, it will encourage the development of an industrial base that on its own initiative is likely to expand into the development of as yet undiscovered hydrothermal resources. For the longer term, Federal RD&D programs are aimed at providing the advanced technology or other incentives required to make the large geopressured and hot dry rock resources attractive to industry. The

encouragement of commercial development may be implemented most effectively by taking advantage of the regional character of the geothermal energy resource base.*

With respect to the reduction of technological and institutional uncertainties, ERDA's Division of Geothermal Energy (DGE) recognizes that effective transfer of technological and other knowledge to the ultimate users is an essential component of the Federal strategy and is structuring its R&D activities accordingly. Thus, R&D at ERDA laboratories and universities involves primarily those early phases that have not yet attracted significant industrial interest, with maximum feasible use of industrial subcontracting. At the same

*In support of the commercialization component of the strategy, the regional studies are carried out in close cooperation with state and local authorities, industry, and various public interest groups. They include all variables that are believed to have a significant impact on the market penetration of geothermal energy, including sensitivity and cost-benefit analyses, which will indicate which options will be the most effective or beneficial on both national and regional scales. While the regional operations research programs are just getting started, preliminary results from California indicate that market penetration of geothermal electric power generation will not be limited by the projected total demand growth in that region; and on the basis of tentative but reasonable assumptions concerning the impacts of Federal R&D programs on both geothermal energy and fossil fuel alternatives, electric power generation from high-temperature hydrothermal resources is projected to be cost-competitive with power from all fossil fuel alternatives, and possibly nuclear, by about 1985. The predicted costs are approximately 20 to 25 mills per kilowatt hour in 1976 dollars. This could be accelerated by providing suitable tax or other economic incentives comparable with those enjoyed by competitive energy sources.

time, DGE is expanding industrial participation in the later phases of technology certification and pilot plant engineering tests. Where appropriate, participation by state and local government agencies is also sought, especially if environmental, socio-economic, or other institutional issues are involved. DGE's socio-economic, policy, and planning studies are improving the definition of the Federal role and resulting in recommendations for the reduction of counterproductive institutional barriers at all levels.

In addition to the more conventional RD&D projects for the reduction of technological and institutional uncertainties, cost-shared demonstration projects and loan guaranties are expected to be key elements in stimulating commercialization. The objective of both is eventually to increase the willingness of all involved components of the non-Federal sector to develop geothermal energy on their own. To be eligible for Federal cost-sharing, the proposer of a demonstration project must show that the project is not eligible for support under the Geothermal Loan Guaranty Program. To be eligible for a loan guaranty, the applicant must show, among other things, that his proposed project shows reasonable promise of adequate economic return and that he cannot otherwise obtain a loan on reasonable terms. A geothermal demonstration project, in this context, is a commercial-scale prototype system that is complete from reservoir to delivery of usable energy. Its purpose is to demonstrate potential economic

feasibility under the conditions of higher-than-normal risk common to first-of-a-kind systems. In electric power applications, the nature of geothermal reservoirs and the technology of geothermal electric power generation are such that geothermal electric power plants are generally expected to be constructed in successive "modules" of 50 to 100 or 200 MWe each. Thus, a commercial-scale module of about 50 MWe capacity is believed to be the minimum necessary to demonstrate economic feasibility, including predictions of both reservoir lifetime and environmental effects. In non-electric applications, such as providing space or process heat, a demonstration project could be physically considerably smaller. Construction of first-of-a-kind commercial-scale geothermal units without some form of Federal support may not be feasible for regulated electric utilities when their economic analyses show large operating deficits on the initial module.

Furthermore, the utilities are by no means the only "targets" for demonstration projects. The supporting industrial infrastructure, including component manufacturers and service and supply companies, needs to be assured that a market for its products and services exists before it will make the necessary investments. Regulatory authorities and the general public also need to be convinced by demonstrations that the development and utilization of geothermal energy will be economically, environmentally, and socially acceptable

to them. Finally, the demonstration program is also important to the financial community, because it must develop confidence in its own ability to estimate the risks involved in geothermal investments.

The primary role of the Geothermal Loan Guaranty Program will be to make capital more readily available to relatively small, independent entrepreneurs of modest credit ratings, during the infancy of the geothermal industry. The Loan Guaranty Program, which includes a service fee, is not, however, attractive to large utilities (and the larger resource developers), even though they could make themselves legally eligible by forming isolated subsidiaries, because it does not realistically reduce their risks or costs or offer them any other significant economic advantages. The eligibility conditions for cost-shared demonstration projects and for loan guaranties, as noted earlier, are largely mutually exclusive. The Loan Guaranty Program is therefore not a substitute or alternative for the Demonstration Program. The latter is intended to reduce the uncertainties and risks for industry; the former is expected to be useful in accelerating the reduction of risk to normally acceptable levels for the financial community. The anticipated roles of these elements are complementary rather than interchangeable, as summarized below:

Cost-Shared Demonstration

- o Reduces risk for developer for first-of-a-kind units
- o Promotes public diffusion of innovation and technical know-how

Loan Guaranty

- o Reduces risk for lender
- o Promotes proprietary application of state-of-the-art

- o Attractive to utilities and large resource developers
- o Stimulates growth of infrastructure and acceptance of regulators, public, and lenders
- o Plant is heavily instrumented and conservatively designed prototype
- o ERDA technical support is an integral component of the demonstration program
- o Attractive to financial community and independent developers
- o Stimulates early commercialization based on predictable risk
- o Plant is economic, commercial derivative of prototype
- o ERDA technical support may be largely limited to initial review

Program Coordination

The development of Federal geothermal programs and policies involves more than just ERDA and ERDA-sponsored activities. Federal programs specifically applicable to the development of geothermal energy and specifically mandated by statute* are being pursued in at least five other agencies. Nevertheless, as statutory lead agency, ERDA is responsible for encouraging and coordinating the development or adoption of appropriate programs or policies by the other agencies. The Interagency Geothermal Coordinating Council, chaired by the ERDA Assistant Administrator for Solar, Geothermal and Advanced Energy Systems, is the formal mechanism for such coordination. Many agencies have significant roles to play in the formulation and implementation

*Public Law 91-581, The Geothermal Steam Act of 1970.

Public Law 93-410, The Geothermal Energy Research, Development and Demonstration Act of 1974.

Public Law 93-438, The Energy Reorganization Act of 1974.

Public Law 93-577, The Federal Nonnuclear Energy Research, Development and Demonstration Act of 1974.

(Many other statutes and programs are applicable but not listed because they are not specific to geothermal energy development.)

of the overall Federal Program, and coordination of these agency activities must itself be a major component of the ERDA's program. Interaction with all involved agencies is important, especially the Department of the Interior. The Geological Survey's national and regional resource exploration and assessment programs, and its environmental programs, directly complement ERDA's related site-specific programs. The leasing policies and programs of the Bureau of Land Management, the Forest Service, and the Bureau of Indian Affairs must also be coordinated as essential parts of the Federal commercialization strategy, because more than half of the estimated potential convective hydrothermal resource is in Federal lands under their jurisdiction. The participation of the Federal Energy Administration and the regulatory agencies is also crucial to timely commercialization.

The Federal Program must address the reduction of such institutional problems as the following:

- o Federal, state, and local policies, laws, procedures, and regulations with respect to taxes, ownership rights, land use, siting, environmental standards, water rights, leasing, and licensing are often inconsistent and uncertain.
- o Social, economic, and local environmental impacts of geothermal development have often not been adequately assessed.

- o The current rate of leasing of Federal geothermal lands in some regions is too slow, and limits on individual holdings are too small, to permit commercial reservoir exploration and assessment at the rate required to meet reasonable goals for continued growth of geothermal energy development to the year 2000 and beyond.

The Panel on Institutional Barriers of the Interagency Geothermal Coordinating Council has already made a number of formal recommendations for changes in policy or regulations. These have been endorsed by the Council and are now under study for implementation by the cognizant agencies.

To obtain essential advisory inputs from the non-Federal sector, ERDA has established an Advisory Committee on Geothermal Energy. Its membership includes representatives from financial institutions, universities, utilities, resource companies, component manufacturers, and public interest groups. Eventually, the participation of the non-Federal sector must be many times larger than the Federal programs if geothermal energy is to make a significant contribution to national energy needs.

The Federal Geothermal Energy Development Program is evolving into a coherent whole consisting of major components that reflect the following needs:

- o The different types of geothermal resources are located in different regions, are in different stages of maturity for

commercialization, and require technological developments to reduce resource uncertainties and utilization problems that are unique in some respects for each resource type.

- o Accelerated commercialization in time to help meet critical national needs in the period 1985-2000 requires accelerated resource assessment and leasing programs, and complementary programs of demonstrations and loan guaranties, to provide to the industrial and financial communities the confidence and incentives necessary for them to take up the geothermal energy option.
- o ERDA's statutory responsibilities require it to take the lead in coordinating the overall Federal geothermal program, which includes technological, regulatory, and other institutional responsibilities outside the purview of ERDA.

Accomplishments

A few selected accomplishments during 1976 in the major sub-program categories of the Federal Program are summarized below.

Resource Exploration and Assessment

Intensive studies to assess eleven Known Geothermal Resource Areas (KGRA's) were initiated. Roosevelt Hot Springs (Utah) and the Snake River Plain (Idaho) were tentatively identified as being areas of much larger resource potential than had previously been estimated. A successful exploratory well on the Island of Hawaii yielded the hottest

geothermal fluids yet discovered (about 350 degrees C) at good flow rates. A project to conduct the first systematic flow tests and geochemical analyses of geopressured fluids, including methane, was initiated in Louisiana.

In the area of exploration and assessment technologies, electronic components and subsystems for geothermal well-logging instruments were successfully laboratory-tested at elevated temperatures in the range 260 to 600 degrees C, simulating the upper temperature range for geothermal borehole conditions. Improved radioisotope methods for estimating deep subsurface temperatures by analyses of geothermal fluid samples and improved magnetotelluric sounding methods should increase the cost-effectiveness of reconnaissance surveys. Other developments included improved computer models of reservoir performance.

Technology Development

Successful laboratory tests of new bits and materials for drilling in hard, hot rocks are expected to lead to significant reductions of drilling costs. Full-scale field tests of a new, deep, down-hole pump led to an industrial decision for commercial development, while small-scale field tests of a direct-contact binary-fluid heat exchanger and of a hydrogen sulfide scrubber showed good promise for future development. Brine chemistry and materials research led to successful experiments on methods for the reduction of corrosion and scaling.

Large projects included successful shakedown and extended operation of a 10 megawatt equivalent thermal loop at Niland (California), construction of a field test facility for components and subsystems at East Mesa (California), and reservoir drilling and testing for a thermal loop to be constructed at Raft River (Idaho). These facilities will permit large pilot-scale testing of equipment and reservoir characteristics over a wide range of temperatures and salinities.

Eighteen engineering and economic studies of non-electric applications were initiated in preparation for later field experiments or demonstrations.

Institutional Development

National and regional operations research programs were initiated (the first in California with the joint support of the California Energy Resources Conservation and Development Commission), to develop credible "growth scenarios," to aid mission-oriented planning, and to identify critical impediments to early and to continued long-term commercial development of geothermal energy. These were accompanied by economic studies of alternative tax policies and other incentives, and by legal studies to clarify the status of geothermal resource ownership rights and related problems. Specific recommendations were formulated for improving Federal land leasing policies and schedules, for expediting or clarifying certain environmental or other regulatory policies and procedures, and for promulgating

environmental protection guidelines. Some of these problems, in which the non-Federal sector is heavily involved, are being approached by improved coordination and information exchange both through the Advisory Committee on Geothermal Energy, and through seminars, workshops, and other meetings of Federal, state, and local officials.

The Geothermal Loan Guaranty Program was initiated in mid-1976.

There were many formal and informal expressions of interest; the first formal applications, principally for resource development, are expected early in FY 1977.

Future Plans

Future program plans are a logical extension of those now in progress, with a continuing orientation toward stimulating the early commercial utilization of energy from hydrothermal resources, while continuing the advanced technology program required for developing the more extensive geopressured and hot dry rock resources. Areas of major emphasis will continue to be resource exploration and assessment, extraction and utilization technology for both electric and non-electric applications, environmental impact control technology, and institutional problems of many kinds, including the development of guidelines for environmental protection and for planning.

The Loan Guaranty Program is expected to be in operation at a level about \$200 million in guaranties per year in FY 1977 and FY 1978, the commercial demonstration program to be initiated early in FY 1978.

SECTION 1

INTRODUCTION

This is the first annual report of the activities of the Federal Geothermal Research, Development, and Demonstration Program (Federal Program). Also reported are a few examples of the related progress achievements and prospects of the non-Federal sector which, together with the Federal Program, comprise the national geothermal energy effort (National effort).

Subsequent to the creation of the Energy Research and Development Administration (ERDA), the Interagency Geothermal Coordinating Council (IGCC) was established to carry out Federal Program coordination and management responsibilities. This report was prepared under ERDA's auspices with the assistance and concurrence of the IGCC. It covers activities during the period from July 1, 1975, through September 30, 1976 (FY 1976 and the Transition Quarter).

BACKGROUND

Geothermal energy, in the context used herein, is the natural heat contained in the crust of the earth. An estimate of the geothermal energy resource base in the United States has been made by White and Williams ("Assessment of Geothermal Resources of the United States," Circular 726, U.S. Geological Survey). The estimate involves that portion of the earth's crust from the surface to a depth of 10 kilometers and where the temperature is above 15 degrees C.

Only a small portion of this large resource base can be considered as available for use as geothermal energy. The available portion consists of different types of geothermal resources broadly classified in the order of their near-term utilization or maturity as follows:

- o Hydrothermal convective
- o Geopressured
- o Hot dry rock
- o Normal gradient
- o Magma

The estimated potential recoverable heat energy content of these resources is shown in Table 1-I. Only a very small fraction of this recoverable heat energy is presently being exploited.

During the past year the near-term (to 1985) development possibilities of hydrothermal resources, the Nation's best understood and most imminently developable geothermal resource, have been further evaluated and refined. Scenarios suggestive of the development possibilities have been generated on the basis of three categories of hydrothermal reservoirs:

Discovered Reservoirs, Such as Those Located at or near:

Heber, California
Roosevelt Hot Springs, Utah
Brawley, California
Salton Sea, California
Valles Caldera, New Mexico
Beowawe, Nevada
Puna, Hawaii

TABLE 1-I

GEOTHERMAL RESOURCES ESTIMATED RECOVERABLE HEAT WITH
PRESENT OR NEAR-TERM TECHNOLOGY, WITHOUT REGARD TO COST (IN QUADS)*

RESOURCE TYPE	KNOWN	INFERRED
<u>Hydrothermal Convective</u> **		
Vapor Dominated (>150° C)	2	2
Liquid Dominated		
High Temperature (>150° C)	20	110
Moderate Temperature (90° - 150° C)	80	250
<u>Geopressedured</u>		
Electrical Utilization	100	230
Methane Production	500	1500
<u>Hot Dry Rock</u>		
Scenario I ⁺	80	240
Scenario II ⁺⁺	600	1900
<u>Magma</u> +++		
Scenario I ⁺	80	240
Scenario II ⁺⁺	650	1900
TOTAL		
Scenario I ⁺	~900	~2500
Scenario II ⁺⁺	~2000	~6000
GRAND TOTAL (Known plus Inferred)		
Scenario I ⁺	3400	Quads
Scenario II ⁺⁺	8000	Quads

*Normal Gradients are not included at this time as they are not presently considered recoverable. 1 Quad = 10¹⁵ Btu's.

**Does not include less than 90° C systems, although such systems may be economically exploitable especially for non-electric applications.

+Scenario I: Assuming 2% Extraction Recovery, 8% Conversion Efficiency.

++Scenario II: Assuming 12.5% Extraction Recovery, 10% Conversion Efficiency.

+++Magma resources may be renewed by natural resupply from the interior of the earth; therefore, this estimate may be conservative.

Source: Definition Report - ERDA-86, October 1975, Energy Research and Development Administration, Division of Geothermal Energy, Washington, D.C. 20545.

Reservoirs with Unknown Potential, Such as Those Located
at or near:

Surprise Valley, California
Long Valley, California
East Mesa, California
Steamboat Hot Springs, Nevada
Brady Hot Springs, Nevada
Castle Creek, Idaho
Soda Lake, California

Reservoirs with Planned Exploratory Drilling, Such as
Those Located at or near:

Cove Fort, Utah
Chandler, Arizona
Crane Creek, Utah

There is not necessarily any intent nor is there any commitment on the part of the Federal Government that these reservoirs would be the sites for geothermal energy developments. They were used primarily for projecting the magnitudes and timing with which geothermal energy could be brought on line. The basic assumption is that the hydrothermal electric generating plant development cycle spans seven to nine years, beginning with geophysical exploration and culminating in the plant's generating electricity. The nature of hydrothermal resources, plus the uncertainties about the risk of development and the state of the art, are such that the first commercial plant at each site is likely to have between 50 and 100 million watts electrical (MWe) power capacity. A second plant, with about twice the capacity (about 100 to 200 MWe), could be brought on line at each site roughly three to four years after the initial plant comes on line.

The resulting 1985 total is a range of about 1000 to 2000 MWe from new liquid-dominated hydrothermal (hot water) resources which, when added to the approximately 2000 MWe capacity projected by industry for installation at The Geysers hydrothermal steam field in California, yields an estimate of 3000 to 4000 MWe of hydrothermally powered electric energy on line by 1985. The estimates, together with expected nominal contributions from advanced resource types (such as geopressured and hot dry rock) and increasing nonelectric uses of geothermal energy, are suggestive of the scale and pace of development that could occur. Since the actual development rests within the purview of the private sector, the estimates represent neither intent nor commitment by the Federal Government for specific developments nor for energy on-line goals. Nevertheless, such estimates will be used by the Federal Government as a framework for designing the Federal Program.

The realization of the promise for exploiting geothermal resources will require:

- o Intensive research efforts to overcome the current major technological problems and uncertainties associated with resource assessment and exploration, with energy extraction and utilization, and with the environmental aspects of geothermal energy.
- o The resolution of existing institutional barriers to private sector development in geothermal energy.

Recognizing these needs, Congress has mandated in Public Law 93-410, the "Geothermal Energy Research, Development and Demonstration Act of 1974," that "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."* Subsequent legislation; i.e., the Energy Reorganization Act of 1974 (Public Law 93-438) and the Federal Nonnuclear Energy Research and Development Act of 1974 (Public Law 93-577), further delineated the basic statutory framework for ERDA and other Federal agencies to vigorously pursue a program aimed at increased and stimulated geothermal energy utilization. The combined efforts of the Federal government, state and local governments, and the private sector comprise the national effort.

Within the national effort, the activities of the various Federal agencies comprise the Federal program. ERDA as the lead Federal agency for geothermal energy development is vested with program coordination management functions for the Federal programs. To facilitate this coordination among Federal agencies, the Administrator of ERDA has formed the Interagency Geothermal Coordinating Council. Individual members of the Council represent the interests of their own Federal agencies in matters involving geothermal energy development and provide the mechanism by which the Federal program can be made responsive to the needs of the national effort.

In order to strengthen cooperation with the non-Federal sector and to expand interaction with state and local government, ERDA has

*The "Geothermal Energy Research, Development and Demonstration Act of 1974," Public Law 93-410, September 3, 1975, Section 2.12.

established the Advisory Committee on Geothermal Energy. The Advisory Committee includes representation from resource developers, utilities, the financial community, public interest groups, state and local governments, and regulatory authorities. The Advisory Committee provides the Federal agencies with information and guidance with regard to the non-Federal geothermal development effort. These data will help ERDA to initiate adjustments to the Federal Program in order to align it to the needs of the National effort.

FEDERAL STRATEGY

Two major thrusts characterize the Federal strategy for assisting in the development of a self-sufficient geothermal energy industry:

- o The encouragement of commercial development of geothermal energy resources for both electric and nonelectric applications by means of research and development, demonstration, and loan guaranties.
- o The reduction of technological and institutional uncertainties to a risk level compatible with normal private sector investment practices.

The major programs and projects that implement the Federal strategy have been developed in response to Public Law 93-410. They are as follows:

- o A resource inventory and assessment program;
- o Research and development programs;
- o Demonstration projects;
- o A loan guaranty program;
- o A Federal land leasing program;

- o Scientific and technical education programs; and
- o An international cooperation program.

FEDERAL PROGRAM

The Federal Geothermal Energy Research, Development and Demonstration Program is aimed at opening the option for early exploitation of the geothermal energy resources of the nation. The structure of the Federal Program was addressed in the Definition Report of October 1975 (ERDA-86). The program as presented in that report emphasized three major areas:

- o Resource Exploration and Assessment. This includes the research efforts aimed at the identification and verification of geothermal resources as well as improvements in exploration and assessment technology. The thrust of these efforts is to reduce resource unknowns, to lower geothermal exploration cost, and to lessen site development risk.
- o Technology Development. This effort is directed at developing new technologies for extracting and utilizing the energy from the different types of geothermal resources and at demonstrating both the technical feasibility and the environmental acceptability of these new technologies. It also includes a scientific and technical education program that is intended to increase the supply of trained personnel to support the research efforts needed for geothermal development.
- o Institutional Development. This effort is directed at establishing a national geothermal energy policy, improving Federal land leasing practice, assessing the value of incentives, and other measures that can be utilized to overcome the existing institutional barriers to geothermal energy development. The goals of this effort are to encourage an active participation of the private sector in the early commercial exploitation of geothermal resources and to assist the fledgling geothermal industry toward self-sustaining growth.

REPORT OVERVIEW

The progress and achievements obtained in the three major areas of emphasis of the Federal Program are discussed in Section 2.

The National Science Foundation (NSF) has conducted a research program in geothermal energy throughout its Research Applied to National Needs (RANN) program. In January 1975, two-thirds (\$14.3 million) of the RANN budget in geothermal energy was transferred to the newly established ERDA and combined with the AEC budget. NSF was authorized to carry over \$2 million of its FY 75 budget for obligation in FY 76. With the obligation of these funds by June 1976, the NSF/RANN program in geothermal energy was completed.

At the time of the activation of ERDA, the NSF program returned to a focus on the fundamental science problems inhibiting the fullest development of the resource. There were two exceptions to this rule: (1) continuation of engineering design research in three novel concepts for down-well pumping of geothermal brines; and (2) studies in the legal and institutional problems confronting the fledgling geothermal industry. All of these remaining projects were later discontinued or transferred to ERDA for continued development. NSF/RANN projects transferred to ERDA will be identified in Section 2.

In addition to the three major areas of emphasis (Resource Exploration and Assessment, Technology Development, and Institutional

Development), achievements in two other important areas of the Federal Program are addressed in this report. These areas are:

- o Interagency Coordination. The thrust of this program area is to elicit the cooperation of and to effectively coordinate the efforts of the various Federal and non-Federal agencies and institutions that are participating in the development of geothermal energy.
- o International Cooperation Program. Efforts in this area are aimed at sharing relevant experience in geothermal energy development and utilization and at establishing mutually beneficial bilateral agreements that will accelerate the growth of the geothermal industry.

A key step in the development of an effective interagency program coordination function was taken in this reporting interval with the formation of the Geothermal Advisory Council, which has been renamed the Interagency Geothermal Coordinating Council. The organization, membership, and program activities of the Council are discussed in Section 3. Achievements in the International Cooperation Program are discussed in Section 4 in terms of bilateral agreements, conventions, and relevant international experience in geothermal energy development and utilization.

A survey of the non-Federal response and activities is presented in Section 5, while the future plans and areas of emphasis in the Federal Program toward achieving the national goal for the next five years are discussed in Section 6.

A comparison of the provisions of Public Law 93-410, the Federal Program implementation plans of the Definition Report (ERDA-86), the Federal Program implementation actions that took place prior to FY 76,

and the Federal Program achievement of ERDA and other agencies for
FY 76 and the Transition Quarter is tabulated in Appendix A.

SECTION 2

PROGRAM ACHIEVEMENTS AND PROGRESS

INTRODUCTION

The Program Definition Report (ERDA-86) has presented the specific objectives, technical and institutional problems, implementation approaches, and utilization plans for transferring the results of the Federal RD&D to the public sector in each of the following major areas:

- (1) Resource Exploration and Assessment;
- (2) Technology Development; and
- (3) Institutional Development.

Ultimately, the crucial indicator of success in the development of the geothermal energy option would be the energy brought on line, should the option be exercised. At this early stage of development, however, the extent to which initial program objectives have been achieved seems to be the appropriate indicator. To this end, the FY 76 achievement and progress in each of the foregoing program areas are reviewed for each of the agencies involved. A tabular comparison of these achievements against the objectives as set forth in ERDA-86 and the provisions of Public Law 93-410 is presented in Appendix A.

RESOURCE EXPLORATION AND ASSESSMENT PROGRAM STATUS

Identified and proven resources are indispensable to the growth of a significant geothermal industry. This is so because the current rate of discovery combined with the leadtime for utilization (up to

eight years) is such that the presently identified resources will be already committed before enough additional resources have been identified to maintain even a modest rate of growth. Moreover, the current lack of reliable exploration technology and the necessity for deep drilling, make geothermal exploration a costly, high-risk undertaking.

The Resource Exploration and Assessment Program is divided into four activities:

- o Geoscience Research
- o Resource Exploration and Assessment Technology
- o National and Regional Resource Assessment
- o Resource Information Dissemination

The U.S. Geological Survey (USGS) is the lead agency for the regional and national assessment effort. ERDA, USGS, and the National Science Foundation (NSF) have been jointly responsible for the remaining program activity. The activities in each of the program areas are elaborated below. The relationships and impacts of the various exploration and assessment program elements on the geothermal program goals are depicted in Figure 2-1.

FIGURE 2-1
RELATIONSHIPS AND IMPACT OF RESOURCE EXPLORATION AND
ASSESSMENT PROGRAM ON GEOTHERMAL PROGRAM GOALS

Geoscience Research

The main contributors in this area were the United States Geological Survey (USGS) of the Department of the Interior (DOI), ERDA, and the National Science Foundation (NSF).

The resource characterization program of the USGS geothermal research program for FY 76 has included studies of the thermal regime, physical dimensions, tectonic development, fluid flow, heat transfer, heat source, recharge zones, composition and permeability of rock, and thermophysical properties and chemistry of the geothermal fluids that would be extracted from the rock. The most significant achievements in this area are:

- o Estimation of the true salinities of water samples from geopressed zones in Texas. This information is crucial to the future development and utilization efforts of such zones.
- o Identification of a major fault zone south of the Clear Lake geothermal area, California. This may be a physical boundary control on the undetermined extent of The Geysers geothermal field.

The results of these studies should clarify the conceptual understanding of the various types of geothermal systems as an aid to industrial exploration efforts. The results will also improve the testing of new exploration technology.

Major geoscience research studies and projects supported by the NSF during FY 76 and subsequently transferred to ERDA include:

- o Investigations of the Salton Sea geothermal field in the Imperial Valley of Southern California. These have confirmed the source of most geothermal fluids in the Salton Trough to be the Colorado River waters.

- o Extensive data (obtained by the University of Utah) on electrical properties and other subsurface geophysical characteristics to describe the hydrothermal system at the Roosevelt Hot Springs geothermal area near Milford, Utah. The steam-producing source of heat is still an intriguing scientific question now under study. Lessons from this survey at Roosevelt Hot Springs will suggest an improved sequence of methods to be followed in commercial searches for geothermal resources. This project was transferred to ERDA in FY 76.

Geoscience Research by ERDA has been conducted by the Division of Physical Research (DPR) which has concentrated on the "hot dry rock" and "magma" types of resource. Major research conducted by DPR during 1976 have included:

- o Studies of the physical properties of rocks and siliceous magma at the high temperatures and pressures where naturally-occurring magmas may exist. These will allow a refinement of geophysical techniques designed to detect the magma chamber.
- o Studies of the physics and chemistry of mass and energy transport in geothermal systems. These data provide an input to computer models of the behavior of geothermal systems under a variety of rock and heat conditions.

Resource Exploration and Assessment Technology

Much of today's technology for geothermal resource exploration and assessment has been acquired from the mineral, oil, and gas industries. It is neither adequate for locating geothermal hot spots nor suitable for obtaining data in very hot boreholes. Deep drilling is required to confirm the existence of the resource, and the drilling is expensive. With unreliable exploration technology the financial risk is increased. The Federal Program is supporting major efforts to improve existing exploration and assessment technology, to apply such technology to accelerate the identification of geothermal

reservoirs, and to confirm the potential usefulness (i.e., flow rates and longevity) of candidate geothermal sites. The main achievements to be reported in these areas are:

(1) Achievements and Progress in Exploration Technology:

- o In FY 76 particular emphasis was given by ERDA to the development of appropriate mixes of surface and down-hole instrumentation and techniques. Reliable down-hole instrumentation that can operate at high temperatures (i.e., greater than 260°C/500°F) typically experienced in geothermal boreholes is being developed. A contract was also awarded to initiate the development of acoustical drill monitoring systems for the wireless transmission of down-hole data during drilling.
- o Development of new electronic circuits and components capable of operating at 275°C.
- o Development by the USGS (Geologic Division) of a passive seismic technique to detect subsurface magma as the source of heat for certain geothermal systems, using the relative delays in seismic waves from distant earthquakes. This technique was tried at Coso, California to help locate potential geothermal sources in this area.
- o Emergence of magnetotelluric (MT) techniques and audio-magnetotelluric (AMT) techniques as promising tools for rapid, cheap and reliable reconnaissance methods.
- o Development by the USGS of a geothermometer based on the temperature-dependent relative distribution of the oxygen-18 isotope between water (H₂O) and sulfate (-SO₄) species to estimate subsurface temperatures in geothermal systems.

(2) Achievements and Progress in Reservoir Assessment Technology:

In order to estimate the potential usefulness of a reservoir once it is discovered, several important reservoir assessments and engineering activities are in progress. They will exercise improved geophysical

techniques and provide comparison data for complex models of geological and reservoir performance. Included are:

- o Radiogenic (natural radioactive decay) heat source reservoir assessment project, which is intended to develop an isotope analysis model that will serve as a geothermometer. The radiogenic program also supports a program to develop a methodology for the targeting of low temperature hydrothermal reservoirs related to radiogenic heat sources in the Southeastern United States. The radiogenic program is administered by ERDA's Los Alamos Scientific Laboratory (LASL).
- o Heat flow mapping. The western portion of the Rio Grande Rift through New Mexico and Southern Colorado. This mapping has been identified by this study to be a region of a relatively high geothermal potential. In addition, ongoing heat flow mapping in the Steamboat-Lemci Rock area of Skamania County, Washington, will reveal more about the occurrence of geothermal reservoirs in the Cascades Mountain Range. These research efforts were supported by NSF.
- o An ERDA program with industry involvement, in the Imperial Valley is testing the application of active and passive seismic techniques to the estimation of reservoir properties through the detailed analysis of velocity data.

The Bureau of Reclamation (BuRec), through its role in developing the technology for water production in association with power generation from a geothermal hot water system, also contributes to the Resource Exploration and Assessment Program through its appraisal studies that are under way in the Pacific Southwest. BuRec also supports geophysical exploration in the Gila and Little Colorado River

basins in Arizona and New Mexico, and in the Virgin River Basin in Utah and Nevada. These investigations are intended to:

- (1) Identify those areas that could be developed for water and/or power production
- (2) Explore and assess these areas
- (3) Develop conceptual plans for the production of water and power in these areas.

National and Regional Resource Assessment

The U.S. Geological Survey is responsible for the regional and national assessment effort. It also provides the geothermal data base that supports and enhances the leasing program. To this end the USGS is investigating eleven additional Known Geothermal Reservoir Areas (KGRAs). Other achievements of USGS include:

- o Indication by potassium-argon dating that volcanic rocks in Southwest Utah are young. This suggests that the thermal anomaly at Roosevelt Hot Springs geothermal area has an extensive magmatic (molten rock) source. This is a strong evidence of the high geothermal potential of the Roosevelt Hot Springs. This geothermal anomaly is one of the resources upon whose early development the near-term growth of a geothermal industry is heavily dependent.
- o Discovery of high electrical conductivity beneath the Snake River Plain, Idaho. This is indicative of regions of high temperature and hence possible geothermal potential.
- o The discovery of the prospect of hot dry rock east of San Francisco Mountain, Arizona.
- o A determination that the volcano at Mt. Shasta, California, consists of four separate but overlapping cones. The age of the youngest of these cones indicates a higher geothermal potential for the Mt. Shasta volcanic system than previously believed.

ERDA in cooperation with USGS (Geologic Division) is now sponsoring a study of mine water temperature and chemistry in Western Montana to identify potential low temperature hydrothermal reservoirs. The study is being conducted by the Montana Bureau of Mines and Geology.

Resource Information Dissemination

Progress in resource information dissemination is the result of the joint effort of ERDA and the Department of the Interior (DOI). Computerized bibliographic and geologic data storage and retrieval projects are already under way at ERDA (Lawrence Berkeley Laboratory, in California) and at the USGS in Reston, Virginia. Other additional regional data banks will follow as needed. The ultimate goal is a National Geothermal Resource Data Bank. This data bank will ensure retention and distribution of data obtained during resource exploration, assessment, and research activities.

A significant achievement is the current updating of the USGS geothermal computerized data file (GEOTHERM) to include the U.S. hot springs data used in USGS Circular 726, "Assessment of Geothermal Resources of The United States." International geothermal field data are also being incorporated into the "GEOTHERM" data file. So far, records have been received from geothermal fields in New Zealand, Mexico and El Salvador. The results of the foregoing research effort should help to:

- (1) Improve, update, and expand the available geothermal field data that are used for planning and operating decisions in geothermal development;

- (2) Provide important information that can help the concerned Federal agencies in establishing priorities among various elements of their geothermal energy R&D programs.

TECHNOLOGY DEVELOPMENT PROGRAM STATUS

Introduction

The technology associated with each of the geothermal resource types (i.e., hydrothermal, geopressed, hot dry rock, magma, and normal gradient) is at a different stage of development maturity. At present the technology exists to commercially utilize only high quality high-temperature hydrothermal resources. Improved and more advanced technology is needed to economically extract and utilize the energy from other types of geothermal resources in an environmentally acceptable way. These improvements and advanced technology developments constitute the achievements and progress in the various program elements of technology development in FY 76, as detailed below. The implementation plan of the Technology Development Program covers:

- o Reservoir Engineering and Field Development, which deals with advanced drilling technology, well logging technology, reservoir modeling development, down-hole pumps and well stimulation.
- o Utilization Technology, which is directed at developing the key equipment and concepts for the advanced utilization cycles (e.g., pumps, heat exchangers, total flow concept, etc.).
- o Brine Chemistry and Materials Research, which is geared to a better understanding of brine chemistry, scale control, and materials compatibility.
- o R&D Test Facilities, established for advanced component testing and evaluation in real geothermal environments.

- o Advanced Systems and Applications needed to examine the feasibility of applying advanced technology and concepts to enhance the utilization potential of geothermal resources (hydrothermal or otherwise).
- o Environmental Effects and Abatement Technology. Studies and research programs to promote health and safety and ameliorate institutional restraints.
- o Demonstration Projects to demonstrate the technical reliability, economic potential and environmental acceptability of geothermal energy development and utilization on a commercial scale.

Reservoir Engineering and Field Development

Drilling Technology

Improved drilling will facilitate and hence accelerate resource exploration, assessment, and evaluation.

ERDA's geothermal technology development program is the key Federal Government program. It was started prior to FY 76, and is structured to reduce the cost of drilling by improving currently existing equipment and by developing new tools and techniques for the high temperatures, hard formations, and other severe down-hole conditions encountered in geothermal drilling. The geothermal program is coordinated with complementary programs at the National Science Foundation and the ERDA Division of Oil, Gas, and Shale Technology.

The development of improved drilling equipment has progressed to the point where prototype hardware will soon become available for field testing. Thus,

- (1) Various configurations of the continuous chain drill bit for slim-hole drilling (4-3/4" diameter) have been evaluated in a drilling research laboratory. Penetration rates in

granite 2.5 times greater than with conventional diamond bits have been achieved.

In the actual drilling environment, a new section of the continuous chain would be rotated into place at the bottom of the hole to maintain an effective cutting surface. Complete units including the hydraulic actuating mechanism will be evaluated in FY 77. Field testing would be conducted in FY 78.

- (2) Research roller cone bits incorporating materials with high strength at elevated temperatures have been evaluated in the laboratory. An optimized configuration for unsealed drill bits will be selected in FY 77 and procurement initiated for fabrication of bits for testing at geothermal sites.
- (3) Several improved diamond bits incorporating man-made diamond compacts will be ready for field test in FY 77.

Progress has also been made in the investigation of advanced rock penetration and rock fracturing techniques, namely:

- o Spark drilling that employs an electrical discharge in a drilling fluid to create a pressure pulse and subsequent bubble collapse to fracture and fragment rock ahead of the spark bit.
- o Water jet drilling where a high-pressure jet erodes the rock. Laboratory testing has demonstrated the capability for drilling a wide range of rock types including very hard granite. A small mobile unit has been developed for limited field demonstrations.

Also in FY 76 work was initiated on the evaluation and development of high temperature drilling fluids for geothermal applications.

Although the geothermal program is directed specifically toward geothermal problems, the technology is also applicable to other areas of drilling, including oil and gas, and mineral recovery. In particular, the basic laboratory work on water jet drilling is currently

being applied in the performance of a Bureau of Mines contract on roof bolting.

Reservoir Modeling Development

Reservoir models are designed to realize one or more of the following objectives: (1) estimate the useful life of a geothermal reservoir, (2) determine the optimum rate of energy removal, (3) indicate the optimum distribution of production and reinjection points within the reservoir boundaries, and (4) identify the environmental effects of geothermal utilization (e.g., land subsidence). Such models will thus aid in controlling and managing fields efficiently and economically while minimizing environmental effects.

A substantial effort in this area was undertaken by ERDA (Lawrence Berkeley Laboratory). Current efforts are directed towards the completion of a computer model of two-phase (steam/water) reservoirs. The accessible operating data of the Cerro Prieto geothermal project in Mexico will be used to validate the model.

The NSF has supported the development of a computerized reservoir performance model at Princeton University. The completed model is expected to provide the capability to predict and to analyze the performance of a producing geothermal reservoir. Its applicability is being assessed by applying it to the Wairakei, New Zealand, geothermal reservoir. Other models have been developed under NSF support and are now transferred to ERDA. These include:

- o The Stanford University Chimney Model. This is a physical model made up of a highly instrumented experimental pressure

vessel holding the porous "reservoir rock." Investigators are able to observe the movement of a steam flash front in the reservoir. This will help determine how boiling is controlled by physical conditions of the reservoir.

- o Pennsylvania State University Experimental Evaluation of Geochemical Conditions in Geothermal Energy Systems. This involved the construction of two experimental systems to simulate hydrothermal circulation through rocks representative of geothermal reservoirs. The main objective of this research is to use this physical model to identify and learn to control the dominant reactions, their rates and their influence on permeabilities and heat extraction rates of hot reservoirs.
- o The University of Colorado Geothermal Basin Problem Study. Stressing a close interdependence of field data analysis and mathematical modeling, the Colorado approach should help: (1) the interpretation of field observations, (2) the assessment of reservoir performance and (3) the evaluation of environmental impacts of geothermal well production.
- o The ongoing investigations at Northwestern University (Evanston, Illinois) of rock-fracturing mechanics. These use transparent epoxy resin models that are fractured by the injection of fluid mercury.

Down-Hole Pump Development

Down-well pumping technology improvement is a key operational requirement to enhance the production of geothermal wells and, where flashing is conducive to mineral scaling, to pressurize the geothermal brine all the way from the well through the surface energy conversion system. To this end the following three novel pumping concepts have been developed:

- o Steam driven down-hole pump, a steam turbine pump that can use the geothermal fluid as a source of pumping energy. A 60-day down-hole test of the pump is under way. The pump has been installed in a well at Heber, California. Test runs are in progress. The boiler, condenser, and pump are functioning to design specifications.

- o Electric down-hole pump. A submersible single-stage centrifugal pump driven by a high-speed electric motor. This pump has the capacity and performance of a multi-stage pump and the high reliability of a single-stage design. It confines the hot brine in a scaled circulation system under sufficient pressure to prevent its premature flashing into steam.
- o Hydraulic turbine down-hole pump. A high-pressure electric surface pump powering a down-hole dynamic turbine.

These three pumping concepts were first evaluated in NSF-sponsored design studies and preliminary laboratory testing of key components. All projects have been transferred to ERDA for field testing, hardware development, and industrial utilization. The first commercial availabilities of these down-hole pumps are anticipated to take place in FY 78.

Well Stimulation

Stimulation of fluid flow in a newly drilled well is essential to testing and completion of the well. It involves cleaning out the borehole and/or lowering the hydrostatic head so that fluid from the reservoir may enter the well. However, some wells drilled in geothermal formations either do not have enough fluid naturally present to sustain useful production or have insufficient permeability to do so. Artificially fracturing the formation or introducing fluids for heat extraction may be solutions to such problems.

To date the efforts in well stimulation supported by ERDA include:

- o A review (by LASL) of geothermal well productivities with respect to the application of well stimulation techniques.

- o Award of a contract for development of suitable liquid explosives for reservoir stimulation.

Utilization Technology

New and improved utilization technology is required for converting geothermal energy to practical uses. Top priority has so far been given to developing technologies that will foster the near term use of the hydrothermal resources for electric production. The development of conversion systems using a total flow (mixed phase) concept has been supported by ERDA. These new energy conversion systems utilize vapor-liquid mixtures directly from geothermal wells and theoretically could increase conversion efficiency over currently employed steam conversion turbines. A cost study on a hybrid (total flow/binary cycle) advanced conversion concept was initiated.

Emphasis has also been given by ERDA to improvements and development of new concepts for geothermal heat exchangers. Experimental heat exchangers are now being prepared for field evaluation. In particular, direct contact heat exchange between geothermal brine and binary cycle working fluids (e.g., isobutane) has been shown to be feasible with great promise for circumventing scaling and corrosion problems. This is a significant step toward the ultimate development of an economic binary cycle system that will play a key role in the utilization of the lower temperature (i.e., less than 200° C) geothermal resources.

Brine Chemistry and Materials Research (Geochemical Engineering Research)

The ERDA geochemical engineering program defines and carries out necessary brine chemistry, associated scale control and materials R&D for geothermal energy extraction. The Bureau of Mines is engaged in the development of alternative materials with improved resistance to scaling and corrosion from geothermal brines and in the development of techniques for the recovery of important metals and minerals from geothermal fluids.

Geothermal utilization processes require the production, handling and disposal of large quantities of geothermal brines. Since the elements of such geochemical processes are highly integrated and, to a large extent, site specific, the solution of geochemically related problems presently requires a detailed technical and economic balancing of all the subsystem solutions for each potential site. Lessons gained from operating experience are likely to lead to more generally applicable solutions in the future.

A high initial priority of ERDA's geochemical engineering program is the compilation and chemical characterization of brines from the most significant U.S. geothermal resources available for development. An ERDA (Lawrence Berkeley Laboratory) program started in April of FY 76 has been systematically collecting and evaluating brine data for resource sites in the U.S. with thermal capacity of greater than or equal to 1×10^{18} calories (USGS Circular 726). As of November 1976, data have been collected for 13 of the 33

geothermal sites most likely to be exploited by 1985. A report identifying problems resulting from the use of brines from specific sites will be published the second quarter of FY 77. In FY 76 this study has already indicated that available geothermal fluid and gas analyses are not adequate for essential economic and environmental cost estimates.

Another ERDA program (Battelle Northwest Laboratories) is developing, with the analytical service industry, standard sampling and analysis methods. By FY 78, information from this program will supply USGS with sampling and analysis technology.

A new industrial program will be initiated by ERDA in FY 77. This program will coordinate the materials selection for energy extraction systems. It will generate and maintain a site-specific geothermal systems Materials Design and Operations Guidelines Handbook. At present ERDA programs at Oak Ridge National Laboratory, Case Western Reserve University, Battelle Northwest Laboratory, Stanford Research Institute, Lawrence Livermore Laboratory, Idaho National Engineering Laboratory, and the program of the Bureau of Mines are generating extensive corrosion data for a large variety of alloys and constructional materials. Additional programs funded in the private sector are supplementing this data base, as are several ERDA FY 76 and FY 77 field tests. The new FY 77 industrial program will evaluate these data for their relevance to nonelectric, pilot, and demonstration plant development.

Since it is estimated that perhaps 5 percent* of the hydrothermal resource involves fluids with 20 percent or more dissolved minerals, the Bureau of Mines mineral recovery and corrosion effort is an integral part of overall brine chemistry management. The Bureau of Mines Material Testing Facility (MTF) is designed to simulate seven typical process environments in a geothermal resource recovery plant. The MTF can be connected to a geothermal well for on-site studies of scaling and corrosion processes. The facility includes a large well-equipped mobile chemistry laboratory. Because of the flexibility of this new in-situ approach to materials studies, it has received national and international recognition. In FY 76, this facility was operated at East Mesa Geothermal Field and at the SDG&E/ERDA Geothermal Loop Experimental Facility (GLEF) at the Salton Sea Geothermal Field near Niland, California. At East Mesa site the MTF conducted the most extensive chemical analyses of a geothermal well flow that were ever undertaken, using 700 test samples over a 60-day corrosion testing series. Other current achievements at East Mesa site include:

- o Development of several new and innovative analytical and brine-sampling techniques.
- o Correlation of corrosion results for 400 metals and alloy samples with the changes in the average chemical composition of the Mesa-1 geothermal fluid during a carbonate scaling failure of this well. This correlation study showed that

*ERDA estimate.

the rate of corrosion had increased by a factor of four, and the scaling rate had increased by over an order of magnitude.

Under a cooperative agreement with the San Diego Gas and Electric Company (SDG&E), the Bureau of Mines has begun a unique materials testing program. This program is being conducted at the SDG&E/ERDA Geothermal Loop Experimental Facility using the Magmamax and Woolsey geothermal production wells and Magmamax #3 injection well.

Extensive studies are currently under way to determine the cause of several severe mechanical-corrosion failures that have occurred at the Geothermal Loop Experimental Facility during the initial tests using fluids from Magmamax #1.

In addition to the important Bureau of Mines field experiments in FY 76, a laboratory program measured gas solubilities and phase distributions of oxygen, carbon dioxide and methane in several brines typical of East Mesa and the Salton Sea Geothermal Fields. The dependence of the solubilities upon minerals content of the brines was also determined for representative temperatures. A number of special alloys that were field tested at East Mesa were also tested in the laboratory using Salton Sea brines.

In FY 76, ERDA programs at Case Western Reserve and Battelle Northwest Laboratories have been directed toward examining corrosion factors limiting geothermal use of inexpensive commercially available low alloy steels. Results in the useful geothermal temperature range of 50°C to 250°C have been reported. Extensive laboratory and field

testing has been carried out by ERDA (Brookhaven National Laboratory) on alternate construction materials. Polymer cements and concrete thus developed are promising substitutes for metal in some pipe applications. Testing and development with industrial participation is continuing.

Geothermal energy extraction processes are dependent on the availability of environmentally acceptable fluid production and disposal technology. FY 76 planning has emphasized significant new geochemical engineering subprograms for geothermal well cementing, the development of high temperature elastomeric materials for well completion, instrumentation support, waste treatment chemistry, and a National Academy of Sciences study of instrument materials for production and injection reservoir monitoring.

In FY 76 dynamic scaling facilities have been designed and operated by ERDA laboratories (Oak Ridge National Laboratory) and contractors and the Bureau of Mines Material Testing Facility (MTF). Fundamental work on nucleation and kinetics of silica scale formation has been carried out under contract, and it should be completed in FY 77.

Computer modeling of dynamic processes at geothermal facilities was initiated in FY 75 and FY 76 at several ERDA laboratories and in privately funded programs. In order to develop empirical predictive computer models, these are being integrated in FY 76 and FY 77 with experimental efforts. The necessary data base for these models is being developed by ERDA (Division of Physical Research and Division

of Geothermal Energy) and with FY 77 input from the USGS National Mineral Thermodynamic Data Bank.

R&D Test Facilities

A test facility has been established by ERDA (Lawrence Livermore Laboratory) for the uniform and objective testing and evaluation of novel power conversion concepts such as the Sprankle helical screw expander, the Possell bladeless turbine, and the bi-phase rotary separator.

Another achievement of significance is the establishment of the ERDA Geothermal Component Test Facility at East Mesa. These facilities will be used by ERDA's contractors, by private companies, and by other institutions to test various components using actual geothermal fluids. At present the Bureau of Reclamation has completed all construction work financed by ERDA, and the facility will soon be available to interested users under the jurisdiction of ERDA.

Advanced Systems and Applications

Hydrothermal Technology Applications

The liquid-dominated hydrothermal resources represent a class of geothermal energy that are most likely to make a significant contribution to national energy needs in the near-to-intermediate time frame. The main objective of hydrothermal technology program is to establish the technical feasibility of using this resource for both electric power generation and for nonelectric uses.

Achievement and Progress in Hydrothermal Technology Applications.
Electric Application Projects

(1) High-Temperature Resources

The construction of a geothermal loop experimental facility with a thermal capacity equivalent to a 10 MW electrical power plant was completed in FY 76. The experimental facility is jointly funded by ERDA and the San Diego Gas and Electric Company (SDG&E). It represents the first of a kind flash-to-binary conversion cycle, and it is an example of the cooperative development effort with private industry. Several hundred hours of operational experience have been gained during FY 76. SDG&E will continue to operate and manage the thermal loop to obtain design data for follow-on commercial power plants. The injection of cooled brine back into the reservoir will be tested and the commercial potential of the Niland geothermal reservoir will also be assessed. Electricity will not be generated during the initial phase of the project. (See Section 6 for future plans.)

Conceptual designs for 50 MW power plants based on the type of brines found at Heber and Niland in the Imperial Valley were completed in FY 76. The conceptual design work was coordinated with a similar effort by the Electric Power Research Institute to ensure that the combined effort incorporated different energy conversion systems in the conceptual designs developed by each organization.

Other research activities are being undertaken by the Bureau of Reclamation at East Mesa to determine the desalting performance of a membrane process on relatively low salinity geothermal fluids. Moreover, in-house conceptual designs and estimates for the three methods of desalting, (i.e., vertical and multistage flash evaporator and membrane process), with and without the generation of electrical energy are now being prepared. These conceptual designs and estimates along with the necessary preliminary economic analysis were completed in 1976. All studies of the test desalting facility are thus scheduled for completion on or before January 1977. These desalting studies will provide the basis for the selection of the process for the pilot plant.

(2) Moderate-Temperature Resources Projects

Study of electric power conversion cycle options for a typical moderate temperature (near 150°C), low- to moderate-salinity hydrothermal resource was completed in FY 76. This study indicates that electric power costs can be significantly reduced by use of advanced design heat exchangers and condensers with a binary cycle system. A conceptual design for a dual boiling binary cycle energy conversion system suitable for electric power generation using moderate temperature fluids has been completed. Plans have been developed for the design, construction, and operation of a 10 MW electric equivalent thermal loop facility using the moderate temperature/low salinity reservoir at the Raft River site near Malta, Idaho. The experimental facility will be installed on a sequential basis in two increments of 40 MW thermal units (each equivalent to 5 MW of electrical power). The first unit will employ currently available hardware, the second unit will provide for testing of advanced design heat exchangers and related advanced technologies. This work will be a logical outgrowth of ERDA's on-going work (at the Idaho National Engineering Laboratory) in resource development, brine management, and small-scale production/reinjection loop tests associated with the completion of three exploratory production wells in the Raft River reservoir.

The development of cost effective systems to use moderate-temperature resources for electric power generation would greatly expand our geothermal energy potential.

Nonelectric Application Projects

Two nonelectric application studies have been completed; one in Idaho and one in California. A report has been presented to the Governor of Idaho concerning the design of a space heating system for public buildings in Boise, Idaho. It states that a geothermal system would provide substantial cost savings when compared with current and anticipated fossil fuel heating costs.

A workshop was held in Susanville, California, to present results of a study dealing with the use of local hydrothermal resources for industrial, municipal, and residential space heating applications. The Bureau of Reclamation has continued exploration work on the area including drilling of exploratory wells for reservoir definition.

Eighteen engineering and economic studies of nonelectric applications of geothermal heat covering four industry sectors: industrial processing, agribusiness, commercial and residential space conditioning have been initiated in an effort to stimulate interest in the use of low- to moderate-temperature (50° to 150°C) hydrothermal resources (see Section 6).

Advanced Technology Applications

Geopressured Resources. While the existing technology can be used to recover energy from hydrothermal resources, the more abundant geopressured and hot dry rock resource types require new approaches. In simplest terms, geopressured resources are hot water aquifers at pressures approaching that of the overlying strata rather than the pressure of an equivalent thickness of water. Geopressured deposits presumably contain appreciable amounts of dissolved gas (mainly methane). As such, exploitation of these resources offers three forms of energy: thermal, kinetic and dissolved methane. Because of the high cost of drilling and well completion under the typical conditions at the depths and high pressures involved, there are two

major reservoir uncertainties that should be resolved before committing to expensive technology development programs. The uncertainties are:

- (1) The number, permeability, and size of individual aquifers, and hence their ability to sustain large flows of water over long intervals of time.
- (2) The amount of recoverable methane, a key factor in the economics of the utilization of geopressured resources.

To this end an assessment of all the known onshore geothermal formations in Texas and Louisiana is now underway. This assessment is intended to define the location of geopressured reservoirs in these areas. ERDA achievements in this area include:

- o Complete identification of principal geopressured reservoir areas for well drilling and long-duration tests in Louisiana and Texas. A ten-mile wide swath thirty miles in length has been delineated in Brazoria and Galveston Counties, Texas, for the detailed studies that will determine the optimum Texas wellsite. Three areas in Calcasieu, Acadia and Cameron Parishes have been demarked in Louisiana. Detailed studies of these four areas are in process.
- o The initial well test contract to gain needed information on the character of geopressured formations and fluids was signed in August 1976. Information on gas content, temperature, pressure and flow characteristics will be available in mid or late 1977.
- o Implementation of environmental assessment studies and determination of the impact of geopressured resource development occurred in June 1976 with the accumulation of background precision survey data and the construction of a plan for accurate releveled over the principal reservoir area in Texas. An overall generic environmental assessment of the Gulf Coast has also been started.
- o Evaluation of proposal responses to ERDA's Program Research and Development Announcement for testing of geopressured geothermal aquifers has been accomplished. Four of the nine proposals received are receiving further critical evaluation.

Available knowledge of the geopressured resource has been collated and analyzed in a study that was completed in FY 76. This study is the outcome of a combined university, state government, and industry effort. It identifies numerous potential technical and institutional impediments to the development of a viable industry based on the utilization of geopressured geothermal resources.

Hot Dry Rock. Hot dry rock extraction technology is currently being tested at the Fenton Hill site in the Jemez Mountains in New Mexico. In particular two closely spaced holes have been drilled by ERDA (Los Alamos Scientific Laboratory) in granitic rock to a depth of 9600 feet. At this depth the bottom-hole temperature is 197°C. The technical objective is to pass water down one hole, circulate it through fractured hot rock to extract heat from the formation, recover the heated water from the other hole, extract energy from it above ground (for generating electricity or other uses), and then recycle the water to the first hole. A hydraulically created fracture about 700 feet in diameter in the hot rock formation is intended to establish a surface area sufficient for significant heat extraction and to provide a connection between the two drill holes. Means for decreasing the resistance to flow of a circulating fluid to extract the heat energy of the hot dry rock is presently under evaluation. The current program emphasis is to develop a controllable and effective fracturing-circulation technology with the highest possible

heat extraction capability and efficiency. It is anticipated that an initial extraction rate of 10 megawatts of heat will be achieved.

FY 76 and Transition Quarter activities also include the initiation of the Coso site assessment project in California's Mojave Desert. This project is intended to investigate the actual extent and characteristic of hot dry rock resources at this site. Toward this end, assessment of the Coso Hot Springs KGRA through geophysical survey and heat flow measurements has taken place under ERDA direction and in cooperation with both the USGS and the Naval Weapons Test Center. These measurements have indicated the most promising location for the first intermediate depth slim hole for confirmation of the nature of the geothermal reservoir. Through a series of such holes this program will ultimately characterize the hydrothermal and hot dry rock potential of this geothermal system.

Normal Gradient Resources. The ultimate technical objective of this part of the program is to extract heat energy from the earth's crust wherein the temperature increases with depth at about the average crustal value (normal gradient). The engineering could be conceptually similar to that for hot dry rock, but depths and costs are likely to be greater. Work on these resources has been limited to geologic investigation of near-surface slightly above normal gradient conditions in some areas of Eastern U.S. Data from a similar on-going effort in France is also being evaluated.

Environmental Effects and Abatement Technology

Research is directed to the development of new methods and techniques for predicting, controlling and monitoring emissions and wastes from geothermal utilization facilities. These efforts also include development of standards, abatement equipment and technologies. The research efforts will provide the knowledge that will allow for an early identification and resolution of environmental effects, resulting in a greater confidence in proceeding with geothermal development.

In addition to ERDA's initiatives in the environmental and institutional area some activities were started by the National Science Foundation. These NSF activities have been transferred to ERDA in accordance with the provisions of Public Law 93-410. The EPA is actively engaged in determining the likely environmental impacts and associated environmental regulation options for geothermal energy utilization, and the USGS, the U.S. Forest Service, the Office of Water Research and Technology, and the Fish and Wildlife Service all support environmental efforts. These are coordinated in the various panels of the Interagency Geothermal Coordinating Council.

ERDA Activities in Environmental Control Technology and Safety Guidelines Development

The current status of ERDA's activities and those transferred to it are as follows:

(1) Environmental Control Technology Research

Environmental control technology research efforts involve gaseous emissions research, subsidence investigations and the studies of environmental hazards. ERDA gaseous emissions research efforts are mainly concerned with control of hydrogen sulfide (H_2S) emissions; an obstacle to further development at The Geysers, and other hydrothermal resources. The ongoing efforts in hydrogen sulfide emission control include:

- o A process for controlling hydrogen sulfide emissions at geothermal power plants such as The Geysers has been evaluated under contract. The process is based on scrubbing geothermal steam with a copper sulfate salt solution to remove and precipitate the entrained hydrogen sulfide. Laboratory scale tests and process engineering analysis have confirmed the workability of the process. Up to 95 percent removal of hydrogen sulfide was achieved in simulated laboratory tests in a 2-inch diameter column. In cooperation with Pacific Gas and Electric Company (the major utility at The Geysers), ERDA is now having the process tested in an 8-inch scrubbing column on real geothermal steam at The Geysers. If the tests prove successful, a pilot test facility will be built.
- o Investigation of hydrogen sulfide removal from simulated geothermal brines by reaction with oxygen. Construction and assembly of equipment has been completed. System shakedown runs with brine have been conducted. Further runs to obtain constant and reproducible sulfide levels in the brine are being conducted.

The results of the foregoing research efforts are expected to produce hydrogen sulfide control systems

which should be ready for testing on a commercial scale by mid FY 78.

The subsidence work includes a study of the Gulf Coast region of Texas and Louisiana which is being carried out under contract by USGS (Geology Division). This study involves collecting and compiling of the historical record of subsidence measurements in the Texas-Louisiana Gulf Coast region. This background information is the first step towards an extensive test of subsidence control technology by reinjection of brines. This extensive test cannot be expected before FY 79.

Another ongoing subsidence study that has been supported by the NSF is directed at geothermal fields in the Imperial Valley of Southern California. An elevation change of two to three feet could disrupt the irrigation system of the Imperial Valley, a prime area for geothermal resource development.

Other environmental research efforts originated in 1974 by the NSF and now transferred to ERDA are directed toward an increased understanding of environmental hazards that are associated with geothermal resource development, and to find out the means of minimizing such hazards.

- o The University of Southern California Study of the Aquatic Chemistry of Toxic Elements. This study is based on samples from geothermal fields in Northern California, Nevada, Mexico and the Imperial Valley; the ultimate objective being the understanding of the chemistry, fate and removal of trace contaminants from low and medium salinity geothermal waste.
- o Environmental Effects of Noise from Geothermal Resource Development. This is being studied at Saint Mary's College, Morgan, California, and is specifically intended to evaluate whether birds and small mammals actively avoid habitats in which geothermally related noise is intense.
- o Behavior of Hydrogen Sulfide in the Atmosphere and its Effect on Vegetation. This study, now under way at the University of California, Riverside, has determined that hydrogen sulfide may be quite toxic to vegetation. Whether existing atmospheric levels

of hydrogen sulfide are causing any problems around geothermal energy fields is yet to be determined.

- o Nature and Environmental Aspects of Heavy Metals Released During Geothermal Energy Development. This investigation is being conducted at ERDA's Battelle Pacific Northwest Laboratories, Richland, Washington. This study is intended to identify, quantify and characterize the physiochemical properties of toxic or potentially toxic heavy metals released during geothermal energy development (e.g., mercury, arsenic, selenium, antimony and zinc). The study also focuses on the potential for accumulation of such heavy metals in the vicinity of geothermal power plants. Emphasis throughout the study is on heavy metals in non-condensable vapors and on heavy metals in high salinity brines (i.e., brines with total dissolved solids greater than 50,000 ppm).

(2) Safety Guidelines Development

Ongoing efforts are now channeled to provide the information base and criteria that are necessary to develop operating safety guidelines for full geothermal commercialization. ERDA is currently conducting a site-specific environmental baseline study of the Imperial Valley of California. This will help evaluate the environmental impacts of proposed geothermal projects in this area. A parallel environmental baseline study has been undertaken by ERDA in the Raft River, Idaho, project area. Other studies have been initiated. These include:

- o Development of environmental impact assessment (EIA) and environment impact statement (EIS) guidelines.
- o The Environmental Support Study that will provide a procedural guideline for environmental analysis.

Geothermal Energy Control Technology and Institutional
Limitations, EPA

The role of EPA is to establish environmental standards to protect public health, welfare, and the general environment and to enforce compliance with such standards.

This standards-setting authority includes responsibility for the development of environmental and health criteria and for performing environmental research to develop such standards.

Standards and criteria relate to limitations on specific pollutants in the environment and to emission and effluent limitations for specifically defined industrial technologies.

In support of this regulatory role, EPA has undertaken research in two areas:

- (1) Geothermal system control technology evaluation and assessment of existing environmental regulations and R&D in support of emission and effluent limitation guidelines.
- (2) Geothermal environmental pollution assessment including the development of groundwater monitoring guidelines.

The current status of each of these research activities is as follows:

Research is being conducted in the EPA's Industrial Environmental Research Laboratory (IERL), to provide environmental assessments and

contribute to the development of geothermal energy extraction and pollution control technologies. The research will:

- o Assess technical regulatory constraints for geothermal exploration and development;
- o Characterize wastes and assess existing or available effluent treatment methods and systems for water, land and air discharges;
- o Assess pollution control systems at existing sites for exploration and power, space heating and industrial uses;
- o Identify and assess the feasibility of multiple uses of geothermal energy at specific sites;
- o Produce information leading to the development of effluent guidelines and other environmental protection requirements for geothermal energy systems.

As an extension to its current activities, IERL awarded a two-phase research contract in December 1975 for the assessment of geothermal energy technology and regulatory constraints. The first phase of the study will result in descriptions of the regulatory and institutional limitations (including environmental) as they apply to geothermal development and system operation. In the second phase, the physical-chemical characteristics, exploitation potential, exploration and development processes, pollution implications, and available control options for known geothermal reservoirs are being described. Non-pollution environmental effects will also be studied and described.

Geothermal Pollution Impact Assessments, EPA

This research effort is being conducted in EPA's Environmental Monitoring and Support Laboratory, EMSL, and is intended to

quantify the effect of the pollutants associated with geothermal energy resource exploitation with emphasis on groundwater contamination. This is specifically of concern because some of the geothermal resource pollutants, which may be of carcinogenic nature, can accumulate in significant quantities in the food chain.

More specifically, the geothermal environmental impact assessment studies will:

- o Identify pollutants, and pathways into the underground water environment.
- o Specify ecological hazards associated to any geothermal development and conversion facility.

In all cases, the initial focus will necessarily be on The Geysers, and the Imperial Valley in California, Klamath Falls in Oregon, Rio Grande Rift zone, and on Roosevelt Hot Springs, Utah, which are most likely to receive earlier development attention. The foregoing research efforts will produce a guideline document that can help the Federal, state and local governments monitor the changes in plants, animals, surface and underground waters as a result of the development of geothermal resources.

A sampling plan has been designed and initial samples have been collected from the Imperial Valley's Salton Sea (Niland) California area and are in the process of being analyzed; and a mobile air monitoring laboratory is continuing to assess pollutants at various Imperial Valley sites.

Personnel from the Las Vegas Laboratory coordinate with ERDA's Division of Biomedical and Environmental Research (DBER) by participating in the environmental assessment efforts of the technical committee for Imperial Valley Project. The laboratory, through discussion with ERDA-DBER, also provides quality assurance assistance.

Environmental Efforts of Department of Interior Agencies

The USGS research program contributes to the environmental research efforts through its Subsurface Environmental Impact research efforts. These effects are geared to describe the nature and expected change in seismic activity and land subsidence, as well as the expected changes in groundwater quality or flow that may take place as a result of the withdrawal or reinjection of geothermal fluids into the ground.

To develop this information various studies have been initiated in FY 76. In particular:

- (1) Analytical models are being developed that reflect the expected tectonic, geological and hydrological processes that may result from large changes in subsurface waters;
- (2) A study began on the expected qualitative and quantitative impact upon the subsurface environment as a result of large changes in subsurface waters.
- (3) A study was begun to evaluate the correlation of high micro-earthquake activity in the vicinity of the Healdsburg fault in California with geothermal development at the Geysers.

The Office of Water Research and Technology, OWRT, also of the U.S. Department of Interior, has, through two of the institutes

authorized by Public Law 88-379, initiated studies on the biological impacts of geothermal development. A University of California research project is investigating the effect of geothermal development on aquatic biota in the Geysers area. In a Nevada project, potential biological impacts at a number of KGRAs in the state are being researched. The results of these subsurface water studies and biological impacts will help judge the environmental acceptability of the development of any particular geothermal reservoir. These results will also guide geoenvironmental policy, standards and controls.

The U.S. Fish and Wildlife Service (FWS), is also conducting research to ensure that the exploration, development, and management of the Nation's geothermal energy resources are conducted in an ecologically sound manner so as to prevent or minimize adverse impacts on fish and wildlife resources, and where possible, to enhance these resources. To this end the ecological studies completed by the FWS in FY 1976 include:

- o The preparation of a Geothermal Handbook.* This manual, which addresses the ecological effects of geothermal development, was designed to meet the emergency informational need of Fish and Wildlife biologists in the nation.
- o The Sage Grouse Study Design for Mono-Long Valley, California. This study is a cooperative effort involving the Fish and Wildlife Service, California

*Geothermal Handbook, 1976. Office of Biological Services, U.S. Fish and Wildlife Service, Department of the Interior, Washington, D.C.

Department of Fish and Game and a private resource developer.

- o A color infrared photography survey for potential geothermal areas in Wyoming and Montana.
- o A study of the recommended Peregrine Falcon critical habitat zone in four counties in California. This study required the cooperation of California Department of Fish and Game, the Fish and Wildlife Service and the Bureau of Land management. A similar study on the recommended critical habitat zone for Yuma Clapper Rail is still in progress. This study is also a cooperative effort on the California Department of Fish and Game, Fish and Wildlife Service and ERDA (Lawrence Livermore Laboratory).

INSTITUTIONAL DEVELOPMENT PROGRAM STATUS

The current Federal Program in Institutional Development includes the implementation and administration of:

- o The Federal Leasing Program
- o The Loan Guaranty Program
- o The Policy Analysis Program
- o Interagency Coordination and Program Management.

Achievements and progress in the Federal Leasing, the Loan Guaranty, and the Policy Analysis programs will be discussed below. The Interagency Coordination and Program Management effort is discussed in Section 3.

Federal Land Leasing Program

The first step toward the exploitation of geothermal energy is the identification and leasing of land with sufficient geothermal energy potential to be economically attractive for further exploration

and development. More than half of the promising land is thought to be under the jurisdiction of the Federal Government. Thus, the Federal Leasing Program is a critical element of the national effort.

The Federal land leasing procedure is guided by the Geothermal Steam Act of 1970 (Public Law 91-581) and the geothermal regulations that were promulgated in December 1973. Basically, it involves the cooperative efforts of the Bureau of Land Management (BLM), the U.S. Geological Survey (Conservation Division), and the U.S. Department of Agriculture (Forest Service). ERDA/DGE participates in an industry capacity through the Interagency Geothermal Coordinating Council.

Participants

The Bureau of Land Management plays a leading role in the issuance of leases in the Federal Land Leasing Program. Under the Geothermal Steam Act of 1970 (PL 91-581), the BLM issues Geothermal leases on the Federal lands. As the lead agency, the BLM in consultation with the USGS is responsible for selecting lands for lease and holding the lease sales. Lands determined by the USGS (Conservation Division) in accordance with the Geothermal Steam Act of 1970 to be valuable for geothermal resource development are designated as Known Geothermal Resource Areas (KGRA's)*. These tracts may then be leased

*Known Geothermal Resource Areas (KGRA): An administrative classification of the DOI for areas having higher than average potential for discovery of geothermal resources with boundaries defined by geoscientific evidence and/or by competitive interest.

only to the highest qualified bidder in a competitive lease sale. On the other hand, leasing of lands not within any KGRA is handled through non-competitive lease applications.

Lease Sales

During FY 76, the BLM has conducted 16 competitive geothermal lease sales and has received and accepted bids for a total of over 118,000 acres.

Within the same period (i.e., FY 76), 671 noncompetitive geothermal lease applications were filed and 466 leases were issued for a total of 771,891 acres. These acreages are located on Federal lands administered by the BLM and the U.S. Department of Agriculture. The number of noncompetitive lease applications processed by BLM in FY 76 shows a significant improvement in the handling of such leases since the inception of the lease program. Eventually, the Bureau expects to be able to handle the noncompetitive leases at a rate of 1000 per year, and to eliminate most of the backlog of applications on BLM lands by the end of FY 77.

Of the 59 million acres of Federal lands having known or potential value of geothermal development, about 17 million acres lie within National Forest System lands which are administered by the U.S. Forest Service. Most of these lands are multiple-use lands with high timber, recreation, wildlife and water resource values. Of the 1640 noncompetitive geothermal lease applications filed to date on National Forest System lands, approximately 700 have been withdrawn,

rejected, or refused by the applicant. Over 40 lease applications on these lands have been cleared for lease. Fourteen leases covering an area of 19,800 acres were issued in FY 76 as compared to only one lease issued in FY 75.

A tentative leasing schedule for FY 76, 77 and 78 was published on April 21, 1976, in the Federal Register, Vol. 41, no. 78, pp 1668-1669. This schedule covers both competitive and noncompetitive leasing.

Leasing Program Problems

Important problems of geothermal land leasing under resolution include the acreage limitation of 20,480 acres per lessee/operator, per state. At present, the Bureau is recommending legislative action to raise this limitation to 51,200 acres. It is hoped that larger acreage limitations will increase the chance for a more productive search for geothermal resources.

The siting of power generating plants and the reclassification of certain Known Geothermal Resource Areas (KGRA) created by competitive interest are being dealt with by both the U.S. Geological Survey (USGS) and the BLM. New regulations or recommendations for legislation needed to handle these problems will be developed.

Also, the BLM, USGS and United States Forest Service of the Department of Agriculture (USFS) are currently preparing Environmental Analysis Records (EAR) on a regional basis, where one EAR can cover

many lease applications. Issuing a lease may thereby be expedited. In fact, the preparation of EARs in environmentally sensitive areas such as Nevada, Washington, Utah and Oregon is now proceeding satisfactorily. Many of these EARs are scheduled for completion in FY 77.

Leasehold Management and Environmental Activities

The Conservation Division of the USGS is responsible for assuring an orderly and environmentally safe development of geothermal resources on Federal lands. Lease management involves:

- (1) A permitting system that includes unit plan development, determination of royalty rates, reviewing plans of operation, and issuing permits and coordination of many prelease activities with other land and resource management agencies (e.g., BLM and USFS).
- (2) Regulation and inspection of critical resource development operations.
- (3) Making environmental assessments of proposed operations.

By the end of FY 76, 104 KGRAs comprising more than 3 million acres were classified. This included the new and promising area of Roosevelt Hot Springs in Utah. Within the same time period, 40 environmental analyses for lease operations of varying complexity were made.

The USGS Conservation Division also reviewed operating plans, issued operating permits, and supervised the drilling of 24 wells. Of these, 16 wells have been drilled in California (in The Geysers, East

Mesa and Mono-Long Valley geothermal fields). The remaining eight wells were drilled in the new area of the Roosevelt Hot springs KGRA. The Roosevelt Hot Springs represent the first Federal Geothermal Unit. This unit was formed and approved in April 1976. It embraces 25,964 acres in Beaver County, of which 79 percent are Federal lands.

In FY 76, the Fish and Wildlife Service (FWS) operational geothermal activities have been directed to biological pre- and post-lease baseline studies of Known Geological Resource Areas (KGRAs). Two of these studies have been completed in FY 76:

- o The identification and distribution of raptors (birds of prey) in northern Washoe County, Nevada, KGRA. This study was the outcome of a cooperative effort of the Fish and Wildlife Service and the Nevada Department of Fish and Game.
- o The development of "Aquatic and Terrestrial Baseline Studies for Geysers KGRA, California." This is an ongoing effort involving the California Department of Fish and Game, Union Oil Company and Pacific Gas and Electric Company (PG&E).

In addition, the FWS has contributed to the environmental analysis/environmental impact studies on specific leases in 13 Western states. An in-house effort has developed environmental baseline data collection requirements for geothermal development and for the monitoring requirements for Federal leases. A site-specific design for an environmental baseline and monitoring program for the Imperial Valley, California, was also completed in FY 76 as a joint effort with ERDA.

The Loan Guaranty Program

The Geothermal Loan Guaranty Program is designed to:

- (1) Make capital more readily available to geothermal developers by guaranteeing to lenders loans made to qualified borrowers, and
- (2) To develop normal borrower-lender relationships which can be available to the emerging geothermal industry without the need for Federal financial assistance.

The ultimate goal is to create, through favorable experience, a strong sense of confidence among lenders in loans made for geothermal ventures.

The current status of the program and its achievements follow.

Regulations

Implementing regulations were completed and published by ERDA in the Federal Register in May 1976, taking into account public comments. The Geothermal Loan Guaranty Program became operational on June 25, 1976. Under the guaranty program, ERDA will work with lenders, reservoir developers, and lease- and land-holders to stimulate early development of steam and hot water resources for commercial electric and thermal power usage. These initial activities will permit growth in the industry and confidence to exploit the much larger geopressured and hot rock resources when the technologies for their utilization are proven.

Applications

As of November 5, 1976, ERDA has received three loan guaranty applications for geothermal projects to be located in California.

During FY 77 an additional 17 to 20 applications are expected for other reservoir development projects to be located in Utah, Idaho, Oregon, Nevada and California.

Management and Administration

The Headquarters Division of Geothermal Energy is responsible for management of the Loan Guaranty Program, including the formulation of policy and establishment of priorities, and for providing assistance to the Administrator in arriving at a final determination on a loan guaranty application. ERDA's San Francisco Operations Office has been assigned responsibility for receiving and reviewing guaranty applications and for preparing a recommendation for the Administrator's consideration.

The Policy Analysis Program

Early identification and resolution of institutional issues is important to the timely development of geothermal resources. ERDA, the Federal Energy Administration (FEA), the National Science Foundation and other members of the Interagency Geothermal Coordinating Council's Institutional Barrier Panel* (IBP) are actively engaged in the resolution of policy issues. Several activities are highlighted below.

*Details on the Institutional Barriers Panel contributions to the identification and resolution of institutional issues are given in Section 3.

(1) Federal Policy Studies:

Studies of Federal policy options have been initiated by ERDA, under the aegis of the Interagency Geothermal Coordinating Council, to assess the effect of Federal tax and land policies now in force on the geothermal development program. Many recommendations have been presented. These recommendations involve changes in the tax treatment and leasing policy. These changes could stimulate more effective participation of the private sector in geothermal energy development, thus accelerating the realization of the national geothermal energy goal.

In addition, the IBP has started various policy evaluation studies. These are intended to assess the effect of Federal and state taxation, Federal, state and local regulatory and licensing procedures, and utility rate structure on the development and utilization of geothermal energy. Recommendations concerning policy modification are expected in FY 77.

Other ongoing evaluations deal with Federal, state and local environmental assessment procedures and standards, as well as land-leasing policy. The ultimate outcome of these evaluations will be a series of recommendations that will enhance the progress of implementation of the Federal Geothermal Program.

(2) Legal Studies:

Analysis of critical geothermal laws at the state level is already under way. A contract has been awarded by ERDA for conducting a study on the legal aspects of geopressured development. This study represents a critical point on the path of development of geopressured geothermal energy because of the need to resolve conflicting definitions of ownership, tax status, water rights, mineral rights, and other jurisdictional questions. A contract has also been awarded for conducting a study on the impact of state water laws on geothermal energy development.

The NSF is also supporting a number of legal studies. These studies are concerned with the analysis of the legal systems which define ownership of the geothermal resources and control its use. Achievements in this area include:

- o A workshop and preliminary study of the legal constraints imposed on geothermal development (completed in FY 76). This workshop was conducted by the Law Center of the University of Southern California in an attempt to establish the appropriate reforms in Federal, state, and local legal and institutional structure to encourage the geothermal resource development.
- o The Law School at the University of California in Berkeley has also examined the fairness and effectiveness of existing laws with regard to the timely development of geothermal energy. The study evaluated the applicability of laws presently used for various other natural resources to the body of law dealing with geothermal resources. The main effort has been directed to the identification of the effects of legal alternatives on stimulating geothermal resource development, controlling external development costs (such as environmental damage) and influencing an equitable distribution of economic gains.

Model geothermal state legislation codes are being developed in modular form. This modular form provides for sets of alternative policies among which states can choose those suitable to meet their specific regional needs.

A series of workshops with Federal and state regulatory officials and legislators has begun. The workshops are intended to develop coordinated policies and procedures to expedite the regulatory process.

(3) Institutional Studies:

Institutional arrangements in the acquisition and sale of power are being examined analytically to describe how geothermal energy is handled now and how it might most efficiently and equitably be handled to provide reliable power for the consumer. These studies are being carried out by various institutions under previous support of NSF.

(4) Economic Studies:

Economic studies of geothermal development were initiated in FY 74. Further microeconomic cost/benefit analysis of geothermal energy systems are now being undertaken by ERDA. These studies are to develop a more refined and

more detailed estimate of the cost of geothermal resource types and utilization technologies. The new detailed cost analysis will allow for possible adverse socioeconomic impacts of geothermal energy development and utilization. Results of these studies are expected in the beginning of FY 77 and will help project the market penetration that can be achieved through various technological advances and policy changes.

In addition OWRT has, through the Water Resources Research Center at Utah State University, completed detailed studies of the energy budget of geothermal development as compared to hydropower development. Geothermal development was found to be competitive with hydropower development in terms of energy invested and retrieved.

(5) Regional Planning Studies:

ERDA has supported planning studies at national, regional, county and individual community levels. Regional-level studies are conducted in cooperation with state governments by regional operations research and systems analysis contractors. Several counties with geothermal resources have received grants (originally under NSF auspices and now administered by ERDA) to help fund the preparation of the geothermal sections of their multiyear development plans.

A few communities intended to serve as prototypes have received planning grants for the utilization of local geothermal resources. The resulting planning approaches and accomplishments will be made available to guide the efforts of other communities. For example, the Boise, Idaho Energy Task Force is examining the full range of local markets for geothermal energy, and the institutional changes needed to supply them. Their work is funded by ERDA and cost-shared with the U.S. Department of Housing and Urban Development (HUD)-financed Boise Urban Observatory. It is being coordinated with an Idaho State effort that is intended to heat several state buildings in Boise, under funding by the Northwest Regional Commission. The City's program extends to the private use of geothermal energy in a downtown urban renewal area and in housing. The Energy Task Force is also investigating issues of the ownership of geothermal energy, hoping to resolve them so that the areawide resources can be developed.

The City of Susanville, California has similarly received planning grants to overcome institutional problems affecting geothermal development. This assistance is being implemented with contracts provided by ERDA, FEA-funded state

financial assistance programs, and/or by direct support from numerous other Federal and state government agencies. For the most part the effort has been interagency oriented, with ERDA participating with three agencies: FEA, EPA and California Energy Resources and Development Commission.

SCIENTIFIC AND TECHNICAL EDUCATION PROGRAM

The National Science Foundation has completed a research program in geothermal energy through its Research Applied to National Needs (RANN) program. NSF/RANN adopted a pluralistic approach to geothermal research in which the tacit objective was to encourage numerous centers of expertise and detailed technical knowledge.

Thus, NSF/RANN energy programs at the end of FY 76 had involved 17 universities, seven private companies, two state governments and three not-for-profit laboratories as principal grantees. Within the grantee universities 55 faculty members, 16 postdoctoral research fellows, 75 graduate students, and 23 undergraduate students were engaged in geothermal research.

In addition to the completed RANN effort, the NSF Education Directorate administers several scientific and technical education programs which support individuals who are engaged in full-time pre- and postdoctoral study and research in energy-related areas. Many of these activities constitute valuable training in disciplines that enhance the science base required in the geothermal energy research effort. NSF education programs are presently supporting:

- o 26 graduate traineeships,

- o 6 postdoctoral fellows, and
- o 3 senior foreign energy scholars.

Other efforts in geothermal education and training are supported by ERDA's Office of University Programs. Thus, 25 workshops and institutes for high school teachers and a few for college teachers were conducted. The workshops were intended to enrich high school and college curricula with the subject of alternative energy sources, including geothermal energy.

SECTION 3

INTERAGENCY COORDINATION AND PROGRAM MANAGEMENT

INTERAGENCY GEOTHERMAL COORDINATING COUNCIL

Inasmuch as the development and commercial application of geothermal energy technology depends on the execution of program responsibilities that are vested in several Federal agencies, the formation of the Interagency Geothermal Coordinating Council (previously named the Geothermal Advisory Committee) constituted a significant step toward realizing the national goals for geothermal energy. This group was organized at ERDA's initiative to carry on the interagency program coordination function of the Geothermal Energy Coordination and Management Project mandated by Public Law 93-410 prior to the formation of ERDA. The Council's mission is to coordinate those Federal plans, activities, and policies that are related to or impact on geothermal energy, including ancillary activities of agencies that are not Council members. These other agencies are represented as the need arises on working groups and panels assigned the responsibility for specific efforts on problems, policies, or programs in which those agencies are involved.

Through its Chairman, the Council makes 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. The Council also reports to the President and to the Congress on the activities of the Federal Program.

MEMBERSHIP

The Interagency Geothermal Coordinating Council is composed of eight members representing ERDA, the Department of the Interior, the Department of Agriculture, the Federal Energy Administration, the Environmental Protection Agency, the National Science Foundation, the Treasury Department, and the National Aeronautics and Space Administration. Table 3-I lists the current membership of the Council.

TABLE 3-I

MEMBERSHIP OF THE INTERAGENCY GEOTHERMAL COORDINATING COUNCIL

ORGANIZATION	REPRESENTATIVE
Energy Research and Development Administration	Assistant Administrator for Solar, Geothermal, and Advanced Energy Systems - Chairman of the Council
Department of the Treasury	Assistant Secretary of the Treasury
Department of the Interior	Assistant Secretary for Energy and Minerals
National Aeronautics and Space Administration	Acting Assistant Administrator, Office of Energy Programs
Federal Energy Administration	Assistant Administrator, Energy Resource and Development
Environmental Protection Agency	Assistant Administrator for Research and Development
National Science Foundation	Assistant Director for Research Applications
Department of Agriculture	Assistant Secretary for Conservation, Research, and Education

ORGANIZATION

The Council is supported by a Staff Committee and three panels (Figure 3-1), each of which addresses a major aspect of interagency geothermal coordination.

FIGURE 3-1

ORGANIZATION OF THE INTERAGENCY GEOTHERMAL COORDINATING COUNCIL

Staff Committee

Eight members compose the Staff Committee, one appointed by each member of the Council. The ERDA representative chairs the Staff Committee and also serves as Executive Secretary to the Council. The Staff Committee is responsible for the formulation of coordinated Federal geothermal program plans. It directs the activities of the panels and reports periodically to the Council on those activities. Membership of the Staff Committee is shown in Table 3-II.

A working group on Budget and Planning has been established by the Staff Committee; its membership is shown in Table 3-III.

Resource Panel

The Resource Panel is responsible for coordinating the Resource Exploration and Assessment Program activities on the national, regional, and local levels, including those required in connection with the development and utilization of geothermal energy. The Panel is chaired by the representative of the Department of the Interior (Table 3-IV).

Research and Technology Panel

The Research and Technology Panel is responsible for coordinating and providing for exchange of information regarding the Federal research, development, and demonstration programs for geothermal exploration, resource assessment, energy, and other product utilization, environmental control technology, and basic and

TABLE 3-II

MEMBERSHIP OF STAFF COMMITTEE

ORGANIZATION	REPRESENTATIVE
Energy Research and Development Administration	Director, Division of Geothermal Energy (Chairman)
Office of Research and Development - Environmental Protection Agency	Deputy Assistant Administrator for Energy, Minerals and Industry
U.S. Geological Survey (Department of Interior)	Assistant Director, Energy and Mineral Resources
Federal Energy Administration	Director, Office of Synfuels, Solar and Geothermal Energy
National Aeronautics and Space Administration	Acting Director, Energy Conversion Division, Office of Energy Programs
National Science Foundation	Director, Division of Advanced Energy and Resources Research and Technology
Department of the Treasury	Petroleum Specialist, Office of Energy Policy
Department of Agriculture, U.S. Forest Service	Watershed and Minerals Area Management Staff

TABLE 3-III

MEMBERSHIP OF STAFF COMMITTEE: BUDGET
AND PLANNING WORKING GROUP

ORGANIZATION	REPRESENTATIVE
Energy Research and Development Administration	Chief, Planning Branch, Division of Geothermal Energy; Chairman
Department of the Interior	
Bureau of Land Management	Chief, Branch of Upland Minerals
Bureau of Mines	Associate Director, Mineral and Materials Research and Development
Bureau of Reclamation	Chief, Resources Planning Branch Division of Planning
Office of Water Research and Technology	Water Research Scientist
U.S. Fish and Wildlife Services	Office of Biological Geochemistry
U.S. Geological Survey	Chief, Office of Geochemistry and Geophysics
Department of Agriculture	
U.S. Forest Service	Watershed and Minerals Area Management
Environmental Protection Agency	Energy Processes Division, Office of Energy, Minerals and Industry; Office of Research and Development
Federal Energy Administration	Chief, Geothermal Energy Division Office of Synfuels, Solar and Geothermal Energy

TABLE 3-IV

MEMBERSHIP OF THE RESOURCE PANEL OF
THE INTERAGENCY GEOTHERMAL COORDINATING COUNCIL

Bureau of Mines

Department of Agriculture

Department of the Interior

Department of the Treasury/Office of Regulatory
and Legislative Energy Policy

ERDA/Division of Geothermal Energy

Federal Energy Administration

NASA/Goddard Space Flight Center

NASA/Office of Energy Programs

U.S. Geological Survey

applied research related to geothermal energy. The Panel is chaired by the representative of the Energy Research and Development Administration (Table 3-V).

Institutional Barriers Panel

The Institutional Barriers Panel is responsible for assessing Federal, state, and local government and non-governmental institutional aspects of geothermal energy that may stimulate or retard its growth. These include laws, environmental standards, leasing and land-use management policies, and other factors. The panel is chaired by the representative of the Federal Energy Administration (Table 3-VI).

PROGRAM ACTIVITIES AND PROBLEM IDENTIFICATION

The initial activity of the Council and its panels has been to identify problem areas that require interagency cooperation for their solution.

Resource Panel

The Resource Panel has prepared an exploration and assessment plan. A key issue in this effort is the need to obtain, and protect proprietary data obtained during private drilling operations and to coordinate the process in order to prevent duplication among agencies. Also needed is a revision to update the information in USGS Circular 726, "Assessment of Geothermal Resources of the United States." This publication has been valuable in the

TABLE 3-V

MEMBERSHIP OF THE RESEARCH AND TECHNOLOGY PANEL OF
THE INTERAGENCY GEOTHERMAL COORDINATING COUNCIL

Bureau of Mines

Bureau of Reclamation

Energy Research and Development Administration

Environmental Protection Agency

ERDA/Division of Geothermal Energy

Federal Energy Administration

National Aeronautics and Space Administration

National Science Foundation

Naval Facilities Engineering Command

U.S. Geological Survey

TABLE 3-VI

MEMBERSHIP OF INSTITUTIONAL BARRIERS PANEL OF
THE INTERAGENCY GEOTHERMAL COORDINATING COUNCIL

Bureau of Land Management

Council of Environmental Quality

Department of Commerce

Department of Treasury

Energy Research and Development Administration

Environmental Protection Agency

Federal Energy Administration

Federal Power Commission

USDA/U.S. Forest Service

U.S. Geological Survey

planning and development of geothermal resources, and needs to be updated as new data are acquired.

Federal Plan for Geothermal Resource Assessment

The Resource Panel has recognized the need for a broad base of information concerning the nature, location, and distribution of geothermal systems and their associated reservoirs. Such information is needed in the early stages of national effort to develop geothermal resources to help reduce the costs and risks of exploration. A substantial Federal program for geothermal resource inventory and assessment is required.

The recommended research program is divided into three broad areas:

- o Characterization of geothermal systems
- o Exploration and assessment technology
- o Geothermal resource inventory and data bank

Characterization of Geothermal Systems. A few representative geothermal systems and reservoirs are being studied in detail so that this knowledge may be extrapolated to a larger number of systems and reservoirs of the same general type to obviate the need to study each in great detail. These detailed investigations should cover both regional and local investigations.

Regional investigations should focus on four types of geologic environments:

- o Young magmatic systems,

- o Environments of regionally high heat flow,
- o Large sedimentary basins with geopressed formations or deep circulation of waters, and
- o Crystalline basement terranes in regions of normal heat flow but where high radiogenic heat production occurs.

Investigations on Federal lands should be carried out in cooperation with industry wherever possible.

Exploration and Assessment Technology. The highest priority for Federal support of efforts to develop exploration technology should be given to: (1) better measurements of properties of rocks and fluids at geothermal temperatures and pressures, (2) quantitative well-log interpretation, (3) improved chemical geothermometers, (4) more cost-effective geoelectrical techniques, (5) novel drilling methods, (6) improved logging devices that are reliable at high temperatures and in corrosive environments, (7) means of determining the permeability of potential reservoir rocks by surface measurements prior to drilling, (8) applications of seismic reflection and seismic array methods, (9) improved understanding of heat flow data, and (10) development of techniques that will reveal hidden resources which are not associated with hot springs or geysers.

Geothermal Resource Inventory and Data Bank. An inventory of geothermal resources should be based on a well-planned and systematic collection and analysis of models and data. An updated inventory should be produced every two to three years, but the data should be

collected and organized on a continuous basis. The next inventory is planned for completion toward the end of 1978.

Research and Technology Panel

The Research and Technology panel discussed a number of candidate problem areas, and agreed that four are generally recognized as being of prime importance:

Brine Injection

Brine injection has been identified as a possible means of controlling subsidence, maintaining reservoir pressures, and disposing of waste fluids in an environmentally acceptable manner. The actual large-scale applications of brine injection in geothermal fields in order to accomplish these objectives have been limited. There is a large body of relevant experience and technology in non-geothermal fluid injection to be transferred to the technologically difficult geothermal brine injection.

Brine Chemistry

A detailed knowledge of brine chemistry is required in the development of practical injection techniques. It is also important to the development of energy extraction techniques because the engineer must be aware of the impurities present and the temperatures at which they may be expected to precipitate or interact. Brine chemistry is essential to the assessment of environmental impacts from individual fields.

Corrosion and Materials Research

The complex chemistry of geothermal brines, combined with the phase and temperature changes involved in energy extraction, present serious corrosion problems and pose other problems of materials research. If a geothermal power station is to be economically feasible, it must combine a long service life--twenty years or more--with minimum maintenance and downtime. Therefore, materials with long service lives in brine environments must be identified and/or developed for use.

Environmental Research

The development of valid environmental safeguards requires knowledge of pollutant types, concentrations, and release points; their impacts; and the performance, energy penalty, and costs associated with control measures. Very little information is available in this area and, until it is obtained, environmental guidance cannot be given and standards cannot be adequately set.

Institutional Barriers Panel

The Institutional Barriers Panel chaired by the Federal Energy Administration has identified a number of important issues confronting the development of geothermal energy:

Federal, State, and Local Environmental Statutes and Regulations.

Problems of environmental regulation were found to involve not only coordination of Federal and state action, but also the existence and uniformity of the standards themselves.

Federal-State Environmental Protection Assessments. An early and continuing activity of the Institutional Barriers Panel has been the coordination of efforts to evolve a common understanding on environmental impact statements. The Panel found that Federal and state environmental protection agencies have not developed mechanisms to coordinate their roles in implementing the laws and regulations affecting geothermal development. Varying and redundant environmental assessment requirements at the Federal, state, and local levels tend to add expense and delay to the development process.

The panel recommended that a series of joint Federal-state environmental conferences and workshops be organized to foster better coordination of all levels of environmental impact assessment requirements and procedures.

Federal-State Environmental Standards for Geothermal Pollutants. To the developer of geothermal energy, environmental protection presents a set of problems that must be solved, but that are ill-defined because the environmental effects may be unclear at this time. The Institutional Barriers Panel recommended that immediate action be initiated to establish interim guidelines for control of geothermal pollutants to be completed and promulgated within 12 months. The guidelines would be based on the best available information and would be developed by EPA after consultation with state environmental agencies and appropriate organizations in the private sector.

Federal Taxation Policy

On occasion, the Congress has legislated tax preference for investment in the exploration for and development of petroleum, coal, uranium, and other mineral resources. It has also reduced these preferences, as in 1969 and 1975 when percentage depletion allowance for oil and gas were progressively lowered. Because geothermal energy differs in some ways from both mining and oil production, it may not be appropriate to adopt existing policies. Tax policy changes, if any, should be based on an evaluation of the specific attributes of the geothermal resource and its developers.

The Institutional Barriers Panel has performed a number of studies to develop the implications of this issue. The panel has:

- o Reviewed Federal and state legal definitions of geothermal resources and resource products and their ownership. The study compared tax practices and noted variation in application to geothermal resource development as opposed to other mineral resources.
- o Studied the boundaries that separate geothermal exploration, production, and utilization and the specific tasks involved from discovery to resource utilization.
- o Reviewed pending legislation pertaining to geothermal development and proposed that certain costs be treated for tax purposes as research and development expenses.
- o Planned a review of state and local ad valorem tax structures as applied to geothermal resources and a formulation of a tax framework addressing requirements for revenue as well as the need for development capital.

Recommendations. The panel has recommended that legislation be prepared to amend Section 174 of the Internal Revenue Code of 1954

so as to permit, for about a 10-year period, research and development expensing (or optional 5-year amortization) of all outlays (other than for real and depreciable personal property) incurred before the pre-commercial stage of project development. Under current law, prototype power-generation systems would appear to be eligible for the special tax treatment under Section 174.

Federal and State Land Use Management and Leasing Policies

The leasing policies involved in geothermal development have been criticized as excessively complicated and lengthy, acting as a barrier to geothermal development. The Institutional Barriers Panel has begun a study of this problem, starting with a review of Federal legislation, rules, and regulations on leasing. This study reviewed proposals to revise legislation regulations and policy to:

- o Increase the acreage limitation
- o Establish an escrow arrangement to expedite lease development on lands in litigation to resolve the question of legal ownership of the geothermal rights
- o Provide for leasing of geopressured and hot dry rock resources
- o Resolve the legal status of offshore geothermal areas

As a result of its interagency review of Federal lands management policy, the Institutional Barriers Panel has recommended a number of measures:

Resource Assessment. The Federal government depends almost entirely on privately financed exploration and on institutional studies for its knowledge about geothermal resource potential on

Federal lands. The recent report, "Assessment of Geothermal Resources of the United States, 1975," published by the U.S. Geological Survey (USGS Circular 726), describes our present understanding of the resource potential, but the resource estimates cited therein should not be taken as final appraisals that are valid into the indefinite future. They are limited by the data available as of 1975, and will need to be revised as more data and better methods of evaluation become available.

The Panel recommended that the Department of the Interior (USGS) prepare an expanded resource assessment program and request the necessary appropriations. The Department of the Interior has since responded to this recommendation.

Overlapping Lease Applications. If two noncompetitive lease applications are filed during the same application filing period and overlap an area by 50 percent or more, the area covered by the applications automatically becomes a Known Geothermal Resource Area (KGRA). The applications are rejected and the area can be leased only by competitive sale. In some cases this has prevented the acquisition of noncompetitive leases and may delay the exploration and development of the resource.

After a review of the effects of the regulations on pending lease applications by the Panel, the BLM is proposing changes in the regulations to permit the noncompetitive leasing of such lands where competitive interest was the only criterion involved in the resource classifications, and competitive lease sales have subsequently resulted in no bids.

Cash Bonus Competitive Bidding. The economic and technical uncertainties associated with geothermal development tend to discourage investment. The fledgling industry includes a number of small, independent operators having inadequate capital resources to sustain high front-end expenditures for both cash bonuses and development of the resources. Consequently, development must be deferred until additional capital resources become available.

The Panel recommended that the regulations to the Geothermal Steam Act of 1970 be amended to provide, under the cash bonus bidding system of competitive leasing, a method for deferring bonus payments, and to allow the developer to recoup part of the bonus due through development work as specified in the Plan of Development.

Cumulative Acreage Limitation. The Geothermal Steam Act of 1970 permits an individual, association, corporation or governmental unit to hold a maximum of 20,480 acres per state under lease at any one time; however, this arbitrary limitation does not take into account the geothermal potential in any one state. Since this potential is uneven, the limitation could allow monopolization in states where geothermal resources are small, and on the other hand it could prevent full development in states where the resources are large. The 20,480 acre limitation corresponds roughly to one prospect per state per company.

Of the approximately 1.9 million acres the U.S. Geological Survey has classified as Known Geothermal Resource Areas (KGRAs), nearly 60 percent are located on Federal lands and over half of this acreage is contained in one state (California). The remaining portion is distributed in varying proportions among the other states, some of which contain fewer than 20,000 acres. Development of these KGRAs, which have the highest potential of all geothermal resource areas, may be affected in two ways: (1) by the possibility that one lessee could hold the total resource acreage available in one state and withhold it from development; and (2) where a developer, because he has acquired the maximum permissible amount of acreage, cannot develop more than one reservoir. In either case, the consequence is that an orderly development of the resource is inhibited. The latter problem is already being experienced and has resulted in lack of interest in recent competitive lease sales because the relatively few companies actively developing are already at their acreage limitations.

The panel recommended that the regulations pursuant to the Geothermal Steam Act of 1970 be revised to apply the acreage limitation only to aggregated undeveloped acreage, and that the Act be amended to increase the leased acreage limitation per state from 20,480 acres to 51,200 acres earlier than the 1985 date provided by the current statute.

Uncertainty by Utilities of Geothermal Supplier's Performance.

All geothermal leases have a primary term of 10 years. If geothermal

steam is produced or utilized in commercial quantities within the primary term of the lease, the lease shall continue for up to 40 years after the end of the primary term, with an option to renew for an additional 40 years if the land is not needed for another purpose. In the situation where a lessee sells geothermal energy to a utility for generation of electricity, there is concern on the part of utilities that a lease might expire or be canceled, thus resulting in the termination of sale of geothermal energy before the generating plant facilities are fully amortized, before resources are depleted, or both. Utilities are reluctant to invest capital to construct power plants without a guarantee that the developer's lease and/or sale of the product will continue at least up to the point where a utility's newest power plant has been fully amortized. This is a disincentive to develop geothermal energy for electric power utilization.

The panel recommended that the regulations to the Geothermal Steam Act of 1970 be modified (or legislation be sought, if necessary) to require that the utility (or applicable subsidiary) be accorded first right of refusal to have the lease assigned to it, subject to applicable state law, in the event the developer stands to lose his lease.

Readjustment of Lease Terms and Conditions. The Geothermal Steam Act of 1970 provides that "...the secretary may readjust the terms and conditions except as otherwise provided herein of any

geothermal lease issued under this Act at not less than 10-year intervals beginning 10 years after the date the geothermal steam is produced, as determined by the Secretary...." The term "produced" is not defined; consequently, it is not clear when readjustments of the terms and conditions of a lease may be applicable. Further, there is no stipulation as to method and timing associated with notification by the Secretary to the lessee as to when the lease has produced.

The interval between readjustments of lease terms is dependent on the interpretation of the language in the lease and without such definition could result in arbitrary time intervals being established between periods of readjustment. This could discourage capital investment for geothermal development because of the uncertainties as to future lease terms.

The panel recommended that the regulations to the Geothermal Steam Act of 1970 be amended to define the term "produced" and specify a time period and method for notifying the lessee when the lease terms may be readjusted. It recommended that the term "produced" be interpreted to mean when steam is first converted into energy.

Leasehold Size. An individual geothermal lease may not embrace more than 2,650 acres, nor less than 640 acres except at the discretion of the Secretary of the Interior. The present minimum acreage size limitations for a single leasehold are unrelated to the identified needs of geothermal development. It is

recognized that in those cases where several small leases are combined for development work, negotiations between leaseholders can become more complicated. On the other hand, the 640-acre minimum size limitation could have adverse effects on development for nonelectric utilization of the resource. Development of geothermal resources for nonelectric utilization is impeded because the issuance of leases less than 640 acres is precluded.

The panel recommended that the regulations pursuant to the Geothermal Steam Act of 1970 be revised to specify an intention to issue leases of less than 640 acres only in the following situations: (1) Where a proven field is involved and/or the lease applicant controls contiguous state or private land and needs the isolated Federal acreage for a block holding; or (2) for purposes of small-scale nonelectric geothermal utilization. The maximum leasehold size should not be changed.

The panel recommended that the work requirements formula be revised to account for development of single leaseholdings of less than 2,650 acres and to adjust the amount of work (and expenditure) required to reflect the intended utilization of the resource (i.e., nonelectric applications). It also recommended that the regulations be amended to enable aggregation of work requirements where several small, independently owned, contiguous leaseholdings exist, and allow one operator to develop a single leasehold in the aggregated unit,

but permit the work performed to be treated as expenditure for all the leaseholdings in the aggregated unit.

Federal, State, and Local Government Regulatory and Licensing Procedures

A complex and protracted series of licensing steps is often required, primarily at the local level of government, to initiate and pursue geothermal exploration, field development, and construction. These extensive licensing procedures inhibit the private sector in the exploration, development, and utilization of geothermal resources.

Federal-State Utility Rate Structure Policy. State electric utility rate structures are highly variable in their treatment of resource development investments in determining rate bases. Electric utility rate structures do not generally allow inclusion of the magnitude of investment necessary for effective efforts in field exploration, appraisal, development, equipment, and power generating processes.

The panel has undertaken the following efforts in addressing this issue:

- o Reviewed utility rate structures to determine the feasibility of recovering costs for geothermal exploration and development in the rate base. This study includes an examination of possible conflicts with alternative tax incentive proposals discussed above.
- o Initiated action to develop a set of guidelines to state public utility commissions to encourage the establishment of relatively favorable treatment for geothermal exploration and development costs.

The panel recommended that relevant Federal regulation be amended in such a manner as will encourage utilities to make greater use of geothermal energy. To this end, the FPC, will issue guidelines to the state public utility commissions. These guidelines will provide greater incentives to the utilities to employ geothermal energy.

ADDITIONAL TOPICS UNDER REVIEW BY THE PANEL

In addition to the above actions, the Institutional Barriers Panel has developed recommendations in other problems of implementation. The recommendations are pending approval by the panel and, in turn, the Interagency Geothermal Coordinating Council as a whole.

The topics addressed include:

- o Delays in the issuance of noncompetitive leases
- o Delays in the issuance of drilling permits
- o Discriminatory regulations that make exploration by non-leaseholders easier than by leaseholders
- o Lack of a force majeure clause in Federal leases
- o The rate at which the U.S. Forest Service is able to prepare requisite environmental impacts statements for leases on lands which it administers; this is the main obstacle to the fulfillment of the Forest Service's part of the BLM leasing schedule.

SECTION 4

INTERNATIONAL COOPERATION PROGRAM

The Energy Reorganization Act of 1974, Public Law 93-438,* vests in ERDA the responsibility for "encouraging and participating in international cooperation in energy and related environmental research and development." ERDA's mission in international cooperation is to conduct mutually beneficial programs that will not only enhance ERDA's ability to develop and demonstrate a wide range of energy options for the future, but will also contribute to the development of markets for U.S. geothermal technology.

The energy R&D policies of countries all over the world must reflect both the differences in endemic resources, requirements, and technology and the international nature of the energy question. The differences in resources are reflected in their unequal distribution in both quality and quantity. This inequality is not confined only to the well-publicized case of petroleum resources. It is also found in the case of geothermal resources. Differences in the energy requirements among countries are related to their level of technological development which in turn affects the near-term potential for energy development and utilization within each country. International cooperation offers a way to find solutions to energy questions that can reduce duplication of efforts, and help to cope

*Section 103(9)

with the rising costs of energy research and the complexity of the emerging energy technologies.

ERDA's participation in international R&D cooperation is based on the simple precept that such cooperation must be mutually rewarding in order to be fruitful. For the United States, two rewards are quickly identifiable.

- o International R&D cooperation enhances our national efforts by:
 - Increasing the technological base
 - Increasing technical manpower and expertise
 - Reducing United States' financial burdens
 - Accelerating technical progress
- o International cooperation affords us an opportunity to enhance the United States influence internationally. Significant aspects of this include:
 - Coordination of major energy-consuming country policies and actions; e.g. utilization R&D, environmental protection policies, data dissemination, etc.
 - Assistance and cooperation with developing countries in meeting their energy needs
 - Expanding commercial opportunities for U.S. industry
 - Increasing world stability by expanding the availability of different sources

International cooperation is achieved either through bilateral agreements with individual countries or multilaterally under the aegis of an international organization such as the International Energy Agency (IEA) or the NATO Committee on the Challenges to

Modern Society (CCMS). Cooperation may take the form of exchanges of information or personnel, cooperative projects such as joint construction or operations of a facility or experiment, coordinated activities where two or more countries each perform a portion of a planned R&D program, or some combination thereof.

To date, technical cooperation agreements in geothermal energy have been or are being arranged with Italy, New Zealand, Japan, Mexico, and Iceland as part of an overall technology exchange program. Bilateral agreements with Italy cover hot dry rock stimulation, utilization of hot brines, reservoir definition, deep drilling, and geothermal long-term environmental effects.

ITALY

Programs in four areas have been established between ERDA and Ente Nazionale per l'Energia Elettrica (ENEL) of Italy.

- o Hot Dry Rock Stimulation--This includes four tasks;
 - The selection of existing non-productive wells in both countries (i.e., the U.S. and Italy) for stimulation tests,
 - The selection of stimulation techniques,
 - The application of the appropriate technique, and
 - The application of ERDA's (LASL) hot dry rock concept to a 5000-meter hole that will be drilled at Larderello during 1977.
- o Utilization of Hot Brines--The Italian wells at Cesano and the U.S. wells at Niland produce high-temperature and high-salinity brines. While the brine composition is not the same and utilization represents somewhat different technical challenges, the possibilities for mutual benefit to both sides exists. ERDA is awaiting Italian initiatives in this respect.

- o Reservoir Definition--A general statement on resource assessment, both regional and local, and on reservoir engineering have been agreed to by both ERDA and ENEL. The estimated costs of the joint project for FY 1977 are \$270,000 for ERDA and \$220,000 for ENEL. The project covers the following areas of investigation:
 - Methods of regional assessment of geothermal reservoirs
 - Assessment of geothermal potential of Central and Southern Tuscany
 - Analysis of reservoir pressure and decline curves in Serrazzano Zone of Larderello
 - Well testing of Travale-Radicondoli Geothermal Field
 - Thermodynamic study of Bagnore Field (Mount Amiata)
 - Study of effects of reinjection with a mathematical model
 - Modeling vapor-dominated geothermal reservoirs
 - Workshop on geothermal reservoir assessment and reservoir engineering
- o Environment--Advanced U.S. instruments, procedures, and techniques will be used to measure the regional concentrations of radon and hydrogen sulphide (H_2S), and their effects at both Lardarello and The Geysers.

In addition, ENEL has expressed genuine interest in ERDA's (LASL) down-hole equipment, instrumentation, and techniques; and in U.S. research efforts in hot dry rock stimulation techniques. This interest is the result of ENEL's discouraging drilling experience at Travale, Cesano, and Larderello, which ended in several dry holes.

ERDA has also entered into a bilateral agreement with Italy to exchange and maintain a computerized file of information and data on the physical characteristics and economics of geothermal well and

field sites throughout the world. This cooperation allows us to draw on about seventy years of Italian experience in generating electricity from geothermal sources. This agreement between ERDA, ENEL, and CNR, (Consiglio Nazionale delle Ricerche) requires ERDA to be responsible for collecting data from the Americas, Oceania, Iceland, and Asia (except for the Soviet Union), while Italian institutions, CNR and ENEL, are responsible for data on Europe (except Iceland), Africa, and the Soviet Union. As a first step in the cooperative exchange the United States has provided several relevant bibliographic computer tapes and a thesaurus of geothermal technical terms to CNR and ENEL.

NEW ZEALAND

The joint U.S.-New Zealand Agreement for Scientific and Technological Cooperation covers research in the geothermal energy area with special emphasis on exchange of information. New Zealand can offer the United States much in the way of day-to-day tactical advice in drilling, well testing, and facility operation. In return, reservoir engineers from the United States could assist in the detailed evaluation of the Broadlands field and in obtaining a better understanding of its nature. In addition, the USGS could provide assistance in undertaking teleseismic measurements of the Okataina volcanic area. Several informal visits and exchanges of information have already taken place with New Zealand.

JAPAN

An agreement that focuses on the development of better technology for both electric and nonelectric usage is under negotiation between ERDA and the Japanese Agency for Industrial Science and Technology. Technology for the development of improved electric and nonelectric equipment, techniques for assessing geothermal resources, and data from both environmental and volcanic studies are included. Cooperation will take place through the exchange of information and visits of technical personnel under the direction of a joint steering panel.

MEXICO

A cooperative study program under the 1972 Science and Technology Agreement is being negotiated with the Government of Mexico. The proposed study of the Cerro Prieto geothermal field will develop a thorough understanding of this field. It will also investigate the best way to exploit the resource, and determine the environmental impact of such exploitation. An understanding of the subsurface system at Cerro Prieto will be beneficial to ERDA's program now in progress in the Imperial Valley. Field work should be under way during 1977. At present, the proposed Cerro Prieto cooperative program covers nine specific activities. These include:

- o Analysis of existing data on Cerro Prieto and model development,

- o Analysis of fluid and core samples, and
- o Geophysical surveys using new and sophisticated techniques and devices.

ICELAND

ERDA and the Icelandic National Energy Authority have had a formal agreement since November 1973 to exchange information and to host visits and conferences. Under this agreement, ERDA has granted the University of Iceland two contracts for the study of the environmental effects of geothermal energy; and under NATO Committee on the Challenges of the Modern Society (CCMS) auspices, Iceland is to provide information on the current or planned small community heating systems of Akureyi, Husavik, and Dalvik, and on a planned large heating system (which includes up to seven communities as well as the American Air Force Base) at Keflavik. This information will be used to develop a model of a heating system that is based upon commonly available demographic and climatological data. This simulated system will provide detailed design information for distribution networks, and will aid in the design of an optimum geothermal heat transmission system. Results of this effort are to be published at the CCMS geothermal meeting scheduled for Spring 1977 in Washington, D.C.

MULTILATERAL COOPERATION

ERDA is participating in multilateral cooperative activity through its membership on four recently formed panels of the IEA

Geothermal Energy R&D Working Party. Mutual benefits to panel members are anticipated in the areas of:

- o Low enthalpy geothermal sources for nonelectric uses,
- o High enthalpy geothermal sources for small electric power plants,
- o Man-made geothermal systems, and
- o Geophysical exploration techniques.

ERDA is also participating in multilateral cooperative agreements under the aegis of the NATO CCMS. The CCMS has directed its attention to information exchanges and the solution of specific short-term problems. The U.S. has been designated the "pilot" or "lead" country for geothermal energy (with Italy and Turkey as coleaders). Three technical areas have been emphasized;

- o The use of hot dry rock as an energy source,
- o Small geothermal power stations, and
- o Nonelectrical uses of geothermal resources.

Foreign scientists have participated in experiments being performed in the U.S. at Los Alamos to determine the practicability of recovering energy from hot dry rocks. This work is stimulating much interest throughout the world. The U.S. has participated in the CCMS-sponsored multilateral design effort to provide specifications for a 5 MW "portable" geothermal plant which could derive its energy from a single geothermal well. For reservoir testing, the plant could be moved from well to well. It is hoped that the construction and operation of such a facility will be undertaken, as a follow-on to this design study, by interested member countries in the IEA.

SECTION 5

NON-FEDERAL ACTIVITIES

The realization of the potential for geothermal resources to contribute to the future energy needs of the United States currently depends upon the active and strong involvement of the private sector to build a self-sustaining geothermal industry. The Federal Program and the non-Federal governmental efforts are aimed at providing the option for the private sector to accelerate the pace of industrial development. This section reviews some of the activities and accomplishments in the non-Federal sector that reflect its commitment to the development of geothermal resources.

The commitment to a geothermal lease is one of the earliest steps taken by the private sector that connotes a bona fide interest in the development of a specific geothermal resource. Much of the identified geothermal resource of the United States that is considered to be potentially developable over the near term exists under land that is owned by the government. Table 5-I provides a tabulation of geothermal leases that have been let for both public land and Indian land as of October 31, 1976. Detailed statistics for leases let on private land are generally not available. In addition, due to the competitive nature of exploration and the leasing of lands, information on the activities taking place on land with geothermal potential and the exact location of these activities is usually held closely by the developers. Some information is available,

TABLE 5-I
STATUS OF GEOTHERMAL LEASES AS OF OCTOBER 31, 1976

State	Producing No.	Acreage	Producible No.	Acreage	Non-Producing No.	Acreage	Total Acreage Under Supervision to Date No.	Acreage
<u>PUBLIC LAND</u>								
Alaska								
Arizona			7	9,594	4	6,508	4	6,508
California					25	34,297	32	43,891
Colorado					38	42,818	38	42,818
Idaho					78	128,906	78	128,906
Montana					5	9,407	5	9,407
Nevada					375	634,683	375	634,683
New Mexico					65	139,203	65	139,203
Oregon					62	94,735	61	94,735
Utah			1	2,463	203	329,678	204	332,141
Washington								
Wyoming					2	2,804	2	2,804
TOTAL PUBLIC			8	12,057	856	1,423,039	864	1,435,096
<u>INDIAN LAND</u>								
California					2	600	2	600
Nevada (Prosp. Permit)					2	291,590	2	291,590
TOTAL INDIAN					4	292,190	4	292,190

SOURCE: Monthly Geothermal Report - October 1976 - Conservation Division, USGS, DOI.

however, and Table 5-II presents a forecast guide for the most active geothermal development areas. It is reasonable to assume that additional activity, beyond that estimated in Table 5-II, will take place between now and 1980, both in the areas identified in the table and in new areas as their geothermal potential is discovered.

Table 5-III shows the numbers of geothermal wells drilled by private developers in 10 states from before 1970 through September 1976. In addition, the following tabulation* shows recent geothermal exploration activity on Federal lands:

Activity	FY 75	FY 76	TQ
Notices of intent to conduct geothermal resource exploration (prospective lessees)	78	123	34
Prelease or research plans of exploration operations (successful bidders who have not yet been granted their leases)	1287	372	81

*Source: U.S. Geological Survey, "Monthly Geothermal Report," Office of the Area Geothermal Supervisor, Conservation Division, June 1975, June 1976, October 1976

TABLE 5-II*

FORECAST GUIDE FOR THE MOST ACTIVE GEOTHERMAL DEVELOPMENT AREAS

Area	Development State	Forecast		
		1975-1976	1977-1979	1980-1985
<u>Dry Steam (Vapor Dominated)</u>				
The Geysers, CA	500 mW of plant installed by PG&E in 11 units; over 150 holes drilled across 18 mi ² , of which 2 in 3 encounter steam; most of remainder are hot but non-productive; wells drilled by Union Oil, Thermal Power, Pacific Energy Company, Burmah Oil, Shell Oil, Sun Oil and others.	To average about 20 holes drilled per year (Union Oil, Shell Oil, Pacific Energy, Burmah Oil, others); step-out drilling to SE and N; occasional redrilling of existing wells.	Units #12-15 to be installed (400 mW); step-out drilling to N, NW, possibly NE and SE, covering additional 10 to 15 mi ² ; continued redrilling within productive area.	Development to exceed 1500 mW; probably the field limits and dimensions will be known; may exceed 25-30 mi ² (2500 mW capacity) in area.
<u>High Enthalpy (>200-250 BTU/lb) Hot Water (324-550°F)</u>				
Valles Caldera, NM	Approximately 9 producible wells, of about 15 holes drilled in 10 mi ² area (Union Oil); negotiations with utility over contract to sell steam.	Continued drilling of development wells and testing of field; possible agreement to construct 50 mW flashed-steam power plant.	Drilling of wildcat holes by other operators; construction of first plant; continued development drilling.	Further construction of plant facilities; definition of field dimensions; continued drilling and testing.
Imperial Valley, CA	4 areas being tested for development. Heber: 9 holes across 3 mi ² ; lower enthalpy hot water; Chevron, Magma Power. Brawley: 3 holes in limited area; lower enthalpy water; Union. Niland: 15 holes in 10 mi ² ; high enthalpy, heavy brine; Phillips, Magma Power, Southern Pacific Co. East Mesa: 4 holes in limited area; lower enthalpy hot water; USBR.	Continued testing of heat-exchanging for Niland brine; further drilling in other areas; testing of heat-exchanging components for binary cycle power generation; testing of desalination apparatus at East Mesa.	Construction of first binary-cycle plant at Heber (20 mW); continued drilling at Heber and Brawley; possible decision to construct pilot desalination facility at East Mesa; possible decision to construct power plant at Brawley and/or Niland; wildcat drilling elsewhere.	Development at Heber continuing; possible continued activity elsewhere.

*Source: Geothermal Handbook, 1976. Office of Biological Services, U.S. Fish and Wildlife Service, Department of the Interior, Washington, D.C., p. 70.

TABLE 5-II* (Continued)

FORECAST GUIDE FOR THE MOST ACTIVE GEOTHERMAL DEVELOPMENT AREAS

Area	Development State	Forecast		
		1975-1976	1977-1979	1980-1985
<u>High Enthalpy (>200-250 BTU/lb) Hot Water (324-550°F) (Continued)</u>				
Roosevelt, UT	Approximately 4 holes drilled in limited area (Phillips Petroleum); testing and further drill drilling underway.	Continuing testing and drilling possible wildcat drilling in adjoining areas (Cove Fort to northeast).	Possible decision to construct power plant, if so, further drilling.	Possible construction of plant, with continuing drilling and testing of wells.
Carson Desert, NV	4 areas have been drilled to varying degree. Brady's: about 12 holes, across 2 mi ² area; Union, Magma Power. Soda Lake: 2 holes, widely spaced; Chevron, Phillips. Fernley: 2 holes; Magma Power. Stillwater: 1 hole; O'Naill-Olliphant.	Continuing drilling and testing (Brady's and Soda Lake); possible wildcat drilling in adjoining areas.	Possible decision to construct power plant at undecided site; if so, further drilling in 1 or more areas.	Possible construction of plant, with continuing drilling and testing of wells.
Surprise Valley, CA	Approximately 7 holes drilled across several square miles; Magma Power, Gulf Oil; sites for 3 additional holes approved.	Continued drilling and testing; possible wildcat drilling in adjoining areas.	Possible decision to construct power plant; if so, further drilling.	
Long Valley, CA	Approximately 10 holes drilled in limited area; Magma Power; surface exploration continuing; drilling delayed because of environmental and leasing questions.	Leasing and drilling of additional holes; testing of wells.	Probable continued drilling and testing of wells.	Possible decision to construct power plant; if so, further drilling and testing of wells.
Beowawe, NV	Approximately 12 holes drilled in limited area; Magma Power, Chevron; additional holes planned.	Continued drilling and testing of wells; possible wildcat drilling in adjoining areas (Crescent Valley to south).	Possible decision to construct power plant; if so, further drilling and testing.	Possible construction of plant, with continued drilling and testing of wells.

* Source: Geothermal Handbook, 1976. Office of Biological Services, U.S. Fish and Wildlife Service, Department of the Interior, Washington, D.C., p. 70.

TABLE 5-II* (Continued)

FORECAST GUIDE FOR THE MOST ACTIVE GEOTHERMAL DEVELOPMENT AREAS

Area	Development Site	Forecast		
		1975-1976	1977-1979	1980-1985
<u>Low Enthalpy (<200 BTU/lb) Hot Water (T=225°-330°F)</u>				
Klamath Falls, OR	Some 400 holes drilled into hot water aquifer; most utilized for space heating via heat exchanging with pure water; supplies heat to homes, schools, businesses for about 10,000 persons.	Continued occasional drilling and construction of facilities for space heating; possible deep drill hole to test higher enthalpy regime.	Probable continued drilling, with possibility of large-scale heat-exchange project.	Probable continued drilling and testing; possible development of higher enthalpy regime.
Raft River, ID	2 holes drilled in limited area; publicly sponsored research; testing and evaluating aquifer for possible application of binary-cycle heat exchanging.	Continued testing; possible drilling of additional holes.	Possible pilot development of heat-exchanging facilities; possible additional drilling	
Calistoga, CA	Over 60 wells produce hot water for space heating in area of 3 mi ² , 1 deep hole; numerous resorts.	Continued occasional drilling of holes for space heating.	Possible deep drill hole to test higher enthalpy regime; continued occasional drilling of holes for space heating.	
Amedee, CA	2 deep drill holes (Gulf Oil); use of hot water for greenhouse operations.	Possible continued drilling of holes for hot water.	Possible deep drill hole to test higher enthalpy regime.	
Susanville, CA	Publicly sponsored research into large-scale development of hot water heating system.	Possible drilling of 1 or more holes to test extent of thermal aquifer.	Possible drilling of additional holes.	Possible construction of pilot facilities to test suitability of development.
Steamboat Springs, NV	Dozens of shallow wells drilled along 20-mile long zone north to Reno; some used for space heating.	Possible continued drilling of holes for hot water; leasing of federal lands.	Possible deep drill hole to test higher enthalpy regime; continued drilling of holes for hot water.	

* Source: Geothermal Handbook, 1976. Office of Biological Services, U.S. Fish and Wildlife Service, Department of the Interior, Washington, D.C., p. 71.

TABLE 5-II* (Concluded)

FORECAST GUIDE FOR THE MOST ACTIVE GEOTHERMAL DEVELOPMENT AREAS

Area	Development Site	Forecast		
		1975-1976	1977-1979	1980-1985
<u>Low Enthalpy (<200 BTU/lb) Hot Water (T=225°-330°F)(Continued)</u>				
Boise, ID	2 wells in Boise supply hot water for space heating; publicly sponsored research underway into this thermal system.	Possible continued drilling of hot water wells.	Possible deep hole to test higher enthalpy regime; possible continuing drilling of hot water wells.	
<u>Geopressured Aquifers</u>				
Gulf Coast, TX and LA	Evaluation of data from very deep oil and gas wells into hot water aquifers.	Probable continued evaluation of existing data.	Possible drilling of deep exploratory hole.	Possible continued drilling and testing of deep hot water aquifers.
<u>Hot Dry Rock</u>				
Valles Caldera, NM	2 holes drilled west of Caldera as research project by Los Alamos Laboratory; testing and evaluation.	Continued testing and evaluation; probable attempt to generate fractures between holes by pumping water under great pressure.	Continued fracturing and evaluation of results; possible drilling of additional holes.	Possibility of decision to develop pilot facilities for heat exchanging in fractured holes.
In addition to these areas, exploratory test drilling may take place at some or all of the following geothermal targets between 1975 and 1977:				
Black Rock Desert, NV		Cove Fort, UT	Ruby Valley, NV	
Dixie Valley, NV		Buena Vista, CO	Crump-Adel, OR	
Coso, CA		Animas, NM	Vale, OR	
San Emidio, NV		Borax Lake, CA	Weiser, ID	
Lakeview, OR		Bieber, CA	Mountain Home, ID	
Alvord Desert, OR		Wilbur Springs, CA	San Luis Valley, CO	
Grand View, ID		Crescent Valley, NV	Preston, ID	
			Beryl, UT	

Surface exploration is underway at each of these sites, and at very many other places in the western U.S. Details of exploration, and even the precise locations, often are not available, because of the competitive nature of exploration and leasing of lands.

*Source: Geothermal Handbook, 1976. Office of Biological Services, U.S. Fish and Wildlife Service, Department of the Interior, Washington, D.C., p. 71.

TABLE 5-III

U.S. GEOTHERMAL WELLS DRILLED BY PRIVATE DEVELOPERS
(By year and state, The Geysers excluded)

	Pre- 1970	1970	1971	1972	1973	1974	1975	(Sept.) 1976	Total
Arizona					2	2			4
California	44			13	11	8	10		93
Hawaii	5				1				7
Idaho						1	3		5
Montana									0
Nevada	47					6	6		59
New Mex.	3	1	2	3	3	2	3		17
Oregon	2				1	1	1		6
Utah						1	10		12
Wyoming									0
Totals	101	1	2	16	18	21	33	22	214

Source: U.S. Geological Survey, "Geothermal Wells in the United States", R. Witham, M. Reed, Area Geothermal Supervisor's Office, Conservation Division, May 1976.

Some of the organizations that are currently involved in activities related to developing domestic geothermal resources have been identified in a recent survey performed by INFORM, Inc. A summary of their findings that identifies the name of the organization and the major products/services/objectives, that are contributing to the growth of the geothermal industry in the United States, is presented in Table 5-IV. A review of this survey, which was intended to be representative but not comprehensive, shows that fourteen of these organizations are either acquiring land, are supplying steam, are involved in drilling, or are generating power from the dry steam geothermal resource at The Geysers in California. Seventeen companies are shown to be engaged in drilling and exploration or are improving or developing new technology to exploit the liquid-dominated (i.e., hydrothermal) geothermal resources. For example, three companies, Magma Power, J. Hilbert Anderson, and Ben Holt, are developing various types of flash evaporation systems. Scale control, particularly where scale deposits build up on heat exchanger walls and rapidly reduce thermal efficiency, is an area of research and development that has attracted seven of the firms listed in Table 5-IV:

TABLE 5-IV

SUMMARY OF INFORM SURVEY
GEOTHERMAL ENERGY*

COMPANY - BUSINESS	MAJOR PROJECTS AND OBJECTIVES
Aerojet Nuclear Government contractor	Managing a geothermal R&D program, under contract to ERDA, at the Idaho National Engineering Lab at Idaho Falls; no commercial goals.
Amax Miner and producer of metals	Involved in two geothermal drilling and exploration programs, one with Petro-Lewis, and the other with a group of companies; has leased 300,000 acres of potential geothermal land; wants to sell geothermal steam.
J. Hilbert Anderson, Inc. Engineering firm	Has done engineering and design work on wet-steam heat exchangers for Magma Energy; wants to continue contract design work and to license technology it develops.
Arizona Public Service Electric and gas utility	Partially funding Geothermal Kinetics' drilling and exploration in Arizona; wants to buy geothermal steam to generate electricity.
Austral Oil Oil company	Exploring and drilling on its 10,000 acres of potential geothermal land in Colorado; wants to sell geothermal steam.
Bechtel Engineer and constructor of process plants and powerplants	Conducting research into wet-steam systems for ERDA.

*Source: Steward W. Herman, James S. Cannon, and Alfred J. Nalefatto, Energy Futures (INFORM, Inc., 25 Broad Street, New York City 10004).

TABLE 5-IV (continued)

COMPANY - BUSINESS	MAJOR PROJECTS AND OBJECTIVES
Geo-Energy Systems Geothermal-technology development venture	Marketing a patented heat ex- changer to exploit wet-steam; wants to prove and license its technology
Geothermal Kinetics Geothermal development venture	Exploring and drilling in Arizona, Utah, and California; controls 800,000 acres of potential geothermal land, alone and through joint ventures; wants to sell geo- thermal steam.
Geothermal Resources International Geothermal development venture	Providing land for three Standard Oil of California drilling projects; controls 65,000 acres of geothermal land in five states; wants to receive royalties on the sale of geo- thermal steam, and eventually sell steam itself.
Gulf Oil Oil company	Has done some drilling and exploration in California, Oregon, Idaho, and Nevada; controls more than three million acres of potential geothermal land; wants even- tually to sell geothermal steam; no commercial plans at present.
Ben Holt Co. Engineer and constructor	Has designed heat exchangers for wet-steam systems on its own and for the government and for other firms; wants to license technology it develops, and to design and construct geothermal power-plants for clients.

TABLE 5-IV (continued)

COMPANY - BUSINESS	MAJOR PROJECTS AND OBJECTIVES
Magma Power geothermal development venture	Produces and sells geothermal steam to Pacific Gas and Electric, at The Geysers in northern California, in a joint venture with Thermal Power and Union Oil; controls 120,000 acres of potential geothermal property, alone and through joint ventures, in six states; wants to continue to sell geothermal steam.
Morton-Norwich Products food, drug, and chemical producer	Has assigned the rights of its geothermal leases to the Southern Pacific Land Co.; controls 17,000 acres of potential geothermal land; wants eventually to produce salt and energy; no commercial plans at present.
Pacific Energy (affiliate of Hughes Aircraft) geothermal development venture	Has contracted to provide geothermal steam to Pacific Gas & Electric for a planned 55 MW power plant at The Geysers; has leased or subleased over 21,000 acres of potential geothermal property; wants to sell geothermal steam.
Pacific Gas & Electric electric and gas utility	Generates 502 MW of electricity from geothermal steam at The Geysers; wants to increase the electrical capacity of the installation.
Petro-Lewis oil company	Has leased 21,000 acres of potential geothermal property in Colorado; wants to sell geothermal steam.
Public Service Co. of Colorado electric and gas utility	Wants to generate electricity from geothermal steam.

TABLE 5-IV (continued)

COMPANY - BUSINESS	MAJOR PROJECTS AND OBJECTIVES
Rogers Engineering engineer and con- structor specializing in geothermal projects	Designed and built four power plants for PG&E at The Geysers; wants to continue to build geothermal power plants for clients.
San Diego Gas and Electric electric and gas utility	Involved in two joint ventures to exploit the wet geothermal resources of California's Imperial Valley; wants to generate electri- city from geothermal steam.
Shell Oil oil company	Explored and drilled at The Geysers; has leased 4,000 acres of potential geothermal property; wants to sell geothermal steam.
Southern California Edison electric utility	Involved in four joint ventures, with various partners, to exploit wet geothermal resources; hopes eventually to generate electricity from geothermal steam.
Thermal Power geothermal development venture	Produces and sells geothermal steam to PG&E at The Geysers, in a joint venture with Magma Power and Union Oil; has leased 17,000 acres of geothermal property, through joint ventures; wants to continue to sell geothermal steam.
Thermex geothermal land venture	Has bought 75,000 acres of potential geothermal property in six states; wants to acquire more geothermal land, and eventually sell geothermal steam.

TABLE 5-IV (continued)

COMPANY - BUSINESS

MAJOR PROJECTS AND OBJECTIVES

Union Oil

Produces and sells geothermal steam to PG&E at The Geysers, in a joint venture with Magma Power and Thermal Power; controls 120,000 acres of potential geothermal property, alone and through joint ventures; wants to sell more Geysers steam and eventually to develop other deposits.

Ben Holt, Magma Power, Geo-Energy Systems, J. Hilbert Anderson, Aerojet Nuclear, Bechtel and Austral Oil. San Diego Gas and Electric (SDG&E) is constructing a thermal test loop facility (i.e., combination heat exchanger and flash evaporation test system at Niland, California). Rogers Engineering, of California, has explored for hot dry rock in Montana under contract with NSF, and Geo-Energy Systems of Los Angeles is involved in developing a heat exchanger for use with hot dry rock resources.

Power generation companies in various states have shown interest in the application of geothermal energy to the generation of electrical power. These include the Utah Power and Light Company, Portland General Electric Company, Sierra Pacific Power Company and the Nevada Power Company. The greatest interest has developed in the State of California. In that state, at The Geysers geothermal field located about 50 miles north of San Francisco, in excess of 500 megawatts (MWe) of electrical generating capacity is currently installed and is serving the customers of the Pacific Gas and Electric Company. Current plans project a generating capacity increase to about 1900 MWe by the year 1985. Other private organizations and non-Federal entities in California are also projecting development of electrical generating capacity in this same time frame (Table 5-V).

In California, both government and industry are showing particular interest in the development of the Imperial Valley. Such interest is reflected in the activity that is now going on in the Valley in

TABLE 5-V

PROJECTED GEOTHERMAL UTILIZATION (ELECTRIC GENERATING CAPACITY)
IN THE STATE OF CALIFORNIA (MWe)*

Electric	Year	Before									Total
		1978	1978	79	80	81	82	83	84	85	By Utility
Pacific Gas & Electric ¹		502	271	135	220	110	220	110	220	110	1898
Southern California Edison										100	100
San Diego Gas and Electric							50				50
California Dept. of Water Resources ¹								50			50
Northern California Power Agency ¹				55	55	55	55				220
City of Burbank							50 MW (date not given)				50
Cumulative On-Line Power		502	773	1013	1288	1453	1778	1938	2158	2368	2368

¹At Geysers

*SOURCES: Table compiled from data in:

- Jet Propulsion Laboratory, Report on the Status of Development of Geothermal Energy Resources in California, O. Citron et al., 5040-25, California Institute of Technology, Pasadena, California, 31 March 1976.
- MITRE Corporation - METREK Division, Analysis of Geothermal Energy Development Scenarios, Trehan et al., MTR-7220, Westgate Research Park, McLean, VA, November 1976.

terms of experiments, research, and the construction and operation of test facilities. Examples of such activities are listed in Table 5-VI.

The Federal Program is also supporting research activities at various universities and university-associated research groups. These activities are quite varied and range from fundamental and applied scientific efforts to nontechnical issues related to institutional impacts on geothermal development. A partial listing of these activities is provided in Table 5-VII.

TABLE 5-VI

EXAMPLES OF FEDERAL AND NON-FEDERAL
ACTIVITIES IN THE IMPERIAL VALLEY*

Agency	Activity
Union Oil	A flowing geothermal well, with a separator, expansion test equipment, and a reinjection well in the Brawley area.
The San Diego Gas and Electric Company and ERDA (joint effort)	A thermal loop installation near the Salton Sea, to provide design information for binary power systems using high-temperature, high-salinity brines.
ERDA's Lawrence Livermore Laboratory	Development of a total-flow geothermal energy conversion system with emphasis on evaluating nozzle and turbine blade designs to withstand high temperatures and corrosivity of the geothermal fluids near Niland in the Salton Sea area.
Electric Power Research Institute	A feasibility study for a 25 to 50 MW demonstration facility in the Heber area.
ERDA and Sperry Rand Corp. (using a Chevron well)	Field test of the Sperry Matthews down-hole pump system in the Heber area. (R&D development supported by ERDA).

*Source: Extracted from Stahrl Edmunds, "Economics of Geothermal Energy Development in Imperial County, California," Dry Lands Research Institute, University of California, Riverside, October 1976.

TABLE 5-VII

EXAMPLES OF FEDERAL PROGRAM-FUNDED
UNIVERSITY-LEVEL RESEARCH ACTIVITIES

University or Institute	Research Activity
Institute of Geophysics and Planetary Physics (University of California)	Geological, geochemical and geophysical investigation of the Salton Sea Geothermal field.
University of New Mexico	Experiments on the deep electric resistivity coupled with hot dry rock geothermal resources in New Mexico.
University of Texas at Dallas	Experiments for evaluation and improvement of seismic ground noise prospecting method for geothermal energy.
Stanford Research Group	Stimulation and reservoir engineering of geothermal resources.
Princeton Research Group	Computerized performance evaluation of geothermal reservoirs.
University of Colorado	Study of the geothermal basin problem: transport of mass and energy due to natural convection in the geothermal field.
Northwestern University, Evanston, Illinois	Experiments on heat extraction from hot dry rock geothermal resources.
University of California, Riverside	Behavior of geothermal field hydrogen sulfide (H_2S) gas emissions in the atmosphere and its effect on vegetation.
School of Law, University of California, Berkeley	A study on the legal and economic aspects of geothermal development.

TABLE 5-VII (Continued)

EXAMPLES OF FEDERAL PROGRAM-FUNDED
UNIVERSITY-LEVEL RESEARCH ACTIVITIES

University or Institute	Research Activity
University of California, Riverside; and The Environmental Quality Laboratory of California (joint effort)	Assistance with inputs to the general plan for geothermal development in Imperial County.
Utah State University	Water resource management alterna- tives for hydropower and geothermal development.
University of California	An evaluation of the effects of geothermal energy development on aquatic biota in The Geysers area of California.
University of Arizona	Geothermal water resources in Arizona: feasibility study.
University of Nevada	Evaluation of geothermal activity in the Truckee Meadows, Washoe County, Nevada.
University of Nevada	Nevada geothermal resource areas: a preliminary biological survey.

SECTION 6

FUTURE PROGRAM PLANS

The direction of the Federal Geothermal Research, Development, and Demonstration Program for the near future will continue to be in three major areas:

- o Resource Exploration and Assessment
- o Technology Development
- o Institutional Development

While some of the activity described in this section is generally applicable to the development of geothermal energy utilization, much of the activity will be specific to the geologic provinces where the different types of geothermal resources are located.

REGIONAL PLANNING WITHIN THE FEDERAL PROGRAM

Geothermal resources are distributed in such a way that they may properly be called localized or regional resources. Thus, many of the problems of exploiting geothermal energy are of a local or regional nature. ERDA is addressing these problems through regional planning and analysis, which will receive added emphasis in the near future. A series of regional studies in California, in the eastern states, and in the Texas-Louisiana Gulf Coast region have been initiated. Other studies will follow in the Southwest and in the Northwest.

The future energy needs of each local area will be identified, along with the problems, requirements, constraints, etc., that are related to that area. The local area information will be aggregated and then used to develop alternative scenarios for geothermal growth. In these scenarios, the most promising geothermal resources will be considered and the differing sets of conditions or hypotheses suitable to each region or subregion will be reflected. These studies will be conducted in close cooperation with state and local authorities, industry, and various special interest groups. Sensitivity and cost/benefit analyses will indicate which mix of programs will be the most effective on both national and local scales. Priorities will be assigned to the scenarios that hold the most promise for furthering the goals of the national geothermal effort. The results of these studies will be used to refine and regionalize Federal program strategies and plans.

RESOURCE EXPLORATION AND ASSESSMENT

Geothermal Characterization

A clearer understanding of geothermal phenomena and characteristics of major geothermal systems and reservoirs will be obtained through:

- o Studies basic to the understanding of the geothermal process
- o Studies of regional and local geological environments
- o Studies in hydrology and geothermal reservoir engineering

The studies basic to the understanding of the geothermal process deal with the fundamental processes and the ways in which they are combined in natural systems. They include:

- o Development and verification of geodynamic models of heat generating mechanisms
- o Storage and transfer of heat by magmas
- o Transport and storage of energy and mass by circulation of liquids
- o Determination of reliable physical and thermodynamic properties of rocks, magma, and liquids
- o Chemical studies of geothermal fluids including major elements, trace elements, and isotopes.
- o Experimental studies on the geochemical interaction of water and rock
- o Studies of the mechanical behavior and permeability of rocks at different temperatures and pressures.

Regional studies will delineate the boundaries of the geologic environments (i.e., determination of the geological age, tectonic deformation and volcanism, and heat-flow patterns) of geothermal systems. They will focus on four areas:

- o Those exhibiting active and recent volcanism, and active and recent tectonics. This includes areas such as the Snake River Plain (Idaho), the Eastern margin of the Sierra Nevada, the Wasatch front, the volcanic terrain around the Southern margin of the Colorado Plateau, the Cascades, the volcanics of Southeastern Oregon, and the Aleutian (Alaska) and Hawaiian Chains
- o Those that have a high regional heat flow. This includes the Great Basin Region, the Rio Grande Rift (New Mexico), and the Imperial Valley (California);

- o Large sedimentary basins with geopressed formations. This includes the Gulf Coast Region (Texas and Louisiana)
- o Crystalline basement terranes in regions of normal heat flow. Terranes with high radiogenic heat flow near energy markets will get special attention

Detailed local studies will be carried out on systems representative of each major type of geothermal environment. Table 6-1 indicates the main parameters for selecting critical areas to investigate and a time frame for assigning priorities to the types of geothermal systems in which detailed studies are needed.

Studies in subsurface hydrology and geothermal reservoir engineering will be used to develop a methodology for forecasting the long-term response of a geothermal system to development. The basic processes operating in a geothermal system, including the material properties of the fluids and reservoir rocks, will be investigated, and mathematical modeling to match known performance and to forecast behavior will be undertaken. In the United States, only The Geysers, a vapor dominated system, has undergone sufficient development to provide adequate performance data. Adequate validation of models for a high-temperature liquid-dominated hydrothermal system will require complete production data from the Wairakei (New Zealand) and the Cerro Prieto (Mexico) geothermal fields.

Efforts by the USGS in resource characterization will be increased in FY 77 and beyond. The subsurface environmental impact

TABLE 6-I

PARAMETERS AND PRIORITIES FOR DETAILED LOCAL STUDIES OF GEOLOGIC ENVIRONMENTS TO CHARACTERIZE GEOTHERMAL SYSTEMS

	Status of Information ^{1/}			National Resource ^{2/} Importance		Significance ^{3/} Of Federal Effort	Priorities for Research in 5-Year Time Frames ^{4/}				
	Selection Of Type Localities	Local Studies (May Include Intermediate-Depth Drilling)	Confirmation Of Models (May Include Deep Drilling)	Short-Term	Long-Term		1977-1981	1982-1986	1987-1991	1992-1996	1997-2001
Geopressured sedimentary basins (e.g. Gulf Coast)	B	C	D	B	A	A	H	H	M	M	L
Environments of regionally high heat flow (e.g. northern Great Basin, Rio Grande Rift)	B	C	D	B	A	C	H	H	M	L	L
Large young basaltic volcanic systems (e.g. Snake River Plain, Hawaii)	B	C	D	C	B	B	H	H	M	M	L
Large young silicic volcanic systems with calderas (e.g. Long Valley, Valles, Island Park)	A	B	D	A	C	D	H	L	L	L	L
Large young silicic volcanic systems without calderas (e.g. Coso, Roosevelt, Clear Lake)	A	B	C	A	B	D	M	M	L	L	L
Active plate-margin rift (e.g. Imperial Valley)	A	A	B	A	A	D	L	L	L	L	L
Large andesitic stratovolcano (e.g. Cascades, Aleutian chain)	C	D	D	C	B	B	L	L	H	M	M
Partially cooled silicic pluton (e.g. southeastern Oregon)	D	D	D	D	C	A	L	L	L	H	M
Buried radiogenic heat source (e.g. Appalachian region)	C	D	D	C	D	A	M	L	L	L	L

^{1/} Status of information: A=well understood, D=poorly understood^{2/} National resource importance: Short term=before 1987; A=high relative importance, D=low relative importance.^{3/} Significance of Federal effort: A=Federal effort essential, D=Federal effort needed mainly to spur industrial effort^{4/} Priorities for research: H=high priority or high level of effort desired in time frame, L=low level of effort desired in time frame.

research activities will also be accelerated. The expected target dates for the various near-term USGS resource characterization and subsurface research activities are given in Table 6-II.

Exploration and Assessment Technology

Improved exploration and assessment technology involves:

(1) optimization of exploration strategy and (2) development of new exploration and assessment methods. These are needed to accelerate the identification of geothermal resources, to verify their utilization potential, and to evaluate candidate geothermal sites for commercial development.

Optimization of exploration strategy will be critically dependent on the results of the regional and local geological studies since they will define the nature of the resource being sought and the principles that determine its occurrence. In its planning and execution of exploration programs, industry can be expected to take note of the results of local and regional studies of the Federal Program and to utilize new and improved exploration methods and techniques for the integrated interpretation of data. It is anticipated that emphasis on the development of exploration strategy will receive increasing emphasis during the near term.

Specific areas for research and development of new exploration and assessment methods include:

- o New or improved geologic methods of dating young volcanic rocks

TABLE 6-II

EXPECTED DEVELOPMENTS IN USGS GEOTHERMAL RESEARCH PROGRAM

<u>Program Activity</u>	<u>Target Date</u>
Completion of Resource Data Bank	1978
Detailed Characterization in Snake River, Idaho, Plain and Gulf Coast Areas (Texas, Louisiana, Mississippi)	1978
Detailed Characterization in Northern Basin and Range Province, parts of Oregon, Nevada, Idaho, Utah and in Imperial Valley, California	1979
Detailed Characterization in the Cascades, parts of Oregon and Washington, and The Geysers, California	1980
Complete Seismic-Subsidence-Hydrologic Models for Hydrothermal and Geopressured Zones	1979
Complete Geochemical Models for Subsurface Permeability	1980
Validation of Models against Reservoir Data	1981

- o Development and testing of geochemical methods to locate "blind" geothermal deposits with no apparent surface features; geothermometers for evaluating systems with surface hydrothermal expressions; and analytical instruments for quicker, cheaper, more accurate analysis of chemical and isotopic constituents in ground water
- o Improvements in data interpretation of gravity and magnetic methods currently in use
- o Measurements of electrical properties of rocks at moderate to great depths along with improvements in magnetotelluric equipment and data processing
- o Continued development of remote-sensing methods
- o Continued development of both active and passive seismic exploration methods and new and improved methods of data interpretation
- o Development of methods to apply heat-flow techniques as exploration tools
- o Development of methods, techniques, and instrumentation to improve the information that is obtained from wells during and after exploratory drilling

Geothermal Resource Inventory

It is the policy of the Federal government to maintain up-to-date assessments of the Nation's energy resources, including geothermal. Accordingly, the future Federal geothermal resource assessment program includes specific tasks for systematic data acquisition and collation, with a revised geothermal resource inventory to be produced at appropriate intervals. The 1975 geothermal resource assessment (i.e., USGS Circular 726) provides a model upon which the resources inventory planned for 1978 will be based.

Proposed future programs include tasks that will provide data to support the 1978 Geothermal Resource Inventory. These tasks include:

- o Refinements of the temperatures, areas, and depths of the known hydrothermal convection systems, including the low-temperature systems ($<90^{\circ}\text{C}$) that were cataloged but not evaluated in the 1975 assessment
- o Acquisition of data on new systems not yet discovered or found to be larger or deeper than was assumed in 1975
- o Implementation of a coordinated system of computer-based geothermal storage and retrieval incorporating the present GEOTHERM and GRID
- o Acquisition and collation of data on by-products associated with geothermal resources
- o Continued evaluation of the geopressured resources of the Gulf Coast
- o Refinement of the estimates of size and age of young igneous anomalies
- o Systematic evaluation of the regional distribution of heat flow and heat production
- o Refinement of methods for estimating magnitudes of undiscovered resources of all types
- o Refinement of methods for estimating the recoverability of energy from various types and categories of geothermal systems

It is recognized that some of these proposed tasks will continue beyond the 1978 inventory. Those tasks that continue will provide updated information for a periodic review, at three-year intervals, of the extent and character of the Nation's geothermal resource. It is anticipated that the effort on these tasks will peak in 1978 with a somewhat lesser effort before and after.

The main milestones and their associated target dates for the near-term overall regional assessment and National Inventory are shown in Table 6-III. In addition, three future site-specific programs are being initiated by ERDA. These involve industry, state authorities, and Federal agencies in cooperative efforts designed to assess the potential of various types of geothermal reservoirs.

These programs are:

- o An industry-coupled program designed to involve industry on a cost-sharing basis in studies of potentially significant geothermal resources.
- o A precommercial program that involves reservoir assessment activities in sites which, for a variety of institutional or technical reasons, are not being investigated by industry.
- o A nonelectric reservoir program that is being initiated, largely with state authorities, which will stimulate the assessment of individual reservoirs that appear to have a marked potential for nonelectric utilization.
- o A reservoir engineering program (a continuation and expansion of the NSF reservoir program) that will include an emphasis on reservoir case studies of locations, such as Cerro Prieto (Mexico), Raft River (Idaho), Salton Sea (California), and Roosevelt Hot Springs (Utah).

TECHNOLOGY DEVELOPMENT PROGRAM

Demonstration Program

A commercial-scale demonstration project, a measure made available to the Federal Government by the Geothermal Research, Development, and Demonstration Act of 1974 (Public Law 93-410) for stimulating the commercialization of geothermal energy, is to be initiated in FY 78, if authorized by the Congress as explicitly required by Public Law 93-410.

TABLE 6-III

FUTURE USGS NATIONAL AND REGIONAL RESOURCE ASSESSMENT
MILESTONES AND TARGET DATES

<u>Program Activity</u>	<u>Target Date</u> (FY)
<u>USGS Regional Assessment</u>	
1. Completion of major phases of regional appraisals for California	1977
2. USGS Circular 726 Update	1978
3. Completion of major phases of regional appraisals for Hawaii, New Mexico, Utah, Arizona and the Gulf Coast	1978
4. Completion of major phases of regional appraisals for Washington, Colorado, Montana, and Wyoming	1979
5. Completion of major phases of regional appraisals for central and eastern U.S.	1980

The need for demonstration projects is greatest in those cases where there are significant technical and economic risks in proceeding from pilot to commercial-scale plants, and when the Loan Guaranty Program does not qualify as an appropriate alternative risk-reducing mechanism. It is also critically important to be able to offer convincing evidence of acceptability to public utility commissions and to the electric utility industry, by demonstrating reliability at acceptable costs. Without the industry's participation in the accelerated construction of power plants, the development of geothermal resources will continue to be slow.

On the basis of the outcome of existing programs, of the surveys of the industrial-user community, and of preliminary conceptual design studies, ERDA is convinced that the implementation of the demonstration program is now timely. It is an essential part of the Federal geothermal program strategy and plan.

A first demonstration project for the hydrothermal resource is planned for FY 78 to help resolve the many technical and nontechnical issues associated with a first-of-a-kind commercial-scale plant. Further analyses will be conducted in FY 77 to determine the desirability of additional demonstration projects, particularly for other resource types. Program Opportunity Notices will be issued for demonstration plants, as and if approved, to indicate ERDA's intent to

undertake these projects. These projects will involve joint industry and government funding.

The first 50 MW geothermal demonstration plant would be designed to confirm the technical reliability and economic feasibility of an electric power plant using a high-temperature, low- to moderate-salinity resource with a binary or flashed steam power conversion cycle.

With the initiation of project activities in FY 78, the demonstration plant could be made operational as early as the end of FY 81 or mid-1982. The Federal interest in the plants would be disposed of after the demonstration objectives are completed, as required by P.L. 93-410. The major activities are shown with their associated target dates in Table 6-IV.

R&D Test Facilities

Niland. Achievement of the near-term goals for hydrothermal electric power generation will depend primarily on using the liquid-dominated resources, particularly those yielding the highest temperature fluids that ensure a low unit cost for electric power. The largest presently known reservoir of the highest temperature brine within the U.S. is located in the Salton Trough region near Niland, California. Unfortunately, the utilization of these hot high-salinity brines present scale, corrosion, and other technical problems. However, the potential size of the hot water geothermal resource at Niland and its possible early utilization have motivated ERDA to

TABLE 6-IV

ERDA'S COOPERATIVE, COMMERCIAL SCALE DEMONSTRATION PROJECTS
MILESTONES AND TARGET DATES

<u>Program Activity</u>	<u>Target Date</u> (FY)
<u>Demonstration Plant #1</u>	
Start of Site Planning and Design	Early 1978
Start of Plant Construction	Early 1980
Start of Plant Operation	Mid-1982

establish a jointly funded geothermal loop experimental facility to examine these technical problems. This thermal loop test facility using a flashed-to-binary energy conversion cycle with the hypersaline brines of the reservoir near Niland, California was placed in service in June 1976. The thermal loop test programs will continue until mid-1978, after which the facility may be converted to a pilot plant by the addition of a hydrocarbon (working fluid) turbine with generator (Table 6-V).

A Geothermal Component Test Facility is also being considered as part of ERDA's near-term plans for the Niland site. This component test facility will enable industry, government, and individual innovators to test prototype components and subsystems using the hypersaline brines of the reservoir near Niland, California.

Raft River Moderate-temperature (90-150°C) resources are more abundant and widely distributed geographically and present minimum corrosion and scaling problems. Use of these resources, in the upper temperature range, for electric power generation is considered feasible, but advanced energy extraction/conversion technology is required for economic production of electricity. Plans have been developed for the design, construction, and operation of a 10 MW electric equivalent thermal loop facility using the moderate-temperature low-salinity reservoir at the Raft River site near Malta, Idaho, to test the suitability of a dual-boiling binary cycle energy conversion system to generate electric power. The experimental facility will be installed sequentially in two increments of 40 MW thermal units (each

TABLE 6-V

ERDA TEST FACILITIES AND PILOT PLANT PROJECTS
MILESTONES AND PROJECTED TARGET DATES

<u>PROGRAM ACTIVITY</u>	<u>PROJECTED TARGET DATE, FY</u>
<u>High-Temperature Resource Geothermal Loop Experimental Facility, Niland, CA</u>	
o Thermal test loop, tests complete	1978
o Fabrication and installation of hydrocarbon turbine and generator	1978
o Pilot plant - begin operation	1979
<u>Moderate-Temperature Resource Thermal Loop Facilities, Raft River, Idaho</u>	
o Begin construction of first 40 MWt facility	1978
o Begin construction of second 40 MWt facility	1979 Last quarter
o Operation of first facility	Last quarter 1980
o Operation of second facility	Last quarter 1981
<u>Hydraulic Fracturing Technology Development (Fenton Hill), New Mexico</u>	
o Permeable rock technique development, Begin	First quarter 1980
o Hydraulic fracturing technology verification, Complete	First quarter 1981
o 10 MWt experiment Complete	Mid 1978

TABLE 6-V (Concluded)

ERDA TEST FACILITIES AND PILOT PLANT PROJECTS
MILESTONES AND PROJECTED TARGET DATES

<u>PROGRAM ACTIVITY</u>	<u>PROJECTED TARGET DATE, FY</u>
<u>100 MWt Heat Extraction Test Facility</u>	
o Construction Complete	Mid 1979
o Government operation of facility Complete	Mid 1982

equivalent to 5 MW of electric power). The first unit will employ currently available hardware; the second unit will provide for testing of advanced design heat exchangers and related advanced technologies. Work toward the development of a pilot-scale moderate-temperature electric power plant at the Raft River site involves cooperation and cost-sharing with the State of Idaho, the Northwest Public Power Council, and the local rural electric power cooperative.

Fenton Hill. Detailed knowledge of hot dry rock resources is presently limited to one site at Fenton Hill, in the Jemez Mountains of New Mexico, where hydraulic fracturing technology is being tested by ERDA's Los Alamos Scientific Laboratory (LASL).

In FY 77 a 10 MW thermal loop experiment is expected to test the feasibility of a thermal crack propagation concept, in which rapidly circulating heat transfer fluids would cause additional fracturing of the hot rock mass due to differential cooling and induced thermal stresses. If this experiment is successful, a 100 Mwt heat extraction test will be proposed. The target dates for each of the above-mentioned test facilities and the pilot plant are indicated in Table 6-V.

Advanced Technology Applications

The geopressured resources program is at present focused on defining the resource characteristics. In FY 77 a three-dimensional computer model of geopressured resources will be completed. This model will use data from existing well logs and seismic surveys to produce maps characterizing promising onshore geopressured aquifers. During FY 77

and FY 78, several geopressured well production tests are planned to be conducted using either existing wells, new wells designed specifically for geopressured water production, or new wells drilled for conventional hydrocarbon production but dedicated temporarily to geopressured aquifer tests. Several tests are needed, since resource characteristics are known to vary considerably across the region.

These experiments will provide information on fluid composition, gas content, and formation response to production conditions. Of particular interest are the phenomena of sand production (which can damage equipment), and formation compaction (which can lead to land surface subsidence). If research on the quantity and quality of the resource indicates a substantial potential for electric power production, component test facilities and a pilot plant to test conversion technology will be constructed. By the end of FY 79 enough data should have been obtained to support a major decision whether to proceed with development and demonstration of a technology to utilize the resource.

Regardless of the potential for electric power generation, there is believed to be a significant prospect for methane production and for direct application of geopressured geothermal heat to Gulf Coast industry and agribusiness. Market and process heat studies now under way will further define this potential in FY 77.

Brine Replacement Source Studies

The increasing salinity of the lower Colorado River led to the enactment of Public Law 93-320, The Colorado River Basin Salinity

Control Act, which establishes a requirement to reduce the salinity of the river at the Mexican boundary to acceptable levels. Studies concluded that one way to reduce the salinity was to desalinize the Welton-Mohawk drain water. A feasibility study of a desalting plant at Yuma, Arizona is being carried out. The desalination process would remove about 40,000 acre-feet/yr of concentrated brine from the river, leaving a shortfall in river flow. One of the proposals to make up the shortfall is to utilize fresh water from desalted brine from the East Mesa KGRA. Studies will be made of the technical and economic data provided by the Bureau of Reclamation's test desalting facility completed at East Mesa in FY 76. These studies will help to determine whether the brines of the East Mesa KGRA can be utilized to provide fresh water to satisfy the Colorado River Basin Salinity Control Act.

Brine Chemistry and Materials Research (Geochemical Engineering Research)

Closely related to the operations at test and pilot facilities is a new ERDA-sponsored industrial program. The program will seek to develop materials guidelines to reduce the deleterious effects of geofluids on equipment in facilities of the future. The effort for FY 77 will coordinate the materials selection for specific source chemistries and generate and maintain a Geothermal Systems Materials Design and Operations Guideline. The first edition of this logical grouping of materials, environmental parameters and experimentally determined limitations will provide a concise reference for geothermal

plant materials selection and operational guidelines. Energy conversion systems will be subdivided into major components. For each equipment subdivision, the specific information regarding the various failure mechanisms of scaling, pitting, stress corrosion, corrosion fatigue, impingement, cavitation, erosion-corrosion, crevice corrosion, embrittlement etc., would be listed for the potential design materials.

Environmental Effects and Abatement Technology

Future activities will provide a timely environmental, health, and safety support program to meet the anticipated future expansion in geothermal resource development and utilization. Specifically, these programs will include preparation of environmental assessment and impact statements for proposed ERDA-sponsored geothermal facilities, and for nonelectric field experiments, thermal loop experiments, and confirmatory test drilling projects. These programs will also cover the development of environmental, health, and safety criteria, guidelines and standards among Federal, state, and local agencies and for monitoring guidelines.

The major contributors to the foregoing programs are ERDA and the Environmental Protection Agency (EPA).

The ongoing efforts of ERDA include the development of brine disposal and subsidence research programs, with plans to implement specific projects under these tasks in the latter part of FY 77. Removal of hydrogen sulfide from geothermal brines by oxidation and a

scrubbing process to reduce hydrogen sulfide concentrations in geothermal steam are currently being investigated. Direct application of the steam scrubbing processes will begin in a field test facility in FY 77. Cooperation with the Italian ENEL Commission in hydrogen sulfide and radon monitoring studies at the Larderello field in Italy began in late 1976.

Other ERDA environmental research tasks currently in progress include the gathering of microseismic and water quality data to monitor the progress of hot dry rock hydrofracturing experiments. A broad spectrum of environmental research, including air and water quality surveys and archeological/socioeconomic studies, is being conducted as part of the DGE Raft River geothermal project. Regional environmental characterization studies support is being provided by AES in the Imperial Valley and will be extended to cover other geographic areas of prime interest to the Geothermal Energy RD&D program.

In addition, ERDA will support the development of environmental criteria and standards that will identify environmental consensus guidelines which provide the basis for development of control technology. Development of new standards applicable to ERDA contractors will be initiated for areas in which consensus standards are lacking.

Guidelines to the preparation of environmental reports for geothermal development projects will be published in FY 77, and guide-

lines for environmental monitoring of such projects are scheduled for issuance in FY 78.

The future research activities of EPA will address geothermal energy control technology, evaluation, and regulation of pollution as well as geothermal environmental impact assessment. A waste emission and control technology field survey of existing development sites will be conducted in FY 78 to assess ecological effects and control options. The sampling collection for the baseline study around the San Diego Gas and Electric Power Plant in the Imperial Valley will also be completed during the same fiscal year. Other efforts in FY 77 include the development and subsequent implementation of a ground-water monitoring strategy for the East Mesa area and the Imperial Valley in California.

EPA intends to propose post-operational residue monitoring in the Imperial Valley in FY 79, and later (i.e., FY 80 and beyond) in Roosevelt Hot Springs and Raft River. These monitoring efforts would continue to be updated to FY 83. A report on baseline air monitoring data at Roosevelt Hot Springs and the Raft River area would be expected in FY 79. Another report on air monitoring strategy would follow in the same fiscal year.

The projected milestone and target dates for the major near-term activities of each ERDA and EPA are shown in Table 6-VI.

Nonelectric (Direct) Application of Geothermal Energy

The direct application of geothermal energy in the United States began during the 1890s with a district heating system in

TABLE 6-VI

FUTURE PROGRAMS
FOR
ENVIRONMENT, HEALTH, AND SAFETY

<u>Program Activity</u>	<u>Projected Target Date (FY)</u>
<u>ERDA: Environmental Control Technology Research</u>	
o Hydrogen sulfide system tests	Mid 1978
o Subsidence control technology and brine disposal tests	Mid 1979
<u>Environmental Criteria and Standards</u>	
o Publish guidelines for environmental reports for geothermal development projects	1977
o Publish guidelines for environmental monitoring of geothermal develop- ment projects	1978
<u>EPA: Environmental Control Technology Studies</u>	
o Characterize geothermal wastes and available technology	Mid '77
o Waste emission and control technol- ogy field survey at existing development sites--assess control options	2nd Quarter 1978
o Assess environmental and regulatory implications of multiple uses at specific sites	1st Quarter 1978
o Compile state-of-the-art control technology information and assess ecological effects	2nd Quarter 1978
o Control technology evaluation	Mid '78

TABLE 6-VI (Concluded)

FUTURE PROGRAMS
FOR
ENVIRONMENT, HEALTH, AND SAFETY

<u>Program Activity</u>	<u>Projected Target Date (FY)</u>
<u>Environmental Impact Analyses</u>	
o Sample collection for the base- line study around San Diego Gas and Electric power plant in the Imperial Valley	1st Quarter 1978
o Post-operational residue monitoring in Imperial Valley	1979-1982
o Post-operational residue monitoring Roosevelt Hot Springs and Raft River	1980-1983
o Development of a strategy for biological monitoring	2nd Quarter 1982
o Groundwater monitoring strategy and methodology for East Mesa Area	Last Quarter 1977
o Implementation of groundwater monitoring strategy in Imperial Valley, California	2nd Quarter 1978
o Report on baseline air monitoring data at Roosevelt Hot Springs and Raft River	1st Quarter 1979
o Report on air monitoring strategy	1st Quarter 1979

Boise, Idaho. Klamath Falls, Oregon, also uses geothermal energy to heat houses and businesses. At present the combined rate at which energy can be supplied in both cities is less than 15 megawatts.* Other examples of the direct application of a geothermal resource in the United States include heating greenhouses and warming fish-breeding ponds. Direct use of geothermal heat in several industry sectors has been successfully demonstrated abroad. ERDA is fostering diverse applications of the direct use of geothermal energy in the U.S. to encourage wider utilization of the low- to moderate-temperature geothermal resources. A total of 18 projects performed by private industry, universities, and state and local governments have been initiated by ERDA to conduct engineering and economic feasibility studies of a number of nonelectric applications of geothermal heat in FY 77. The applications include food production and processing, sugar refining, fertilizer production, refrigeration for food processing, residential space conditioning, salmon aquaculture, and integrated industrial-agricultural complexes. Additional studies and application experiments are anticipated in FY 78 and beyond. Early indications are that direct thermal applications may have much greater potential than had been anticipated and will merit closer attention.

*SOURCE: J. N. Howard, "Principal Conclusions of the Committee on the Challenges of Modern Society Non-Electrical Application Project," Lawrence Livermore Laboratory, University of California, Livermore, CA, May 1975.

INSTITUTIONAL DEVELOPMENT

Federal Leasing Program

At the present rate of lease issuance, the major backlog of Bureau of Land Management applications will be removed by the end of FY 77. The leasing rate of United States Forest Service administered lands should maintain at least its present level through FY 78. After FY 79 it is expected that the continuing leasing level will be dependent on the success of the exploration programs that will be conducted on presently leased lands.

Geothermal energy has attracted various oil companies and small geothermal ventures, who find their plans enmeshed in Federal policies, regulations, and actions. To ease this situation, the BLM is taking the initiative to implement various measures that are intended to speed up the Federal land leasing process. The BLM is in the process of formulating regulations governing future power plant siting on Federal leases to encourage more participation of the utilities in geothermal development. Proposed amendments of the Geothermal Steam Act of 1970 increase the acreage limitation per state from 20,480 acres per lessee to 51,200 acres. This reduces the financial risk accepted by industry by broadening the area of potential exploration in each state.

Loan Guaranty

As expected, initial reaction to the implementation of the Loan Guaranty Program in FY 76 indicated favorable acceptance by

both the financial community and the smaller, independent geothermal resource developers. Growth in the use of the guaranty is expected to increase. Methods for improving the implementation of the Program are under study.

SCIENTIFIC AND TECHNICAL EDUCATION PROGRAM

In FY 77 the National Science Foundation is broadening the scope of its energy-related program to include all national needs; geothermal energy is an eligible area. The Foundation is planning to offer the following energy-related support in FY 77:

- o 70 graduate traineeships
- o 150 faculty fellowships
- o 100 postdoctoral fellowships

Of these, a few could reasonably be expected to be applicable to geothermal energy.

In FY 77 the Undergraduate Research Participation Program will continue to consider proposals for energy-related research as well as proposals in other areas. Beyond FY 77 the Foundation will continue its role of supporting the education of persons in scientific disciplines, many of which support the nation's energy enterprises.

ERDA will begin in FY 77 a comprehensive assessment of the utilization and needs for specially trained and skilled manpower in geothermal energy R&D. The assessment will provide baseline data on current employment across the various components of the geothermal

enterprise, a profile of occupational characteristics, and an estimate of future requirements in each occupational category. Such in-depth manpower assessments in all energy fields, including geothermal, will be updated regularly and will provide a basis for recommending the type and magnitude of necessary education and training assistance.

APPENDIX A

COMPARISON OF PROVISIONS OF PL 93-410,
THE GEOTHERMAL PROGRAM AS DEFINED IN ERDA-86, ERDA'S AND
OTHER AGENCIES' ACHIEVEMENTS IN FY 76 IN SUPPORT OF THE PROGRAM

APPENDIX A

COMPARISON OF PROVISIONS OF PL 93-410, THE GEOTHERMAL PROGRAM AS DEFINED IN ERDA-86, ERDA'S AND OTHER AGENCIES' ACHIEVEMENTS IN FY76 IN SUPPORT OF THE PROGRAM

PL 93-410	ERDA-86	IMPLEMENTATION ACTION	ACHIEVEMENTS IN FY '76 ERDA AND OTHER AGENCIES
<u>Title I</u>			
<u>Sec. 101 Establishment</u>			
(Establishes, specifies the composition of, and delineates the authorities of the Geothermal Coordination and Management Project (GCMP).)		Program established, operated until the transfer of its functions to ERDA pursuant to Title 3, Sec. 303 of PL 93-410.	
<u>Sec. 102 Program Definition</u>			
(a)(1) The Chairman (of GCMP), acting through the Administrator of NASA, is authorized and directed to prepare a comprehensive program definition of an integrated effort and commitment for effectively developing geothermal energy resources.	"The Definition Report, ... (ERDA-86), has been prepared in response to the requirements of ... PL 93-410," (Forward, P ii) "... This definition report is in response to this mandate." (P I-3)	ERDA supported the NASA effort with \$636K in FY '75 and \$296K in FY '76. The NASA report was modified to reflect late information on resources and a strategy for their effective exploitation.	
(a)(2) (Sets reporting schedule)		The Definition Report has been submitted to the Congress in October, 1975.	
(a)(3) As part of the comprehensive program definition required by para.(1), the Chairman, acting through the USGS, shall transmit...	Pg III-8 of Definition Report gives order of assessment, (ERDA-86) states major phases will be completed by end of 1980.	USGS has published Circ. 726, "Assessment of Geothermal Resources of the United States - 1975," and plans to complete a more detailed and more accurate assessment by the end of 1978.	

APPENDIX A (CONTINUED)

COMPARISON OF PROVISIONS OF PL 93-410,
THE GEOTHERMAL PROGRAM AS DEFINED IN ERDA-86, ERDA'S AND
OTHER AGENCIES' ACHIEVEMENTS IN FY76 IN SUPPORT OF THE PROGRAM

PL 93-410	ERDA-86	IMPLEMENTATION ACTION	ACHIEVEMENTS IN FY '76 ERDA AND OTHER AGENCIES
<p><u>Sec. 102 (Cont'd.)</u></p> <p>schedule and objectives for the inventorying of geothermal resources.</p>			
<p><u>Sec. 103 Resource Inventory and Assessment</u></p> <p>(a) The Chairman shall initiate a resource inventory and assessment program... The specific goals shall include --</p>			
<p>(1) The improvement of ... techniques necessary for locating and evaluating G/T resources;</p> <p>(2) The development of better methods for predicting the power potential and longevity of G/T resources;</p>	<p>The Assessment and Exploration Technology effort is directed toward "... the development of the instrumentation and analysis techniques for improving the capability to locate and determine the energy potential of geothermal reservoirs from surface and near surface measurements." (P III-4)</p>	<p>ERDA and its predecessor agencies obligated \$2.1M in FY '75 for this effort. Support for the development of assessment technology was increased to \$2.34M in FY '76.</p>	<p><u>Resource Assessment and Exploration Technology</u></p> <ul style="list-style-type: none"> • In FY '76 particular emphasis was given by ERDA to develop appropriate mixes of surface and downhole instruments and techniques. ERDA is also supporting the on-going development of acoustical drill monitoring for wireless transmission of downhole data during drilling. (Sec. 2, P 18) • USGS has developed: (1) passive seismic technique that was tried at Coso to help locate potential geothermal sources in this area.

APPENDIX A (CONTINUED)

COMPARISON OF PROVISIONS OF PL 93-410,
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PL 93-410	ERDA-86	IMPLEMENTATION ACTION	ACHIEVEMENTS IN FY '76 ERDA AND OTHER AGENCIES
<u>Sec. 103 (Cont'd.)</u>			<p data-bbox="1541 597 1864 849">(2) the use of magnetotelluric techniques as a promising tool for rapid, cheap and reliable reconnaissance method, (3) a geothermometer to estimate sub-surface temperature in geothermal systems. (Sec 2, P 18)</p> <ul style="list-style-type: none"> <li data-bbox="1514 870 1845 963">• Several reservoir assessments and confirmation activities are in progress. These include: <li data-bbox="1514 984 1855 1393">• (1) Initiation of static and dynamic well tests of geopressed reservoirs; (2) development of a computerized reservoir performance model, (3) heat-flow mapping of the Western portion of the Rio Grande Rift through New Mexico and Southern California, (4) on-going heat flow mapping in Steamboat, Lemci Rock area of Skamania

APPENDIX A (CONTINUED)

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PL 93-410	ERDA-86	IMPLEMENTATION ACTION	ACHIEVEMENTS IN FY '76 ERDA AND OTHER AGENCIES
<u>Sec. 103 (Cont'd.)</u>			County, Washington. All NSF/RANN on-going activities are now either supported by ERDA or were trans- ferred to ERDA.
(3) The determination and assessment of the nature and power potential of the deeper unexplored parts of high temperature G/T convection systems;	The Geoscience Research effort "is con- cerned with understanding the geothermal processes in the earth's crust and their associated manifestations." (P III-4)		<p><u>Geoscience Research</u></p> <ul style="list-style-type: none"> Resource characterization program of USGS for FY '76 has included: <ol style="list-style-type: none"> (1) an estimation of true salinities of formation water samples from geopressured zones in Texas, and (2) the identification of a major fault zone south of Clear Lake, California. The results of these studies should clarify the conceptual understanding of the various types of geothermal systems as an aid to industrial exploration efforts. The results will also improve the testing of new exploration technology. <p>(Sec. 2, P 16)</p>

APPENDIX A (CONTINUED)

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PL 93-410	ERDA-86	IMPLEMENTATION ACTION	ACHIEVEMENTS IN FY '76 ERDA AND OTHER AGENCIES
<u>Sec. 103 (Cont'd.)</u>			<ul style="list-style-type: none"> ● Research efforts that were supported by NSF and later transferred to ERDA included: (1) geoscientific investigations of the Salton Sea Geothermal field in the Imperial Valley of southern California, (2) extensive data obtained by the University of Utah - on electrical properties and other geophysical characteristics of the subsurface to describe the hydrothermal system at Roosevelt Hot Springs near Milford, Utah. (Sec. 2, P 16) ● Geoscience Research by ERDA has concentrated on hot dry rock and magma types of resource. Major research efforts conducted by ERDA's Division of Physical Research included: (1) studies of the physical properties of rocks and silicious magma, (2) studies to provide input data to computer models of the behavior of geothermal systems under a variety of rock and heat conditions. (Sec. 2, P 17)

APPENDIX A (CONTINUED)

COMPARISON OF PROVISIONS OF PL 93-410,
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PL 93-410	ERDA-86	IMPLEMENTATION ACTION	ACHIEVEMENTS IN FY '76 ERDA AND OTHER AGENCIES
<u>Sec. 103 (Cont'd.)</u>			<ul style="list-style-type: none"> Bureau of Reclamation appraisal studies in Pacific Southwest to develop exploration technology and conceptual plans for production of water and power. (Sec. 2, P 19)
(4) The survey and assessment of regional and national G/T resources of all types.	"Regional and national assessment of our G/T resources" is a major activity of the G/T program. (P III-4)	Funds have been programmed to expand this activity in FY '76.	
(b) The Chairman, acting through the USGS and other appropriate agencies, shall --			<u>National and Regional Assessment</u>
(1) Develop and carry out a general plan for the orderly inventorying of all forms of G/T resources of the Federal lands, and, where consistent with property rights and determined by the Chairman to be in the national interest, of non-Federal lands;	"The recently published USGS study, "Assessment of the Geothermal Resources of the United States - 1975" is the first step in developing a National assessment. Regional assessments will be used to upgrade the National Assessment and will play a significant role in identifying the potential resource areas for development Deep slim hole drilling is planned to help improve the accuracy of the assessment Areas of greatest suspected potential are being assessed first. The planned sequence for the	The USGS has completed geologic, geophysical, geochemical, and hydrologic investigations of ten known geothermal resource areas (KGRA'S), establishing a data base for the classification and evaluation of geothermal resources on Federal and Indian lands. A comprehensive inventory and assessment of geothermal resources in the U.S., based on available data, was published as USGS Circular 726. Detailed studies at Long Valley and at the Coso Hot Springs,	<ul style="list-style-type: none"> USGS regional studies (Sec. 2, p 20) included: (1) age identification of the volcanic rocks in SW Utah, (2) flow tests at Raft River, Idaho, (3) electric conductivity beneath the Snake River, Idaho, (4) discovery of prospect hot dry rock east of San Francisco Mountain, Arizona, (5) determining the geothermal potential for the Mt. Shasta volcanic system, at Shasta, California. ERDA in cooperation with USGS is now sponsoring a study of mine water temperature and chemistry in
(2) Conduct regional surveys, based upon such a ... plan, using innovative ... techniques, which will lead			

APPENDIX A (CONTINUED)

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PL 93-410	ERDA-86	IMPLEMENTATION ACTION	ACHIEVEMENTS IN FY '76 ERDA AND OTHER AGENCIES
Sec. 103 (Cont'd.)			
to a national inventory of G/T resources in the United States.	accomplishment of regional assessments can be generally defined by the follow- ing state and regional boundaries: (1) California and Nevada (2) Oregon, Idaho, Alaska, Utah (3) Colorado, Gulf Coast, New Mexico, Arizona (4) Washington, Hawaii, Montana, Wyoming (5) Central and Eastern U.S. The major phases of these assessments should be completed by the end of <u>1980.</u> " (P III-8, 9. See also <u>Resources</u> , P II-2)	California, have indicated these areas may be geothermal targets of very large potential. In FY '75 the USGS accelerated its assessment program and initiated preliminary studies in several more areas of promise: the San Francisco volcanic field in Arizona, the Jemez Mountains in New Mexico, and the Weisner Area in Idaho. Regional studies are also being conducted in the High Lava Plain of Oregon, the Great Basin in Northern Nevada, the Snake River Plain in Idaho, the Colorado Plateau, and in Alaska. The geopressured sands along the Gulf Coast are also being mapped. Further studies by the USGS by 1978 will include recoverability estimates based on the expected capability of new technology now being developed by ERDA.	Western Montana to identify potential low temperature hydro- thermal reservoirs. (Sec. 2, P 21) ERDA's LASL (Sec. 2, P 19) Radiogenic Heat Source Reservoir Assessment Project, for targeting low temperature hydrothermal reservoirs in the Southern-Eastern United States.
(3) Publish and make avail- able maps, reports, and other documents developed from such surveys to encourage and	"Resource assessment ... will produce much information that will be of con- tinuing value to industry and govern- ment.	ERDA, in cooperation with the USGS, has a computerized data storage- retrieval project underway at the Lawrence Berkeley Laboratory in	<u>Resource Information Dissemination</u> • Computerized bibliographic and geologic data storage and retrieval projects are already

APPENDIX A (CONTINUED)

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PL 93-410	ERDA-86	IMPLEMENTATION ACTION	ACHIEVEMENTS IN FY '76 ERDA AND OTHER AGENCIES
<u>Sec. 103 (Cont'd.)</u>			
facilitate the commercial development of G/T resources for beneficial use and consistent with the national interest;	 A national data bank on G/T resources is planned to ensure retention and distribution of these data. The data bank will be ... user oriented, providing information oriented toward both technical and non-technical users in various aspects of the G/T energy development." (P III-9)	California. Public availability of data is a requirement in all ERDA-supported projects.	underway at the Lawrence Berkeley Laboratory (LBL), CA., and in the USGS in Reston, VA., A USGS significant achievement in this area is the current updating of geothermal computer data file (GEOTHERM). (Sec. 2, P 21)
(4) Make such recommendations for legislation as may from time to time appear to be necessary to make Federal leasing policy for G/T resources consistent with known inventories of various resource types, with the current state of technologies for G/T energy development, and with current evaluations of the environmental impacts of such development; and	"The major regulatory and institutional procedures affecting capital formation and rate of industrial growth include leasing policy and procedures Some of the key issues related to the leasing program include whether or not there should be: (1) Processing of lease applications of non-KGRA lands without regard to subsequent reclassification as KGRA after the close of the filing period; (2) Raising of the acreage limitation on Federal leases; and (3) Additional provisions and penalties for lease termination	ERDA is instituting a regional operations research and systems analysis activity which will address this and related questions on a regional basis, and will provide the necessary cost/benefit information ERDA has allocated \$1M in FY '76 to initiate the planning activity. In the meantime, leasing of Federal land is being aggressively pursued. The Bureau of Land Management has issued 356 leases, covering 644,000 acres, on non-competitive lands, and expects to issue 800 additional leases by the end of FY '76. In addition, 22 sales have been held,	<u>The Federal Land Leasing Program</u> o During FY '76, the BLM has conducted 16 competitive geothermal lease sales.... within the above period, 671 non-competitive geothermal lease applications were filed and 466 leases were issued. o A tentative leasing schedule for FY '76, '77, and '78 was published on April 21, 1976, in the Federal Register, Vol. 41, No. 78, pp. 1668-1669. This schedule covers both competitive and non-competitive leasing. (Sec. 2, P 53)

APPENDIX A (CONTINUED)

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PL 93-410	ERDA-86	IMPLEMENTATION ACTION	ACHIEVEMENTS IN FY '76 ERDA AND OTHER AGENCIES
<p><u>Sec. 103 (Cont'd.)</u></p> <p>resulting from inadequate exploration activities.</p> <p>.... These issues require careful study to help define those policies which best balance the public interest and industry development." (P V-4, 5)</p> <p>"The G/T program will explicitly address these and related issues in order to assess the costs and impacts as they apply to the public and to the industry on a regional and National basis."</p> <p>(P V-6. See also <u>Industrial Growth</u>, P II-3)</p>	<p>and 101 leases issued, on KGRA lands.</p> <p>An additional 15 sales are scheduled in 1976.</p>	<p>o The Fish and Wildlife Service's FY '76 geothermal activities supported both in-house and under contract have been directed to biological pre- and post-lease baseline studies of KGRA's. These include cooperative efforts with various agencies in:</p> <p>(1) the identification and distribution of raptors (birds of prey) in the KGRA of northern Washoe County, Nevada, (2) the development of "Aquatic and Terrestrial Baseline studies for Geysers, California," (3) the environmental analysis and environmental impact studies on specific leases in 13 Western States, and (4) site-specific design for an environmental baseline and monitoring program for the Imperial Valley, California. (Sec. 2, P 55)</p> <p>o BLM has undertaken and proposed a number of measures to expedite the Land Leasing Program in geothermal development. (Sec. 2, P 53)</p>	

APPENDIX A (CONTINUED)

COMPARISON OF PROVISIONS OF PL 93-410,
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PL 93-410	ERDA-86	IMPLEMENTATION ACTION	ACHIEVEMENTS IN FY '76 ERDA AND OTHER AGENCIES
<u>Sec. 103 (Cont'd.)</u>			<ul style="list-style-type: none"> • USGS (Conservation Division) has reviewed operating plans, issued operating permits and supervised the drilling of 24 wells (16 wells in the Geysers, East Mesa, and Mono-Long Valley geothermal field, California; and 8 in the new area of the Roosevelt Hot Springs KGRA in Utah). (Sec. 2, P 54) • Of the backlog of 1640 non-competitive geothermal lease applications on National Forest System Lands, 40 lease applications have been cleared for lease by the USFS; 14 leases were issued in FY 76 by the USFS, compared to only one in FY 75. (Sec. 2, P 53)
(5) Participate with appropriate Federal agencies and non-Federal entities in research to develop, improve, and test technologies for the discovery and evaluation of all forms of	"The Geoscience Research effort is concerned with the basic geologic processes in the earth's crust that are fundamental to understanding the existence and nature of potentially useful G/T resources." (P III-4; see ensuing detailed discussion, P III-4, 5)		<ul style="list-style-type: none"> • Apart from the various geoscientific achievements already mentioned, there is now an ongoing joint ERDA-industry program in the Imperial Valley to test the application of active and passive seismic techniques in

APPENDIX A (CONTINUED)

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PL 93-410	ERDA-86	IMPLEMENTATION ACTION	ACHIEVEMENTS IN FY '76 ERDA AND OTHER AGENCIES
<u>Sec. 103 (Cont'd.)</u>			
G/T resources, and conduct research into the principles controlling the location, occurrence, size, temperature, energy content, productivity, and economic life-times of geothermal resources.	"Based in part on an improved understanding of geoscience, the effort in developing assessment and exploration technology is directed at improving the exploration and assessment instrumentation and techniques necessary to locate promising resource areas and to provide accurate estimates of reservoir energy capacity. Efforts to improve the technology are presently being supported under ERDA, NSF, and USGS sponsorship. The USGS is also developing case histories of specific G/T areas in which they can compare the results of as many of these techniques as possible." (P III-6, 7)		the estimation of reservoir properties. (Sec. 2, P 18)
<u>Sec. 104 Research and Development</u>			
(a) The Chairman, acting through the appropriate Federal agencies and in cooperation with non-Federal entities, shall initiate a research and development program for the purpose of resolving all major technical problems inhibiting the			

APPENDIX A (CONTINUED)

COMPARISON OF PROVISIONS OF PL 93-410,
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PL 93-410	ERDA-86	IMPLEMENTATION ACTION	ACHIEVEMENTS IN FY '76 ERDA AND OTHER AGENCIES
<u>Sec. 104 (Cont'd.)</u>			
fullest possible commercial utilization of geothermal resources in the United States. The specific goals of such programs shall include --			
(1) The development of effective and efficient drilling methods to operate at high temperatures in formations of geothermal interest;	<p><u>"Reservoir Engineering and Field Development --</u></p> <p>This area is directed at the development of reliable predictive, control, and management techniques and production technology to improve the economics and reduce the risk associated with the development of geothermal fields. The following tasks are a part of these efforts:</p> <p><u>Advanced Drilling Technology</u></p> <p>which includes the development of: (1) improved drill bits and automated drill rigs; (2) high temperature drilling fluids, elastomers, and cements; and (3) the capability for directional drilling in hard fractured rock.</p>	<p>ERDA and its predecessor agencies obligated \$2M in FY '75, and ERDA will obligate \$4M in FY '76, for development of improved drilling technology. Efforts include the Subterrene project at LASL, advanced drilling techniques development at Sandia, and a number of industrial contracts.</p>	<p><u>Reservoir Engineering and Field Development, Advanced Drilling Technology</u></p> <ul style="list-style-type: none"> • At present ERDA's drilling technology program has progressed to the stage where prototype hardware is becoming available for testing, e.g., <ul style="list-style-type: none"> - a working model of continuous chain slim-hole drill bit with a penetration rate in granite 2.5 times greater than that of conventional diamond bits. - improved tricone bit. (Sec. 2, P 23)

APPENDIX A (CONTINUED)

COMPARISON OF PROVISIONS OF PL 93-410,
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PL 93-410	ERDA-86	IMPLEMENTATION ACTION	ACHIEVEMENTS IN FY '76 ERDA AND OTHER AGENCIES
<u>Sec. 104 (Cont'd.)</u>			
	<p><u>Downhole Pump</u> development for the high-temperature environment of geothermal wells." (P III-14.</p> <p>See also remarks under <u>Geopressured</u>, P III-19, and <u>Hot Dry Rock</u>, P III-20)</p>	<p>ERDA has initiated three contracts in FY '76 for downhole pump development, for a total of \$1.65M.</p>	<ul style="list-style-type: none"> Recent program also includes investigation of several novel rock penetrations, rock fracturing techniques, including spark drilling, water-jet drill and initiation of the evaluation and development of high temperature drilling fluids. (Sec. 2, P 24)
			<p><u>Down-Hole Pump Development</u></p> <ul style="list-style-type: none"> Three novel pumping concepts have been developed: the steam, electric, and hydraulic turbine downhole pumps. Now all projects are ready for field testing, hardware development and industrial utilization. (Sec. 2, P 26,27)
(2) The development of reliable predictive methods and control techniques for the production of geothermal resources from reservoirs;	<p><u>Well-Logging Technology</u> to develop the instrumentation and evaluation techniques for G/T applications</p>	<p>A major expansion of the well-logging technology development effort, from \$0.6M in FY '75 to \$2.67M in FY '76, is underway.</p>	<p><u>Well Logging Technology</u></p> <ul style="list-style-type: none"> New programs were initiated to improve existing systems and to develop new down-hole sondes capable of withstanding 275°C and 10,000 psi. These programs involve assessing existing high-temperature

APPENDIX A (CONTINUED)

COMPARISON OF PROVISIONS OF PL 93-410,
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			circuit components and the development of new ones, for operation at temperatures up to 600°C.
			o USGS is conducting petro- physical studies to aid inter- pretation of well-log data.
(3) The exploitation of new concepts for fracturing rock to permit recovery of con- tained heat reserves;	<u>Well-stimulation technique</u> develop- ment to improve the flow rate of marginal wells. Field testing of these techniques is planned.	A major new effort, totaling \$1.23M of FY '76 obligations, has been initiated in this area.	<u>Well Stimulation</u> • An explosive suitable for reser- voir stimulation at high tempera- tures is being developed. (Sec. 2, P 28)
(4) The improvement of equipment and technology for the extraction of G/T resources from reservoirs;	<u>Reservoir Modeling Development</u> to better predict reservoir character- istics and lifetime.	ERDA's efforts in modeling develop- ment totaled \$0.6M in FY '75, in- creasing to \$0.87M in FY '76.	<u>Reservoir Modeling Development</u> • Princeton research effort to provide a computerized capability for predicting and analyzing the performance of producing geo- thermal reservoir. (NSF support) (Sec. 2, P 25) • ERDA's Lawrence Berkeley Laboratory (LBL) current efforts toward the completion of a code for modeling two-phase (i.e., steam/water) reservoirs. The accessible operating data of the Cerro Prieto geothermal pro- ject in Mexico will be used to validate the model. (Sec. 2, P 25)

APPENDIX A (CONTINUED)

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PL 93-410	ERDA-86	IMPLEMENTATION ACTION	ACHIEVEMENTS IN FY '76 ERDA AND OTHER AGENCIES
Sec. 104 (Cont'd.)			<ul style="list-style-type: none"> ● On-going Stanford University, Chimney Model, a highly instrumental physical model to observe the movement of a steam flash front in the reservoir. This will help determine how boiling is controlled by physical conditions of the reservoir. (Supported by NSF and later transferred to ERDA) (Sec. 2, P 25) ● On-going Pennsylvania State University physical model to identify and learn to control the dominant reaction, their rates and their influence.

APPENDIX A (CONTINUED)

COMPARISON OF PROVISIONS OF PL 93-410,
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PL 93-410

ERDA-86

IMPLEMENTATION ACTION

ACHIEVEMENTS IN FY '76
ERDA AND OTHER AGENCIES

Sec. 104 (Cont'd.)

A-17

on permeabilities and heat
extraction rates of hot reser-
voirs. (Supported by NSF and
later transferred to ERDA).

(Sec. 2, P 26)

- On-going Basin Problem Study.

This study is conducted by
the University of Colorado and
is stressing a close inter-
dependence of field data analysis
and mathematical modeling.

(Supported by NSF and later
transferred to ERDA.) (Sec. 2,
P 26)

- The Northwestern University,
Evanston, Ill. is currently in-
vestigating rock fracturing
mechanics under NSF support.
To this end, the university has
constructed a transparent epoxy
resin model as a visual aid for
observation of crack propaga-
tion induced by the injection
of fluid mercury into the
model. (Sec. 2, P 26)

APPENDIX A (CONTINUED)

COMPARISON OF PROVISIONS OF PL 93-410,
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PL 93-410	ERDA-86	IMPLEMENTATION ACTION	ACHIEVEMENTS IN FY '76 ERDA AND OTHER AGENCIES
<u>Sec. 104 (Cont'd.)</u>			
(5) The development of improved methods for converting geothermal resources and by-products to useful forms;	<p><u>"Utilization Technology</u> - This effort is directed at developing the key technology required for the advanced utilization cycles including non-electric applications. This key technology includes:</p> <p>(1) heat rejection equipment (both water and air-cooled); (2) fluidized bed and direct contact heat exchangers for the binary cycle; (3) total flow systems which include both prime mover development and field evaluation; and (4) advanced absorption refrigeration system for non-electric applications." (P III-15.</p> <p>See also remarks under <u>Geopressured</u>, P III-19)</p>	<p>Some twenty-six efforts at the development of key technology for advanced utilization cycles have been initiated during FY '75 and FY '76. These include research efforts in the properties, behavior, and control of brines, control of scaling, development and testing of materials, analyses of new cycles for utilization, and development of heat exchangers, power conversion equipments, and other advanced components. ERDA obligated \$3.1M in this area in FY '75 and will obligate \$2.6M in FY '76.</p> <p>The Department of Interior, Bureau of Mines, is active in the field testing of structural materials in geothermal brines, and in developing understanding of scale formation mechanisms.</p>	<p><u>Utilization Technology</u></p> <ul style="list-style-type: none"> • Direct contact heat exchange between geothermal brine and binary cycle working fluids (e.g., isobutane) has been shown feasible with great promise for circumventing scaling and corrosion problems. This is a significant step toward the economic and environmentally acceptable utilization of lower temperature (i.e., less than 200° C) G/T. (Sec. 2, P 28) • Development and engineering tests of total flow (mixed phase) turbines or expanders continued. Studies on hybrid advanced conversion concepts were initiated. (Sec. 2, P 28)

APPENDIX A (CONTINUED)

COMPARISON OF PROVISIONS OF PL 93-410,
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PL 93-410

ERDA-86

IMPLEMENTATION ACTION

ACHIEVEMENTS IN FY '76
ERDA AND OTHER AGENCIES

Sect. 104 (Cont'd)

Brine Chemistry and Materials Re-
search

- Many projects have been already initiated by ERDA and are now underway. These are: the Lawrence Livermore Laboratory and the Oak Ridge National Laboratory (ORNL) -- study on the corrosivity of brines.
(Sec. 2, P30)
- Two field investigations in mineral recovery, corrosion and scale formation were undertaken by the Bureau of Mines; one in the Bureau of Reclamation East Mesa Facility and the other at Salton Sea Geothermal Field.
(Sec. 2, P 31) This in situ approach, is a new approach to mineral recovery, corrosion, and scaling studies that fit the site specific nature of the geothermal resource.

APPENDIX A (CONTINUED)

COMPARISON OF PROVISIONS OF PL 93-410,
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PL93-410	ERDA-86	IMPLEMENTATION ACTION	ACHIEVEMENTS IN FY '76 ERDA AND OTHER AGENCIES
<u>Sec. 104 (Cont'd)</u>			<ul style="list-style-type: none"> Gas solubilities and phase distribution of oxygen, carbon dioxide, and methane were measured in the Bureau of Mines laboratory in several brines typical of the East Mesa and the Salton Sea Geothermal fields. (Sec. 2, P 32) ERDA programs at Case Western Reserve and Battelle NW Laboratories have been examining corrosion factors in geothermal use of inexpensive, commercially available, low-alloy steels. Results in the geothermal use temperature range of 50° to 250° C have been reported. (Sec. 2, P 30) Battelle NW Laboratories is currently developing (with industrial analytical Chemistry partners) standard sampling and analysis methods for geothermal fluids. This program will supply EPA and USGS with adequate sampling and analysis technology for implementing control legislation. (Sec. 2, P 30)

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COMPARISON OF PROVISIONS OF PL 93-410, THE GEOTHERMAL PROGRAM AS DEFINED IN ERDA-86, ERDA'S AND OTHER AGENCIES' ACHIEVEMENTS IN FY76 IN SUPPORT OF THE PROGRAM

PL 93-410	ERDA-86	IMPLEMENTATION ACTION	ACHIEVEMENTS IN FY '76 ERDA AND OTHER AGENCIES
<u>Sec. 104 (Con'd)</u>			
(6) The development of improved methods for controlling emissions and wastes from G/T utilization facilities, including new monitoring methods to any extent necessary	<u>"Environmental Effects and Abatement Technology --</u> This effort includes the prediction and evaluation of surface and subsurface environmental effects of geothermal field production and the development of new methods and techniques for predicting, controlling, and monitoring emissions and wastes from G/T utilization facilities.	A major expansion in ERDA's environmental program is occurring in FY '76. In addition to the continuation of H ₂ S abatement technology development, new efforts are being started in seismic and ground water contamination effects in hot dry rock systems, in background studies in the Imperial Valley in California and in the geopressured zones of the Gulf Coast, in defining environmental	<ul style="list-style-type: none"> • In FY 76, dynamic scaling facilities have been designed and operated by Oak Ridge National Laboratories, Dow Chemical Company and the Bureau of Mines Material Testing Facility. (Sec. 2, P 33)
(7) The development and evaluation of waste disposal control technologies and the evaluation of surface and subsurface	<u>Environmental Effects and Abatement Technology --</u> This effort includes the prediction and evaluation of surface and subsurface environmental effects of geothermal field production and the development of new methods and techniques for predicting, controlling, and monitoring emissions and wastes from G/T utilization facilities.	A major expansion in ERDA's environmental program is occurring in FY '76. In addition to the continuation of H ₂ S abatement technology development, new efforts are being started in seismic and ground water contamination effects in hot dry rock systems, in background studies in the Imperial Valley in California and in the geopressured zones of the Gulf Coast, in defining environmental	<u>Environmental Effects and Abatement Technology --</u> <ul style="list-style-type: none"> • ERDA's major research programs currently underway deal with gaseous emissions (e.g., H₂S) and earth subsidence. As a result, the hydrogen sulfide control systems should be ready for testing in mid FY '78. The first extensive test of subsidence control technology by reinjection of brine can be

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<u>Sec. 104 (Cont'd)</u>			
environmental effects of geothermal development; (8) The improvement of the technical capability to predict environmental impacts resulting from the development of geo- thermal resources, the preparation of environ- mental impact statements, and the assuring of com- pliance with applicable standards and criteria:	Key G/T-related environmental prob- lems to be investigated in the re- search and development activities include the areas of gaseous emission, liquid waste disposal, noise regula- tion, and land subsidence, leading to the development of standards and the development of key abatement equipment and technologies." P III-16)	R&D requirements and control tech- nology requirements, in developing siting criteria for geothermal facilities, and in examining means of improving the present EIS pro- cedures. Obligations in this area are rising from \$.34M in FY '75 to \$1.58M in FY '76.	expected by FY '79. Sec. 2, P 42, 43) ● The EPA on-going efforts are directed to: 1) identify pollutants, pathways into the underground water environment; 2) specify ecological hazards associated with long-term operating facilities; 3) design a monitoring system applicable to any geothermal development and conversion facility. In all cases, the initial focus has been on The Geysers, Im- perial Valley, Klamath Falls, Rio Grande Rift zone and on Roosevelt Hot Springs that have received or are more likely to receive earlier development attention. At present, a sampling plan has been designed and initial samples have been collected from the Salton Sea, Niland, Ca.area and are in the process of being analyzed. Also, a mobile air-monitoring laboratory is continuing to

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<u>Sec. 104 (Cont'd)</u>			<p>assess pollutants at various Imperial Valley sites. Sec. 2, P 45, 46, 47)</p> <ul style="list-style-type: none"> ERDA's Division of Biomedical and Environmental Research is currently conducting a site-specific environmental baseline study of the Imperial Valley of California. (Sec. 2, P 48) The USGS Subsurface Environmental Impact research efforts have been geared to provide information on the nature and expected change in seismic activity and land subsidence, as well as the expected changes in ground-water quality or flow associated with geothermal fluid withdrawal from, or reinjection into, the ground. In particular, the USGS effort in FY 76 (Sec. 2, P 48) include: <ul style="list-style-type: none"> (1) developing analytical models that reflect the expected tectonic, geological and hydrological processes that may result from large changes

APPENDIX A (CONTINUED)

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in subsurface waters; (2) a study on the expected qualitative and quantitative impact upon the subsurface environment as a result of large changes in subsurface waters; and (3) correlation of high microearthquake activity in the vicinity of the Healdsburg facility in California.

- The NSF has also been supporting a number of research efforts in the areas of water quality, reservoir problems and biologic considerations. These include:

(1) The University of Southern California study of the aquatic chemistry of toxic elements, based on samples from geothermal fields in Northern California, Nevada, New Mexico, and the Imperial Valley; (2) System Control Inc., analysis of subsidence associated with geothermal development in

APPENDIX A (CONTINUED)

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southern California. In this area, subsidence is of special concern: a movement of two to three feet could disrupt the irrigation system of the Imperial Valley; (3) Saint Mary's College study; this study is designed to evaluate whether birds and small mammals actively avoid habitats in which geothermally related noise is intense; and (4) Lagolla Co's on-going effort of building a highly flexible numerical simulator of the physical processes operative in a producing geothermal field. The computerized model is designed to help the early prediction of both the power productivity and the possible subsidence or induced seismicity of a given reservoir. (Sec. 2, P 43)

● Other ERDA studies include:

(Sec. 2, P 44)

(1) development of environ-

mental impact statement (EIS)

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<u>(Sec. 104 Cont'd)</u>			<p>and environmental impact assessment (EIA) guidelines;</p> <p>(2) geopressured baseline assessment guidelines; and</p> <p>(3) a joint effort with the Fish and Wildlife Service to design a site-specific environmental baseline and monitoring program for the Imperial Valley.</p> <ul style="list-style-type: none"> ● On-going EPA research activities both in-house and under contract to produce the information needed and leading to the development of effluent guidelines and other environmental protection requirements for geothermal energy systems. (Sec. 2, p 46,47) ● The Fish and Wildlife Service (FWS) biological pre- and post-lease baseline studies of the KGRA's. (Sec. 2, P 55) ● Ecological studies completed by FWS in FY 76 (Sec. 2, P 49,50) include: (1) Preparation of geothermal Handbook. (2) the Sage

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<u>Sec. 104 (Cont'd)</u>			<p>Grouse Study Design for an industrial developer, Mono-Long Valley, California; and (3) a study of the recommended Peregrine Falcon critical habitat zone in four counties in CA; a similar study of the recommended critical habitat zone for Yuma Clopper Rail is still in progress; and (4) a color infrared photography survey for potential geothermal areas in Wyoming and Montana; and (5) On-going Office of Water Research and Technology (OWRT) studies on the biological impacts of geothermal development. In particular, OWRT is now investigating the effect of geothermal development on an aquatic biota in The Geysers area.</p>

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<u>Sec. 104 (Cont'd)</u>			
(9) The identification of social, legal, and economic problems associated with G/T development (both locally and regionally) for the purpose of developing policy and providing a framework of policy alternatives for the commercial utilization of G/T resources;	<p>"Policy Analysis --(Quotes Sec. 104(a)(9)....</p> <p>Many such institutional barriers already have been identified that need resolution. These barriers include considerations relative to the leasing program, the environmental approval process, patent rights, and financial incentives. This program activity provides for the conduct of special studies and analyses relative to these types of problems." (P III-27, 28)</p> <p>"...Key to the analysis of these institutional, financial, and technological options will be the development and application of cost-benefit studies. These studies would integrate technological, environmental, and socioeconomic data." (P V-6 See also detailed discussion, P V-1 thru 6, and <u>Institutional Development</u>, P III-24 thru 26)</p>	<p>ERDA recognizes the importance of early resolution of existing legal, social, and economic problems to rapid attainment of commercial growth in geothermal energy. A vigorous program of policy analysis is being implemented in FY '76 to address these problems. Because of the regional character of many of the problems, a cornerstone of the ERDA program is the regional operations research and systems analysis activity mentioned earlier.</p> <p>In addition, economic studies addressing problems common to all geothermal systems are being continued.</p> <p>ERDA has allocated a total of \$2.2M in FY '76 to support these efforts, up from \$0.48M in FY '75.</p>	<p><u>The Policy Analysis Program --</u></p> <ul style="list-style-type: none"> • A series of Federal policy studies has been initiated by ERDA to assess the effect of Federal tax and land-leasing policies now in force on the geothermal development program. Many recommendations have been presented. These recommendations involve changes in the tax treatment and leasing policy, and are geared to stimulate more active participation of the private sector in geothermal development. (Sec. 2, p 58) • Two legal studies have been initiated by ERDA. One of these is concerned with the legal aspects of geopressured development in Louisiana. The other is a study on the legal impact of state water laws on the geothermal energy development. (Sec. 2, p 58)

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PL 93-410 <u>Sec. 104 (Cont'd)</u>	ERDA-86	IMPLEMENTATION ACTION	ACHIEVEMENTS IN FY '76 ERDA AND OTHER AGENCIES'
			<ul style="list-style-type: none"> On-going evaluation of Federal, state, and local environmental assessment procedures and standards, as well as of land leasing policy is taking place. This work is being done under the Interagency Geothermal Coordinating Council's Panel on Institutional Barriers, led by FEA. Recommendations of the Panel are given in (Sec. 3, P 78, 79) The NSF has also supported a number of legal studies concerned with the analysis of the legal systems which define ownership of the geothermal resources and control its use. These studies (Sec. 2, P 58, 59) include: (1) a workshop and preliminary study of the legal constraints imposed on geothermal development which has been completed in FY 76; (2) model geothermal state legislation codes are also being developed in modular form. This provides for sets of alternative policies among which states can

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choose those suitable to meet
their specific regional needs.

- In FY '76, various studies on
the analysis of state utility
regulatory policies and prac-
tices have been initiated by NSF
These studies will identify those
policies and practices that
impede the active participa-
tion of utilities in geothermal
energy development ventures.

(Sec. 2, P 59)

- Microeconomic cost/benefit
analysis of geothermal energy
systems are now being under-
taken by ERDA. Results are
expected in FY '77. (Sec. 2,
P 59, 60)
- A study of the energy budget of
geothermal development as com-
pared to hydropower development
was completed. This study has
been supported by the Office of
Water Resource and Technology.
(Sec. 2, P 60)

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- Two important regional/community planning studies have been initiated by ERDA. One is for the Imperial Valley in CA and the other is for the Gulf Coast in Texas. (Sec 2 P. 60)
- The City of Boise, Idaho, has initiated a study of the full range of local markets for geothermal energy and what institutional changes are needed to supply them. This work is funded by ERDA and cost-shared with the HUD-financed Boise Urban Observatory, which is providing technical assistance. (Sec. 2, P 60)
- Effective institutional arrangements in the acquisition and sale of power are being developed under previous support of NSF by various institutions. (Sec. 2, P 59)

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<u>Sec. 104 (Cont'd)</u>			
			<ul style="list-style-type: none"> ● An interagency effort to assist in the ongoing regional and community planning of Susanville, Ca, to overcome institutional problems affecting geothermal development in this area. (Sec. 2, P 60, 61)
(10) The provision for an adequate supply of scientists to perform required geothermal research and development activities; and		The NSF has funded 17 active geothermal research projects at academic institutions; these currently provide complete or partial support of 53 faculty members, 15 postdoctoral, 68 graduate, and 13 undergraduate students.	<ul style="list-style-type: none"> ● The NSF has funded various active geothermal research projects at academic institutions; these currently provide complete or partial support of 55 faculty members, 16 postdoctoral, 75 graduate and 23 undergradutae students. (Sec. 2, P 61)
(11) The establishment of a program to encourage States to establish and maintain geothermal resource clearinghouses at the	<u>"Geothermal Resources Clearinghouses"</u> -- The establishment and support of geothermal resource clearinghouses at the	The establishment of geothermal resource clearinghouses is included as an integral part of the regional	

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thermal resources clearing- houses,	state level, as authorized in Sec. 104 (a) (11) of Pl 93-410, is being considered.(Quotes referenced section).... The implementation of this program element will provide for expediting the environmental and permit approval pro- cess and will provide a public forum for identifying problems that need to be addressed in the program." (P III-27)	operations research and systems analysis activity. ERDA has also budgeted an additional \$0.18M for other information dissemination ac- tivities.	
(b) The Chairman, acting through the appropriate Federal agencies and in cooperation with non- Federal entities, shall imple- ment a coordinated program of research and development in order to demonstrate the technical means for the extracting and utilization of the resource base, including any by-products of such base, and in order to accomplish the goals established by sub- section (a).		The research and development program described briefly above is being imple- mented in a coordinated fashion through a number of agencies. To assure con- tinued coordination, ERDA has established the Interagency Geothermal Coordinating Council of policy-level representatives from each of the involved agencies; the Council is supported at the program level by three interagency panels, responsible for research and technology, institu- tional barriers, and resource problems, respectively. In addition, to assure proper coordination with private sec- tor activities and responsiveness to private sector needs, ERDA has con- stituted as an official body the Ad- visory Committee on Geothermal Energy	

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<u>Sec. 104 (Cont'd)</u>		with industry, state and local govern- ment, and public representation.	
<u>Sec. 105 Demonstration</u>			
(a) The Chairman, acting through the appropriate Federal agencies and in cooperation with non-Federal entities, shall initiate a program to design and construct geothermal demonstration plants. The specific goals of such program shall include --	<p><u>"R&D Test Facilities</u> - Field test facilities are included for advanced component testing and evaluation in real geothermal environments. These facilities will be made available to industry and educational institutions as well as government laboratories. These facilities will provide a mechanism for developing a cadre of trained personnel, uniformity of test procedures, and support to a large base of equipment manufacturers." (P III-15)</p> <p><u>"Demonstration Projects</u> - Demonstration projects provide for the development of pilot plants for the engineering verification of new systems and components, and full-size and commercial-scale plants for the demonstration of commercial economic viability. These plants will be very effective in increasing user participation in the development and operation of geothermal plants." (P III-16)</p> <p><u>"Utilization Plan</u> - The transfer to the</p>	<p>ERDA, in cooperation with other Federal agencies, state and local governments, and private industry, is engaged in a vigorous program of demonstration of geothermal resources. On-going and newly initiated activities include:</p> <ul style="list-style-type: none"> o Raft River Project, in Idaho, undertaken in cooperation with the Raft River Rural Electric Cooperative o A test facility for moderate-temperature geothermal resources technology at East Mesa, California, undertaken in cooperation with the Bureau of Reclamation o A public building heating project in Boise, Idaho, undertaken in cooperation with the State of Idaho. o A study of the possible role of non-electric applications of geothermal energy in revitalizing a small community, undertaken in 	<p><u>R&D Test Facilities</u></p> <ul style="list-style-type: none"> • The Lawrence Livermore Laboratory test facility has been established by ERDA for the uniform and objective testing and evaluation of novel power conversion concepts such as the Sprinkle helical screw expander, the Possell bladeless turbine, and the bi-phase rotary separator. (Sec. 2, P 34) • The construction of the ERDA Geothermal Component Test Facility with the Bureau of Reclamation. This center has been financed by ERDA to provide test facilities for ERDA's contractors, private companies, and institutions. (Sec 2, P34) • The Bureau of Mines Material Testing Facility designed to simulate seven typical process environments in a geothermal resource recovery plant. (Sec 2 P 31)
(1) The development of economical geothermal resources production systems and components which meet environmental standards;			
(2) The design of plants to produce electric power, and, where appropriate, the large-scale production and utilization of any useful by-products;			
(3) The involvement of engineers, analysts, technicians, and managers from industry, field, and power-plant development, which shall lead to the early			

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<u>Sec. 105 (Cont'd)</u>			<u>Advanced Systems Application (Sec. 2, P)</u>
industrial exploitation of advanced geothermal re- sources;	private sector of the technology de- veloped under this program area will be accomplished primarily by encouraging	cooperation with the City of Susanville, California.	● The Salton Sea Project (high temperature high-salinity)
(4) The provision for an adequate supply of trained geothermal engineers and technicians;	industry's active participation in its development.	● Determination of the geothermal potential in the State of Hawaii, undertaken in cooperation with the State of Hawaii.	construction of the jointly funded ERDA/SDG&E geothermal loop experimental facility.
(5) The provision of ex- perimental test beds for component testing and evaluation by laboratories operated by the Federal Government, industry, or institutions of higher education;	 These (pilot and demonstration) plants will provide "hands-on" experience to expand the cadre of trained person- nel, in addition to introducing geo- thermal energy utilization to regions of large potential." (P III-23)	● A pilot-scale evaluation of multiple-flash steam/binary cycle technology, undertaken in coopera- tion with San Diego Gas and Elec- tric Company	It represents the first- of-its-kind binary cycle system that has the capability for production of elec- tric power using the high- temperature (higher than 200° C), high-salinity (higher than 50,000 ppm) geothermal resources found in the Salton Sea area. (Sec. 2, P 35)
(6) The construction and operation of pilot plants; and		● A preliminary study for a demon- stration plant, undertaken in co- operation with the Electric Power Research Institute.	● Most of the construction work of a small high-temperature low-salinity electrodialysis
(7) The construction and operation of demonstration plants.		● Several studies to assess the potential utilization of geopres- sured resources along the Gulf Coast	desalting unit has been com- pleted by the Bureau of Recla- mation in FY 76. The start- up of this desalting unit is scheduled for January 1977.
(b) In carrying out his responsi- bilities under this section, the	"...Two such commerical-scale facili- ties are tentatively planned. These	● Determination of the practicability of extracting heat from hot dry rock resources.	(Sec. 2, P 35)
		These and related efforts from the	● ERDA contracted with the Bechtel Corporation to develop a

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<u>Sec. 105 (Cont'd)</u>			
Chairman, acting through the appropriate Federal agencies, and in cooperation with non-Federal entities, may provide for the establishment of one or more demonstration projects utilizing each geothermal resource base involved, which shall include, as appropriate, all of the exploration, siting, drilling, pilot plant construction and operation, demonstration plant construction and operation, and other facilities and activities which may be necessary for the generation of electric energy and the utilization of geothermal resource by-products.	and other projects will be considered based on the development of key technology and regional development needs." (P III-16) "As the technology developments associated with each of the various resources reach appropriate levels of maturity, joint government/industry-constructed pilot and demonstration plants will be utilized to establish user confidence in the economic viability of the commercial application of geothermal energy." (P III-23)	largest portion of the ERDA program. They accounted for \$12.4 M of FY 75 obligations, and will account for \$15.8 M of FY 76 obligations. In addition to these ERDA efforts, the Bureau of Reclamation has an active program investigating the feasibility of obtaining fresh water from geothermal brines. Two types of desalting units, a test vertical tube evaporating desalting unit and a test multistage flash evaporator desalting unit, have been installed and tested at the BuRec test site at East Mesa, California. These units will develop the design data and technology for larger units. The ERDA effort with EPRI is aimed at the eventual construction of a jointly funded demonstration plant. Also, the on-going program with SDG&E (jointly funded under cooperative agreement) may if successful lead to jointly funded demonstration plants. Cooperative demonstration projects with other government agencies will be pursued where appropriate.	conceptual design of a flashed-steam energy conversion process for a 50 MW power plant based on the brine condition of Heber in the southern most part of the Imperial Valley. This conceptual design is a part of the ERDA support to a proposed EPRI/industry demonstration plant. The conceptual design has been completed in FY 76. (Sec. 2, P 35)
(c) The Chairman, acting through the appropriate Federal agencies, is authorized to investigate and enter into agreements for the cooperative development of facilities to demonstrate the production of energy from geothermal resources. The responsible Federal agency may consider --			<ul style="list-style-type: none"> • Raft River Idaho Project (moderate-temperature low-to moderate-salinity); ERDA assigned the Idaho National Engineering Laboratory (INEL) the task of developing the necessary conversion technology. As a result: - Three exploratory production wells have been drilled at this site in FY76 and efforts are being directed toward the establishment of a production injection cycle. (Sec. 2, P 36)
(1) Cooperative agreements			

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with utilities and non-Federal governmental entities for construction of facilities to produce energy for commercial disposition; and			- The conceptual design for a
(2) Cooperative agreements with other Federal agencies for the construction and operation of facilities to produce energy for direct Federal consumption.			been completed during the same period. (Sec. 2, P 36)
(d) The responsible Federal agency is authorized to investigate the feasibility of, construct, and operate demonstration projects without entering into cooperative agreements with respect to such projects, if the Chairman finds that,--			• Non-electric Application Projects. Two non-electric applications studies have been completed by ERDA. One study has been initiated at the City of Susanville, CA. The second is a space heating engineering design for public buildings in Boise, Idaho. (Sec. 2, P 36)
(1) The nature of the resource, the geographical location, the scale and engineering design of the facilities, the techniques of production, or any other significant factor of the proposal offers opportunities to		It is possible that certain new technology developments, such as for example total flow systems or hot dry rock utilization systems, will be considered by the industry to be too high risk to warrant investment until they have been demonstrated. In such instances, ERDA will consider wholly	• In addition engineering and economic studies of non-electric applications of geothermal heat covering four industry segments-- industrial processing, agribusiness, and commercial and residential space conditioning-- have been initiated by ERDA in an effort to stimulate interest in the use of low- to moderate-heat (50° to 150°C) hydrothermal resources. (Sec. 2, P 37)

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make important contributions to the general knowledge of geothermal resources, the techniques of its development, or public confidence in the technology; and		government funded demonstration projects. However, because ERDA is above all committed to rapid commercialization of government-developed technology, and because ERDA feels strongly this can best be achieved by direct involvement of the private sector, ERDA will consider such demonstration projects only as a last recourse.	<ul style="list-style-type: none"> Advanced Technology Application (Sec. 2, P 39,40) (1) hot dry rock extraction technology is currently being tested by ERDA at the Fenton Hill site in the Jemez Mountains in New Mexico. The primary emphasis is to develop a controllable and effective functioning circulation technology with the highest possible heat extraction capability and efficiency. (2) the initiation of the Coso site assessment in California Mojave Desert to investigate the actual extent and characteristics of hot dry rock; and (3) geologic investigation of near-surface conditions in some areas of the Eastern U.S. Data from a similar on-going effort in France is also being evaluated as a preliminary step to further application of normal gradient resources in the U.S.; (4) identification of principal geopressured reservoir areas for well drilling and long-duration tests in Louisiana and Texas; and
(2) There is no opportunity for cooperative agreements with a utility or non-Federal entity willing and able to cooperate in the demonstration project under subsection (c) (1), and there is no opportunity for cooperative agreements with other Federal agencies under subsection (c) (2).			
(e) (Sets criteria for favorable consideration of proposals under (c))			
(f) (Limits magnitude of Federal investment without further specific Congressional approval to \$10,000,000)			
(g) (Requires disposal of all plants constructed under this section after completion of demonstration.)		ERDA is in complete agreement with this provision as vitally necessary in stimulating cooperative agreements with the private sector.	

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ACHIEVEMENTS IN FY '76
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Sec. 105 (Cont'd)

(5) Available knowledge of geopressured resources has been collated and analyzed in a combined university, state government, and industry study that has been completed in FY'76. This study identifies numerous potential technical and institutional impediments to the development of a viable industry based on the utilization of geopressured geothermal resources. (Sec. 2, P 39)

Sec. 106 Scientific & Technical

Education

(a) (Affirms the policy of the Congress is to encourage education of trained personnel)

(b) (Authorizes the NSF to support programs carrying out the policy of subsection (a))

(c) The NSF is authorized and directed to coordinate its actions, to the maximum extent practicable, with the Project or any permanent Federal organization or agency having jurisdiction over the energy research and development functions of the U.S.,

In FY75 the National Science Foundation was supporting 22 graduate traineeships, 4 post-doctoral fellows, two senior foreign energy scholars, and 1 faculty fellowship in science applied to societal problems in disciplines directly related to geothermal energy

• The NSF is currently supporting an educational program involving 26 graduate traineeships, 6 post-doctoral fellowships, and 3 programs for senior scientists, all engaged in research opportunities

APPENDIX A (CONTINUED)

COMPARISON OF PROVISIONS OF PL 93-410,
THE GEOTHERMAL PROGRAM AS DEFINED IN ERDA-86, ERDA'S AND
OTHER AGENCIES' ACHIEVEMENTS IN FY76 IN SUPPORT OF THE PROGRAM

PL 93-410	ERDA-86	IMPLEMENTATION ACTION	ACHIEVEMENTS IN FY '76 ERDA AND OTHER AGENCIES
<p><u>Sec. 106 (Cont'd)</u></p> <p>in determining the optimal selection of programs of education to carry out the policy of subsection (a)</p> <p>(d) (Authorizes the NSF to encourage international cooperation in carrying out policy of subsection (a))</p>			<p>encompassing various geothermal energy fields. (Sec. 2, P 61)</p>
<p><u>Title II - Loan Guarantees</u></p> <p><u>Sec. 201 Establishment of Loan Guarantee Program</u></p> <p>(a) (Affirms the policy of the Congress is to encourage commercial development; and to provide for loan guarantees for such purpose)</p> <p>(b) In order to encourage the commercial production of energy from geothermal resources, the head of the designated (by the Chairman) agency is authorized to, in consultation with the Secretary of the Treasury, guarantee, and to enter into commitments to guarantee, lenders against the loss of principal or interest on loans made by such lenders to qualified borrowers for the purposes of --</p>		<p>The Loan Guaranty Program is most likely to be used for projects with an early potential for producing income, rather than for research and development. Inquiries received to date indicate that most applications would be for the purpose of developing resources for production, and for the drilling of test wells to prove reservoir potential. Most of the inquiries which are expected to result in guaranty applications during the</p>	

APPENDIX A (CONTINUED)

COMPARISON OF PROVISIONS OF PL 93-410,
THE GEOTHERMAL PROGRAM AS DEFINED IN ERDA-86, ERDA'S AND
OTHER AGENCIES' ACHIEVEMENTS IN FY76 IN SUPPORT OF THE PROGRAM

PL 93-410	ERDA-86	IMPLEMENTATION ACTION	ACHIEVEMENTS IN FY '76 ERDA AND OTHER AGENCIES
<u>Sec. 106 (Cont'd)</u>			
(1) The determination and evaluation of the resource base;		first months of the program have been for further development in The Geysers area in Northern California.	
(2) Research and development with respect to extraction and utilization technologies;			
(3) Acquiring rights to geo- thermal resources; or			
(4) Development, construction, and operation of facilities for the demonstration or commercial production of energy from geo- thermal resources.			
(c) (Limits loan guaranty to 75% of aggregate cost of project)			
(d) Loan guarantees under this title shall be on such terms and conditions as the head of the designated agency determines, except that a guaranty shall be made under this title only if --		In December '75, proposed regulations were published. Final regulations, taking into account the public comments received, were published in the Federal Register on May 26, 1976. The geothermal loan guaranty program became opera- tional one month later.	<ul style="list-style-type: none"> As of November 5, 1976, ERDA has received 3 loan guaranty applications for geothermal projects to be located in California. During FY 77, an additional 17 to 20 applications are expected for other reservoir development projects to be located in Utah, Idaho, Oregon, Nevada and California.
(1) (Limits the interest rate)			
(2) (Limits the period of re- payment)			
(3) In the judgment of the head of the designated agency, the amount of the loan (when			

APPENDIX A (CONTINUED)

COMPARISON OF PROVISIONS OF PL 93-410,
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IMPLEMENTATION ACTION

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Sec. 201 (Cont'd)

combined with amounts available
to the qualified borrower from
other sources) will be suffi-
cient to carry out the project;
and

(4) In the judgment of the
head of the designated agency,
there is reasonable assurance
of repayment of the loan by
the qualified borrower of the
guaranteed indebtedness.

(e) (Sets dollar limits on the
guarantees per project and per
borrower)

(f) (Defines "qualified borrower")

Sec. 202 Payment of Interest

(a) (Establishes criteria for pay-
ment of interest on guaranteed loans)

(b) (Establishes provisions in case
of default)

Sec. 203 Period of Guarantees and

Interest Assistance

(Provides for termination of the
Loan Guaranty Program after ten
years)

APPENDIX A (CONTINUED)

COMPARISON OF PROVISIONS OF PL 93-410,
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Sec. 204 Geothermal Resources

Development Fund

(a) (Establishes a Geothermal Resources Development Fund in the U.S.

Treasury)

(b) There shall be paid into the fund the amounts appropriated pursuant to section 304(c) and such amounts as may be returned to the United States pursuant to section 212(b), and the amounts in the fund shall remain available until expended, except that after the ten-year period established by section 203, such amounts in the fund which are not required to secure outstanding guaranty obligations shall be paid into the general fund of the Treasury.

(c) (Establishes reporting requirements.)

Title III - General Provisions

Sec. 301 Protection of Environment

In the conduct of its activities, the Project and any participating public or private persons or agencies shall place particular emphasis upon the objective of assuring that the environment and the safety of persons

APPENDIX A (CONTINUED)

COMPARISON OF PROVISIONS OF PL 93-410,
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PL 93-410

ERDA-86

IMPLEMENTATION ACTION

ACHIEVEMENTS IN FY '76
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Sec. 301 (Cont'd)

or property are effectively protected;
and the program under Title I shall
include such special research and
development as may be necessary for
the achievement of the objective.

Sec. 302 Reporting Requirements

- (a) (Establishes requirement for
annual reports to the President
and Congress on Project activi-
ties)
- (b) (Establishes requirement for
final report on all demonstration
projects within one year of their
completion)

Sec. 303 Transfer of Functions

- (a) (Provides for transfer of all
RD&D functions, including Loan
Guaranty Program, to ERDA within
sixty days after its formation)
- (b) Upon the establishment of a
permanent Federal organization or
agency having jurisdiction over
the energy research and develop-
ment functions of the United

"In order to coordinate these activities
ERDA is considering the formation of a
Geothermal Advisory Council with repre-
sentation from the Federal Energy
Administration, the National Science

The transfer of the Project's func-
tions to ERDA was directed by Exe-
cutive Order 11834, establishing
ERDA, and effectuated by an OMB
Determination Order dated January
17, 1975.
The Geothermal Advisory Council
has been formed, composed of policy-
level representatives of the

This is the first Annual Report
of the activities of the Geother-
mal Energy Research, Development
and Demonstration Program for Fis-
cal Year 1976 and Transition Quar-
ter. It is submitted in accor-
dance with the intent of section 302(a)
of the Geothermal Energy Research
Development and Demonstration Act
of 1974, PL 93-410. (P S-1)

The name of the Council was
changed to the Interagency
Geothermal Coordinating Council,

APPENDIX A (CONTINUED)

COMPARISON OF PROVISIONS OF PL 93-410,
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PL 93-410	ERDA-86	IMPLEMENTATION ACTION	ACHIEVEMENTS IN FY '76 ERDA AND OTHER AGENCIES
<u>Sec. 303 (Cont'd)</u>			
States, and when all research and development (and other) functions of the Project are transferred, the members of the Project may provide advice and counsel to the head of such organization or agency, in accordance with arrangements made at that time.	Foundation, Environmental Protection Agency, Department of the Interior, Department of the Treasury, the National Aeronautics and Space Administration and other cognizant agencies. This Council would advise ERDA on carrying out the policy and functions previously assigned to the Geothermal Energy Coordination and Management Project under Public Law 93-410."	agencies listed. A proposed charter for the Council has been submitted to the agencies for their review.	and the Department of Agriculture was added to the membership.
	P IV-5)		
<u>Sec. 304 Authorizations of Appropriations</u>			
(a) (Limits appropriations for all fiscal years through 1980 to the amounts authorized by Congress)			
(b) (Authorizes NASA to be appropriated \$2,500,000 for program definition activity)			
(c) Authorizes appropriations for Loan Guarantees).			

APPENDIX B

PARTICIPANTS IN THE FEDERAL GEOTHERMAL PROGRAM

APPENDIX B

PARTICIPANTS IN THE FEDERAL GEOTHERMAL PROGRAM

This appendix identifies, in summary form, the Federal agency participants in the national geothermal resource development process. It provides an overview of their major roles and their areas of contribution to the goals and objectives of the Federal Program.

BACKGROUND

ERDA was created in accordance with the provisions of the Energy Reorganization Act of 1974 (Public Law 93-438). The Non-nuclear Energy Research and Development Act of 1974 (Public Law 93-577) gave ERDA a considerable range of authority, including incorporation of the geothermal program that had been established previously by the Geothermal Research, Development, and Demonstration Act of 1974 (Public Law 93-410). In addition to programmatic geothermal functions, the Congress gave ERDA authority to coordinate all Federal agency geothermal activities.

The Geothermal Research, Development, and Demonstration Act of 1974 (Public Law 93-410), in assigning roles to the several agencies discussed herein, established interagency coordination through the Geothermal Energy Coordination and Management Project. Since a significant number of non-ERDA agencies within the Federal establishment have retained substantial responsibilities for the activities within the Federal program, the coordination function

remains of prime importance. Thus, ERDA established the interagency Geothermal Advisory Council (since renamed the Interagency Geothermal Coordinating Council) as a successor to the Project, as the means of achieving a comprehensive Federal Geothermal Program. The Interagency Geothermal Coordinating Council is composed of representatives from ERDA, the Department of the Interior, the Department of Agriculture, the Environmental Protection Agency, the Federal Energy Administration, the Treasury Department, the National Science Foundation, and the National Aeronautics and Space Administration. Other agencies are represented as the need arises. The Council is broadly concerned with the impacts of the participating agencies' policies on the rate of geothermal development.

FEDERAL ACTIVITIES

An overview of the present functional relationships among the Federal agencies represented on the Interagency Geothermal Coordinating Council and a discussion of the issues arising from this interaction are presented here. Figure B-1 shows the interrelationships of the responsible Federal agencies with respect to the several aspects of the Federal Geothermal Program (note that program categories may vary slightly from those used in the body of this report).

Budgetary

Program development and modification are closely coupled to the budget cycle. Implementation of new policies may often involve developing new regulations, which may take from one to three

FIGURE B-1
FEDERAL GEOTHERMAL PROGRAM

years, including any required environmental impact statement (EIS) preparation. New policies, requiring not new regulations but new funding, will be subject to the regular and supplemental appropriations schedules of the Congress. Only those actions that do not require significant changes in funding or in regulation will have a chance of full implementation in less than about a year's time.

Federal Tax Policy

The Department of the Treasury has a significant impact on the commercial utilization of geothermal resources through its functions in developing and implementing Federal tax policies. ERDA and Treasury are currently engaged in an analysis of geothermal development economics as a first step in formulating new policies for IRS implementation of new tax legislation. Tax incentives in the form of intangible drilling cost deductions and a 22 percent exhaustion allowance were included in Congressionally proposed tax legislation, but did not survive in the bill that was signed into law. Current ERDA-supported tax analysis activities are scheduled to produce quantitative results (which could support policy recommendations) during FY 77. Initial results from a number of independent studies sponsored by ERDA have indicated that Federal tax incentives would play a significant role in stimulating the growth of a geothermal industry at least until such time as the technology would be well proven and economically competitive. However, many other factors must be considered to place the potential incentives to support geothermal

development in the context of overall Federal fiscal policy. Possible additional tax incentives may be formulated for Administration consideration during FY 77 and FY 78.

Leasing of Geothermal Resources

The Department of the Interior's (DOI) involvement in geothermal resource development precedes ERDA's by several years, dating from the passage of Public Law 91-581, which created the Federal geothermal leasing program. The Geological Survey (USGS) and the Bureau of Land Management (BLM) have been assigned responsibility for this program--the USGS to prepare Federal lands for leasing and to oversee lease operations, and the BLM to administer the lease sales. The Forest Service (FS) is responsible for the approval of geothermal leases on lands administered by the Department of Agriculture (USDA). Current rates of leasing of Federal lands under Forest Service jurisdiction, if continued, will become a matter of concern for future development. However, there should soon be no significant backlogs in either competitive or noncompetitive leasing on lands administered solely by the BLM. Overall lease processing times should range from six to 24 months. Projected rates of leasing, given current regulations and staffing levels, suggest that if present trends continue roughly three to five million acres of Federal lands (plus about the same amount of non-Federal lands) are anticipated to be under geothermal leases by the early 1980s. Depending on the validity of various differing estimates, exploration and development of

this much acreage could lead to 3,000 MW to 10,000 MW of geothermal energy on line by the late 1980s, which is near the low end of the range of estimates and goals. Since this acreage represents no more than about 10 percent of the lands in the U.S. that may be of geothermal value, acceleration of current rates of leasing could be useful. According to industry sources, accelerated leasing of Federal lands may be better accomplished by changing some of the BLM's leasing regulations and procedures.

Although the FPC has some jurisdiction over geothermal leases, its impact will be greater when geothermal resource development is closer to fruition.

Two areas of leasing operations have been identified as possible hindrances to fuller industrial participation: current bonus-bidding procedures which can serve to exclude lesser-capitalized bidders, and the broad definition of a Known Geothermal Resource Area (KGRA). DOI has generally favored bonus bidding, which requires substantial investment of initial capital. However, if examination of the effectiveness of current DOI leasing regulations should suggest that alternative procedures might enhance the rate of geothermal resource development, it may be possible to set them up without seeking new legislation. This could result in significant reductions in time to implement new policies from perhaps several years to less than one year.

Policy Coordination

The Energy Resources Council (ERC) was established by Public Law 93-438 to provide interim coordination in energy affairs among Executive agencies pending further reorganization of the Executive Branch, and to make recommendations on possible reorganization.

The Federal Energy Administration (FEA) is concerned mainly with near-term energy shortages and regulatory and policy development activities that can reduce their impacts. In policy development it functions in staff support to the Energy Resources Council (ERC). The FEA has no statutory functions in geothermal development but has programs in overcoming institutional barriers to geothermal commercialization.

Environmental Assessment and Regulation

The Council on Environmental Quality (CEQ) has been given a broad mandate to oversee environmental aspects of Federal activities. The Environmental Protection Agency (EPA) may in time develop geothermal standards and regulations in accord with its own statutory responsibilities. At this time EPA has no specific geothermal regulations in force but has established an internal working group to examine the subject, since it has undertaken to develop guidelines in the relatively near future. Coordination within the Interagency Geothermal Coordinating Council is indicated.

The Water Resources Council (WRC) is given a function in commercial applications of energy technologies by Public Law 93-577. As a precondition of Federal assistance, WRC is required to provide ERDA with an assessment of the relevant water use situation.

PROGRAMMATIC SIMILARITIES AND JOINT ACTIVITIES

At the present time there appear to be only a few programmatic conflicts or overlaps among the geothermal activities of the Federal agencies. Since all NSF geothermal grants have been completed or transferred to ERDA, close interagency coordination is needed only in a policy-related energy study having a geothermal component. This research concludes in June 1977. The regulatory activities of the EPA should be coordinated with geothermal development plans, in terms of both timing and regulatory approach, in order to give potential developers a clear expectation of realistic regulatory requirements. Otherwise, development might be impeded, since developers usually adopt a wait-and-see posture before investing large sums in plants that might not meet unknown future requirements. This possibility could be avoided or at least substantially mitigated through coordination in the Interagency Geothermal Coordinating Council.

Another potential area of immediate programmatic overlap concerns ERDA and USGS programs in resource assessment and exploration. However, these have been designed to be different and complementary in purpose and scale. ERDA and USGS have also coordinated their programs on technology development and environmental control.

Thus, present concern is less warranted over possible overlapping than over inadvertent gaps in the Federal program.

Although the FEA is not an R&D agency, there is still an area of potential overlap between it and ERDA, mainly in those activities that are required to carry new technologies to full commercialization.

Other important potential overlap areas with ERDA are tax policies as developed by the Treasury Department and leasing policies as developed by DOI. ERDA is authorized to conduct research and make recommendations in these areas. Once more, coordination of policy options and recommendations within the Council is indicated.

Other joint activities present no apparent potential for undesirable overlapping. Most of the overlaps or conflicts that could appear in the future would result from the differing policy objectives of the various Federal agencies. Resolution of these potential conflicts could be most effectively achieved through the Council.

AUTHORITY FOR THE INTERAGENCY GEOTHERMAL COORDINATING COUNCIL

Clearly there is need for coordination of the activities of the several agencies (named herein) among which the Federal role in geothermal energy has been distributed. Because of the absence of an explicit Congressional or Executive Office direction to establish the Interagency Geothermal Coordinating Council (formerly the Geothermal Advisory Council) as the successor to the Geothermal Energy

Coordination and Management Project, legal review of the Administrator's authority for the reconstitution of the Project as the Council has been obtained. The legal opinion is that "the programs authorized by Public Law 93-410 and assigned to the 'Project' and its 'Chairman' were in fact transferred to the Administrator of the Energy Research and Development Administration by Public Law 93-438 and Public Law 93-577."

APPENDIX C

GLOSSARY OF TERMS

GLOSSARY

ACTIVE FAULT - A fault along which measurable displacement has occurred in comparatively recent geologic time (usually late Quaternary or Holocene).

ACTIVE SEISMIC METHOD - Uses explosives to produce acoustic waves which are reflected and refracted through the earth and recorded by arrays of sensitive pickups (geophones); geologic structure is inferred from the recorded signals.

ANOMALY - In geology, a local feature distinguishable in a geophysical, geochemical, or geobotanical measurement over a larger area; a feature considered capable of being associated with commercially valuable deposits.

BASALTIC - Designates a volcanic rock low in silica, and rich in iron and magnesium; opposite of silicic.

BASIN AND RANGE PROVINCE - A large region characterized by tilted fault-block mountains separated by basins filled with young sediments.

BINARY CYCLE - In geothermal power-plant design, denotes the use of a heat exchanger to conduct heat from a geothermal brine to the working fluid (low-boiling-point fluid such as isobutane) which drives a turbine.

BLOWOUT - The sudden, often explosive escape of steam and perhaps hot water from a geothermal well; may be caused by improper drilling procedures or rupture of casing and wellhead equipment.

CASING - The steel pipe used to line a drill hole.

CONVECTION - A process of mass movement in a fluid medium (gas, liquid or plastic solid), in which cooler, denser material settles, and lighter, hotter material rises, causing vertical, near-circular flow. The process thus moves both the medium and the heat.

CORROSION - A process in which a solid (usually a metal) is eaten away by a fluid (usually an acid).

GLOSSARY (Continued)

- CRUST - The outmost layer of the earth, composed of relatively cool, brittle, low-density rocks (compared with the mantle), and ranging in thickness from 5 kilometers (beneath ocean floors) to 30 to 50 kilometers (under continents).
- DIRECT-CURRENT RESISTIVITY SURVEY - Uses a direct-current generator to produce an electrical field in the earth, which is then measured with a voltmeter at many different points; many different electrode configurations (connections of generator and voltmeter to the ground) are employed; the resistivities of buried rock units can be inferred by calculation.
- DRILLING RIG - Equipment used to drill through rock formations; shallow temperature-gradient holes are drilled with a truck-mounted rig; deep exploration holes are drilled with a large, stationary rig.
- DRY STEAM - Steam without entrained liquid water, i.e., pure steam.
- ENTHALPY - Heat content per unit mass, expressed in Btu/lb or cal/gm.
- FLASHED STEAM - Steam produced by the boiling of superheated water upon release of confining pressure.
- GEOCHEMICAL INDICATORS - In the geothermal context, geochemical anomalies indicating the presence of a potentially valuable geothermal prospect.
- GEOCHEMISTRY - Chemistry of the earth; applied geochemistry uses chemical analyses to find economic resources, including minerals and geothermal fluids.
- GEOPHYSICS - Physics of the earth; applied geophysics uses various methods of measuring physical characteristics of the earth's crust to locate economic resources.
- GEOPRESSURE - Fluid pressure exceeding hydrostatic pressure.
- GEO THERMAL - Of or relating to the earth's natural heat.
- GEO THERMAL GRADIENT - The rate of temperature increase with depth below the earth's surface in degrees C/km or degrees F/100 feet.

GLOSSARY (Continued)

GEOHERMAL IDENTIFIED AND PROVEN RESOURCES - Areas where geothermal resources may be identified from the distribution and abundance of such manifestations as hot springs, geysers, fumaroles, or indications of recent volcanic activity.

GEOHERMAL RESERVES - Those geothermal resources now recoverable at prices which are competitive with other forms of energy.

GEOHERMAL RESERVOIRS - Confirmed geothermal prospects.

GEOHERMOMETER - A geochemical method which uses groundwater chemistry to estimate the temperature of a geothermal reservoir.

HEAT FLOW - The amount of earth heat moving radially outward per unit surface area per unit time, expressed as microcalories/cm²/sec.

HOT DRY ROCK - Type of geothermal energy derived from deposits in which heat is contained in dry rock formations which are normally impermeable and of very poor porosity.

HYDROTHERMAL CONVECTIVE - Type of geothermal energy derived from hot water systems. When this energy is found in systems containing mainly steam they are called "vapor dominated." When they contain steam and large amounts of liquid or liquid alone they are called "liquid dominated."

IMPERMEABLE - Not permeable (see permeable).

INJECTION - The returning of produced geothermal fluids back into the reservoir from which they came through disposal wells.

INTRUSION - The process of injection of magma into the shallower portion of the earth's crust; an igneous (solidified magma) rock body formed by this process.

KGRA - (Known Geothermal Resource Area) - An area which the Mineral Land Classification Committee of the United States Geological Survey has designated as potentially valuable for production of geothermal energy.

LAND SUBSIDENCE - The sinking of land, usually due to withdrawal of natural underground fluids (oil or water) by man.

GLOSSARY (Continued)

LITHOLOGY - The character of a rock formation.

MAGMA - Molten rock.

MAGNETIC SURVEY - Uses a magnetometer (either airborne or on the ground) to measure the intensity of the earth's natural magnetic field at many points in the survey area; the data are then used to interpret geologic structure.

MAGNETOTELLURIC SOUNDING - Relies on the earth's natural electrical (telluric) and magnetic fields which are induced in subsurface conductive rocks; the resistivity of buried conductive rock units can be inferred from measurements of these fields at the earth's surface.

MANTLE - The spherical shell of the earth's interior, lying beneath the crust and above the core; it is about 2,900 kilometers (1,800 miles) thick, hot, plastic.

MEGAWATT - One thousand kilowatts.

NORMAL GRADIENT - Type of geothermal energy derived from the change in temperature of the earth with depth.

PASSIVE SEISMIC METHOD - An exploration technique relying on naturally occurring seismic waves (e.g., from earthquakes).

PERMEABLE SOLID - A solid through which a fluid can move.

RADIOGENIC - Formed as a consequence of radioactive decay of materials in the earth's crust.

RECONNAISSANCE - The initial investigation of a large area in order to locate prospects or targets.

RECHARGE ZONE - Area where water is added to the zone of saturation in a formation.

RESERVOIR - A space in which a fluid is stored, as in the pores or fractures of a rock body.

RESISTIVITY - Electrical resistance of a unit cross-section per unit length in any material; this varies widely with rock type, porosity, temperature, mineral composition, fluid content, and salinity.

GLOSSARY (Continued)

- SALINITY - A measure of the total dissolved solids of water; for comparison, sea water has a salinity of about 30,000 ppm.
- SCALING - Precipitation and deposition of dissolved solids in pipes or other containers (of geothermal or other fluids.)
- SEDIMENT - In geology, rock and mineral debris which has been eroded, transported, and deposited by wind, water, or ice (glaciers).
- SEDIMENTARY - Composed of sediments, usually deposited in water.
- SEISMIC - Pertaining to, characteristic of, or produced by earthquakes or earth's vibration, or by artificial elastic wave generation.
- SEISMICITY - Earthquake activity.
- SEISMIC NOISE - Ambient or background seismic energy which can be measured anywhere on the earth's surface; its characteristics vary with local geologic structure.
- SILICIC - Applied to igneous rock containing 66 percent or more of silica, such as rhyolite, dacite, granite and quartz monzonite.
- SPACE HEATING - Heating of air inside a building.
- SUBSIDENCE - A large-scale sinking or downward settling of part of the earth's crust.
- TDS - Total dissolved solids.
- TECTONIC - Refers to those processes by which rocks of the crust and upper mantle are deformed (faulted, fractured, folded).
- TECTONIC PLATE - A large area of the crust and upper mantle (shallower than about 100 kilometers or 60 miles) that moves or is rafted across the underlying mantle as a unit over a long period of geologic time; the process of shifting leads to continental drift.

GLOSSARY (Concluded)

TELLURIC - (See magnetotelluric).

TEMPERATURE-GRADIENT SURVEY - Uses a probe to sample temperature at successive points in a drill hole, in order to determine the rate of temperature increase with depth.

TOTAL FLOW - Conversion techniques capable of using both liquid and steam in a combined flow to turn a turbine.

VAPOR-DOMINATED RESERVOIR - One in which produces dry steam without significant liquid water content.

VOLCANISM - Natural processes resulting in the formation, movement, eruption, and crystallization of magmas, forming volcanoes and volcanic rocks.

WELL-LOG - A record of certain geophysical properties of rocks penetrated by a well, from which lithology can be inferred.

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