ERDA-86

Definition Report

Geothermal
Energy Research, Development
& Demonstration Program

October 1975

Energy Research & Development Administration

Division of Geothermal Energy
Washington, D. C. 20545

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DEFINITION REPORT

GEOTHERMAL ENERGY RESEARCH, DEVELOPMENT AND DEMONSTRATION PROGRAM

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
Division of Geothermal Energy
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FOREWORD

This report, the "Geothermal Energy Research, Development and Demonstration Program, Definition Report" (ERDA-86), has been prepared in response to the requirements of the Geothermal Energy Research, Development, and Demonstration Act of 1974, Public Law 93-410. The report is devoted to the broad definition of the Geothermal Energy RD&D Program involving the activities of ERDA and other cognizant Federal agencies.

The purpose of this document is to delineate the major thrusts associated with an overall Federal effort. A more detailed definition of the ERDA Geothermal Energy Program published in "A National Plan for Energy Research, Development and Demonstration: Creating Energy Choices for the Future," (ERDA-48); June 1975, will be updated on an annual basis.

The ERDA wishes to express its gratitude to the participating cognizant Federal agencies for their valuable support and critique of this report.

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SUMMARY

The Geothermal Energy Research, Development and Demonstration Act of 1974 (PL 93-410) authorizes a coordinated Federal program of research, development, demonstration and loan guaranty for geothermal energy development with the goal of establishing this energy source as a realistic option for the partial satisfaction of the Nation's energy needs.

A fundamental premise of the Federal program defined herein is the provision of assistance to the Nation's industrial community for the achievement of National energy goals. Geothermal energy offers the promise of a significant contribution to at least three of the eight specific energy RD&D goals,* namely:

- Expand the domestic supply of economically recoverable energy producing raw materials,
- Increase the utilization of essentially inexhaustible domestic energy resources,
- Protect and enhance the general health, safety, welfare and environment relating to energy.

The goal of this Geothermal Energy RD&D Program is to work with industry to provide the Nation with an acceptable option which, if exercised, would permit the timely exploitation of our geothermal resources. Federal efforts which will assist industry in accelerating

*The eight goals (reproduced on page I-2) are stated in, "A National Plan for Energy Research, Development and Demonstraton: Creating Energy Choices for the Future," Energy Research and Development Administration, Washington, D.C., June 28, 1975 (ERDA-48), prepared in response to the requirements of the Energy Reorganization Act of 1974 (PL 93-438) and of the Federal Nonnuclear Energy Research and Development Act of 1974 (PL 93-577) which provides for the integration of the goals and strategies of the Geothermal Steam Act of 1970 (PL 91-581) and of the Geothermal Research, Development and Demonstration Act of 1974 (PL 93-410) into the National Plan for Energy RD&D.

geothermal development have been defined in the areas of resource assessment; research, development and demonstration in areas of high technical risk; information dissemination and loan guaranties to reduce financial risk; and assistance in the reduction and removal of institutional impediments to healthy industry growth. Integral to the Federal program is the continued development and adoption of appropriate measures necessary for protection of the environment.

Program planning for this Geothermal Energy Research, Development and Demonstration (RD&D) Program has been carried out as part of a coordinated interagency effort and within the overall framework of the National Plan for Energy RD&D.*

The Potential of Geothermal Energy

The magnitude of the Nation's geothermal resource base is very large. With the appropriate technology development and reduction in nontechnical problems, a considerable fraction of this resource could be made economically exploitable while maintaining the protection of the environment.

The accelerated industrial exploitation of this resource is presently impeded, however, by a number of obstacles of widely-varying nature, including:

- lack of reliable detailed resource information
- lack of proven technology for definition, extraction and utilization of most of the recoverable resource
- complexities of administrative and regulatory requirements on geothermal development
- insufficient knowledge of possible environmental impacts and control technology needs and methods.

These factors coupled, until recently, with the availability of more economically attractive energy alternatives, has resulted in the

*Ibid.

slow development of a domestic geothermal industry. These obstacles may be removed or substantially reduced through a well planned and executed Federal program in cooperation with industry, state and local governments, and with appropriate participation of universities and non-profit institutions.

Implementation of the program defined herein is intended to assist industrial adoption and rapid commercialization of the energy options thus provided. This could result in environmentally acceptable geothermal resource utilization on the order of: 0.6 Quads/year by 1985, 4.4 Quads/year by 2000 and 18.6 Quads/year by 2020.*

These estimated potential energy impacts include both electrical and nonelectrical applications. The estimates are based on ERDA's interpretation of recent resource estimates developed in cooperation with the U.S. Geological Survey, and assume growth rates for geothermal resource development similar to historic trends in other energy industries.

Nature of the Resource

Geothermal energy is the natural heat contained in the earth's crust. The exploitability of the resource is dependent on anomalies which produce hot spots near the earth's surface. Five types of geothermal resources have been defined:

- Hydrothermal Convective
- Geopressured
- Hot Dry Rock
- Magma
- Normal Gradient

Of these types, the hydrothermal convection systems, which occur where ground waters infiltrate into formations of heated rock, represent a fraction of the total resource, but provide the only resource presently

*1 Quad equals 10^{15} Btu's.

** D.F. White, et. al., "Assessment of Geothermal Resources of the United States," USGS Circular No. 726, Reston, Va., 1975.

being utilized (primarily in the form of dry steam) and the greatest potential for immediate industrial expansion. The other four forms of geothermal energy represent the bulk of the resource, but each of them requires substantial technological research, development and demonstration to bring it to the point of commercial exploitation.

Strategy

In order to open the option for industrial development of geothermal resources and to avail the estimated levels of resource utilization, a Federal strategy with three major thrusts has been defined:

(1) reduce resource uncertainties

(2) assist industry in developing the capability of rapid future exploitation of the more extensive geopressured, hot dry rock, normal gradient and magma resources, by facilitating the present industrial development of identified hydrothermal resources, and

(3) assist industry in development of the advanced technology needed to exploit geopressured, hot dry rock, normal gradient, and magma resources.

To carry out this strategy, programmatic activities have been defined in three program areas; resource exploration and assessment; technology development; and institutional development relating to governmental and industrial cooperation.

Program Areas

Resource Exploration and Assessment - Efforts in this area are aimed at reducing the risks associated with exploration and the unknowns associated with the location and extent of geothermal resources. Included are: geosciences research to improve the fundamental understanding of the geothermal processes in the earth's crust and their associated surface manifestations; assessment and exploration technology development to improve the efficiency, reliability and economics of assessment and exploration; regional and national assessment to identify and quantify the Nation's geothermal resources; and, resource information dissemination for processing and effective distribution of data on the Nation's geothermal resources.

Technology Development - Technology research, development and demonstration projects included in this program area are directed at assuring the availability of options for the commercial extraction and utilization of the energy from each of the various types of geothermal resources in an environmentally acceptable manner. The major needs associated with the extraction and utilization of each resource type that are addressed include: improved drilling technology; reservoir engineering; conversion equipment development; and pollution abatement technology development. Where appropriate, commercial scale demonstration plants will be considered for demonstration of economic viability and environmental acceptability of a resource type and its associated utilization technology.

Institutional Development - To enhance the potential for early commercial exploitation of geothermal resources in an environmentally acceptable manner, the program incorporates the development of incentives, institutional relationships, and policy to facilitate industrial commitment. It includes: the leasing program to make federal lands available for geothermal development; the Geothermal Loan Guaranty Program to reduce the financial risk; and policy research to identify and develop policy alternates to resolve the social, legal, economic, and environmental problems associated with development of these energy resources. The scope of this effort goes beyond the technology RD&D program. It is, however, an integral part of the total Federal effort.

Coordination and Management

As provided by the Energy Reorganization Act of 1974 (PL 93-438), ERDA will manage the major portion of the Federal Geothermal Energy RD&D Program. It will carry out its responsibilities in cooperation with the National Science Foundation, which conducts basic and long-range advanced research; with the Department of the Interior, which conducts resource characterization, regional assessment, and exploration technology research, and which, in cooperation with the U.S. Department of Agriculture, administers the Federal geothermal leasing programs; with the Environmental Protection Agency to assure that geothermal development shall be within acceptable environmental bounds; with the Department of the Treasury which participates in the administration of the Geothermal Loan Guaranty Program; and with other cognizant Federal, state and local agencies whose responsibilities relate to the development and operation of a geothermal energy industry. ERDA will also cooperate with the Federal Energy Administration in the development of National energy policy, particularly in attempting to reduce or eliminate unnecessary fiscal and institutional constraints which affect the development of a geothermal industry.

Prior to the formation of ERDA, the overall responsibility for coordination and management of Federal geothermal RD&D activities was the responsibility of the Geothermal Energy Coordination and Management Project created under Public Law 93-410. The legal responsibilities of the Project were acquired by the Administrator with the transfer of these functions to ERDA. The continuation of policy level coordination among key Federal agencies is being considered.

The ERDA Division of Geothermal Energy will be responsible for the implementation of the major portion of the technology RD&D defined herein. The Division will work with other ERDA divisions and offices to coordinate pertinent and related research areas. Specific attention will be given to: developments in conservation and transmission technology under the Assistant Administrator for Conservation, drilling and fracturing technology development in cooperation with the Assistant Administrator for Fossil Energy, assessment of health and environmental impacts of new technologies under the Assistant Administrator for Environment and Safety; basic materials and geosciences research within the Division of Physical Research; and direct thermal applications within the Division of Solar Energy.

The ERDA Office of Industry and State and Local Government Relations, will take an active role in providing a two-way communication channel between ERDA and all segments of the geothermal industry, state and local governments.

Issues and Impacts

The lack of reliable, quantitative information about the magnitude, location and longevity of individual geothermal reservoirs is a serious obstacle to the willingness of industry and the financial community to commit capital for their development. Similarly, the absence of proven, reliable technology for exploration, reservoir definition, field development, conversion and utilization of most forms of geothermal energy has resulted in the postponement of development of all but high quality hydrothermal resources.

Present regulatory requirements at several levels of government, and present complexities of leasing regulations may present impediments to accelerated geothermal development. Geothermal energy utilization, as other extraction industries, entails considerable financial risk that, without compensating incentives, may inhibit development. However, some of these other industries, including energy industries in direct competition with geothermal energy, have tax and fiscal incentives which geothermal utilization does not presently enjoy. Issues involved here go far beyond the RD&D scope but will be considered in the Federal effort. Additionally, the lack of comprehensive knowledge of the possible environmental impacts and control technology requirements for geothermal development may also inhibit rapid industrial growth.

Investigation of these and other issues and associated Federal policies which may impact industrial development of geothermal resources form a key and integral part of a continuing refinement and improvement in the program plan defined in this document. Cost-benefit studies, throughout the course of the program implementation, will provide the basis for evaluation and decisions regarding the technology RD&D efforts as well as the desirability and extent of other forms of direct and indirect federal support of geothermal industry development.

It is expected that implementation of the Federal strategy, with continued program review, refinement and update, will overcome many of these problems and enable the industry to provide inexpensive, and clean geothermal energy to help fulfill a portion of our National energy needs.

SECTION I

INTRODUCTION AND BACKGROUND

THE NATIONAL ENERGY PROGRAM

The National Plan for Energy RD&D has been designed to create a wide range of energy options for the future. Its intent is to stimulate a changeover from the Nation's current dependence on dwindling supplies of oil and gas to the larger resources of coal, uranium, solar energy, geothermal energy, and fusion energy. The Nation has little time to accomplish this change, for without rapid development of our more extensive resources, a serious shortfall in domestic energy availability may occur, with associated severe economic and social impacts. The U.S. economy is presently 75 percent dependent on petroleum and natural gas, 20 percent dependent on coal, 2 percent on nuclear, 2 percent on hydroelectric, and 1 percent on wood. U.S. rate of petroleum production has been estimated by ERDA to be insufficient to meet national needs beyond the 1990's.*

Development and commercialization of new energy alternatives is a time consuming process, requiring early planning and commitment. The decisions made now can determine the options for future generations. Development of our domestic resources, including geothermal energy, under an accelerated National program can reduce our reliance on imported fossil fuels, improve our balance of payments position in foreign trade, and help to stabilize our political, social and economic future.

*"A National Plan for Energy Research, Development and Demonstration: Creating Energy Choices for the Future--Volume I: The Plan," ERDA-48. The Energy Research and Development Administration, June 1975, pp. S-2 and S-3.

In response to the present energy problem, eight national RD&D goals have been established by ERDA:*

- expand the domestic supply of economically recoverable energy producing raw materials
- increase the utilization of essentially inexhaustible domestic energy resources
- efficiently transform fuel resources into more desirable forms
- increase the efficiency and reliability of the processes used in the energy conversion and delivery systems
- transform consumption patterns to improve energy utilization
- increase end use efficiency
- protect and enhance the general health, safety, welfare and environment related to energy
- perform basic supporting research and technical services related to energy.

The Congress has mandated in the Geothermal Energy Research, Development and Demonstration Act of 1974,** that "The Federal Government 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." The Act calls for activities in:

- resource inventory and assessment
- RD&D projects
- scientific and technical education

*Ibid., p. S-4.
**The "Geothermal Energy Research Development and Demonstration Act of 1974," Public Law 93-410, September 3, 1975, Section 2.12.

- financial assistance to private industry for the ultimate purpose of accelerating production of geothermal energy in environmentally acceptable ways.

Subsequent legislation; i.e., the Energy Reorganization Act of 1974 (PL 93-438) and the Federal Non-nuclear Energy Research and Development Act of 1974 (PL 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. This Definition Report is in response to this mandate.

GEOTHERMAL ENERGY

The extent of geothermal energy utilization is highly technology dependent, in that the exploitable resource can increase substantially each time a new advanced method of utilization is developed. The resource base, from which exploitable resources derive, is defined by the U.S. Geological Survey to be the entire heat content of the earth's crust in the U.S. above 15°C to a depth of 10 km.* Non-uniformities in the geological structure of the earth's crust can allow heat from the earth's interior to be transported preferentially to certain limited areas near the surface. It is in these "hot spot" areas that geothermal energy is most easily extracted, technologically and economically. Thus, only a portion of the resource base is currently considered to be exploitable, and estimates of the portion that may be exploited are dependent upon the maturity of extraction and utilization technology.

Five types of geothermal energy resources with distinctively different characteristics have been defined. These are:

*D.E. White and D.L. Williams, Editors, Assessment of Geothermal Resources of the United States - 1975. The United States Geological Survey, Geological Survey Circular No. 726, Reston, Virginia, 1975, in cooperation with ERDA's Division of Geothermal Energy.

(1) Hydrothermal Convective: systems containing relatively high-temperature water at shallow depths. These systems are generally subdivided into:

Vapor-dominated - at a characteristic temperature of greater than 150°C (300°F) and capable of producing superheated steam.

Liquid-dominated - ranging from below 90°C (190°F) to above 350°C (660°F) and capable of producing a mixture of liquid and vapor or hot liquid only.

(2) Geopressured Resources: pressurized water reservoirs within sedimentary basins capable of supplying both heat and mechanical energy, and dissolved methane.

(3) Hot Dry Rocks: non-molten but very hot rock structures with insufficient water to be considered a hydrothermal convection system. Temperature is usually less than 650°C (1200°F).

(4) Normal or "Near Normal" Gradients: conduction-dominated areas produced by heat flows, radiogenic heat production and thermal conductivity of rocks, exhibiting temperature ranges from 15°C (60°F) to about 300°C (570°F) within the first 10 kilometers of the crust.

(5) Magma: molten rock at temperatures in excess of 650°C (1200°F).

Each of these resource types presents differing problems in exploration, development and extraction of the energy contained therein.

EXTENT OF GEOTHERMAL RESOURCES

The USGS has estimated the heat content of domestic geothermal resources.* These estimates for the resource base** are shown in Table I-1.

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*Ibid.

**It should be noted that the grouping of resource estimates presented in the USGS Circular No. 726, varies slightly from the definitions presented above. The quantities presented in Table I-1 are, however, consistent with the USGS estimates.

TABLE I-1
HEAT CONTENT OF GEOTHERMAL RESOURCE BASE BY TYPES, (HEAT IN THE GROUND ABOVE 15°C WITHOUT REGARD TO RECOVERABILITY) IN QUADS*

RESOURCE TYPE	KNOWN	INFERRED
Hydrothermal Convective** (<3km)		
Vapor Dominated (>150°C)	100	100
Liquid Dominated		
High Temperature (>150°C)	1,500	4,900
Low Temperature (90°-150°C)	1,400	4,100
Geopressured (<10km)	44,000	132,000
"Hot Dry Rock" (<10km)	48,000	150,000
Magma (<10km)	52,000	150,000
Normal Gradient (<10km)	32×10^6	0

*1 Quad = 10^{15} Btu's, and is equivalent to approximately 170 million barrels of oil or 50 million short tons of coal. Although somewhat uncertain, these estimates are based on the best available data. They will be updated as additional field data become available.

**Does not include less than 90°C systems due to lack of data.

Table I-2 presents estimates of the amount of heat that may be extracted from this resource base with present or near-term technology, without regard for cost or type of application, for each resource type. The normal gradient is not included because it is the most diffuse form and presently viewed as very difficult to recover economically. The grand totals in Table I-2 indicate that the estimated recoverable heat is of the order of the entire energy consumption of the United States for 50 to 100 years. The concentration of these resources in the Western and Gulf Coast areas makes them particularly valuable to those regions. Much of the total resource is suspected to be renewable, lying in close proximity to active magmatic flows which transport energy from deep within the earth.

GEOTHERMAL ENERGY EXTRACTION AND UTILIZATION

Technology to utilize each of the types of geothermal resources is in varying stages of development. Technology exists today for generation of electricity from vapor-dominated hydrothermal resources producing high-quality steam, and to a more limited extent, from liquid-dominated hydrothermal resources. Hydrothermal resources have been used for the production of electricity in Italy since 1904, and have been used for space heating in Reykjavik, Iceland, since 1928. Other countries actively using or building hydrothermal plants for electric and/or nonelectric applications* include El Salvador, France, Hungary, Japan, Mexico, New Zealand, The Philippines, and the USSR.

In the United States, the primary application has been for the production of electricity at The Geysers dry steam field in northern California. The Pacific Gas and Electric Company has an installed capacity there of 520 megawatts (MW) of electric power, and plans to increase this to 1400 MW by 1985. In Mexico, the Cerro Prieto wet steam geothermal plant in the Mexicali Valley of the Baja Peninsula

*These nonelectric applications include space heating, industrial process heat and agricultural applications.

TABLE I-2
GEOTHERMAL RESOURCES
ESTIMATED RECOVERABLE HEAT WITH PRESENT OR NEAR-TERM TECHNOLOGY, WITHOUT REGARD TO COST; (IN QUADS)*

RESOURCE TYPE	KNOWN	INFERRED
Hydrothermal Convective**		
Vapor Dominated (>150°C)	2	2
Liquid Dominated		
High Temperature (>150°C)	20	110
Low Temperature (90° - 150°C)	80	250
Geopressured		
Electrical Utilization	100	230
Methane Production	500	1500
Hot Dry Rock		
Scenario I+	80	240
Scenario II++	600	1900
Magma+++		
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 = 10^{15} 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.

utilizes two turbo-generators with a combined electrical generating capacity of 75 MW. These units have been operational since 1973. In the Rotorua-Wairakei area of New Zealand, extensive use is made of geothermal energy for both nonelectric and electric applications including commercial use of geothermal energy for space cooling. The nonelectric use of geothermal energy in all of New Zealand amounts to approximately 140 MW. The total New Zealand geothermal electric capacity is about 170 MW and an additional 210 MW are planned. The combined electrical power production capability at Larderello and Mt. Amiata in Italy is over 405 MW. Several sites for geothermal electric power generation have been developed in Japan. At the present time these sites have a capacity of 53 MW and an additional 75 MW are planned. At Ahuachapan, El Salvador, wet steam will be used in 1976 to feed the first of three 30 MW electric generating plants that have been planned by the Salvadorean Government. Development of a geothermal electric generating capacility is also being planned by the Nicaraguan Government and at La Bouillante, in Guadeloupe.

The nonelectric application of geothermal energy in the United States has developed on a small scale when compared to that in Russia, Hungary and Iceland. Utilization of geothermal energy for space heating in the United States has developed primarily in the cities of Boise, Idaho and Klamath Falls, Oregon. The Boise system has served about 200 houses and 10 to 12 businesses and is one of the oldest district heating systems. It was built during the 1890's. In 1970 it had a capacity of slightly over 9 megawatts. Plans are also underway to use geothermal energy for heating the capitol building in Boise, Idaho. In Klamath Falls, the Oregon Institute of Technology and many private homes are heated by fluids from geothermal wells. Single wells are generally used to heat the private homes with several users sharing one well. In 1974 there were 468 residences in Klamath Falls that were heated by geothermal waters. The total developed heating capacity in Klamath Falls is estimated at slightly over 5 megawatts. Utilization of small amounts of geothermal energy for heating greenhouses has also been achieved in both Oregon and in Idaho. The total nonelectric utilization of geothermal energy in the United States has been estimated at between 15 to 16 megawatts. In addition, liquid-dominated hydrothermal resources have been proposed as a possible source of water in arid regions of the country. The U.S. Bureau of Reclamation has for several years been working on the desalinization of geothermal waters for this purpose. Other experimental uses include mineral recovery and enhanced petroleum recovery.

Geothermal research in Russia has been given practical and scientific attention in national planning since the 1920's. In January 1964, the Scientific Council for Geothermal Research was formed under the USSR Academy of Sciences. Under the current Five Year Plan (1971-1975), the Ministry of the Gas Industry has a goal to drill over 10,000 meters of additional geothermal test wells and has established several organizations and prospecting expeditions for the development of geothermal resources in general, and of steam resources in particular. Using data available at the present time, the USSR appears to be the world's largest user of geothermal energy for nonelectric applications with over 5100 megawatts being available for residential and industrial heating, agricultural use such as hothouse/greenhouse heating, refrigeration, thawing of frozen soil and for swimming pools and baths.

In Budapest, Hungary, a section of the city with a population of about 20,000 has been heated by geothermal fluids since the 1930's. Individual space heating and district heating has been successfully utilized in other Hungarian cities, however, agricultural applications account for most of the geothermal energy use. It has been reported that 131 geothermal wells in Hungary have a total output of 4000 kg/sec and that the total energy production at peak load is about 770 megawatts.

The city of Reykjavik, Iceland, began a 70-house pilot heating program in 1928. Today the city uses geothermal fluids almost exclusively for home heating and hot water. At present, about 46 percent of the Icelandic population live in houses centrally heated by geothermal fluids. In addition, the geothermal fluids are used to provide heat to over 120,000 square meters of greenhouses that are used to provide fresh vegetables and flowers to the domestic market. It has been estimated that in Iceland, between 275 to 300 megawatts of geothermal power are utilized for nonelectric applications.

Utilization of geopressured resources, hot rock, magma and the normal gradient has not yet reached a state of demonstrated technological feasibility and requires differing degrees of fundamental and applied research, field testing and experiments, and pilot and demonstration projects to bring them to a point of economic viability and environmental acceptability. Of these resource types, geopressured is the nearest to commercialization. Tests are needed to confirm the ability of geopressured resources to sustain flow over extended time periods and to assess the economic viability of recovering the methane found in these resources. Hot rocks, normal gradient and magma, are furthest from commercialization, requiring considerable and relatively long-lead-time basic and applied research. These larger resources, however, provide the basis for the greatest potential impact of geothermal energy.

EXPECTED IMPACTS OF GEOTHERMAL ENERGY DEVELOPMENT

Development of each type of geothermal resource will result in a significant contribution to at least three of the above mentioned National Energy RD&D goals, specifically:

- Expand the domestic supply of economically recoverable raw materials used for producing energy.

- Increase the utilization of essentially inexhaustible domestic energy resources.

- Protect and enhance the general health, safety, welfare and environment related to energy.

Preliminary estimates of the recoverable geothermal resource, using present or near-term technology and without regard to cost, are shown in Table I-2.

Given successful implementation of this Geothermal Energy RD&D Program and provided that the option made available is exercised by the Nation to use our geothermal resources by rapid commercialization, potential impact on geothermal utilization is estimated as:

ESTIMATED GEOTHERMAL UTILIZATION GIVEN SUCCESSFUL FEDERAL PROGRAM IMPLEMENTATION*

estimates are too high

	1985	2000	2020
Electric Capacity (MW)	6,000	39,000	140,000
Electric Applications - Equivalent Energy (Quads/yr)	0.5	2.9	10.4
Nonelectric Applications (Quads/yr)	0.1	1.5	8.2
Total Energy (Quads/yr)	0.6	4.4	18.6

The associated potential geothermal industrial growth rate is estimated at 0.1 Quads per year in 1985, 0.4 Quads per year in 2000 and 0.6 Quads per year in 2020.

Under this program the various resource types will reach commercial demonstration earlier than otherwise expected, opening the option to utilize the larger resources more rapidly:

*The rationale for these estimates is presented in the following pages. It should be noted that a variety of different impact estimates have been made over the past few years, and that there is a fair degree of uncertainty in the estimates presented above. These estimates are, however, based in part on the latest data available from the USGS resource assessment (Circular No. 726). Such resource assessment was not available prior to this analysis. These estimates will be continually updated as improved resource estimates become available and utilization technology develops.

For the purpose of this table, geothermal electrical capacity was converted to Quads (10^{15} BTU's) by assuming a net conversion efficiency equivalent to fossil fuel combustion of 1 megawatt-hour = 10^7 BTU's and an 85 percent load factor.

RESOURCE DEVELOPMENT OPTIONS UNDER FEDERAL PROGRAM

1985	2000	2020
Hydrothermal	Hydrothermal	Hydrothermal
Geopressured	Geopressured	Geopressured
	Hot Dry Rock	Hot Dry Rock
		Normal Gradient
		Magma

With no Federal program, by 1985 an estimated 1500 MW will be on-line,* and by the year 2000 perhaps only the geopressured resource may be added to the list of resource options:

PROBABLE RESOURCE DEVELOPMENT WITHOUT FEDERAL PROGRAM

1985	2000	2020
Hydrothermal	Hydrothermal	Hydrothermal
	Geopressured	Geopressured
		Hot Dry Rock

Implementation of the Federal Geothermal Energy Program may thus be expected to significantly contribute to the national energy supply in the critical 1985-2000 time frame while providing options for development of significantly large geothermal resources beyond the year 2000. As the bulk of the presently identified resources is located in the Western and Gulf Coast states, the impact on regional energy supply is much more significant.

These estimates of the utilization potential resulting from the Federal program are based on the assumptions that:

*The bulk of this development is the planned expansion of The Geysers dry steam fields with limited additional development of liquid-dominated hydrothermal resources in Southern California and scattered small scale nonelectric applications.

(1) The implementation of the Federal program along with reduction in institutional barriers in the near-term would result in accelerated hydrothermal development. Site-specific estimates are used; i.e., about 2,500 MW at The Geysers, about 3,000 MW in the Imperial Valley, and about 500 MW in Texas and Louisiana.

(2) For the period beyond 1985, the rate of utilization of the geothermal resource over time follows the same general bell-shaped curve as those exhibited by oil, gas and other highly exploited finite resources.*

(3) The total exploitable resource (supply) is finite and equal in magnitude to that shown in Table I-2.

(4) The peak utilization rate is a function only of the supply and a time scale factor which represents a measure of the rate of growth; and is defined as the time, measured from both sides of the year of peak utilization, during which 80 percent of the resource is exploited. This factor is 17 years for Hydrothermal, 20 years for Nonelectric, 30 years for Geopressured, 35 years for Hot Dry Rock, and 45 years for Magma. No factor is chosen for Normal Gradient as it is not presently considered recoverable.

(5) The year at which peak utilization occurs, the peak of the bell-shaped curve, depends on when the resource is first exploited. For this analysis these "first exploited" dates are the expected year when utilization of each resource type will reach 500 MW. The estimates are based on successful implementation of the RD&D program defined herein followed by a commercialization period ranging from 2 to 6 years. The first exploited dates are 1983 for liquid-dominated hydrothermal electric, 1981 for nonelectric, 1985 for geopressured, 1987 for hot dry rock, and 2000 for magma. Normal gradient is not included.

The Federal program was assumed to have the effect of shortening the time required to reach commercialization (through the RD&D program) and decreasing the time scale factor (through removal of institutional and financial impediments). The rate of growth for the geothermal

*The model for projecting utilization of finite resources, developed by M. King Hubbert of the USGS, has been used in developing these preliminary resource exploitation estimates for the period beyond 1985.

industry under this accelerated development scenario is comparable to that of the U.S. nuclear industry between 1965 and 1985. It is expected that such growth is possible if the industry exercises the options made available by the Federal program.

The level of uncertainty in the estimates of future geothermal resource utilization may be such that the range of utilization and growth rate may vary significantly above or below the values presented. Greater values are possible if few alternative energy options prove to be viable, bringing a greater industrial effort to bear on geothermal utilization. Inaccuracies in the assumed values for the amount of the exploitable resource supply, the expected dates of initial commercialization, and the time scale factors impact strongly on the accuracy of these utilization and growth rate estimates. Further, some of the resources may prove to be renewable (e.g., magmatic flows replenishing magma chambers near certain magma, hot dry rock, and hydrothermal reservoirs), thus nullifying the finite resource assumption and raising the potential growth and utilization rates. Also, the Hubbert model depends heavily on historical values of the utilization so that more accurate estimates of the time scale factor can be made as development proceeds. Time scale factors for the estimates presented were chosen to be comparable with the light water nuclear reactor industry for hydrothermal development (17 years), with the oil and gas industry for the geopressured and hot dry rock resources (30 to 35 years) and a longer period for magma (45 years).

SECTION II

GOAL, STRATEGY

GOAL OF THE NATIONAL GEOTHERMAL ENERGY PROGRAM

Given the characteristics of the Nation's geothermal energy resources and the present fledgling state of our domestic geothermal industry, the goal of the National Geothermal Energy RD&D Program is:

> To work with industry to provide the Nation with an acceptable option which, if exercised, would permit the timely exploitation of our substantial geothermal resources.

In order to meet this goal and thus assist the development of a substantial geothermal industry prior to 2000, a concerted effort will be required to reduce the present costs and financial and technical risks. These risks, if not reduced, would probably maintain the relatively slow rate of geothermal energy development, even if other, relatively cheap energy sources, were not available.

Industry today is actively seeking to develop the limited number of high quality steam resources, as the required technology has been proven and the economics demonstrated in commercial applications. With somewhat greater hesitancy, industry is moving toward the development of our higher temperature, liquid-dominated hydrothermal resources, principally in California's Imperial Valley. This hesitancy stems primarily from the risks and high costs associated with unproven technology for energy extraction and utilization, uncertainties regarding reservoir extent and useful life, institutional impediments associated with leasing, environmental issues, taxing and incentive policies, and limited capital availability from lending institutions faced with assessing these uncertainties. Also, other fuels such as oil and gas are presently available at a relatively lower cost.

The development of the more abundant geothermal resources (geopressured, hot dry rock, magma and the normal gradient), has been prevented by the greater uncertainties associated with the extent of the resources and the absence of proven technology to develop them. Thus, attainment of the above goal requires the implementation of a multi-faceted strategy to overcome these uncertainties and impediments.

PROGRAM STRATEGY

Three major thrusts characterize the Federal strategy for assisting in the development of a viable geothermal energy industry:

(1) reducing resource uncertainties

(2) assisting industry in developing the capability of rapid future exploitation of the more extensive geopressured, hot dry rock, normal gradient and magma resources, by facilitating the present industrial development of identified hydrothermal resources, and

(3) assisting industry in developing the advanced technology needed to exploit geopressured, hot dry rock, magma and normal-gradient resources.

The Federal Program is aimed at opening the option for early exploitation of the geothermal energy resources of the Nation. Such an option, when exercised by the national industrial community, will provide meaningful contributions to satisfying the Nation's energy needs.

Resources

Reduction of resource uncertainties will be approached through the resource assessment activities of both the U.S. Geological Survey and ERDA in support of present and future exploration activities on the part of industry, and the field and site-specific reservoir confirmation associated with federally-assisted projects. Under appropriate arrangements, Federal lands will be open to exploration under the Geothermal Leasing Program administered by the Department of the Interior in cooperation with the U.S. Department of Agriculture. Both of these activities will be enhanced by the development of improved exploration and reservoir assessment technology, and drilling to confirm estimates.

Industrial Growth

It is likely to take differing time periods (ranging from ten to 25 years) to develop and demonstrate the technology for extraction and utilization of geopressured, hot dry rock and magma resources. During this time frame, an industrial infrastructure would have to be developed so as to allow for rapid commercialization of the new technology when it becomes available. Near-term development of hydrothermal resources in both electric and nonelectric applications would form the foundation of such an industrial infrastructure. Plants may be brought on-line in the near-term that could supply energy in the interim period while advanced technology is being developed. The development of hydrothermal resources would allow equipment manufacturers to develop product lines and distribution channels, financial institutions to gain confidence in the technology and its applications, and governmental bodies at all levels to gain the data base needed for effective evaluation and planning.

It is expected that hydrothermal development within these objectives would require the demonstration of technical and economic viability, coupled with implementation of the Geothermal Loan Guaranty Program to assist in making capital available from lending institutions, and acceleration of the Geothermal Leasing Program to make federal lands available for development. Additionally, early emphasis will be placed on analysis of institutional impediments and development of appropriate incentive policies to further geothermal industry growth. Throughout this effort, continuous attention will be placed at all times on protection of the environment, and reduction of adverse regional social and economic impacts associated with resource development.

Technology Development

The development of advanced technology to provide the capability of exploiting the considerably more abundant geothermal resource types constitutes the third part of the strategy. Significant unknowns still exist regarding the nature of these resources and economic means of extracting energy from them. Of these resources, geopressured zones offer the highest potential for utilization within the next ten years, and as such, early research and development will be undertaken for their exploitation. Hot dry rock utilization is expected before 1990, provided that RD&D efforts are launched now to support its development. Technology for improved resource discovery and utilization of the normal gradient requires extensive research and development and consequently, a longer term R&D effort is anticipated for this nearly ubiquitous and essentially inexhaustible resource. The economic problems of normal-gradient exploitation are also significant. The utilization of magma presents greater difficulties of a basic science and materials nature requiring more basic and exploratory research.

Strategy Dynamics

As technology development continues and the industry grows through successive utilization of larger classes of geothermal resources, the potential profitability of successful R&D may be expected to increase. Thus, a greater share of the future R&D and demonstration project burden may be expected to shift toward industry. Similarly, it is expected that as the financial community becomes more familiar with the nature of geothermal resources and the economic viability of its development, appropriate lending policies will develop and the Geothermal Loan Guaranty Program may be phased out. Cost-benefit analysis of the total geothermal program will be instituted to support its goals and objectives and to provide insights into their implementation. This analysis will not only include the phasing of major shifts in emphasis, but will also provide a basis for evaluation of many of the policies and issues which will develop in the course of program implementation.

The geothermal energy program will thus be maintained dynamic and goal-oriented. Program plans will be updated annually, to maximize effectiveness, on the basis of both the progress of the Federal program and the response of the industry in achieving the National goals.

SECTION III

GEOTHERMAL PROGRAM DESCRIPTION

The Federal Geothermal Energy Program addresses three major areas: (1) Resource Exploration and Assessment; (2) Technology Development; and (3) Institutional Development. The content of each of the program areas is indicated in Figure III-1. Specific objectives, technical and institutional problems, and an implementation approach and utilization plans for transferring the results of the Federal RD&D to the public sector have been developed for each of these major areas in formulating this program definition.

RESOURCE EXPLORATION AND ASSESSMENT

Objective

The Resource Exploration and Assessment area is directed at assisting industrial development by reducing the risk of exploration and improving the technology for reservoir assessment.

Problems

At present, the scientific understanding of the geothermal processes in the earth is incomplete. Detailed knowledge regarding the location, size, energy potential, and availability of geothermal resources is limited. Most of today's geothermal resource assessment and exploration technology has been acquired from mineral, gas and oil exploration. Reliable surface assessment and exploration methods for locating subsurface concentrations of heat and water are lacking, and difficulties are encountered where there are few or no surface manifestations. The final step for confirming that a commercially viable geothermal resource exists is to deep drill to tap the reservoir, and then to perform flow tests for extended periods of time to provide data

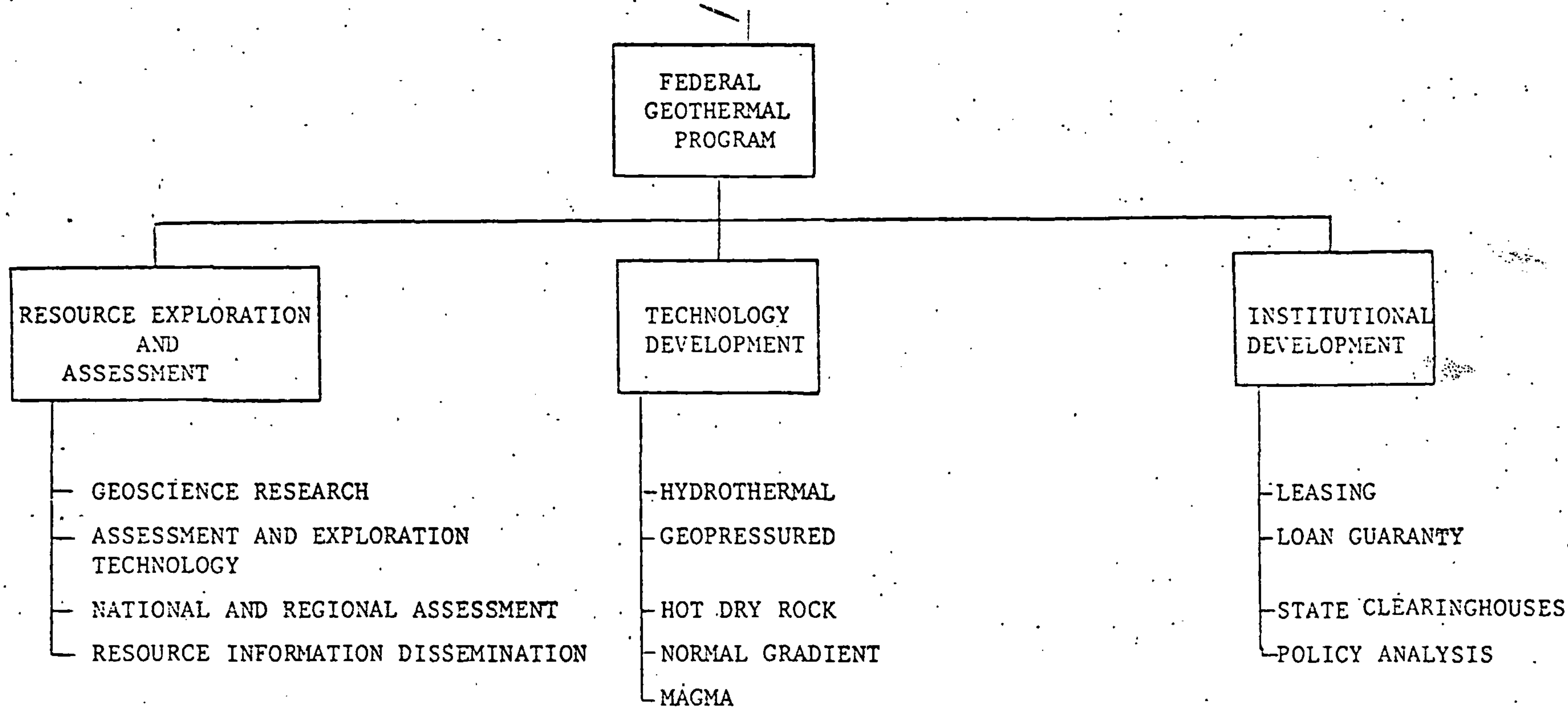

FEDERAL GEOTHERMAL PROGRAM
RESOURCE EXPLORATION AND ASSESSMENT
TECHNOLOGY DEVELOPMENT
INSTITUTIONAL DEVELOPMENT
GEOSCIENCE RESEARCH
ASSESSMENT AND EXPLORATION TECHNOLOGY
NATIONAL AND REGIONAL ASSESSMENT
RESOURCE INFORMATION DISSEMINATION
HYDROTHERMAL
GEOPRESSURED
HOT DRY ROCK
NORMAL GRADIENT
MAGMA
LEASING
LOAN GUARANTY
STATE CLEARINGHOUSES
POLICY ANALYSIS

FIGURE III-1

on the energy potential. Deep drilling in fractured, hard rock within high temperature geologic formations is expensive and time-consuming. The current lack of a reliable exploration technology and the necessity for deep drilling make geothermal exploration a costly, high-risk undertaking. The lack of adequate exploration and assessment technology also hampers the process of accurately estimating the regional and National geothermal potential by the United States Geological Survey (USGS).

Improvements in surface and shallow hole assessment and exploration technology are necessary to increase the accuracy of prediction for both resource assessment by the Federal Government and exploratory site selection by industry. Such efforts could improve the success ratio in exploratory drilling, significantly improving the economics of exploration.

There are many assessment and exploration techniques that are available for use prior to deep drilling. Geological, geophysical, geochemical, and hydrological data and information in various forms and extent can be obtained from surface and shallow hole measurements and used to locate geothermal resources. It is difficult to comprehensively determine the strengths and weaknesses of these techniques for the following reasons: the resource could be situated in a variety of geological structures and rock type; too few utilizable reservoirs have been found to provide sites for test and evaluation of improved techniques and instrumentation; and the technology currently in use or potentially available is complex.

There is a real need to be able to correlate the data of various assessment and exploration techniques with the reservoir characteristics determined by deep drilling to better interpret surface and near surface measurements. Industry is a potential source for this deep hole data.

Implementation Plan

The Resource Exploration and Assessment effort is divided into four activities: Geoscience Research; Assessment and Exploration Technology; Regional and National Assessment; and Resource Information Dissemination. Geoscience research is concerned with understanding the geothermal processes in the earth's crust and their associated manifestations. Basic data from this activity should be of great help to the Assessment and Exploration Technology effort in 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. These technology developments will help reduce the risk associated with exploration and will facilitate the accomplishment of the task of the Regional and National Assessment of our geothermal resources. The last of the four efforts, Resource Information Dissemination, provides for establishing and maintaining a data bank for the storage and rapid retrieval of geothermal resource data. A description of the four activities follows.

Geoscience Research - 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 geothermal resources. The geoscience research tasks that are included in the geothermal program are:

(1) Investigations of the "natural geothermal background" away from local anomalies to understand the relationship of regional heat flow and geology.

(2) Investigations of inactive geothermal systems (i.e., systems no longer operating but in which the deep portions are now revealed by erosion).

(3) Studies of active geothermal systems to investigate factors such as geothermal heat sources and mechanisms of heat transfer, reservoir dimensions and characteristics (especially nature of reservoir and country rocks, permeability, and lifetimes), hydrogeology, hydrology, and hydrogeochemistry.

(4) Laboratory experiments in the physical chemistry and geochemistry of geothermal systems.

(5) Studies of the effect of geothermal systems on crustal physical and chemical properties that can be used for remote detection (exploration).

Because of its large impact on program cost, the role of drilling in this research effort needs special attention. Three activities directly involving drilling are being considered:

(1) An effort to measure and understand the heat flow pattern over a geological region and its relation to the geology, using a large number of small holes to reduce drilling costs, 3 to 10 cm (~1 to 4 in.) in diameter and perhaps 30 m (~100 ft) deep. Occasionally, deep hole (~1 km) drilling will also be required.

(2) An effort to obtain increased scientific data from holes drilled commercially, for geothermal energy, oil, gas, or minerals. Holes of no commercial interest (abandoned or to be abandoned) and new holes of commercial value may be used.

(3) Though much useful information will be obtained from the above and other research efforts, a few deep research holes drilled into the crystalline basement are also needed. Objectives include understanding of heat and fluid flow in the deeper portions of geothermal systems and interchange of volatiles between the country rock* and underlying magma.

The basic knowledge gained from the geoscience research effort will provide a basis for developing a better assessment of the Nation's geothermal energy potential and materially aid the development of improved assessment and exploration technologies by the early 1980's,

*Rock that existed at the geothermal site before the anomaly was formed, usually in close proximity to rock carried up by the fissure or magma chamber which caused the "hot spot" near the surface.

Assessment and Exploration Technology - 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. A number of resource assessment and exploration techniques are in use today that have the potential for improvement.

Regional assessments presently utilize surface and aerial studies of regional geology, volcanology, hot springs and other surface geothermal phenomena; electrical, electromagnetic, magnetic, seismic, and gravity surveys; heat flow measurements; chemical and isotopic analyses of surface and subsurface water; and hydrologic reconnaissance.

Exploration surveys using similar techniques, including aerial and surface geological observations serving to identify recent fault and volcanic activity (intersecting faults are of special interest); hydrologic studies of subsurface water flow and temperature; electrical surveys, particularly DC resistivity techniques with large electrode spacing (hundreds of meters) to identify the presence of deep water with high temperature and/or high salt content; and electromagnetic techniques.

Several passive seismic techniques are used to define fault positions by local low-level seismic sources and by seismic velocity changes through an area, indicating the presence of subsurface intrusions. Generally speaking, magnetic and gravity studies have been of less value so far. Analyses of silicon (SiO_2) content and sodium, potassium, calcium (Na/K/Ca) ratios in water samples are indicative of reservoir temperatures. Chloride contents in excess of 50 parts per million characterize most high-temperature hot water systems, whereas vapor-dominated systems consistently display less than 20 ppm. Other geochemical measurements are also of value.

Measurements of local thermal gradients and heat flows, obtained in shallow, small-diameter drill holes (depths to a few hundred meters) are also useful. A core from the hole is usually needed for the heat-flow determination. Some techniques that do not require a core sample are being examined.

The federal program to improve the assessment and exploration technology includes the following activities:

- a detailed definition of the present capabilities and limitations to gather data, to analyze data and to predict geothermal resources.
- an evaluation of the state of knowledge of individual geothermal sites or reservoirs.
- an analysis of the potential for improving the major techniques, technology, and/or instrumentation.
- planning of efficient use of multiple instruments and data analysis techniques in a systematic sequence to converge reliably on selection of a drilling target.
- studies of new and/or improved analytical techniques
- a determination of geological, geophysical, geochemical, and hydrological parameters and circumstances (such as detailed descriptions of formations) of geothermal resources and their relationships to location.
- efforts to improve or devise new advanced exploration instruments and supporting equipment.
- field work to evaluate the new exploration techniques and improved hardware, software, analytical techniques, and methods of interpretation including verification of results with information from deep wells and their logs.

Efforts to improve the technology are presently being supported under ERDA, NSF, and USGS sponsorship. The USGS also is developing case histories of specific geothermal areas in which they can compare the results of as many of these techniques as possible. Extramural work is funded to support this effort. It is expected that much of the technology evaluation effort will be completed by 1980. It will then be possible to concentrate the development effort on the more promising activities, which could then be made available for widespread use by the mid-1980's and could significantly reduce the current high risk of exploration and improve the accuracy of the assessment program.

National and Regional Assessments - The early assessment of the extent of our geothermal resources at the national and regional level will help industry (particularly the smaller companies) in selecting sites for potential development, will provide data for financial institutions to develop preliminary investment plans, will provide state and local governments with planning and resource development data, and will provide the Federal Government with information needed to establish program priorities. 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. Periodic updating of this study will be necessary as resource data become available. Deep slim hole drilling is planned to help improve the accuracy of the assessment.

The National and regional assessment effort has been emphasized in the Geothermal Act of 1974, Section 102(a)(3), and is a continuation and acceleration of an ongoing effort under the direction of the U.S. Geological Survey. Areas of greatest suspected potential are being assessed first. The planned sequence for the accomplishment of regional assessments can be generally defined by the following 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 1980.

Resource Information Dissemination - Resource assessment, research and exploration will produce much information that will be of continuing value to industry and government. Such information will be used by new and continuing participants of the exploration industry in the development of exploration techniques and reservoir analysis methods and by the government in future energy planning. A National data bank on geothermal resources is planned to ensure retention and distribution of these data. The data bank will be organized for ease of access and data retrieval, and will be user oriented, providing information oriented toward both technical and non-technical users in various aspects of the geothermal energy development. A key part of the resource information dissemination activity is the preparation of synthesized data and handbooks oriented to user education. These efforts will be directed toward educating future geothermal personnel and encouraging new participants in the geothermal exploration and utilization industries.

ERDA, with the cooperation of USGS, has a computerized data storage/retrieval project underway.

Utilization Plan

The utilization by the private sector of the technology developed under this program area will be facilitated by their active participation in its development through contracts. In addition, data on the technology will be disseminated through the preparation of the technical material for professional, semi-professional and specialized journals of the various user groups. Research results will be made available through information systems, educational institutions, workshops, and symposia.

Data on the resource base will be made available through the periodic updating of the USGS assessment study as well as from the data bank established for resource information dissemination.

TECHNOLOGY DEVELOPMENT

Objective

Technology Development is directed at developing and demonstrating the technology to economically extract and utilize the energy from the different types of geothermal resources in an environmentally acceptable manner. Many of the development activities included under Hydrothermal Technology Development will benefit the commercial development of the other resource types. This includes improvements in drilling technology, utilization technology, and brine chemistry and materials research. However, each of the resource types does have unique technology problems associated with its use that must be resolved before it can be used commercially. The technology associated with each of the resource types is at a different stage of development maturity. The expected sequence in which these resources will be brought to commercial maturity is as follows:

(1) Hydrothermal

(2) Geopressured

(3) Hot Dry Rock

(4) Magma

(5) Normal Gradient.

Hydrothermal

Problem

Even though the hydrothermal technology is the most advanced of all the resource types, the technology exists to commercially utilize only the high quality, high temperature resources.

One of the more important requirements in developing hydrothermal resources more extensively is to reduce the cost of drilling. At present, the cost of drilling a geothermal well is two or three times that of drilling a petroleum well of similar depth. The drilling equipment presently in use was developed for drilling of petroleum wells at relatively low temperatures in sedimentary rock. Geothermal well drilling involves much higher temperatures (up to 350°C) (662°F) and sometimes takes place in hard, abrasive volcanic rock that is difficult to drill even with the best tungsten carbide insert bits. Penetration rates are low with excessive bit wear.

Present drilling muds, used to lubricate and cool the drill pipe string and bit, as well as to remove cuttings from the hole, rapidly deteriorate above 177°C (350°F). This deterioration results in increased mud viscosity which affects its circulation rate. The mud can also form a hard, caked lining in the well bore, which can ruin a producing formation. As a result, wells are usually drilled into low pressure strata using air. The high air velocity required to remove cuttings can destroy a drill string by abrasion. It is necessary to replace the pipe more frequently after use in drilling.

Work is required to improve cementing compounds and techniques and elastomers for use in drilling equipment such as bits, logging devices and blow-out preventers.

The capability to log in high-temperature geothermal wells does not presently exist. Most of today's devices and instruments operate at temperatures up to 177°C (350°F) and some up to 260°C (500°F). Logging cables suffer from similar problems. Consequently, only limited and stop-gap measurements are made. In addition, the high temperatures and a variety of other conditions in geothermal wells may create unusual device corrosion problems. Because geothermal exploration imposes new and different well-logging applications, the requirements for and the interpretation of downhole logging measurements are not well defined.

One of the most significant limits on geothermal growth rate is the risk of premature reservoir failure. This risk can be eliminated by developing reliable reservoir modeling techniques to predict reservoir lifetimes and production rates, and by the development of well stimulation techniques to restore aging wells and improve the flow rates in marginal wells.

Improvement and development in utilization component technology are required for the advanced power cycles to commercially utilize the lower temperature hydrothermal resources. These components include: downhole pumps; heat exchangers; heat rejection equipment; and advanced absorption refrigeration systems for nonelectric applications.

A better understanding of brine chemistry, scale control, and materials compatibility (corrosion/erosion) and dissemination of the resulting information to potential users is required. This information is essential for coping with the severe chemical and thermal environment encountered with these fluids in order to increase the plant availability factor.

Production of electricity from geothermal energy is considered to be attractive environmentally compared with fossil-fueled plants because no solid atmospheric pollutants are emitted. However, geothermal generation is not without potentially detrimental environmental effects. Effluents from either a hot-water or a vapor-dominated system can pollute streams or ground waters. Consequently, federal and state regulations may require injecting objectionable fluids and gases back into a deep reservoir if practical. Noise, objectionable gases, land use, visual impact, potential subsidence of the land surface due to fluid withdrawal, and potential seismic disturbances are other problems faced in geothermal energy development. Very little data is available on the effects of geothermal energy on the environment. As a result of this lack of data and associated standards, the environmental approval process is slowed.

Implementation Plan

The hydrothermal technology development effort includes the following activities:

(1) Reservoir engineering and field development.

(2) Utilization technology.

(3) Brine chemistry and materials.

(4) R&D test facilities.

(5) Advanced systems and applications.

(6) Environmental effects and abatement technology.

(7) Demonstration projects activities.

Descriptions of each of these activities follows:

Reservoir Engineering and Field Development - 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 this effort:

- Advanced drilling technology 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.

- Well-logging technology to develop the instrumentation and evaluation techniques for geothermal applications.

- Reservoir modeling development to better predict reservoir characteristics and lifetime.

- Well-stimulation technique development to improve the flow rate of marginal wells. Field testing of these techniques is planned.

- Downhole pump development for the high-temperature environment of geothermal wells.

Activities are currently underway on downhole pumps and drilling technology development. They should begin to reach fruition by the late

1970's. The advanced well logging, well stimulation and reservoir modeling efforts are targeted for completion in the early 1980's.

Utilization Technology - This effort is directed at developing the key technology required for the advanced utilization cycles including nonelectric applications. This key technology includes: (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 includes both prime mover development and field evaluation; and (4) advanced absorption refrigeration system for nonelectric applications.

Many of these efforts can be completed by the late 1970's. If successful they will help provide improved methods for converting geothermal resources and their by-products into useful forms. They will also help extend the commercially exploitable resources and will enhance the utilization of geothermal resources in regions of limited cooling water availability.

Brine Chemistry and Materials - This program element will develop a better understanding of brine chemistry, scale control, and materials compatibility (corrosion/erosion) and will provide for the dissemination of the results to potential users. This information is essential for coping with the severe chemical and thermal environment encountered with geothermal fluids.

R&D Test Facilities - 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.

The construction of these facilities will be coordinated with key R&D activities. The first is planned for completion in 1977.

Advanced Systems and Applications - There will be a continuing effort to examine the feasibility of applying advanced technology and concepts to enhance the utilization potential of geothermal resources. It will provide guidance in identifying key technology problems, establishing programmatic priorities, and in evaluating technical alternatives.

Environmental Effects and Abatement Technology - 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 geothermal utilization facilities.

Key geothermal-related environmental problems to be investigated in the research and development activities include the areas of gaseous emission, liquid waste disposal, noise regulation, and land subsidence, leading to the development of standards and the development of key abatement equipment and technologies. This research and development will provide powerful tools for predicting environmental effects, result in better Environmental Impact Statements, and yield greater confidence in proceeding with geothermal development.

Demonstration Projects - 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. Two such commercial-scale facilities are tentatively planned. These and other such projects will be considered based on the development of key technology, and regional development needs. Nonelectric demonstrations are being given special emphasis in ongoing application studies involving the cities of Susanville, California and Boise, Idaho and through the issuance of program opportunity notices for more nonelectric pilot plants and nonelectric applications experiements.

These plants will be very effective in increasing user participation in the development and operation of geothermal plants. In addition, data from these plants should stimulate additional industrial commitments to the development of similar facilities. Both these efforts could stimulate the expansion of the related service industries.

Geopressured

Problems

There are strong indications of large volumes of geopressured water located in three zones in the United States: a wide onshore and offshore belt along the Gulf of Mexico from Mexico to Mississippi and two areas from Northeastern Texas to Florida. Well data from thousands of deep wells, drilled for oil and gas, confirm the existence of high pressure, high temperature zones and provide data on the geologic conditions where these zones occur. However, the actual volume and permeability of these aquifers have not been demonstrated by prolonged flow tests. Consequently, the economic viability is unconfirmed.

A geopressured resource is distinctly different from hydrothermal geothermal resources in three ways.

	Hydrothermal	Geopressured
(1)	Localized thermal anomalies associated with volcanic and/or tectonic (crustal movement) activities.	Located in large deep sedimentary basins.

(2)	Areas of high near-surface heat flows, often with hot springs and/or fumaroles.	Low surface heat flow.
(3)	Energy is derived entirely from the earth's heat.	Energy derived can be in three forms: thermal, kinetic, and dissolved methane.

The pressure in a typical geopressured aquifer in Texas, for example, is between 10,000 and 14,000 psi at 4 km to 5 km depths and the temperature is between 160°C (320°F) and 200°C (392°F). The top of the aquifer can be as shallow as 1 km deep or as deep as 6 km. Temperatures of up to 275°C (527°F) have been measured and pressures may reach 20,000 psi. Because of the depths and high pressures involved, the development of economic drilling technology to accomodate the unique requirements of geopressured resource is a key to its commercial exploitation. The development of a high pressure turbine is also needed.

Because of the high cost of drilling and well completion, the size and energy potential of these geopressured reservoirs has not been demonstrated to date in flow tests. As a result there are two major reservoir technical uncertainties that should be resolved before committing to expensive technology development programs. These uncertainties are:

(1) The unknown number of aquifers with sufficient volume and permeability to sustain large flows of water over long intervals of time,

(2) The unknown methane gas content in the geopressured water. (The amount of gas which can be recovered is a primary factor in the economics of utilizing geopressured water.)

Implementation Plan

The approach to the geopressured development is first to verify the existence, viability, and utility of geopressured resources and then to develop the technologies necessary to the commercial utilization of these resources. State surveys of the resources will be made. Exploratory drilling at representative sites will be initiated. Upon successful completion of the wells, drawdown tests will be conducted to determine reservoir characteristics, natural gas content, well interaction effects, and brine composition. Brine disposal techniques will also be investigated.

Reservoir modeling and mapping of the Gulf states will be undertaken to evaluate the resource and to identify additional candidate sites for exploration. Resource studies of this type are presently in process using existing well logs to get a better understanding of geopressured zone boundaries, temperatures, pressures and gas content.

If these exploratory studies prove successful, advanced technology development activities would follow. The development of the following new technologies is envisioned: high pressure prime mover, improved water well construction techniques, improved drilling techniques, high temperature elastomers for wellhead dynamic seals, well logging instrumentation, and resource parameter modeling. Concurrently, environmental R&D will be initiated including the conduct of subsidence, seismic, and tilt monitoring studies will be undertaken along with the acquisition of background data to assess the effects of geothermal production upon the environment. During this phase of development, an additional set of wells in the geopressured geothermal reservoirs typical of the Southern Mississippi Salt Basin (early-stage medi-sedimentary rocks) will be considered.

Test beds and experiments will be prepared to evaluate heat exchanger fouling factors, materials compatibility, mineral recovery feasibility, and pollution abatement equipment adequacy at each of the resulting producing fields.

These activities will be completed by the early-1980's at which time consideration could be given to the construction and operation of commercial scale demonstration plants.

Hot Dry Rock

Problems

The hot dry rock geothermal resource is defined as those geological formations having an abnormally high heat content but not containing sufficient water or sufficient rock permeability to permit withdrawal of hot water as a heat transfer medium. The resource is estimated to be very large and its exploitation could be significant to the nation. At this time locating hot dry rock areas as opposed to hydrothermal areas is difficult on the basis of surface evidence. Even high temperature gradients measured in relatively shallow holes can be misleading, as evidenced by the Marysville, Montana project where a large convective system was found with no surface manifestations. Hence, a need exists to develop improved hot dry rock resource assessment and exploration techniques.

The key to the extraction of the energy from this resource is to establish a circulatory fluid flow loop through the hot rock by fracturing the rock between wells. In this way injected water can be circulated through the rock to extract the heat. Demonstration of this technology is underway at Los Alamos, New Mexico. Another key factor to the economic viability of this resource is the availability of low cost drilling technology. An extension of the drilling technology pursued under "hydrothermal" is required for the hot dry rock development. It is expected that the utilization technology developed under "hydrothermal" can be used directly in hot dry rock applications.

Implementation Plan

Los Alamos Scientific Laboratory (LASL) has been conducting a research project on hot dry rock on the Jemez Plateau near the western edge of Valles Caldera, New Mexico. Hot dry rock has been discovered in deep drilling operations, and preliminary rock fracturing tests performed. Drilling of a second hole to establish the fluid circuit is completed. A circulation loop has been constructed and heat extraction at various rates will be evaluated. These activities will be completed by the late 1970's.

A laboratory simulation and modelling study will be conducted in parallel with the field operations. The efforts planned under the "Resource Exploration and Assessment" program will provide more data on the extent of the resource.

After establishing the feasibility of extracting heat from hot dry rock, at the Jemez Plateau, consideration will be given to establishing a test loop at a second site, probably utilizing a different extraction technology, oriented to the verification of commercial potential by the early 1980's. This could then be followed by a commercial-scale demonstration plant.

Normal Gradient

Problem

Most of the eastern and central U.S. has a relatively low ("normal" or "near-normal") heat flow and relatively low geothermal temperature gradient as a result. Rather deep holes are necessary to reach even moderate temperatures i.e., 4 km for 100°C or 10 km for 200°C (12,000 ft for 212°F or 30,000 ft for 392°F). Because of the cost of drilling the utilization of geothermal heat is more expensive in these regions than where the heat flow and geothermal gradient are high. Moreover, the deeper rocks in substantial portions of the eastern and central states may have low permeability, so the flow of geothermal water into wells may be low. Reservoir stimulation may be required.

Implementation Plan

Because of the long-range nature of normal gradient applications, the initial activity in this area will be to investigate the character of the near-normal gradient resource and possible nonelectic applications. A group of studies is planned to define the factors affecting the use of the deep, low-temperature geothermal resources typical of the Central and Eastern states. These studies would be completed in the 1978-1979 time period. If these studies indicate that these applications are promising, then feasibility experiments would be initiated.

Near normal gradient development would draw heavily upon the drilling, well stimulation, and utilization technology developed as a part of the "hydrothermal" and hot dry rock developments.

Magma Resources

Problems

Magma (hot, liquid or partly-liquid rock) lies beneath the entire crust of the earth, starting at 20 to 50 km (66,000 to 164,000 ft) depth and extending downward. These depths are too great for economic utilization. In some areas however, magma exists closer to the surface, even at the surface in active volcanoes, for example. This near-surface magma potentially could supply a great deal of geothermal energy. The temperature is very high (650°-1500°C) and the volume of magma very large. No techniques are known, however, for converting this energy into useful forms in commercial quantities. Because of the magnitude of the technical difficulties, it is not expected that magma energy utilization can reach the pilot plant stage before the 1990's. This will be constantly evaluated as new technologies emerge.

Implementation Plan

Long-term research and studies on magma utilization are in progress under ERDA sponsorship. These research and study activities will continue at a low level. Experiments and advanced development will be initiated when the problems associated with the utilization of magma resources are better defined.

Utilization Plan

The transfer to the private sector of the technology developed under this program area will be accomplished primarily by encouraging the industry's active participation in its development. The breadth of the program requires the support of industry, universities, non-profit organization and government laboratories. Much of the work will be contracted. In addition, data on the developments will be disseminated through the preparation of technical material for professional and specialized journals of the various interest groups. Research results will be made available through information systems, educational institutions, workshops, and symposia.

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. These plants will provide "hands-on" experience to expand the cadre of trained personnel, in addition to introducing geothermal energy utilization to regions of large potential.

INSTITUTIONAL DEVELOPMENT

Objective

The objective of the Institutional Development area is to enhance the potential for early, commercial exploitation of the resource in an environmentally acceptable manner through development of national policy, incentives and institutional relationships.

Problems

In addition to the technical barriers described, there are major institutional barriers to the growth in the commercial utilization of geothermal energy that need to be resolved. Much of the geothermal resource is located on federal land. The progress in leasing of these Federal lands, as provided for in the Geothermal Steam Act of 1970, has been slow. The first competitive leases became effective August 1, 1974. The first noncompetitive lease had an effective date of February 1, 1975. The processing of leases has accelerated considerably over the past few months. The industrial response to the leasing program has been disappointing in that no bids have been received on some competitive lands and applications have been disallowed or withdrawn on noncompetitive lands.

Because of the many technical uncertainties currently associated with the utilization of geothermal energy, its development is viewed as a high risk venture. As a result, most industrial investment to date has been limited to the development of the high temperature hydrothermal resources. This is reflected in the leasing activities. The investment in geothermal development is further retarded by the lack of economic parity between the development of geothermal energy and the industrial development of other energy resources (e.g., coal, uranium, oil, gas, etc.). One of the key disincentives may be the inequity in tax treatment with respect to the write-off of intangible drilling costs and the depletion allowance.

Geothermal development also has been slowed by the lack of environmental data, technology, and standards necessary for environmental approval. These problems are being addressed in the technology development program. However, the environmental approval and permitting process also is slowed by the lengthy, complex, and often inconsistent rules, laws and regulations at the local, state, and Federal levels of governments. The overlap of jurisdiction of the responsible agencies further compounds the approval process.

There are many other institutional factors that act as disincentives to geothermal development including issues relative to tax treatment; leasing policies; patent rights; and, utility regulatory practices.

Implementation Plan

The current Federal program in Institutional Development includes the implementation and administration of the Federal Leasing Program and the Loan Guaranty Program. Consideration is being given to establishing and maintaining geothermal resource clearinghouses at the state level. Finally, a policy research activity is included for the evaluation of various alternatives associated with policy issues, or barriers, affecting the implementation of the Geothermal Energy Program. In addition to these activities, the Federal Government is establishing institutional relationships between the involved agencies at the Federal level of Government to provide a forum for the coordinated resolution of policy related issues.

Leasing - This activity provides for the implementation and administration of the program to lease Federal lands for geothermal exploration and development as authorized by the Geothermal Steam Act of

1970. This program is administered by the Department of Interior and is supported by the United States Forest Service. The activities included in this effort include:

- the establishment of "Known Geothermal Resources Areas" (KGRA'S)
- the scheduling of areas to be leased and the preparation of environmental assessment reports (EAR's) and/or environmental impact statements (EIS's)
- the processing of competitive bids as well as noncompetitive applications
- the administration of the lease operations by the USGS.

The leasing program will be coordinated with the "Resource Assessment" activity in establishing leasing priorities. Leasing rates recently have been established to minimize "backlogging" of applications to assure the availability of federal lands for industrial exploration and development.

Loan Guaranty - This element provides for the administration of the Loan Guaranty Program authorized under Title II of PL 93-410. The Guaranty Program is provided to encourage commercial production of energy from geothermal resources. The Guaranty Program is designed to protect lenders against loss of principal or interest on loans made by such lenders to qualified borrowers the purpose of:

- the determination and eval .tion of the resource base,
- reservoir development projects,
- research and development with respect to extraction and utilization technologies,
- acquiring rights in geothermal resources,
- development, construction and operation of facilities for the demonstration or commercial production of energy from geothermal resources.

However, the Loan Guaranty Program may be used for projects with an early potential for producing income rather than for research and development. Inquiries received to date indicate most applications will have the purpose of drilling test wells to prove reservoir potential and for field development. It is expected that future applications will also include the development of utilization plants once the planned demonstration projects have been completed.

The proposed regulations for the Loan Guaranty Program will be published in the Federal Register. A final regulation is planned to be published early in 1976.

Geothermal Resource Clearinghouses - The establishment and support of geothermal resource clearinghouses at the state level, as authorized in Section 104(a)(11) of PL 93-410, is being considered. These clearinghouses could serve to: (1) provide geothermal resource developers with information with respect to applicable local, state and federal laws, rules and regulations, (2) coordinate the processing of permit applications, impact statements, and other information which geothermal resource developers are required to provide, (3) and encourage uniformity with respect to local and state laws, rules, and regulations with respect to geothermal resources development.

The implementation of this program element will provide for expediting the environmental and permit approval process and will provide a public forum for identifying problems that need to be addressed in the program.

Policy Analysis - The Geothermal Energy Research, Development, and Demonstration Act of 1974, Section 104(a)(9) of PL 93-410, provides for the identification of social, legal, and economic problems associated with geothermal development (both locally and regionally) for the purpose of developing policy and providing a framework of policy alternatives for commercial utilization of geothermal resources.

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.

Utilization Plan

The industrial and public sectors will be encouraged to contribute to institutional development and policy analysis activities through their participation in special panels or working groups and through workshops and symposia. Data and reports will be made available through normal information dissemination processes.

SECTION IV

PROGRAM COORDINATION AND MANAGEMENT

ERDA, under the general provisions of the Energy Reorganization Act of 1974 (Public Law 93-438), will manage the major portion of the Federal Geothermal Energy Research Development and Demonstration Program.* It will promote coordination of its activities with those of other Federal agencies. ERDA will establish and conduct an RD&D program that addresses all technologies applicable to the development of the geothermal resources contained within the United States, and will seek the assistance of private institutions, public institutions and industry in the conduct of the RD&D program and in the effort to apply the results of the program to the rapid development of geothermal energy utilization within the United States. ERDA will disseminate the scientific, technical, economic, and institutional information acquired in the geothermal energy program and will promote the free interchange of ideas in pursuit of scientific and industrial progress and public understanding of geothermal energy technologies. Realization of program goals will

*Specific responsibilities assigned to the administrator of ERDA by PL 93-438 include: (1) central responsibility for policy planning, coordination, support and management of research and development programs with respect to all energy sources, (2) encouraging and conducting research and development, including demonstration of commercial feasibility of energy sources, (3) engaging in and supporting environmental, biomedical, physical and safety research related to energy, (4) taking into account other public and private research, (5) participating in and supporting cooperative research, (6) collecting and distributing scientific and technical energy information, (7) creating and encouraging development of information for distribution to the general public, (8) encouraging and conducting energy conservation R&D, (9) encouraging and participating in international cooperation in energy R&D, (10) helping to assure an adequate manpower supply for energy RD&D, and (11) encouraging and conducting R&D in clean and renewable energy sources.

require that industry be encouraged to accomplish its own R&D, participate in joint projects with the Federal Government, and introduce new geothermal technologies when they appear to be commercially viable. The Federal program will be continually reviewed to identify those activities which are no longer appropriate candidates for government support and for which industry is capable of taking the lead.

ERDA MANAGEMENT ORGANIZATION

Within ERDA, responsibilities for geothermal energy development are centered in the Division of Geothermal Energy under the Assistant Administrator for Solar, Geothermal and Advanced Energy Systems (see Figure IV-1). The ERDA Division of Geothermal Energy provides management for the determination and evaluation of resource availability, for the development and utilization of geothermal energy, for research and development of geothermal technologies to improve system performance and economic viability, for demonstration of new engineering approaches and system capability and reliability, and for implementation of programs of data dissemination to support widespread commercial use of geothermal energy. The Division administers the Geothermal Loan Guaranty Program, designed to make capital from private lending agencies available for the support of those activities critical to geothermal development.

The ERDA Division of Geothermal Energy is organized into three technical offices and an administrative office. This structure is shown in Figure IV-2.

PRIVATE SECTOR PARTICIPATION

The success of a national geothermal energy development effort depends not only on the successful conduct of the research, development and demonstration projects, but on the integration of geothermal technology into the national economy on a widespread and continuing basis. This success

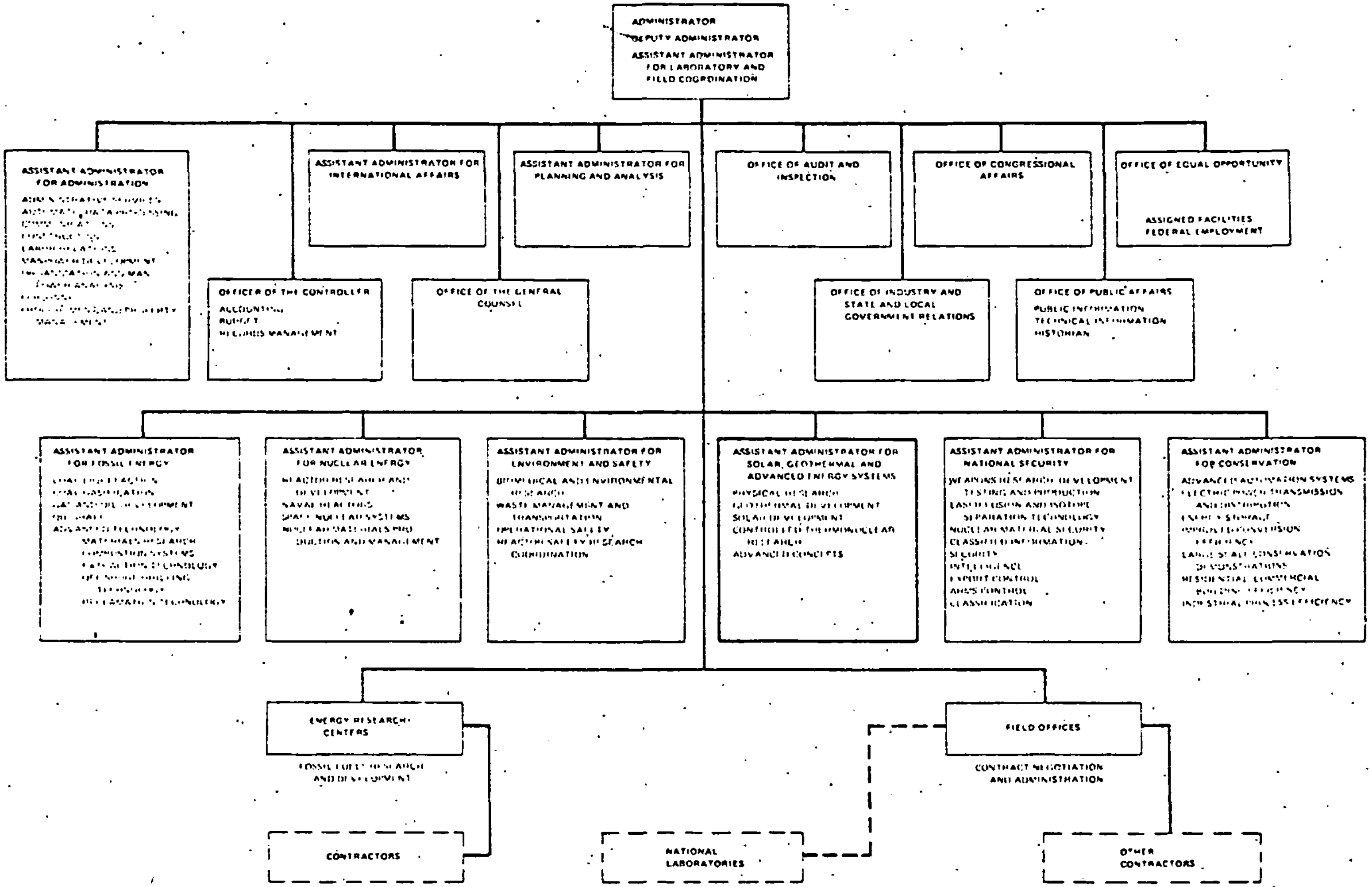


FIGURE IV - 1
FUNCTIONAL ASSIGNMENTS IN ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

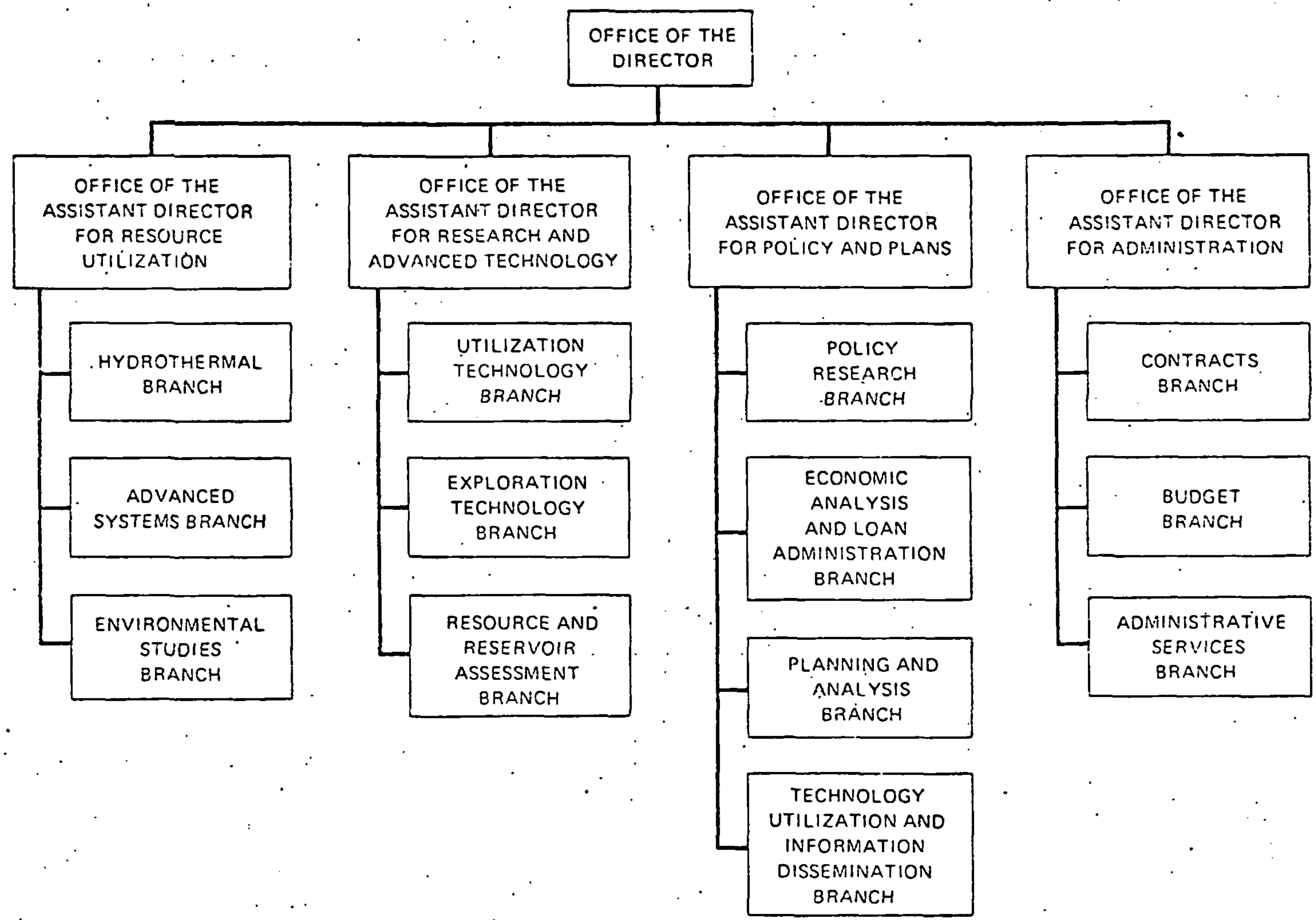


FIGURE IV-2
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION DIVISION OF GEOTHERMAL ENERGY

is dependent upon the involvement in the program of the many small and large business entities, private organizations, and institutions to help develop the guidelines, criteria and specifications that the program will require in order to produce those technological and institutional developments needed to accelerate the utilization of geothermal energy. Throughout the program, careful attention will be paid to the needs of small business, especially with respect to nonelectric RD&D areas likely to be commercialized by these activities.

One of ERDA's primary considerations in structuring the plan for geothermal energy development is to provide the opportunity for and to encourage the private sector to participate in all phases of the research, development and demonstration program. ERDA will seek to design approaches and select participants for specific projects in a manner that will ensure the early and continuing participation of those segments of the economy whose acceptance of geothermal technology will be essential to its general adoption.

SPECIFIC RELATIONSHIPS BETWEEN ERDA AND OTHER FEDERAL AGENCIES

The Energy Reorganization Act of 1974 (PL 93-438), specifies that the Administrator of ERDA "...shall utilize, with their consent, to the fullest extent he determines advisable, the technical and management capabilities of other executive agencies having facilities, personnel, or other resources which can assist or advantageously be expanded to assist in carrying out (ERDA's) responsibilities."

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

Additionally, the Interagency Panel on Geothermal Energy Research (IPGER) may continue in operation providing working level coordination among all Federal agencies involved in geothermal related activities.

STATE AND LOCAL GOVERNMENT

ERDA, through the Division of Geothermal Energy, the Office of Industry, State, and Local Government Relations and other appropriate Federal agencies, and in cooperation with non-Federal entities, shall establish programs that will encourage the states to establish and maintain geothermal resources clearinghouses, which shall serve to:

- Provide information with respect to applicable local, state and Federal laws, rules, and regulations,
- Coordinate the processing of permit applications, impact statements and other information that developers are required to provide,
- Encourage uniformity in local and state laws, rules and regulations with respect to geothermal development.

ERDA will also develop a plan that will encourage individual community acceptance of geothermal energy and that will guard against adverse impact on a community in the immediate locality of a geothermal development activity.

UNIVERSITY AND NON-PROFIT INSTITUTIONS PARTICIPATION

Universities and, where appropriate, private non-profit institutions through the normal request-for-proposal mechanism, will participate in the research, development, and demonstrations. Unsolicited proposals will also be accepted according to ERDA and other Federal agency guidelines.

PROFESSIONAL SOCIETIES AND INDUSTRIAL ASSOCIATIONS PARTICIPATION

The appropriate professional societies and industrial associations will be solicited to support the program through symposia, technical meetings, technical and consumer information dissemination, and, where appropriate, RD&D activities. They will also be solicited to participate, as appropriate, in the promulgation of standards, criteria and codes.

SECTION V

MAJOR ISSUES AND THEIR POTENTIAL IMPACTS

The development of a new industry in this country depends on the interaction of many activities including the perception of a need, the creation of a concept to satisfy the need, the technological development required to transform the concept into a feasible process, system or product, the ability to commercialize the process through appropriate marketing, sales and service functions and, of course, financing the entire venture. Traditionally, private industry assumes the initiative for these activities. Under normal circumstances, the Government's role involves protection of the public interest and the maintenance of a political, social and economic environment which allows private enterprise to pursue appropriate opportunities. Because of the national concern with the energy problem ERDA, in collaboration with cognizant Federal agencies, is examining the role of the Federal government with respect to energy development generally and development of geothermal resources specifically. The following sections highlight some specific characteristics of the industry which affect the rate of development of the geothermal energy resource to be considered in the definition of the Federal Government role.

INDUSTRIAL DEVELOPMENT CHARACTERISTICS

The geothermal industry in this country is faced with technical and economic uncertainties which have a significant impact on the rate of exploitation and utilization.

In electric power generation, for example, key technical uncertainties which affect the rate of development include: (a) reliable information about the location, extent and magnitude of exploitable resources; (b) information about resource lifetime and ability to sustain a given level of power generation; and (c) lack of proven technology to exploit the more abundant resource types.

Technical uncertainties create economic difficulties because the lack of reliable, quantitative information about the geothermal resource poses a serious obstacle to the willingness of industry and the financial community to commit capital to the development of geothermal resources. Absence of proven, reliable technology for exploration, reservoir definition; field development, conversion and utilization of most forms of geothermal energy also postpones the exploitation of geothermal energy. There is also a geographic factor that impacts on geothermal economics. If a geothermal reservoir is used for production of electricity and is located in a remote area away from potential users, then additional capital is required for construction of a transmission system.

There are institutional uncertainties which impact geothermal investment. Because of the long lead times arising from leasing, environmental assessment, resolution of siting issues and technical development discourages investors from providing the needed capital due to the high risk associated with achievement of ultimate profitability. Furthermore, even if a geothermal development venture were to be profitable, unacceptably long times may be involved in realizing monetary returns on investment. Time delays arising from Federal, state and local jurisdictional requirements for lease processing and environmental assessments also contribute to increased capital requirements. State public utilities commissions differ widely in their policies concerning the amount of development expenditure which will be allowable in the establishing of the utility's rate base. Thus, a singular approach to solving capital problems may not be appropriate.

Nonelectric applications of geothermal energy for space heating and industrial process heat may show considerable promise for reducing reliance on scarce nonrenewable resources. With the exception of long distance transmission needs, and allowable development costs on which to establish a rate base, the previous discussion of technical uncertainties and related economic and institutional issues for geothermal electric applications applies also to nonelectric applications. However, based upon the premise that geothermal energy utilization contributes to the national welfare, it is reasonable to explore the extent to which the risks of development should be borne by the developer, the utility, the beneficiaries of the power and the Federal Government.

FEDERAL APPROACH TO REDUCING UNCERTAINTIES

The Federal Government is actively engaged in a research and development program to help assure that appropriate technology is available for industry use in the development of geothermal resources. The Federal Government is determining to what extent additional incentives may be useful in helping to insure that industry uses the available appropriate technology. The preceding discussion has indicated that risks and uncertainties tend to discourage industry from making the necessary investments which could result in harnessing this potentially significant resource for the benefit of the U.S. economy by the year 2000. Increased capital availability and investment is necessary in order to achieve this result. An important step towards this end is the Loan Guaranty Program in which the government will assume 75 percent of the risk associated with projects that have an early potential for producing income. Capital formation also may be stimulated by other means, such as financial incentives and regulatory procedures, that can make investment more attractive. Financial incentives tend to reduce capital requirements while favorable regulatory procedures tend to reduce the time to recovery of invested capital.

ERDA believes that the institutional, environmental, and legal issues will be extremely important in determining the rate of geothermal development.

FINANCIAL INCENTIVES

The range of possible federal policies with respect to financial incentives that may have significant impact on capital formation includes loan guaranties, tax incentives, and direct subsidies. Of these, only the loan guaranty is at present a part of the ERDA geothermal program. Other future incentives may take the form of depletion allowances, a reservoir investment indemnity program, allowance to write-off intangible drilling costs against income, subsidies for high risk projects or for cost of delivered energy, cost sharing for pilot and demonstration programs, and financial support to local communities for planning grants related to geothermal development. The precise impact of these incentives is not clear. Their implementation would be likely to favor capital accumulation and accelerate development. However, detailed studies will establish quantitatively the degree of acceleration and ultimate energy price as well as the associated costs of these options. This data could be used to define the optimum mix of incentive options.

REGULATORY PROCEDURES

The major regulatory and institutional procedures affecting capital formation and rate of industrial development include leasing policy and procedures, environmental assessments, permits for operations and rights to data and patents.

Some of the key issues related to the leasing program include whether or not there should be:

(1) processing of lease applications on 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 resulting from inadequate exploration activities.

These issues have important implications. For example, at the present time, if a discovery is made on private, state or federal KGRA lands near unleased federal non-KGRA lands, then the adjacent non-KGRA lands would be reclassified, lease applications on file would be rejected, and leasing delayed because all leases would be obtained through competitive bids. Changing this procedure according to Item (1), above, would undoubtedly stimulate more exploration but could result in disposal of public resources to industry at less than true value. Also, any increase in acreage increases the likelihood that a leaseholder may find and develop this resource on his site, but it also increases the capital required and thus might result in large energy companies obtaining a dominant position in the geothermal industry at the expense of less affluent independent operators. These issues require careful study to help define those policies which best balance the public interest and industry development.

Uncontrolled geothermal development could result in adverse environmental impacts. As a result, careful planning and proper use of control technology is required to reduce these impacts to an acceptable level from a regulatory as well as from an aesthetic point of view. Environmental assessments and impact statements are required to indicate how environmental control can best be accomplished. These are time consuming and costly to prepare and involve obtaining concurrence or approvals for operations from multiple federal, state and local government agencies.

Key environmental issues include whether there should be greater coordination and standardization of reporting and public hearing procedures while maintaining separate decision authorities for the multiplicity of jurisdictions which may be involved. Consideration could also be given to separate environmental assessment requirements for exploration in contrast to development and utilization activities. These issues, as those associated with leasing, are being carefully examined from the standpoint of cost and impact on capital formation and rate of development in order to achieve a proper balance between public interest and industry growth and development. Streamlining of procedures for granting leases and permits and for preparing environmental assessments may reduce both cost and time to achieve commercial operations, thereby reducing capital requirements for exploration and development.

In the area of patent and proprietary data rights, it is desirable to strike a proper balance between satisfying those industries that receive government funding to provide commercial level development of necessary technologies, and preserving public interest in the form of providing for government patent and data rights from the technology developed with public funds. The Federal Nonnuclear Energy Research and Demonstration Act of 1974 permits the Administrator of ERDA to waive title to inventions at the time of contracting. Prudent application of the waiver policy might stimulate participation of these firms without proliferating private rights to technologies developed at public expense. Suitable guidelines for granting these waivers should be developed to achieve a proper balance between the general public interest and support to industry development.

Policy Research

The geothermal 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. Key to the analysis of these institutional, financial and technological options and issues will be the development and application of cost-benefit studies. These studies would integrate technological, environmental and socioeconomic data. The results of these studies would then form a basis for evaluation and decision-making regarding the technical R&D program as well as the manner and extent to which the Federal Government should support the development of a geothermal industry.

Form ERDA-333
ERDAM 0201
(1-75)

SERIAL NO.: 67

UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
ERDA MANUAL

IMMEDIATE ACTION DIRECTIVE

ERDA IAD NO.: 8000-1

November 19, 1975

SUBJECT: ESTABLISHMENT OF ERDA PROGRAM APPROVAL SYSTEM

Purpose: This Directive establishes the ERDA Program Approval System and describes the policy and management process for obtaining approval to execute major research and development programs.

Definition: The ERDA Program is implemented (and documented) through a series of agreements between various organizational entities. The Program Approval Document (PAD) is the top level document in the series. A PAD documents program agreements between the Administrator/Deputy Administrator and a Program Assistant Administrator governing the execution of programs included in agency budgets and planning documents. These agreements set forth the essential elements of the plan for program execution, state the resources that will be committed to accomplishing the objectives, and list the schedule and milestones for evaluation of the results against what was planned.

The PAD serves as an instrument of the Administrator/Deputy Administrator to provide definition, control and approval of programs. It is the document through which the Administrator/Deputy Administrator:

- approves program execution, including annual operating plans for specific programs;

- establishes the controls which govern implementation by the operating elements and prescribes the control limits requiring review, and approval by the Administrator/Deputy Administrator, if exceeded;

- establishes the milestones or other means for management review considered essential to control the program and prescribes the framework for timely reporting against those milestones.

PAD Preparation: A PAD will be prepared by the cognizant Program Assistant Administrator for approval by the Administrator/Deputy Administrator for each element of the agency-wide coding structure identified in Attachment A. Additional elements of our structure may be added as the PAD system evolves and matures.

Published in advance of incorporation in
ERDA Manual Volume 8000
File and retain in Manual until superseded.

The PAD's will be prepared in accordance with Attachment B, which provides general instructions for preparation. The FY 1976 PAD's will be submitted in accordance with Attachment C.

In future years when the Program Approval System is fully operational, the PAD's will be updated annually, and beginning with FY 1977, will be submitted for approval three months prior to the beginning of the new fiscal year. The PAD will be prepared assuming congressional approval of the agency budget request. The lack of final congressional action on the budget request prior to PAD preparation and submission should present no major problem except possibly for new starts or program additions. The PAD will be revised, as required, to reflect the impact of any budget decisions on the program.

Compatibility: This Directive prescribes the policy and management process for obtaining Administrator/Deputy Administrator approval to execute programs defined and approved in the planning and budgeting process. The emphasis is on near-term operational planning, current resource requirements and near-term milestones in program execution. The documentation to be used by the Program Assistant Administrators and their suborganizational elements is not being specifically prescribed by this issuance. Many different management documentation techniques are currently being used in the management of the diverse ERDA program. As long as these documentation systems are compatible with the agency-wide Program Approval System and feed in a natural way into the PAD and PAD reporting system, and are consistent with agency management objectives, no changes in these systems are being proposed in connection with this IAD. At some point in the future, it may become desirable to specify a more nearly uniform agency-wide documentation system.

Responsibilities: The Program Assistant Administrators are responsible for the preparation and submission of their respective PAD's and review of other Activity PAD's, as required. Also they are responsible for reporting periodically to the Administrator/Deputy Administrator actual accomplishments against the milestones and understandings contained in their approved PAD's.

The Controller is responsible for developing and implementing the ERDA Program Approval System. Within the Office of the Controller, the Office of Program Approval and Control will coordinate this effort and is responsible for providing assistance in the preparation of PAD's, will supervise the coordination and approval process, and is responsible for overall administration of the system.

The Assistant Administrator for Administration is responsible for developing reporting procedures for the monthly status reviews and other information processes which will be against the milestones and understandings contained in the approved PAD's.

The Assistant Administrator for Planning and Analysis, in conjunction with the Controller, is responsible for establishing planning factors, and standards for such related data and information which is to be incorporated into a PAD. This includes review and concurrence of PAD's to assure consistency with agency-wide planning processes, goals and documentation as well as with indices used to measure a program's effectiveness.

The Assistant Administrator for Environment and Safety is responsible for reviewing all PAD's from the standpoint of environment and safety.

The Director, Office of Public Affairs, will advise Program Assistant Administrators on the formulation of public awareness/technology transfer programs.

Submission: PAD's and PAD revisions will be prepared by the cognizant Program Assistant Administrator. They will be circulated for comment to all other Program Assistant Administrators and the Assistant Administrator for Laboratory and Field Coordination, Assistant Administrator for Administration, Assistant Administrator for Planning and Analysis, General Counsel, the Controller, Office of Public Affairs and the Office of Industry and State and Local Relations in all cases, and to other Headquarters Offices by exception whenever their responsibilities are involved. Five working days should be allowed for comments. The Office of Program Approval and Control will assist in the coordination process by serving as a central distribution and collection point, setting schedules for review and coordinating the resolution of problems that may arise.

Upon resolution of comments the PAD will be submitted by the cognizant Program Assistant Administrator to the Administrator/Deputy Administrator for approval. The comments received during the coordination phase will accompany the formal submission.

For this initial year, submittals will be in accordance with the schedule contained in Attachment C. In future years, the Controller will issue a coordinated annual PAD Call which will contain the schedule for submittal.

Reporting: Status reporting is an integral part of the system. The primary status reporting mechanism is the monthly status reviews. Status reporting at these reviews will be against the milestones and understandings contained in the approved PAD's. Specific reporting requirements and format are being developed by the Assistant Administrator for Administration. The Controller will be responsible for keeping the Administrator/Deputy Administrator currently informed on the status of PAD preparation and approval schedules.

System Evolution: It is vitally important to ERDA to install quickly basic management system elements that will aid in achieving and sustaining excellence in program management. The Program Approval System is considered to be a basic and requisite element of any management system. It is for that reason we are installing now the Program Approval System even before all elements of a total management system are defined. However, we are mindful that it is absolutely necessary to integrate elements into a coherent system at an early date.

Executive Summary: An Executive Summary of each PAD will be prepared by the cognizant Program Assistant Administrator. This PAD summary will be submitted along with the PAD, and it is this document that will actually be signed and approved by the Administrator. The summary will be limited to approximately five pages or less and will embody the essence of the PAD. It will summarize the program scope and objectives, major milestones and schedules, funding, reprogramming authority and limitations, Administrator controlled items, management approach, and any special key considerations (e.g. environmental, public awareness, commercialization, or other policy aspects).

Robert C. Seamans, Jr.
Administrator

Attachments:
A. Required Program Approval Documents
B. Guidelines for Preparation of PAD
C. Planning Schedule FY 1976 PAD Approval

REQUIRED PROGRAM APPROVAL DOCUMENTS

Budget Activity		Number
Fossil Energy Development		
Coal		1
Petroleum and Natural Gas		1
Oil Shale		1
	Total	3
Solar, Geothermal and Advanced Energy Systems Development		
Solar Energy Development		1
Geothermal Energy Development		1
Physical Research		1
Fusion Power Research and Development		1
	Total	4
Conservation Research and Development		
Transportation Energy Conservation		1
Interprogram Applications		1
Electric Energy Systems		1
Buildings Conservation		1
Conservation in Industry		1
Conservation Research and Technology		1
	Total	6
Nuclear Energy Development		
Fission Power Reactor Development:		
Liquid Metal Fast Breed Reactor Technology Program, Reactor Safety and Advanced Fuels		1
Clinch River Breeder Reactor Project		1
GCFR and MSBR-Technology and Safety (Breeder Reactors)		1
Light Water Breeder Reactor Program		1
Thermal Reactors - Technology and Safety		1
Naval Reactor Development		1
Space Nuclear Systems		1
Nuclear Fuel Cycle & Production:		
Uranium Enrichment and Resource Assessment		1
Special Materials Production		1
Fuel Cycle R&D		1
	Total	10
National Security		
Weapons Activities		1
Laser Applications		1
Nuclear Materials Security		1
	Total	3
Environmental and Safety Research		
Biomedical and Environmental Research		1
Operational Safety		1
Environmental Control Technology		1
	Total	3

Attachment A

GUIDELINES FOR PREPARATION OF PROGRAM APPROVAL DOCUMENT (PAD)

General

This attachment contains a general description of the information to be included in a PAD. All PAD's will have some common elements; on the other hand, certain elements may be unique to a particular program. Where specific elements of the illustrated format are not applicable to a given program, the title of the element will be followed with a notation of "not applicable." Where additional information is required which does not logically fall within the format captions, additional captions may be used.

The PAD is not the place for justification of approach or historical background. The PAD should be addressed to program content and essential elements of the plan for execution and should emphasize the management and programmatic aspects of the program rather than technical information. Because this document serves as an agreement between the Administrator/Deputy Administrator and a Program Assistant Administrator, its content should be limited to that level of information requiring the agreement of the Administrator/Deputy Administrator before it may be changed. Statements should be clear and concise and verbiage should be kept to a minimum.

Material should be presented in a way that the Administrator and Deputy Administrator can readily see the impact of their decisions on the program. The use of network, flow diagrams, graphic displays and charts is encouraged. For Advance Research and Supporting Technology Programs, networking may not be feasible; therefore, words may be used to describe the program content. Be consistent in the use of program and program element titles and in the use of such terms as goals, objectives, strategies, and priorities. Acronyms should be explained and graphical symbols footnoted.

Decision points, key milestones and events should be laid out in the Program Activity Schedule. Detailed information will be available only for the initial increments of work and subsequent increments will have to be presented in a more general way. These later increments would be developed more fully in later annual updates of the PAD.

Redundancy should be avoided. For example, since program and subprogram objectives and program strategy are included in Volume 2 of the National Energy R,D&D Plan, there is no need to repeat them in the PAD.

The PAD should be an unclassified document whenever possible. However, if the use of classified material cannot be avoided, the document must be appropriately classified or the use of a classified supplement may be considered.

The Annual PAD Call will identify any special issues which are to be addressed in the preparation of the PAD.

The FY 1976 Budget will be used as the basis for the preparation of the FY 1976 PAD's. At such time as the budget is amended, the PAD's for the affected programs will be revised accordingly.

PAD STRUCTURE AND CONTENT

Title Caption

The following standard title caption will appear on the top center of the first page of all PAD's.

Program Approval Document

Energy Research and Development Administration

Activity Title (e.g., Fossil Energy Development or Conservation Research and Development)
Program Title (Write Title in Caps)
Date of Submission ________________

1. Program Elements: Specify by title and Budget and Reporting Classification all elements covered by this PAD, for example:

BA 00 Coal
BA 01 Liquefaction
BA 02 High-BTU Gasification
BA 03 Low-BTU Gasification
BA 04 Advanced Power Systems
BA 05 Direct Combustion
BA 06 Fossil Energy Research
BA 07 Demonstration Plants
BA 08 Magnetohydrodynamics

HD 0100 Buildings Conservation
HD 0101 Commercial Buildings
HD 0102 Residential Buildings
HD 0103 Performance Standards
HD 0104 Community Systems
HD 0105 Appliances
HD 0106 Technology
HD 0107 Dissemination and Transfer

2. Program Division: Title of applicable ERDA program division (e.g., Coal Conversion and Utilization or Reactor Research and Development Division). If a program cuts across more than one Division or Office, the title of the lead Division or Office is noted first, followed by a tabulation of all other Divisions or Offices involved.

3. Program Plan: This section will be structured as appropriate for the program involved and tailored to the particular characteristics and needs of the program. The major emphasis and focus at this time should be on fiscal year 1976. Future PAD's will be on the upcoming fiscal year. In all cases the work discussed in this section will directly relate to approved agency planning and budget documents, e.g., the National Energy R,D&D Plan.

The intent of this section is to communicate clearly and concisely the results expected from the program, the content of the program, and the overall plan for proceeding with the execution of the program. Toward this end, and as an aid in communication, program content, program output, decision points, major program actions, key events and milestones should be conveyed in network form whenever possible. Elaborateness should be commensurate with the magnitude and complexity of the program. Results expected from the program (e.g. quads of energy) can best be shown in near-term, mid-term, and long-term time frames.

State the major programmatic results to be achieved during the fiscal year. Obviously the key results to be achieved do not guarantee success; however, each planned accomplishment should represent the best technical and schedule judgment as to what is to be accomplished.

4. Management Plan: Identify the responsibilities of all major participants in the management of the program. Identify the Field Offices, Laboratories, and Energy Research Centers involved in the program and their areas of responsibility in support of the program. This can best be portrayed in the form of organization charts and flow diagrams depicting the flow of responsibilities through the organization together with the related resources required, financial and manpower, for major activities.

Define roles and responsibilities of government and industry in mutually funded programs.

Describe the involvement of and interface with other agencies involved. Include the scope of any work assigned to other agencies for execution.

5. Resource Requirements:

A. Funding: Total ERDA funding will be identified in the following table.

Summary of Resources Required

(Dollars in Thousands)

Funding Category	Current Fiscal Year				Transition Quarter				TOTAL AT COMPLETION	
	Obligs.		Costs		Obligs.		Costs			
	M.Y.'s	$	M.Y.'s	$	M.Y.'s	$	M.Y.'s	$	M.Y.'s	$
Operating Expenses (Detail by Sub-program)										
Plant and Capital Equipment (obligs.) Equipment Construction Proj.										

"Total at Completion" represents the total funding (including prior year funds) for discrete major programs with definable end-point (e.g., Liquid Metal Fast Breeder Reactor). Five-year run-out funding details will be shown in Attachment 2 of the PAD.

In addition to the summary resources table, curves depicting the funding buildup for major elements of the program (e.g., major contractor) will be displayed.

Where applicable, include tabulation of industry cost participation. Identify by fiscal year and/or total for all years.

Where appropriate, other agency funding should be displayed in tabular form. Funding in prior years, for the current year, total to completion and total at completion should be displayed.

B. Manpower: Where manpower build-up is a major management concern, curve or table showing program manpower buildup for each major element of the program to program completion or for the next five years beyond the current year will be included.

Note: Resources data should be included in such a way so that a relationship may be drawn between the employment of funds and manpower and program activity.

6. Additional Considerations and Special Issues: This section may include any special considerations appropriate for additional discussion and may be structured as appropriate for the program. These considerations could include such items as: special environmental considerations, public awareness considerations, cooperative agreements with industry, etc., and special licensing requirements and considerations.

Set forth the key assumptions with respect to commercialization. When appropriate, identify the manner in which the program will ultimately be commercialized and the steps that will be considered. Describe the type of demonstration program and method of achieving as broad an approach to industry as possible. Describe the incentives which should be considered including possibility of loan guarantee, grants, etc. List the constraints which exist toward commercialization and describe the manner in which they may be alleviated.

In the areas of basic research and advanced and supporting technology, this section may be used for identifying supplementary information (other than key milestones) which the Administrator/Deputy Administrator can most appropriately use for evaluating the status of the program.

PAD ATTACHMENTS

Attachment 1: Program Activity Schedule: The activity schedule is a comprehensive, tabular summary of major program milestones, both technical and administrative, for the current fiscal year. Milestones from the charts in the Program Planning should be included along with other important events. The activity schedule should be structured as a logical sequence of major program activities with clearly identified program milestones and should include such items as:

- Major procurement actions
- Initiation or completion of key activities

- Preparation and approval of technical and economic feasibility statements
- Preparation and approval of environmental impact statements
- Program and subprogram objectives
- Execution dates of agreements with other agencies, state governments, or other nations

Because of their significance, certain elements of the Program Activity Schedule will be controlled by the Administrator and cannot be changed without his approval. An asterisk should be used to identify those elements.

Attachment 1 will serve as the basis for the preparation of the ERDA Annual Operating Plan which is a compilation of the major programmatic results to be achieved by each of the ERDA programs during the upcoming fiscal year.

<u>Attachment 2</u>: <u>Funding</u>: The funds shown in this attachment are expressed in terms of Budget Authority (BA) and Budget Outlays (BO). The funds shown in this attachment must be consistent with the funds shown in the National Energy R,D&D Plan, Volume 2: Program Implementation. The tabulation will show dollars for prior years, for the current year, for each of the next five years beyond the current year, total to completion and total at completion (for those programs with definable end-point). Generally, the funding level displayed should be one level below the total funding level covered by the PAD.

<u>Attachment 3</u>: <u>Key Milestone History Chart</u>: The intent of this chart is to provide a simplified history of the programs and subprograms with program changes, accompanying explanations and costs. The current milestones on this chart must agree with the key milestone chart of Attachment 1 of the PAD. The former milestones will be identified from the previous PAD's, the approval dates of which are shown on the chart.

Project costs which have been reported in the PAD funding attachments will also be tracked in the milestone history chart. Those projects which have not identified individual project costs in the funding attachment will not be required to report costs in this chart. (Costs will be "total at completion.")

Milestones are shown as △. Changes in milestones will be shown with the original milestone plus the new symbol moved to a new date and a reference number alongside the symbol. The reference numbers for each program or subprogram will start at "1" and will correspond to the "explanation of change" number.

November 19, 1975

ATTACHMENT 1

PROGRAM ACTIVITY SCHEDULE

SUB-PROGRAM/ CATEGORY	ACTIVITY	DATE
	* -- -- -- -- --	-- -- -- -- -- -- --
	* -- -- --	-- -- -- -- --

* Administrator Controlled Item

ATTACHMENT 2

FUNDING

(Dollars, Thousands)

OPERATING EXPENSES (Budget Authority, Budget Outlays)

SUB-PROGRAM/CATEGORY	Fiscal Years PY	76	TQ	77	78	79	80	81	TO COMPLETION	TOTAL AT COMPLETION
PROGRAM TOTAL										

PLANT & CAPITAL EQUIPMENT* (Budget Authority, Budget Outlays)

ITEM	Fiscal Years PY	76	TQ	77	78	79	80	81	TO COMPLETION	TOTAL AT COMPLETION
CONSTRUCTION PROJECT										
CONSTRUCTION PROJECT										
CONSTRUCTION PROJECT										
EQUIPMENT CATEGORY										
TOTAL										

* Plant and capital equipment identified here will include all items in the Five-Year Plan for the program.

NOTE: Funding beyond budget year for planning purposes only.

ATTACHMENT 3

KEY MILESTONES HISTORY CHART

PROGRAM/SUB-PROGRAM/CATEGORY	CALENDAR YEARS 1974	1975	1976	1977	1978	1979	1980	EXPLANATION OF CHANGE
Coal - Liquefaction								(1) Design delay due to inadequate bench-scale data.
Project X								
PAD (Approval Dates)		7/14	6/15					
Total Cost (Millions)		NA	NA					
Site Selection		▽						
Start Construction			▽ -	▽ (1)				
Operational					▽-▽ (1)			
Project Y								
PAD (Approval Dates)		-	-					---
Total Cost Millions		-	-					
-			-					
-								
-						-	-	
Project Z								
-								
-								
-								

PLANNING SCHEDULE
FY 1976 PROGRAM APPROVAL DOCUMENT APPROVAL

BUDGET ACTIVITY	SCHEDULE BY WEEK																
	DEC				JAN				FEB				MAR				
	8	15	22	29	5	12	19	26	2	9	16	23	1	8	15	22	29
FOSSIL ENERGY DEVELOPMENT	X					X						X					
SOLAR, GEOTHERMAL, AND ADVANCED ENERGY SYSTEM DEVELOPMENT								X			X		X			X	
CONSERVATION RESEARCH AND DEVELOPMENT		X X			X			X				X			X		
NUCLEAR ENERGY DEVELOPMENT					X		X X				X X			X X X			X X
NATIONAL SECURITY			X						X				X				
ENVIRONMENTAL AND SAFETY RESEARCH				X		X				X							

Mike

Larry Ball – Exploration Technology –
Al Jelacic – Development Technology – res. eng., ind. seismicity
Cliff MacFarland – Production Technology –

by Al Jelacic

DRAFT

PROGRAM APPROVAL DOCUMENT

FOR

GEOSCIENCES TECHNOLOGY DEVELOPMENT

OVERVIEW SUMMARY

Development Technology

Introduction

The greatest technical issue hindering the commercial use of geothermal energy is the assured production of heated fluids. As long as uncertainty exists about the long term productivity of geothermal reservoirs, geothermal energy will never become a viable energy source. A competitive geothermal industry will not develop: bankers will be reluctant to lend capital for geothermal projects; developers will be unable to explore systematically for geothermal resources nor develop them quickly to their maximum potential; and users will be cautious about making long term commitments to geothermal energy. The perceived high risk associated with extracting geothermal energy must be reduced.

Although some geothermal fields such as Larderello, Wairakei, and the Geysers are pointed to as examples of mature, reliable sources of geothermal energy, they are largely regarded as fortuitous exceptions. Geothermal fields are not considered reliable until they have produced large quantities of fluids over many years.

The problem of reliability is manifest, perhaps unknowingly, in geothermal nomenclature. Geothermal energy supplies are invariably referred to as "resources" rather than "reserves." "Reserves" is a mineral industry term meaning the amount of economically extractable commodity. Even the most ardent proponents of geothermal energy stop short of estimating geothermal reserves. And yet the petroleum industry calculates oil and gas reserves all the time.

Goal

Recognizing the importance of removing the uncertainty surrounding reservoir productivity, the Division of Geothermal Energy is creating a Geosciences Technology Program. This program seeks to promote the development of reliable, economic, and environmentally acceptable geothermal reservoirs. In other words, the program's goal is to provide the means to transform geothermal resources into reserves.

The economic impact of the program can be illustrated by a sensitivity analysis of the major cost factors affecting geothermal power. The results of such an analysis by Bloomster are ahown in Table 1. Only those factors reducing the cost of power by 10% or greater are included. Of the 8 cost factors listed, 4 will be affected directly or indirectly by the Geosciences Technology Program. The program will not only create geothermal reserves but in so doing cause a substantial reduction in the cost of power.

If the program's goal is attained, every geothermal reservoir for which sufficeint data exist will be defined in terms of its recoverable reserves by 1985. And the cost of power rate should measurably decrease. Then, and only then, will geothermal energy assume its proper place as a commercial energy alternative.

Approach

The success of the program revolves around the three attributes of a useful geothermal reservoir: it must be reliable, economic, and

Table 1. Sensitivity Analysis of Geothermal Power Cost Factors
(Modified from Bloomster, 1975)

Cost Factor	Change in Factor	% Change	% reduction in Cost of Power
Cost of Capital	-	-50	31
Well Cost	$500K to $300K	-40	20
Wellhead Temperature*	200°C to 250°C	+25	19
Well Flow Rate*	500,000lb/hr to 750,000lb/hr	+50	17
Injection Costs*	Injection to No Injection	-100	16
Plant Capital	$15M to $7.5M	-50	14
Internal Power Consumption	10.5 MWe to 5.25 MWe	-50	10
Well Life *	10 years to 20 years	+100	10

*Factors influenced by Geosciences Technology Program environmentally acceptable. Of these, reliability is most important; other considerations are immaterial if the reservoir is not a proven source of extractable energy. Reliability is the outcome of predictability which, in turn, implies a model. Hence the key to reaching the program's goal is a model that can predit reservoir performance and productivity (i.e., reliability) over a long period. The economics of energy extraction and environmental factors are very important considerations as well, but their importance is site dependent. The need to prove reliability is universal.

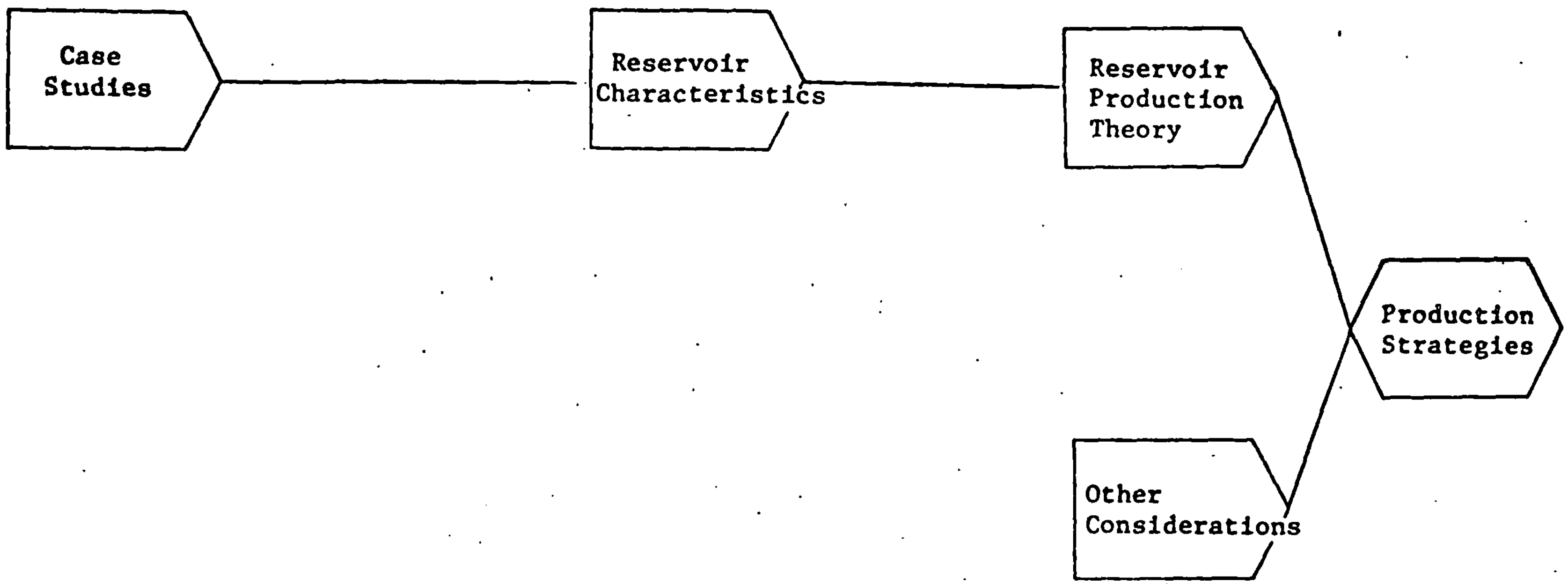
Therefore, the focus of the Geosciences Technology Program plan is the consutrction, testing, and verification of a geothermal reservoir model or models. The major program elements are designed to support model development. They supply the scientific and technical information needed to build and maintain the models.

The modeling elements of the program are: (1) Case Studies, the compilation of knowledge gained from past experience; (2) Reservoir Characteristics, the detailed specification of those factors that determine or describe reservoir performance; and (3) Reservoir Production Theory, the physical and chemical description of reservoir behavior.

The plan also includes economic and environmental considerations as a separate program element. When combined with the product of the modeling elements these considerations lead to a set of production strategies, strategies that define the limits of a reservoir's productivity, its reserves. Production strategies comprise the goal element of the program.

The program elements and their relationships are shown in Figure 1. The element, Other Considerations, includes the economic and environmental issues; Note that the product of the modeling effort is an essential input to resolving these issues. This interface between the elements is

Figure 1. Major Functional Elements of the Geosciences Technology Program



the unifying tie that binds the program.

Organization

To facilitate program management and for budgetary and administrative purposes, a hierarchical program organization has been adopted. The organization has five levels:

Program

Element

Component

Subprogram

Project

This is in contrast to the more typical tri-level organization: program-subprogram-project. The two intermediate levels, element and component, have been added to give logical coherence to the program plan. More importantly they serve to focus and define the program into manageable units of increasing complexity.

The five elements of the Geosciences Technology program were previously identified (Figure 1). They describe the program's goal orientation for planning purposes, but they have a passive role with regard to program implementation. Elements are too unwieldy to be useful in a practical managerial sense. The components are the real structural framework on which the program will be carried out.

Components

Each program element may consist of one or more components. There are a total of 10 components in the Geosciences Technology Program, and they are listed in Table 2 under their respective elements. The objectives and current status of the components are summarized below.

Table 2. Working Components of the Geosciences Technology Program

Element	Component
I. Case Studies	A. Case Studies
II. Reservoir Characteristics	A. Borehole Geophysics
	B. Well Testing
	C. Surface Geophysics
III. Reservoir Production Theory	A. Material Properties
	B. Physical Processes
	C. Geochemistry
IV. Other Considerations	A. Economics
	B. Environment
V. Production Strategies	A. Production Strategies

Case Studies involves the collection and documentation of field experience from producing geothermal reservoirs. The studies should give valuable insights about geothermal development as well as feed real data about reservoirs into other program components. (Status: At present the Case Studies component has several subprograms, each devoted to the examination of a particular geothermal field. Work has begun to build a data base for the following fields: Wairakei, New Zealand; Cerro Prieto, Mexico; East Mesa, CA; Raft River, ID; of these the effort at Cerro Prieto is the most comprehensive and should have the greatest impact on the remainder of the program.)

Coso
Roosevelt
Long Valley

Borehole Geophysics involves the taking and analysis of well logs. Geothermal well logging is one of the best tools available for understanding the geology and hydrology of reservoirs. The component's objectives are: (1) to find the best means of evaluating geophysical variables; (2) develop logging instrumentation capable of withstanding the geothermal environment; (3) improve interpretive techniques for analyzing well logs; (4) build a geothermal well log data base. (Status: These objectives are currently being met by two subprograms, Geothermal Logging Instrumentation and Geothermal Log Interpretation. The instrumentation program is funded and managed apart from the geosciences program. This inconsistency should be corrected.)

Well Testing deals with evaluating production and injection wells under flow conditions; it is the basic technique for determining well flow capacity. As such well testing is a critical factor in assessing reservoir productivity. The component's objectives are: (1) develop improved instrumentation for testing; (2) define a testing methodology;

(3) improve interpretive techniques. (Status: Except for some overlap from the Geothermal Logging Instrumentation subprogram, there are no subprograms functioning under the well testing component. Some project-level activities are underway, but they have to be integrated as part of one or more subprograms.)

Surface Geophysics is concerned with using geophysical techniques to help define the boundaries and characteristics of a geothermal reservoir. These techniques can also be applied to improve well drilling success ratio and monitor overall reservoir behavior during production. The objectives of the component are: (1) develop better geophysical instrumentation and measurement techniques; (2) improve existing data interpretation methods with greater emphasis on geothermal applications. (Status: The component has not yet been totally defined; a question remains as to the degree to which geothermal exploration activities should be included. Consequently, subprogram development has not advanced beyond the conceptual stage).

Material Properties deals with measuring the physical properties of reservoir rocks. Such measurements are obtained from core samples and are performed under simulated reservoir conditions. Some specific measurements include: porosity, permeability, compressibility, sonic velocity, electrical conductivity, thermal conductivity, thermal expansion, and heat capacity. The component is directed at perfecting instrumentation for making physical measurements on rocks and building a rock properties data base. (Status: At present there are no formal subprograms under Material Properties.

However, an instrumentation development effort underway for some time at Terra Tek is nearing completion. The results of this work, especially the rock mechanics test apparatus, should form the basis of a rock measurements subprogram.)

Physical processes lies at the center of the entire program. This component addresses the theoretical development, testing, and verification of a comprehensive reservoir model or models. And, as stated previously, modeling is the key factor in reaching the program's goals. The component's objectives are to (1) understand the processes taking place in geothermal systems and (2) simulate those processes such that reservoir behavior can be reliably predicted. (Status: Subprogram planning has not yet been done. Several projects, including work at LBL, S^3, Princeton, and elsewhere have involved reservoir modeling; they should be critically examined in light of the program's goal. An implementation plan for handling Physical Processes is badly needed because this component will dictate the success or failure of the program.)

The Geochemistry component is concerned with understanding the chemical reactions that take place in geothermal reservoirs. Specific study areas include reservoir petrology, fluid geochemistry, isotope fractionations, and behavior of dissolved gases. The component seeks to determine the chemical interactions taking place as geothermal fluids flow through reservoir rocks. (Status: Work in brine chemistry has been done in other programmatic areas of DGE. Much of this work is ongoing and should have direct application to the Geochemistry component. A component plan has not been developed. When planning is done, considerable attention should be paid to coordinating like activities among programs.)

The Economics component involves the proving of geothermal reserves based on the economic value of a reservoir under a given production strategy. The component's objective is to develop an assessment methodology which evaluates economic risk from geothermal energy production. The methodology would combine the economic aspects of reservoir performance prediction and energy conversion technology in its approach to minimizing risk. (Status: Considerable work on the economics of geothermal development has been done in other program areas of DGE. Some of this work would apply to the objective of this component. The extent to which Economics is developed as an independent program component would depend on the applicability of the work already done and scheduled to be done.)

Environmental factors of a geologic nature that could impede geothermal energy development are included under the Environment component. This component has the objective of minimizing or mitigating damage to the environment due to geologic hazards that might arise from geothermal reservoir production. Note the limitation to geologic hazards. Other hazards, such as hydrogen sulfide emission, are covered in other program areas. (Status: A subprogram dealing with the subsidence issue is in place and functioning. Another subprogram on induced seismicity is entering the planning stage. A question remains whether institutional environmental constrains in the geosciences should be included as part of the component.)

The goal component, Production Strategies, is designed to synthesize information generated by the other components and arrive at optimum procedures for extracting geothermal energy. These production strategies are an estimation of reserves as well as a guide for geothermal reservoir development. (Status: No work as yet has been done to plan this component.)

Integration

The structural components of the geosciences program have been identified. They have been characterized as the framework on which the program will be carried out. In order to function properly, that framework must be tied together or integrated: the relationships between components should be well defined. This is the key to sound program planning.

The integrated structure of the Geosciences Technology Program is illustrated in Figure 2. Case Studies is the initial component, the bank of knowledge about how known geothermal reservoirs operate. Such knowledge is useful, if not essential, to the other program components; experience is the foundation on which new work can be based. Furthermore, active case studies can be used as test sites for products from other components (e.g., field testing of a new well logging instrument). Such studies can be so closely related to subprogram tasks in other components that the distinction between components vanishes.

Although Case Studies can provide information of varying types to all components, the bulk of the information is applicable to Borehole Geophysics, Surface Geophysics, and Well Testing. Well Testing in particular is especially dependent on case study input, since, by definition case studies are largely composed of well test data.

Physical Processes is the focal point of the program. This component receives input from those components that directly affect reservoir production: Borehole Geophysics, Well Testing, Surface Geophysics, Material Properties, Geochemistry, (and Case Studies). This information becomes the working materials for building, testing, and verifying the general-purpose reservoir model(s). The model(s) in turn feeds back results that influence activities under each [illegible] model(s). This iterative process is the means for perfecting the model(s).

Important as the feedback mechanism is, the thrust of the program is forward to the goal. The output of Physical Process, the model(s), is the essential factor in devising production strategies that satisfy the program goal. The two other factors affecting those strategies, economics and environment, also depend on Physical Processes for input in meeting their objectives. When properly combined these three factors determine reserves and dictate production strategies for individual geothermal reservoirs.

Figure 2. Geosciences Technology Program Strucutre

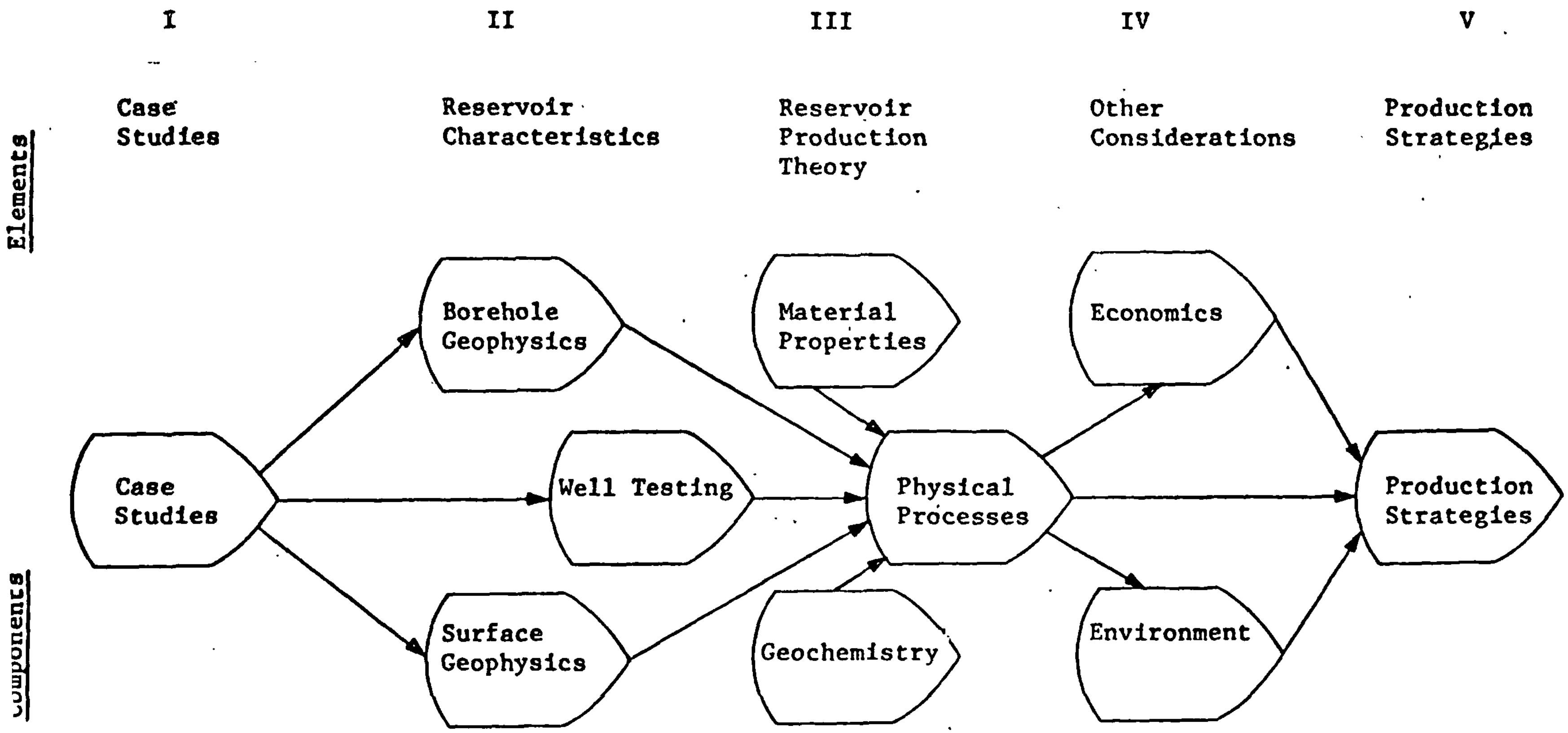


Figure 3. Program Management Structure