DRAFT

Geothermal Energy

Multi-Year Program Plan
FY 1994-1998

Geothermal Division
U.S. Department of Energy

April 1993

This material is for internal planning and management purposes. Budget figures, similarly, are for purposes of planning and for making assumptions explicit. They have not been approved as U.S. Government budget figures or projections.

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I. INTRODUCTION

Geothermal energy is the Nation's most versatile and reliable renewable energy resource. Geothermal and other renewable energy technologies are expected to play an important role in meeting the Nation's future energy needs. The Department of Energy's Office for Renewable Energy Conversion objectives include facilitating geothermal and wind technologies such that they will capture 3 percent of the Nation's electricity market and 50% of new international markets by the year 2000. These objectives are in keeping with and reinforced by the Energy Policy Act of 1992 which contains provisions specific to renewable energy. The purpose of these provisions are: 1) to promote increased production and use of renewable energy resources, 2) to advance renewable energy technologies, and 3) to increase export of U.S. renewable energy technologies and services.

Utilities, state commissions and others involved in planning future electricity needs are actively considering geothermal supply and demand-side options. Where geothermal energy is a supply option, the Integrated Resource Plans (IRP) of utilities, state commissions and regional power authorities reflect expectations for significant future geothermal capacity expansion. Nationwide, the geothermal heat pump is a demand-side management option that is gaining a growing share of the home heating and cooling market. Recent reports show that they have lower life-cycle costs than traditional air-source heat pumps. Other direct use applications of geothermal heat continue in their role as load reduction and conservation options.

In this Multi-Year Program Plan, the Geothermal Division outlines its strategy for facilitating technology transfer that will enable industry to realize these supply and demand-side management opportunities. Through research, development, demonstration and commercialization activities, the division's goal is to facilitate geothermal energy use with as little cost as possible to the taxpayer while taking full advantage of these resources in serving the Nation's energy needs.

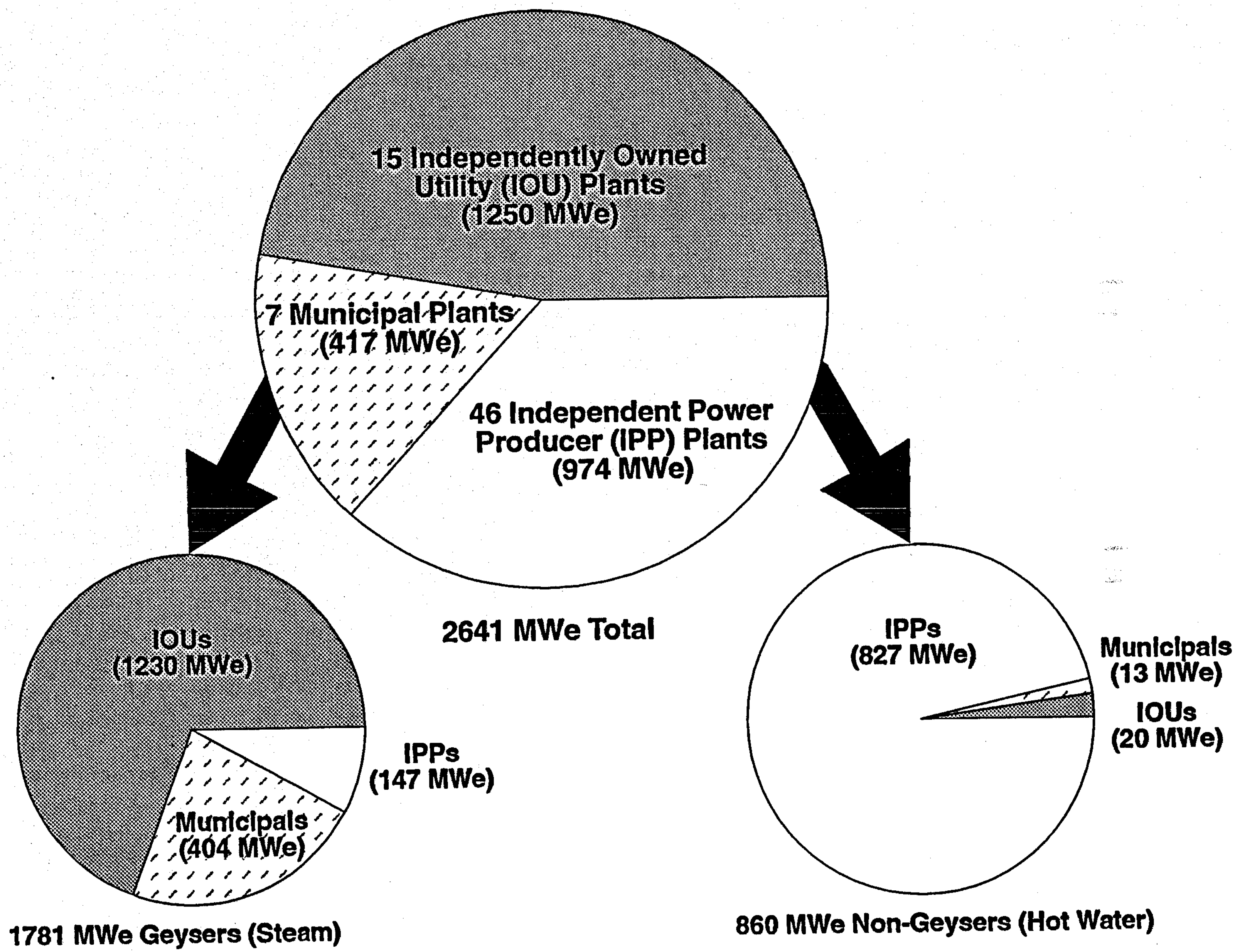
II. THE STAKEHOLDERS

Developers of geothermal power include utilities (investor-owned and municipal), and developers and other independent power producers (IPPs). The industry also contains some geothermal energy entrepreneurs and partnerships formed by non-geothermal industries and the financial community. Currently, utility-owned steam plants at The Geysers dominate the capacity mix (Figure 1). These plants are generally larger than the hot water plants typically installed by IPPs. However, hot water plants (using flash and binary technologies) represent the current trend in geothermal power generation. IPPs already own over half the powerplants and generate nearly 40 percent of geothermal electric power. They are expected to install the vast majority of future geothermal capacity, as already illustrated by their overwhelming presence outside The Geysers.

A wide range of service and supply companies provide essential support to geothermal developers and operators. These companies engage in activities needed to bring a geothermal project on-line, such as conducting geophysical and other geoscience surveys; providing drilling expertise; and supplying the chemicals, piping, materials, equipment, and services needed in power plant construction.

Non-industry stakeholders include researchers and others in the R&D community (e.g., universities, national laboratories) involved in actively improving technologies to advance geothermal development; public utility commissions and regulators whose decisions ultimately affect the use of the Nation's geothermal resources; and end-users such as electric power customers interested in direct-use applications such as geothermal heat pumps.

Figure 1
Geothermal Power Generation (1992)
(MWe owned)



III. STATUS OF GEOTHERMAL RESEARCH DEVELOPMENT

The Investment

Since 1976, the Federal Government, through the Department of Energy and its predecessors, has invested over $1.3 billion towards developing and encouraging the application of geothermal power generation, geothermal heat pumps and direct use applications (Figure 2). Additionally, industry and utilities have spent an estimated $5 billion for electric power projects alone.

The Benefits

The U.S. Energy Information Administration projects growth in geothermal capacities (net summer capability) ranging from 7,300 to 9,700 MW by 2010, with a reference case projection of 8,500 MW[1]. A more aggressively funded federal exploration and R&D program could result in almost 18,000 MWe by 2010[2].

Supply Options - Electric Power Generation

The primary direct benefit of DOE's research investment is commercialization of hydrothermal electric power, and of related technologies developed through the Geothermal Division's R&D programs. The Division has had, and is continuing to play, a significant role in developing an industry representing over 2600 MWe of net generating capacity. Sixty-seven geothermal plants are now operating at 17 geothermal fields in California, Nevada, and Utah (Figure 3), and new

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[1] DOE/EIA-0561, *Renewable Resource in the U.S. Electricity Supply*, February 1993. The reference case assumes moderate growth in electricity generation (1.5%/year) overall with renewable resources increasing slightly more rapidly (1.8%/year).

[2] EIA/DOE-0544, *Geothermal Energy in the Western United States and Hawaii: Resources and Projected Electricity Generation Supplies*, September 1991.

Figure 2
Geothermal Energy Appropriations History
(ERDA and DOE)

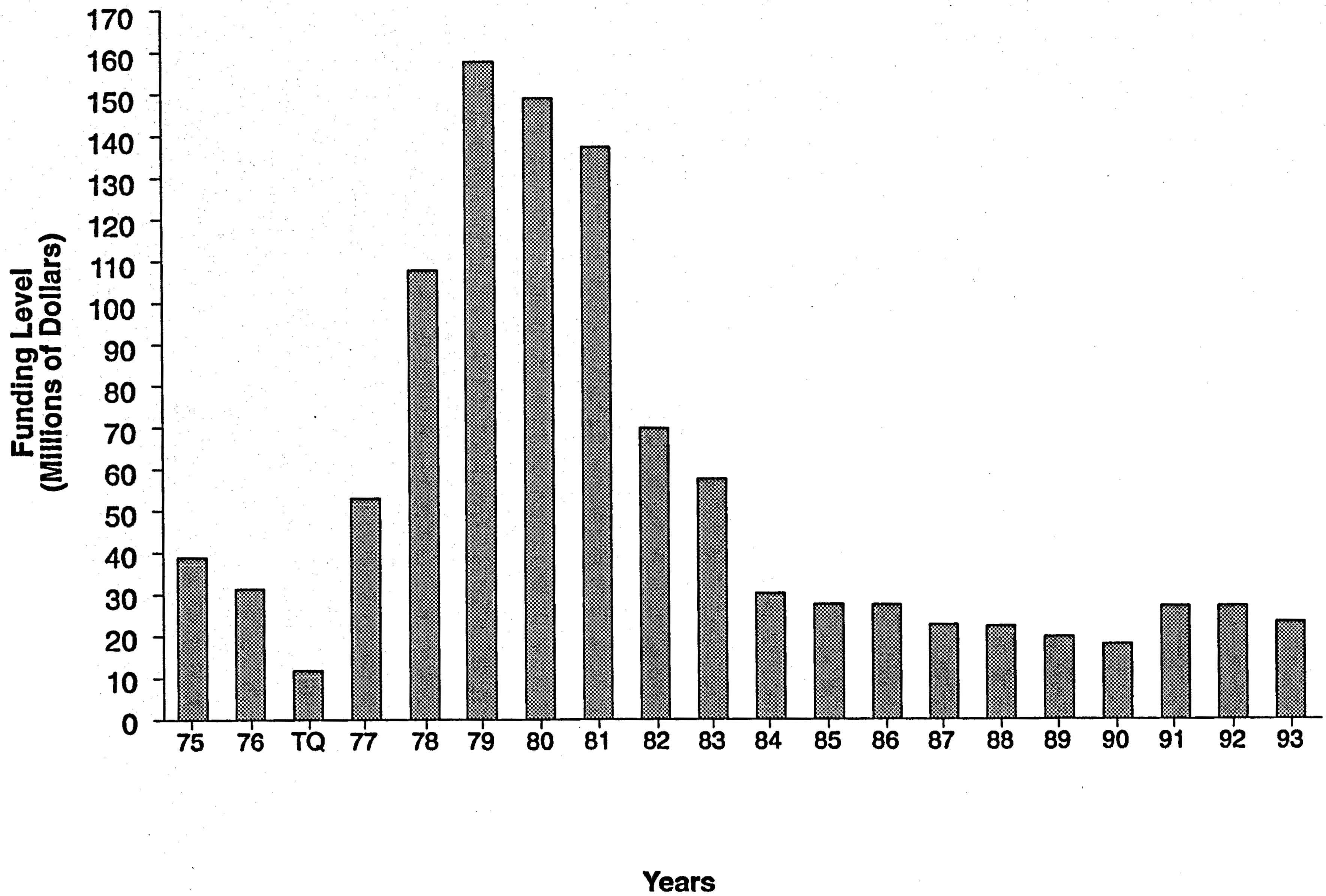
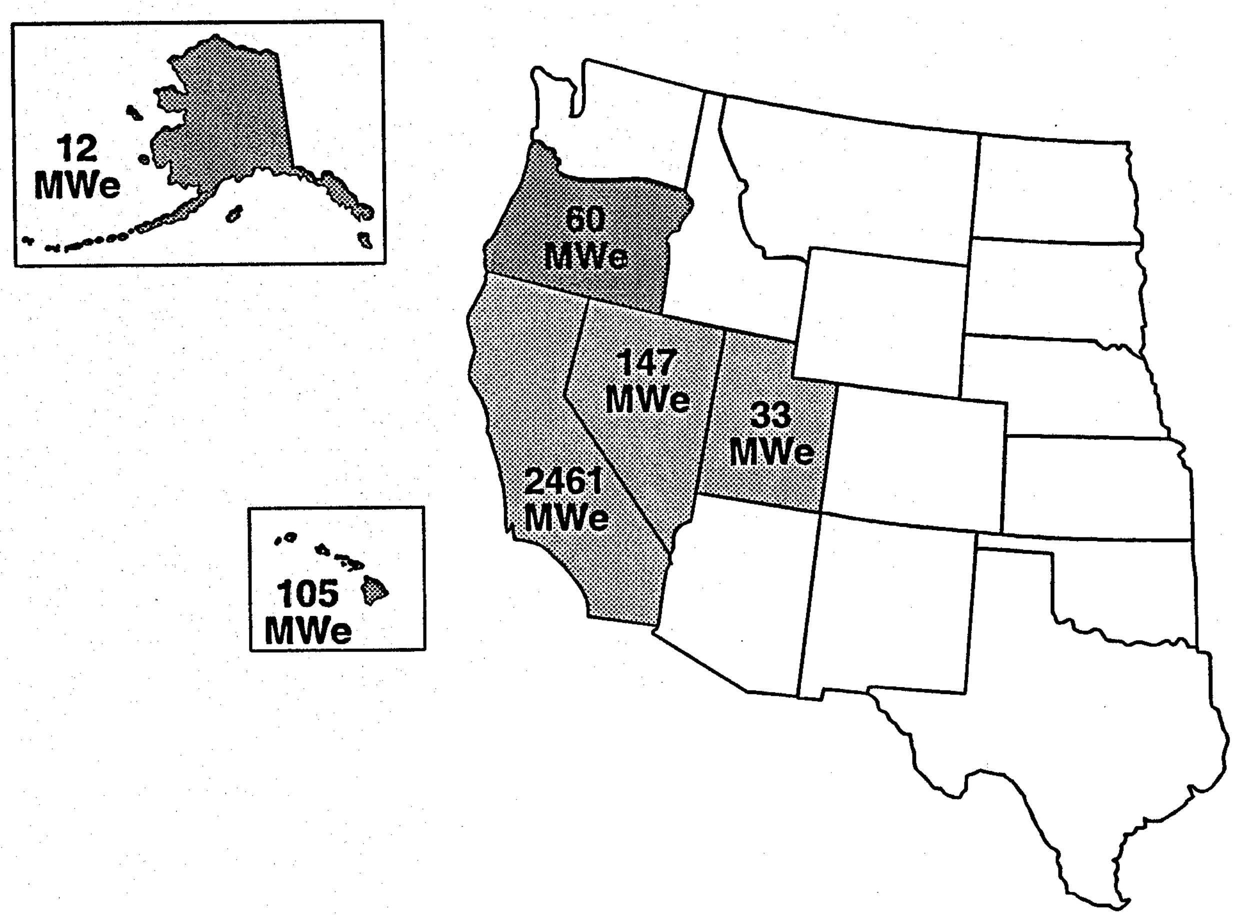


Figure 3
States with Existing and Planned Geothermal Power Plants (1992)



Established Geothermal Generation

First Power Plants Planned or Under Construction plants are underway in the Pacific Northwest, Hawaii and Alaska. About six percent of California's power needs in 1991 was supplied by geothermal plants.

Timely cooperative efforts between the Federal government and industry were key to overcoming early institutional barriers to development. These barriers included expensive remedial actions to satisfy environmental regulations and exclusion of promising resource areas. Solutions such as an accelerated federal leasing program in the western states and revision of taxation and regulatory procedures reduced construction costs and lead times.
In part due to early Federal government efforts, geothermal baseload and some load-following electric power generation is competitive with other supply options. Geothermal energy has the added important advantage of providing a capacity option with exceptional reliability and little to no adverse effects on the environment.

The use of geothermal power by utilities resulted in a $125-$250 million cost-savings to consumers in 1988, primarily due to the low cost of power from The Geysers (CA). Most geothermal power plants are sited on federal leases, and in 1991 these leases returned more than $17 million in annual revenues to the Federal and state governments from royalty and rental fees.

Demand-side Options - Direct Use Applications including Geothermal Heat Pumps

Direct use applications provide alternatives that assist load reduction and conservation measures. Geothermal heat pumps and other direct use applications are providing demand-side management and conservation options designed to reduce and manage the need for electricity. The annual energy savings from direct geothermal heat applications in the U.S. is over 18 trillion Btu, or the equivalent of over 9 million barrels of oil at 35% conversion efficiency. These applications are expected to grow at a rate of 7 to 11 percent annually[3]. Twenty-five geothermal municipal

[3]Projections generated by the Oregon Institute of Technology, based on historical data and assuming current technologies and economic conditions.

and institutional district heating systems are in operation, while individual systems serve a growing number of commercial and industrial enterprises.

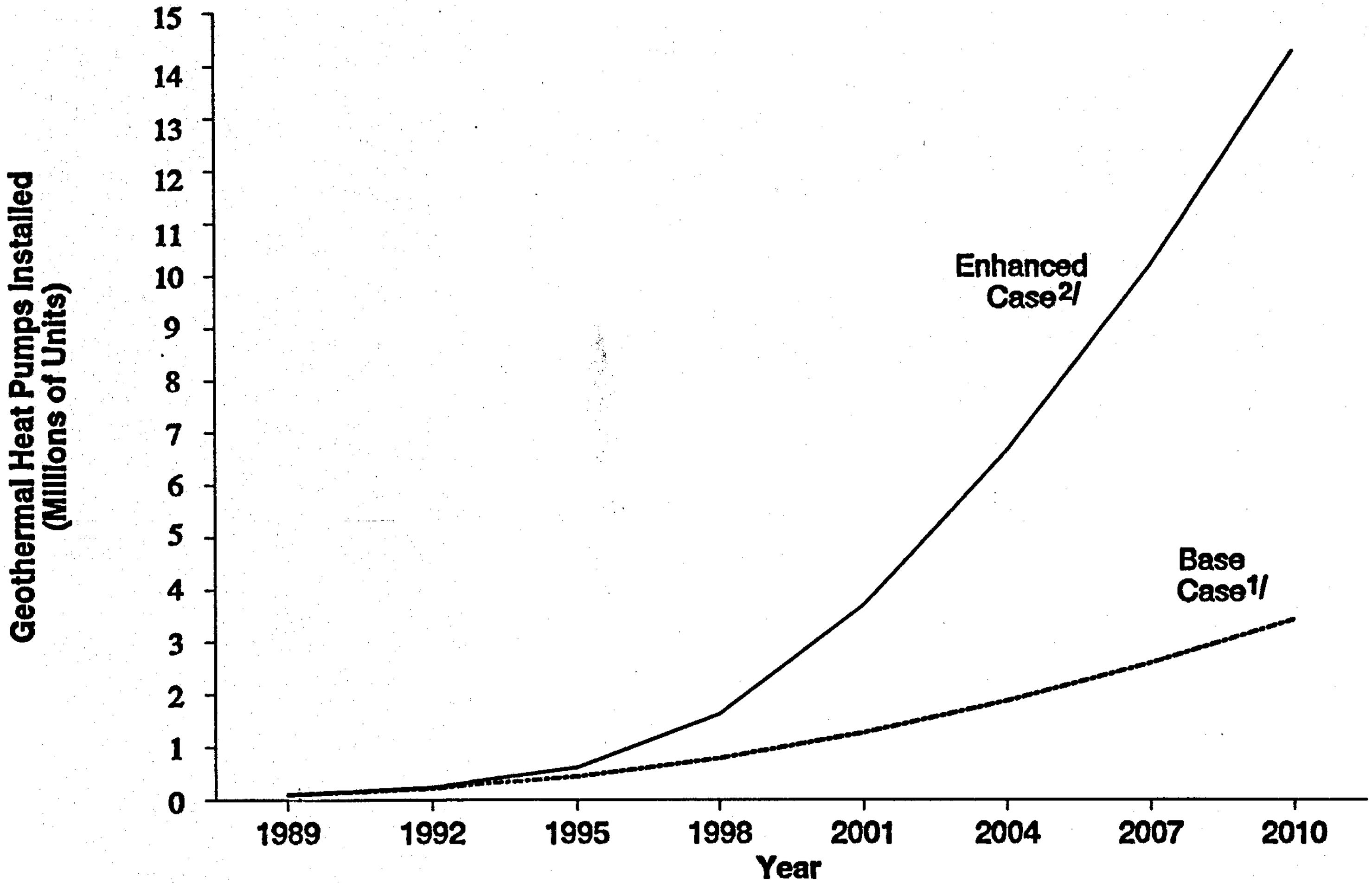
Geothermal heat pumps are a nationwide option for reducing overall demand or managing peak periods. The use of geothermal heat pumps (GHP) is expected to expand rapidly for the remainder of the decade and into the 21st century. An estimated 150,000 geothermal heat pumps are currently in use, with double digit growth expected in the near-term (Figure 4). As the leading renewable energy demand side management option, geothermal heat pumps are charting new territory, expanding geothermal applications to a truly nationwide scale. Responses to DOE's nationwide GHP teleconferences indicate a high level of interest among utilities and HVAC manufacturers in this renewable energy demand-side management technology.

Geothermal energy also contributes other important benefits such as reducing the nation's oil vulnerability and mitigating environmental concerns; two major objectives of the National Energy Policy Act of 1992. Geothermal energy can potentially reduce demand for imported oil and free some domestic oil for other uses, such as chemical feedstock. Use of geothermal energy assists a number of western U.S. metropolitan areas in meeting local air quality standards. Nationally and globally, use of geothermal resources can assist in meeting energy demands without detriment to the environment. In developing countries with large untapped resources, geothermal energy use could reduce the clearing of rain forests or burning of fossil fuels. Geothermal facilities also can exist in scenic and recreational areas, such as the Mammoth Plant near Mammoth Lakes in the Mono-Long Valley area of California. These factors combine to make geothermal energy a prime candidate for increasing the supply of power with the least impact in sensitive environments.

Government's Role to Date

The Federal Geothermal Program was initiated in the early 1970's to investigate the feasibility of using the various forms of geothermal resources. The Atomic Energy Commission, the National Science Foundation through the Research Applied to National Needs program, and the

Figure 4
Projected Growth of Geothermal Heat Pump Installation



1/ Base case assumes current technology and economics.

2/ Enhanced case includes utility incentives and GHP R&D.

U.S. Geological Survey were charged with directing the early resource and technical assessments. The program started as a scientific/technical effort with only marginal commercialization interest.

Passage of the Geothermal Energy Research, Development, and Demonstration (RD&D) Act of 1974 initiated a formal commercialization program. These projects, located in Idaho, Nevada and California, were cost-shared cooperative ventures done in partnership with industry. From 1977 to 1981 this program represented the largest element of DOE's total geothermal funding.

During the early 1980's, a policy decision was made to rely on the market and on incentives from the National Energy Act of 1978 for geothermal energy commercialization. The program's emphasis shifted away from commercialization and back to research and technology development. Since 1982, DOE's expenditures have concentrated on improving technologies for locating and developing geothermal reservoirs, along with managing the production of geothermal fluids and their conversion to electric power. The R&D program was characterized by lower budgets and emphasis on high-risk research with long-term payoff. The government began to rely on industry facilities for testing new or improved equipment and materials developed by the DOE program.

Since 1988, the Federal role has changed again. The emphasis has shifted to applications research and development activities, while continuing some long-term, high-risk research. DOE's Office of Energy Efficiency and Renewable Energy, which includes the Geothermal Division, was reorganized to create an end-use oriented structure. The geothermal research program was adapted to respond to the needs of the utility sector. Currently, the program's objectives are focused on developing additional energy supplies, reducing energy demand, reducing institutional barriers that constrain renewable technologies, and accelerating market penetration by new technologies.

The Geothermal Division, working with the DOE's Office of Building Technologies and the Office of Technical and Financial Assistance, has been cooperating with various utilities in expanding the use of geothermal heat pumps and incorporating geothermal energy into their integrated resource plans. Industry has also been exploring the use of geothermal energy for thermally enhanced oil recovery, the detoxification of pollutants, and other innovative applications derived from earlier DOE research.

Throughout the life of the federal program, R&D involving magma, geopressured and hot dry rock resources has been almost exclusively a government function. Technology to harness these resources lay beyond the present financial capabilities of the geothermal community, but the potential future payoff cannot be ignored. This R&D is consistent with: 1) the mandate of the RD&D Act of 1974 to determine and improve the scientific, engineering, and economic feasibility of using energy from all types of geothermal systems; and 2) the objectives of the Energy Policy Act of 1992 to reduce oil vulnerability, mitigate global climate change, and increase conservation and the use of renewable energy resources.

Given the stage of geothermal development today, what is the rationale for a continued federal role in various geothermal-related affairs...reduction of institutional impediments to geothermal growth...transfer of advanced technologies to industry...contributing to geothermal education? Overall, the geothermal industry is appreciably smaller than the industries that supply fuel and generate electric power from conventional energy sources. This situation leaves geothermal companies lacking the financial resources to wholly fund essential research. They are still unable to make the substantial investment risks that accompany major geothermal development. Also, potential markets for geothermal-generated power are often located some distance from the resource, and construction of transmission lines to tie into the grid is costly. In the past, federal support stimulated the initial commercialization and expansion of the abundant moderate-temperature hydrothermal resources, both in terms of R&D and institutional factors. Without continued substantive federal leadership and involvement, geothermal energy will not reach its full potential as a competitive energy supply option.

IV. THE VISION

The challenge, or opportunity, confronting the Geothermal Division is to help increase the amount of our country's geothermal energy that can be economically recovered and used for beneficial purposes. Accordingly, the Geothermal Division will work with industry to incorporate renewable resources into the Nation's supply mix, such that geothermal energy industries will help provide better than 3 percent of the Nation's electricity, and capture 50 percent of new international markets by the year 2000.

One very important means for accomplishing these goals is to increase geothermal reserves, reserves being defined as identified resources which can be extracted economically under existing conditions. The most recent estimate of U.S. geothermal reserves is 5,000 MWe[4] and consists entirely of hydrothermal energy from identified and producing fields. Based on the U.S. Geological Survey's estimates[5], these fields have the potential of generating 12,000-13,000 MWe.

Expansion by the geothermal industry both within and beyond the 17 fields currently in production will require innovative technologies. These technologies could, in turn, put the U.S. at the forefront in international markets. In addition, the resource characterization required to expand the reserve base will provide the level of detail needed to satisfy the siting and risk criteria of utilities, entrepreneurs and capital lenders. The use of geothermal energy will become standard for grid-connected and dispersed electric generation while geothermal heat pumps set the standard in satisfying demand for space heating and cooling.

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[4] Based upon industry communication.

[5] Muffler, L.J.P., editor, *Assessment of Geothermal Resources of the United States - 1978*, U.s. Geological Survey Circular 790, 1979.

The Energy Policy Act of 1992 (EPACT) contains nearly forty provisions designed to assist the Geothermal Division in achieving these goals. Three programs authorized, but yet to be funded by appropriations, include: (1) a 5-year Renewable Energy Research, Development, Demonstration and Commercialization and Cost Sharing Program; (2) a provision for federal cost sharing of demonstration and commercial applications projects; and (3) a 5-year program to improve energy efficiency and renewable energy use in the buildings, industry and utility sectors. A geothermal production incentive and permanent extension of the geothermal tax credit are also part of the Act. EPACT contains one section specifically designed to encourage the use of geothermal heat pumps and six others that could potentially benefit this demand-side technology.

Other EPACT provisions are designed to assist geothermal and other renewable technologies when competing in the international market. Among these are two international technology transfer programs: one specific to promoting export of renewable energy technologies and the other concentrating on transfer of environmentally sound energy technologies. Additionally, EPACT contains a U.S. renewable energy export technology training provision targeted for developing countries.

V. THE STRATEGY

The Geothermal Division's strategy is to advance technology improvements that will increase the availability and accessibility of geothermal resources in meeting the Nation's energy needs. Emphasizing applications-oriented projects, identified in close cooperation with industry and utilities, the Division works to assist in bringing new and/or improved technologies to commercialization. These efforts will result in more power-on-line; at lower cost and greater reliability; advancement of geothermal direct-use applications' share of the dispersed energy market; and significant contributions by geothermal heat pumps in reducing the Nation's electricity demand.

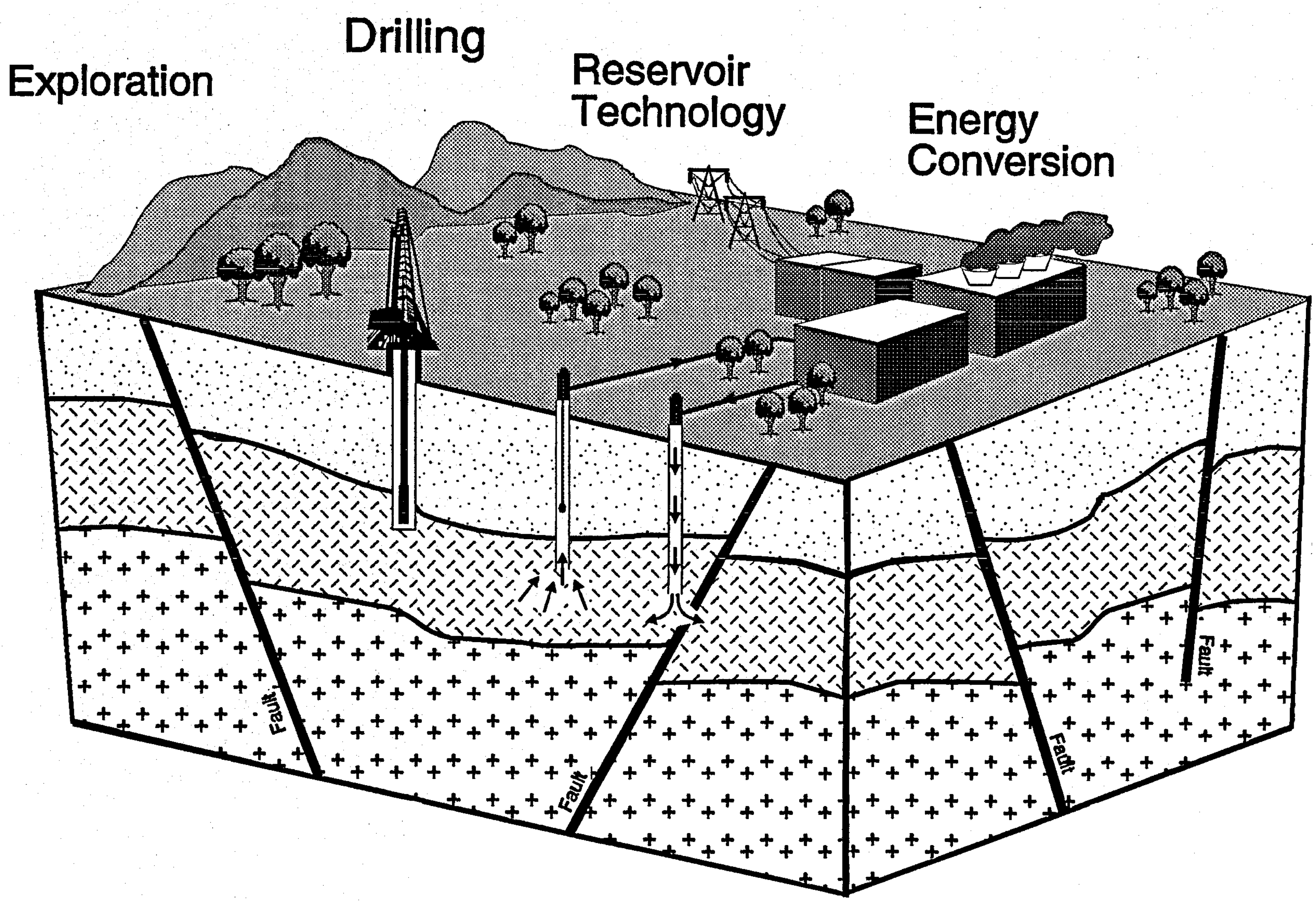
Implementation of the strategy involves open and interactive planning; collaborative projects based on industry-driven priorities; cost-shared R&D; industrial investment commitments for development; partnership relationships among government, industry, labs and universities; and technology transfer. These activities encompass both applied research, and development and applications. The Division's applied research covers investigations that the undercapitalized industry cannot afford. Development and applications activities involve cost-shared research with industry partners, as well as other funding agencies. These activities focus on eliminating near-term technical obstacles through the rapid, efficient transfer of new technology.

V. THE PROGRAM

The Geothermal Division plans to implement its strategy through a program that sponsors research in four technology areas representing the components (or stages) of geothermal project developments. These are exploration, drilling, reservoir technology, and management, energy conversion (Figure 5). The strategy contains two program scenarios: a base case and an enhanced case. In the base-case scenario, the program plan is derived from recent funding trends. The base-case is essentially a "business as usual" program that continues support of currently funded projects. Funding changes, such as cuts in existing programs or provisions for new initiatives are incorporated within modest budget increases, largely intended as inflationary adjustments. The Industry-Coupled Drilling Program is the only one major new initiative planned in this scenario.

The enhanced-case scenario adds eight additional projects designed to expand the identified geothermal resource base, expand geothermal energy use into frontier areas such as the Pacific Northwest, improve drilling and conversion technologies for all geothermal applications, and re-vitalize the Hot Dry Rock and Geothermal-geopressured programs. These proposed projects are joint venture initiatives identified and defined according to the objectives outlines in the Energy Policy Act of 1992.

Figure 5
Geothermal Technology Areas



Program Rationale

The Geothermal Division's plan for advancing exploration and reservoir technologies focuses on techniques that will expand the current reserve base. Expansion of geothermal reserves both within and beyond currently producing fields will require advanced and innovative technologies. Little experience exists in managing production from geothermal reservoirs. Thus, analytical tools are needed to determine the effects of existing operations on the reservoir and to optimize placement of new plants, new production wells, and new injection wells.

The Geothermal Division's base-case plan includes an ongoing cost-shared program to stabilize production at The Geysers. The Geysers complex offers the first opportunity in the U.S. to study the behavior of a mature geothermal field. Managing the remaining resource to arrest or slow the production decline at The Geysers is critical to ensuring utility and investor confidence in all proven and yet-to-be-proven geothermal fields.

Expansion beyond producing fields will require innovative methods to find and characterize new hydrothermal reservoirs and to identify the best sites for drilling. In cooperation with industry, development of such methods will result in discovery of new fields that have no obvious surface manifestations.

Drilling of geothermal wells is another area that will benefit from technology advances. While integral to all stages of geothermal development (exploration, reservoir development, and production/injection), drilling costs 2 to 3 times more then conventional oil and gas wells. If successful, new technologies will reduce the number and/or costs of wells needed to discover and confirm reservoirs, and increase the amount of geologic data obtained from each well.

Drilling technology is also the principal limitation to reducing the cost of installing geothermal heat pumps. Development of better and less intrusive drilling techniques should significantly increase the installation rate of GHPs in developed industrial and residential areas.

Increases in conversion efficiencies will optimize the heat value of the resource and offset large investments in finding and producing the resource. In addition, advancing modular technology will provide a better means to test new reservoirs, allow for early power production and cash flow, encourage step-by-step development, and reduce financing costs.

Key Participants Needed for Success

All elements of the U.S. geothermal community contribute to the success of the federal R&D program. This collaboration helps to assure an infrastructure in which geothermal development can flourish as more market opportunities become available. The community is an especially close-knit one and cooperation is the norm. This group includes other federal agencies -- the U.S. Geological Survey, the Bureau of Land Management, the U.S. Forest Service -- state energy and resource agencies, the national laboratories, utilities, and industry.

Two unique DOE/industry organizations, the Geothermal Drilling Organization (GDO) and the Geothermal Technology Organization (GTO), are critical to the successful transfer of technology to the marketplace. The GDO focuses on geothermal drilling technologies, whereas the GTO focuses on technology related to reservoir performance and energy conversion. Both organizations support projects designed to market the products of research. These projects are jointly funded by DOE and participating industry partners, with industry providing at least 50% of the total cost.

The Geothermal Division is kept apprised of the industry's status and needs through the annual Stanford University Reservoir Engineering Workshop, The Geysers Research Consortium, and the annual DOE Geothermal Program Review. Regular interaction with state geologists, state energy offices, and state energy commissions is maintained with inquiries frequently directed to state regulatory agencies to ascertain their views on compliance by the geothermal industry. Dialogue is continual between the Geothermal Division and regional power agencies such as the Bonneville Power Administration.

Funding of geothermal research programs at academic institutions gives "hands-on" experience for students who provide the professional workforce for the geothermal industry. The Geothermal Division also participates in and actively supports the public information and educational programs of the Geothermal Resources Council, including the creation of the Geothermal Education Office.

Program Objectives

The base-case program plan carries current levels of effort on the Geothermal Division's existing activities to their logical conclusion. These projects focus on expanding hydrothermal resources and reducing their costs. The enhanced-case program plan expands efforts in the four technology areas (exploration, reservoir technology, drilling and conversion) and adds projects on hot dry rock and geothermal-geopressured resources.

The Geothermal Division's primary objective is to identify, develop and assist commercialization of geothermal technologies. The goal is to reduce cost of accessing and using geothermal resources such that geothermal energy becomes a mainstream utility supply and demand-side management option. To attain this goal, advances are required in all areas associated with geothermal development.

In exploration and reservoir management, methods and technologies need to be developed and refined for:

- reducing the pressure decline at The Geysers steam field in California and stabilizing productivity
- locating and characterizing geothermal resources in both identified and undiscovered fields
- reducing the number of exploratory wells required to prove a field.

Drilling costs are a major factor in developing geothermal resources and increasing market penetration for geothermal heat pump technologies. The Geothermal Division contributes to reducing development costs and associated risks through projects designed to:

- explore, develop, apply and test alternative drilling methods and technologies
- reduce the downtime due to lost circulation
- develop and test advanced non-metallic well casing liners and materials for in situ conversion of drilling fluids into cements
- improve technologies related to installing ground loop systems for geothermal heat pumps.

Geothermal conversion technologies are more mature than other areas of geothermal development. However, improvements to existing geothermal conversion systems would result in a net positive impact on the cost of generating electricity. The Geothermal Division's objectives in this area are to:

- improve binary cycle efficiencies
- develop low cost, environmentally sound waste disposal processes
- identify higher-efficiency, standardized energy conversion technologies.

R&D Activities

Research activities for the five year planning horizon of this multi-year program plan are summarized in Table 1. The activities are categorized depending upon whether they are part of

Table 1
Geothermal Division Program Outline

	EXPLORATION	RESERVOIR	DRILLING	CONVERSION
Base-Case	Integrated Exploration Strategy Industry-Coupled Exploration and Development-Selected Sites	Reservoir Management Models and Practices The Geysers Hot Dry Rock: Transition to Industry-Based Technology	Slim-hole Coring System Lost Circulation Control Advanced Drilling Instruments and Materials Geothermal Heat Pumps	Electric Generator Systems Biochemical Processes Brine Chemistry Modeling
Enhanced-Case	Advanced Geothermal Exploration Pacific Northwest Geothermal Initiative	Hot Dry Rock: Joint Venture for a Second Site Geothermal Enhanced Oil Recovery	Advanced Drilling and Excavation Technology	New Generation Geothermal Power Plant Waste Reduction/Mineral Recovery Project

the base-case scenario or the enhanced case. Each activity is discussed in greater detail in Appendix A. Appendix A groups the present and proposed activities into technology areas, differentiating between base-case or enhanced-case components.

Technical milestones have been established for research tasks in the base-case program plan. These milestones are used as targets and provide a basis for evaluating program accomplishments. Periodic reevaluations ensure that the milestones meet the latest program objectives and consider current budgetary constraints. Milestones for FY 1994-1998 are shown in Table 2.

Given the risks and uncertainties of research, the objectives expressed in this plan are subject to change. In addition, the potential for changes in policy directives, industry needs, new concepts for technology improvement, and funding levels requires the Geothermal Division maintain a degree of flexibility in its R&D approach. But for now, the base case represents the direction the Division intends to move in managing its research program.

Management Structure

The Geothermal Division is responsible for overall program management and operates under the administrative oversight of the Office of Renewable Energy Conversion under the Office of the Deputy Assistant Secretary for Utility Technologies. With the oversight of these offices, the Geothermal Division implements energy policy at the program level and allocates the necessary technical and budgetary resources for program activities. In addition, the Division works in cooperation with other offices within DOE (e.g., the Office of Energy Research, and the Office of Technical and Financial Assistance) on activities of mutual interest.

Under the guidance and leadership of the Geothermal Division, field organizations at the Albuquerque and Idaho Operations Offices implement program plans, execute prime contracts for research, direct contractors and review their performance, and provide the Geothermal Division with recommendations on program needs and direction. Actual implementation of the

Table 2
Geothermal Key Milestones

PROGRAM	FY94	FY95	FY96	FY97	FY98
EXPLORATION TECHNOLOGY					
INTEGRATED EXPLORATION STRATEGY					
1 Complete Development of Integrated Exploration Model (IEM)		1			
2 Field Verification of IEM			2		
3 Transfer Technology to Industry				3	
INDUSTRY-COUPLED EXPLORATION AND DEVELOPMENT - SELECTED SITES					
4 Field Surveys and Exploratory Drilling	4				
5 Complete Cost-Shared Drilling			5		
6 Demonstration of New Reserves (5 New Fields)					6
RESERVOIR TECHNOLOGY					
RESERVOIR MANAGEMENT					
7 Complete Geochemical Reservoir Model	7				
8 Test New Reservoir Simulators Incorporating Geochemical Processes				8	
THE GEYSERS					
9 Complete Major Cost-Shared Injection Experiment	9				
10 Test New Injection Technology at The Geysers		10			
11 Conduct Joint Demonstration of New Injection Technology/ Strategy			11		
HOT DRY ROCK					
12 Transition to Industry-Based Technology	12				
DRILLING TECHNOLOGY					
SLIMHOLE CORING SYSTEM					
13 Field Test Comparing Large and Small Wellbores	13				
14 Cost-Shared Demonstration of Advanced Slimhole Coring System			14		
15 Assist Industry in Technology Transfer				15	
LOST CIRCULATION CONTROL					
16 Transfer Drillable Straddle Packer and Borehole Televiewer Fracture Diagnostic Techniques to Industry		16			
REVOLUTIONARY DRILLING SYSTEM					
17 Select Alternative Drilling System for Prototype Development		17			
18 Cost-Shared Drilling of Production-Size Well with Advanced Prototype					18
ADVANCED DRILLING INSTRUMENTS AND MATERIALS					
19 Develop Elastomeric Well Casing Liners		19,20			
20 Test Lost Circulation Control Expert System		19,20			
21 Field Test Measurement-While-Drilling-Tools				21	
22 Field Test Fiber Optics System					22
GEOTHERMAL HEAT PUMPS					
23 Complete Ground Loop Design Manual for Commercial Buildings		23			
24 Industry Cooperative Demonstration of One-Day Compact Geothermal Heat Pump Installation			24		
CONVERSION TECHNOLOGY					
ELECTRIC GENERATORS					
25 Complete Construction and Initiate Testing of an Advanced Geothermal Electric Generator	25				
26 Test Improvements in Binary Cycle Efficiency		26			
27 Complete Cost-Shared Tests of Advanced Generator			27		
BIOCHEMICAL PROCESSES					
28 Initiate Cost-Shared Testing of Pilot Bioreactor for Geothermal Sludges		28			
29 Complete Cost-Shared Testing of Pilot Bioreactor			29		
30 Build Commercial-Scale Bioreactor with Industry				30	
31 Transfer Brine Chemistry Models to Industry	31				

geothermal research program and day-to-day management of the research activities are performed by contractors, including the national laboratories, universities, and industry. As a result of substantial contractor investment in human, technological, and analytical resources, as well as for laboratory equipment and facilities, centers of excellence specializing in various aspects of geothermal research have been established. These include national laboratories, universities, and industry contractors.

Budget Assumptions

The Geothermal Division proposes a 5-year, base-case budget of $135.3 million and Division staff of 16 full-time equivalents (FTE) for FY 1994-1998. The enhanced-case budget adds funding for proposed joint ventures and new initiatives. Table 3 presents the resource plan for the geothermal program for both scenarios during the FY 1994-1998 planning period.

Table 3
GEOTHERMAL RESOURCE PLAN*

Resource Plan (Dollars in Millions)	FY94	FY95	FY96	FY97	FY98	Total
Base-case Budget	23.9	25.5	27.0	28.6	30.3	135.3
Enhanced-case Budget	55.5	72.5	94.4	102.4	108.2	433.0

* Budget figures are for internal planning purposes and reflect current DOE policy. They have not been approved as U.S. Government budget figures or projections.

Appendix A

PRIMARY RESEARCH ACTIVITIES OF THE GEOTHERMAL DIVISION FOR FY 1994-1998 AND EXPECTED RESULTS

PROGRAM ELEMENT	RESEARCH ACTIVITIES	EXPECTED RESULTS
Exploration Technology Base Case	Actively involve industry in technology development to produce the new generation of instruments and techniques necessary to discover hidden geothermal systems.	Enhanced superiority of U.S. industry in the international market for geothermal exploration and a competitive advantage for U.S. companies. Increased effectiveness of exploration tools and methods for identifying potential new geothermal fields.
	Publish a collection of geothermal development case studies based on geothermal systems in the western U.S.	Documented experiences of geothermal development in active, producing fields to use as a reference in the exploration, development, production and management of new fields.
	Conduct joint ventures with industry to select the most innovative exploration methods and implement the best exploration techniques.	Characterization of the large number of undiscovered geothermal resources in the U.S., building an inventory of sites for future industry development.
	Initiate cost-shared joint drilling venture with industry to confirm and develop new hydrothermal resources located by industry.	Accelerate the growth of electrical generation from geothermal resources, to an estimated 5400 MW within five years.
Enhanced Case	Pacific Northwest geothermal initiative will address new technology and environmental concerns and contribute to regional energy goals. Some cost-sharing by the site operator is expected, but the amount is likely to be initially small because of experimental nature of the wells.	The successful application of new technologies (i.e. slim-hole drilling, advanced heat rejection technology) will spur geothermal development in the Northwest with a potential of 100 MW of power-generation capacity at the chosen sites.

Appendix A

PRIMARY RESEARCH ACTIVITIES OF THE GEOTHERMAL DIVISION FOR FY 1994-1998 AND EXPECTED RESULTS

PROGRAM ELEMENT	RESEARCH ACTIVITIES	EXPECTED RESULTS
Drilling Technology Base Case	Develop technology for emplacing encapsulated cements and bridging materials to control lost circulation; develop and field test an expert system for lost circulation operations; field test the drillable straddle packer and porous packer, and measure durability, pumpability, and density of lost circulation control materials that harden like cements when they enter fractures in rock formations.	30-50% reduction in drilling costs due to lost circulation episodes. Commercialization of reliable in-situ lost circulation materials.
	Conduct field tests to compare production in large and small wellbores; develop and field test slimhole coring exploratory drilling system; initiate development of measure-while-coring system with industry.	Development of inexpensive core holes which can assess reservoir productive potential at half the cost of conventional wells.
	Develop fiber optic cables and sensors for high-temperature (above 300°C) logging.	Reduction in the number of exploratory wells needed through advanced measurement techniques.
	Develop borehole televiewer fracture diagnostic techniques.	Reduce uncertainty in locating and analyzing fractures.
	With industry participation, field test advanced modular downhole memory tools and develop borehole instruments.	Reduction of 15% in number of exploratory wells needed.
	Begin new GDO projects on near-term technology improvements that are selected and cost-shared by industry on a 50-50 basis.	Accelerated technology advancement and technology transfer.

Appendix A

PRIMARY RESEARCH ACTIVITIES OF THE GEOTHERMAL DIVISION FOR FY 1994-1998 AND EXPECTED RESULTS

PROGRAM ELEMENT	RESEARCH ACTIVITIES	EXPECTED RESULTS
Enhanced Case	The Advanced Drilling and Excavation Technology Program (ADET) is a new national R&D initiative designed to leapfrog conventional techniques for penetrating rock while dramatically reducing cost.	Improved drilling economics will enable the drilling of more wells and deeper wells in search for energy and resources. It will create new market opportunities in rebuilding infrastructure for the 21st century, such as urban rapid transit, utility conduits, storage space for hazardous materials and power generation.
	A joint venture with industry to improve the truck mounted drilling rigs for large commercial geothermal heat pumps (GHP) projects, develop a small portable drilling rig for residential use, improve grouts and develop a commercial design manual.	GHP serve the space heating/cooling and water heating markets which consume 40% of the residential and commercial building electricity market. EPA projects that GHP can avoid 6,000 MW of winter generating capacity and lower CO_2 emissions.
	Develop advanced drilling bits through cost-shared ventures with the geothermal and petroleum industries.	Achieve 45,000 MW by the year 2010 as projected by EIA by reducing drilling cost. The new commercial bits that result from this work will help U.S. diamond-bit industry maintain its leadership position in worldwide sales.
Reservoir Technology Base Case	Determine basic thermodynamics of hydrogen chloride gas in steam.	Ability to control HCl corrosion in valves and surface pipes at The Geysers and other geothermal fields.
	Investigate the mechanism of water adsorption on fractured rock surfaces.	Ability to determine water saturation in fractures and the productive lifetime of reservoirs.
	Begin adapting subsurface dual-well seismic technology to locate fractures.	20% reduction in dry hole ratio in fractured reservoirs due to improved identification of drilling target.

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	Investigate the development of integrated reservoir simulation that combines hydrology and geochemistry in a single computer model.	Ability to track the migration of injected geothermal fluids and to predict their thermal and chemical changes in both vapor- and liquid-dominated systems.
	Extend and refine existing brine chemistry model to include new experimental data to improve the capability to predict scaling tendency of geothermal brines and apply model to assist industry in solving on-site problems.	Reduction in plant maintenance costs by 10%.
	Conduct long-term flow test (LTFT) of hot dry rock reservoir at Fenton Hill, NM and analyze data.	Estimation of thermal lifetime; determination of reservoir productivity; compilation of reliable record of HDR engineering, operational, and maintenance factors, especially water consumption; validation of the commercial viability of HDR.
	Verify behavior of diagnostic tracers for HDR applications.	Demonstrate that tracers can predict reservoir thermal lifetime for 10-20 years into the future.
	Continue microseismic monitoring and improve 3-D models of the HDR reservoir performance using seismicity and tracer data.	Determination of reservoir expansion parameters and improved accuracy of reservoir mapping technology for easier development of new HDR systems.
	Extend HDR modeling analysis to multi-well, multi-reservoir configurations that simulate full-scale commercial systems.	Enhancement of efficient reservoir operational modes and improved accuracy of forecasting production and cost.
	Conduct mineral dissolution studies.	Prediction of changes in flow impedance.
	Investigate zone isolation and impedance reduction technology.	Advanced techniques for reservoir enhancement and multi-reservoir facilities.

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	Conduct HDR technology transfer activities in cooperation with the utility sector.	Dissemination of HDR technology to the private sector to improve commercialization potential.
	Evaluate enhanced power production modes for a HDR reservoir.	Determination of alternative modes of economic reservoir production.
	Work with utilities and field operators at The Geysers to test and evaluate water injection strategies for maximum energy recovery.	Determination of the most effective method of water injection to reduce the pressure decline at The Geysers and return the steam field production closer to the installed 2,000 MW capacity; if successful, extension of reservoir lifetime by an order of magnitude.
	Field test surface-based high frequency seismic monitors for accurate measurement of fracture planes in The Geysers.	Improve ability to locate major producing zones and reduce the risk and cost associated with drilling production wells.
	In cooperation with the Geothermal Technology Organization, conduct industry-directed, joint-venture research to design the production wells and methods needed to operate a geothermal reservoir as a load-following energy source.	Significantly increased economic value of reservoirs through the ability to operate in a peaking mode.
	This initiative involves completion of the ongoing Fenton Hill Hot Dry Rock (HDR) experiment under a fundamentally revised management approach, which will assign the major responsibilities for field work to the industry.	HDR can potentially supply a vast new class of geothermal resources, based at over 10 million quads. HDR technology can open up a market for drilling and related services in excess of $8 billion annually.

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Enhanced Case	Hot Dry Rock (HDR) joint venture for a second site.	This second site will addresses many of the HDR commercial viability questions.
	Determine the technical and economic feasibility of using geothermal fluid to enhance the recovery of liquid hydrocarbons of high-viscosity that would otherwise be unrecoverable.	The technique would allow the recovery of a significant amount of heavy oil that would otherwise be unrecoverable. The technique would also reduce the environmental impact from enhanced oil recovery.
Conversion Technology Base Case	Document field tests of heat-resistant, lightweight cements and complete technology transfer.	Development of materials which can be used in the completion of geothermal wells.
	Perform laboratory evaluations of chemical systems that will bond elastomers to steel.	Reduce cost of wells by the availability of advanced drilling equipment.
	Measure the resistance of ceramic-based cements to scaling and corrosion under simulated conditions at 300°C.	Extension of casing life by 10 years, costing one-third as much as metal alloys.
	Continue development of a system to detoxify geothermal wastes with bacteria; design continuous process prototype for commercial geothermal site; examine process economics.	Potential for over 25%reduction in waste disposal costs. Potential for mineral recovery to offset costs. Removal of 80% of the metals.
	Develop advanced heat rejection system.	Reductions in consumptive water use for heat rejection.
	Develop advanced non-metallic well casing liners.	Reduction in well costs and extension of well life.

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	Test supersaturated expansions in binary cycle turbines.	Potential 5%-10% improvement in advanced binary plant performance.
	Demonstrate commercial power generation by employing innovative technology with superior design or operating characteristics.	Improve the conversion of thermal energy to electric power at reduced cost.
	Design drilling hardware for rapid emplacement of vertical heat exchangers and horizontal heat exchange loops for geothermal heat pumps.	Reduced installation costs and expansion of cost-effective market penetration of geothermal heat pumps in higher density urban markets.
Enhanced Case	Develop the next generation of geothermal power plants structured as a cooperative governments/utility/industry effort.	By stimulating a step-change improvement in geothermal plant technology, this initiative could enable the industry to competitively develop a vast untapped resource. The initiative will also reducing plant cost and improving geofluid utilization.
	A joint venture with geothermal developers to reduce waste and facilitate mineral recovery.	This venture will develop technologies to offset portions of cost associated with the generation of hypersaline brines, turn liability (waste) into an asset and eliminate long-term risk of storing wastes.