

THE NSF/RANN FY 1975 PROGRAM
FOR
GEOTHERMAL RESOURCES RESEARCH AND TECHNOLOGY

Paul Kruger
National Science Foundation
Washington, D.C.

The NSF program for geothermal resource research and technology is a component of the Research Applications Directorate mission to serve as a bridge linkage between the Foundation's support for research applied to national needs (the RANN program) and the utilization of research results in the national economy. The specific goal of the NSF geothermal program is the rapid development by industry of the nation's geothermal resources that can be demonstrated to be commercially, environmentally and socially acceptable as alternate energy sources. NSF, as the lead agency for the federal geothermal energy research program, is expediting a program which encompasses the objectives necessary for significant utilization. These include: acceleration of exploration and assessment methods to identify commercial geothermal resources; development of innovative and improved technology to achieve economic feasibility; evaluation of policy options to resolve environmental, legal, and institutional problems; and support of experimental research facilities for each type of geothermal resource. Specific projects in each of these four objective areas are part of the NSF program for fiscal year 1975.

I. INTRODUCTION

Geothermal energy is vitally needed as an alternate source of energy in the United States. The National Science Foundation is embarked on an aggressive research and advanced technology program as part of a national effort to assist industry in the development of geothermal resources. The goal of the NSF/RANN program for geothermal energy research and technology is the development, at the earliest feasible time, of those applications of geothermal resources that can become economically competitive and environmentally acceptable as alternate energy sources in the national economy.

Although the magnitude of potential power production from geothermal energy is disputed by many competent earth scientists, the resource base is uniformly agreed to be quite vast. In the United States the total generating capacity of electric power from geothermal energy is only some 400 MW, considerably less than that from one modern nuclear power plant. In fact the 1000 MW generating capacity of electric power from geothermal resources over the entire world is just about equal to that of one such plant.

If the potential resource base of geothermal energy is so vast, why has not a greater utilization occurred? If we are to develop our national resources of geothermal energy to succeed in making a significant contribution to the Nation's energy supply, we must find a solution to this enigma.

The solution is complex. It involves factors which span the entire spectrum of the geothermal energy cycle from exploration to utilization. The answer may lie not so much with the magnitude of the potential resource, but more with our ability to extract, convert, and utilize commercial quantities of geothermal energy in an economic and environmentally acceptable manner.

The spectrum of the geothermal energy cycle is complex. Geothermal resources come in many forms, sizes, and shapes. Problems occur, also in many forms, sizes, and shapes. They include:

- (1) The need for reliable surface exploration methods to locate subsurface concentrations of geothermal heat, especially where natural surface manifestations are lacking.
- (2) The high cost of drilling deep exploratory holes in areas suggested by surface reconnaissance, especially in hard-rock, high-temperature geologic formations.
- (3) The need for adequate evaluation of potential reservoirs to ensure sufficient deliverability and reserves to warrant the capital investment in a power plant.
- (4) The need for optimum utilization for both electric power and nonelectric power applications, consistent with the wide variation in geothermal resource characteristics.
- (5) The concern for proper environmental, economic, legal, and institutional controls in the development and utilization of geothermal resources.

A program to address these problems clearly requires a comprehensive and coordinated national effort by both industry and government, and it is the basic objective of the NSF/RANN program in Advanced Geothermal Energy Research and Technology. To ensure that the many aspects of the geothermal energy cycle are adequately investigated, the RANN program has been organized in four major program categories:

- (1) Resource Exploration and Assessment
- (2) Advanced Research and Technology
- (3) Resource-Type Research Facilities
- (4) Environmental, Legal, and Institutional Aspects

The objectives of these categories are, respectively:

- (1) To provide technology for the exploration and assessment of potentially-commercial geothermal resources.

- (2) To develop methods for efficient extraction and conversion to bring each type of geothermal resource into commercial fruition.
- (3) To support the experimental research facilities needed to test the technologies and evaluate problems specific to each type of geothermal resource.
- (4) To evaluate policy options to resolve key environmental, legal, and institutional problems to minimize delay in the technology utilization.

II. RESOURCE EXPLORATION AND ASSESSMENT

Prospecting for natural resources below the earth's surface is at best a difficult undertaking. Although much progress has been achieved in locating oil, gas, and mineral deposits, exploration for geothermal energy involves two additional factors:

- (1) The resource itself is not a material fuel; it is concentrated deposits of heat located below the surface in the earth's crust and with or without the presence of geofluids;
- (2) As thermal energy, it cannot be transported very far and must be converted or utilized directly at the site of each reservoir. Thus the location of suitable reservoirs must match the location of suitable energy markets and transmission networks.

There are many exploratory techniques available for locating geothermal resources. They include surveys based on airborne magnetic and infrared mapping and geophysical, geochemical, geologic, and hydrologic methods. The great variability of geothermal energy deposits with respect to depth, shape, size, pressure, temperature, geofluid quality, and other parameters challenges greatly the prospector's ability to evaluate his many data taken at the surface. Great opportunity exists for innovative theoretical and field experimental methods to probe deeper and with greater precision.

Private industry, with the need to invest its exploration money prudently, seeks the high-grade vapor-dominated and high-temperature hydrothermal reservoirs in the hope of locating commercial fields exploitable with current technology. However, high-grade resources may represent only a small fraction of the total geothermal resources that could be exploited in the future with new technologies.

It is these "higher-risk" resources that need the support of the Federal government to locate them, assess their commercial potential, and develop the necessary technology for efficient energy extraction and conversion. Among these "higher-risk" resources are included the geopressed basins of the Gulf States, the deep hot dry rock formations in the western, and perhaps eastern, states, and the magmatic heat prevalent in Hawaii.

Geoscience methods to explore and assess these types of resources needs continuous improvement. A major part of the NSF program in geothermal energy research and technology is devoted to the specific objectives of:

- (1) Support of research in airborne, surface, and subsurface methods for geothermal resource exploration.
- (2) Support of research to improve geophysical, geochemical, geologic, hydrologic and other techniques for evaluating specific geothermal resources.
- (3) Support of research to develop better methods for predicting the productivity and longevity of potentially commercial geothermal resources.
- (4) Research support to the U. S. Geological Survey program for national and regional surveys of potential geothermal resources.

The NSF program expects to have well underway in FY 1975 several projects for the assessment of several types of geothermal resources. Some of these projects include:

- (1) Continuation of the geophysical assessment of the deep exploratory hole drilled to 7000 ft in a possibly hot intrusive near Marysville, Montana.
- (2) Continuation of the geophysical assessment of hydrothermal systems associated with magmatic heat sources in the Hawaiian Islands at sites selected for an exploratory drilling program.
- (3) Resource assessments of the geopressured basins in the vicinity of the Texas and Louisiana Gulf coasts.
- (4) Initiation of projects to explore the potential of various temperature - various salinity hydrothermal resources located in many of the western states. Possible states include: Alaska, Arizona, California, Colorado, Idaho, Montana, New Mexico, Nevada, Oregon, Utah, and Washington. For these resources the NSF program will not only support the technology research which might make them feasible for commercial electric power generation, but also programs for utilization of the thermal waters.

III. ADVANCED RESEARCH AND TECHNOLOGY

The NSF program in advanced research and technology encompasses the geothermal energy cycle from exploration to utilization. The need to have proved reserves has already been stressed and technology advances to aid in the assessment are needed. Technology advances are also needed even with proved reserves to make utilization of geothermal energy commercially feasible and environmentally acceptable.

Because of the variety of resource types, several methods of extraction and conversion technology may be needed. For example, in hot brine resources the feasibility of electric power production may hinge on the development of suitable down-hole pumps to prevent the brine from flashing in a binary fluid, heat exchanger system. Whereas, in hot, dry rock resources, the feasibility of electric power production may hinge on obtaining sufficient heat transfer surface in a fractured-rock formation and a suitable artificial circulation system to extract the heat economically.

Some of the specific objectives of the NSF program to support the development of the appropriate technologies for the several types of geothermal reservoirs are:

- (1) Efficient drilling and well-completion methods in high temperature geologic formations.

Drilling is presently accomplished by the type of rotary drilling employed for oil wells, using either mud or air as the drilling fluid. Drilling represents a major investment in the development of a geothermal field. Obviously, any technical improvements for drilling in geothermal environments, such as deep hot water or dry hard rock formations could result in great economic savings. Alternate drilling methods, such as turbine drilling, melting drilling, and erosion drilling, need to be investigated; none are yet commercially available.

- (2) Efficient reservoir engineering and management techniques.

An evaluation of a reservoir for deliverability, reserves, and longevity is required for optimum field development and production. Research is needed for methods to evaluate formation characteristics, with borehole measurements, production testing, and theoretical models. In some cases, economic justification for power plant construction may require by-product utilization, perhaps in the form of desalinated water, commercial minerals, and process heat.

- (3) Increased extraction efficiency.

Many geothermal resources will be found to be submarginal for economic exploitation. Perhaps there will be insufficient geofluid production to amortize a power plant of the size needed. An artificial circulation system may be required.

Perhaps there will be insufficient surface area for sufficiently rapid heat transfer from the formation to the produced fluids. Fracturing of the aquifer formation may be required.

Perhaps the deposition of silica, calcite, or other minerals may decrease formation porosity or permeability. Other stimulation techniques may be required.

Several stimulation techniques have been proposed. They include hydraulic fracturing, thermal stressing, and explosive fracturing with chemical or nuclear explosives. Each of these methods, as well as the development of artificial circulation systems, is yet undeveloped and requires considerable

research effort before any one of them will be ready for commercial utilization.

NSF is supporting studies for increased extraction efficiency. The first laboratory demonstration of heat extraction from fracture-stimulated hard rock was completed at the Stanford University geothermal laboratory. First results from the geothermal chimney model indicated a significant increase in nonisothermal heat extraction from a simulated fractured rock hydrothermal system compared to isothermal flashing of hydrothermal fluids, which is practiced at existing hot water geothermal fields. Other such studies will be supported under the NSF program during FY 1975; for example, concepts to stimulate production in dry holes drilled in zones of known geothermal steam and hot water reservoirs.

(4) Increased conversion efficiency.

It is generally accepted that hydrothermal systems with hot water at temperatures below 200°C will be more abundant relative to steam fields. Thus improved technology to utilize such low-quality thermal fluids for electric power production is urgently needed.

Many investigations are underway to seek such technologies. Several types of geothermal power plants are being considered, such as low-pressure steam turbines; binary cycle systems; and hybrid systems.

Each type requires multiple-well and gathering-line complexes to bring sufficient production to the power plant. Although research and development of such near-commercial systems are more properly within the domain of private industry, research for the development of innovative components to make them more effective, efficient, or even possible, at an early time, are well within the scope of the NSF program.

Innovative conversion systems, in which the power plant is brought to the individual well, deserves consideration. Demonstration of electricity production by a helical rotary screw expander was achieved at the East Mesa geothermal field. Continuation of this research concept is part of the NSF FY 1975 program. Perhaps there are other mobile conversion systems that can be used on an individual well basis.

(5) Increased utilization efficiency.

Planning and development of geothermal fields must consider the physical characteristics of the produced fluid, the gathering and steam-water separation facilities, the turbine and generator equipment, the cooling cycle, the well productivity and spacing, environmental impacts, and condensate disposal methods.

All this presupposes that electric power generation is the sole purpose of developing geothermal resources. It may turn out, however, that a very significant savings of fossil and nuclear fuels may be achieved by direct utilization of geothermal resources for its heat, water, and mineral content.

Hydrothermal fluids with insufficient temperature or enthalpy for commercial power production might be used as water and mineral sources and for space and process heating. However, since major interest in geothermal energy lies in the production of electric power, the combined or total utilization may help make geothermal fields that are submarginal in power production economically feasible. Research in methods for stimulation of geothermal resource utilization in all forms is thus an important part of the NSF geothermal program.

(6) Environmental control technology

This area of advanced research and technology has become a significant aspect of advanced technology in the last decade. It is covered in the section on environmental, legal and institutional aspects.

IV. RESOURCE-TYPE RESEARCH FACILITIES

There comes a time for each type of geothermal resource when research has been taken to an important milestone, when the resource assessment has led to a promising site, when the technology concepts have been taken beyond the drawing board and laboratory, and when a system for extraction and conversion (or its components) must be tested under actual field operating conditions.

Suitable electric power generating systems at a size consistent with the estimated reservoir capacity and utility needs must be demonstrated under geothermal operations which are economically feasible, environmentally acceptable and conform to federal, state, and local regulations.

Geothermal resources are needed to provide fluid production on a continuous basis for such demonstrations. They are needed to test components, to evaluate nonelectric utilizations, to monitor potential environmental impacts, and to test environmental control systems.

Some geothermal resources are also needed to test the very important aspect of resource feasibility itself. Some types of resources, such as high temperature-low salinity, are very close to commercial exploitation. Other types, such as hot, dry rock, require much research and technology before they can be considered close to commercial exploitation.

All of these reasons lead to a need for geothermal research facilities by resource type. The NSF program envisions a series of resource-type research facilities which span both the spectrum of state of development of geothermal type and state-of-the-art of its exploitation. Two such studies, seeking suitable sites for research facilities, are currently being supported by the NSF program.

The scope of work appropriate to each type of geothermal resource will vary widely. The most advanced type is the dry steam field, exemplified by the Geysers in California. The production of electric power at this field is well established; and yet sufficient need for improvement and sufficient problems still exist to consider a research facility at this resource type.

The hot brine deposits of the Salton Sea for many years have been considered to have great commercial potential. Yet the breakthrough needed to handle this fluid for power production has not yet been achieved. A research facility for this geothermal resource is urgently needed both for demonstration of power production and as a production source for technology testing. It has been noted on several occasions that any technology that works with hot brines will work readily with any other type of geofluid.

There are many potential sites for a research facility at moderate temperature and low to moderate salinity reservoirs. Several states have already been named that have such resources. The NSF program envisions the funding of one or more such research facilities under a research team of university, industry, utility, and state and local regulatory agencies for developing a comprehensive research program appropriate for the specific geothermal resource.

Similar programs are sought for geopressured basin resources, magmatic resources, and dry, hot rock resources. A major effort of the FY 1975 NSF program is planned for these resource-type research facilities.

Some of the benefits which are likely to result from this phase of the program include:

- (1) Economic data for geothermal production systems and components which meet technical and environmental standards.
- (2) Industrial operating experience in reservoir engineering and management.
- (3) Early operational experience with demonstration power plants which may hopefully serve as Unit No. 1 of commercial field development.
- (4) Operational characteristics and potential of each type of geothermal resource.
- (5) Trained engineers, technicians, analysts, and managers from industry with early field and power plant development experience.
- (6) The basis for satisfying environmental and institutional requirements for geothermal resource utilization.

V. ENVIRONMENTAL, LEGAL, AND INSTITUTIONAL ASPECTS

A major component of the NSF geothermal research program is focused on the environmental, legal, and institutional aspects of geothermal resource utilization.

The problems are complex and involve public acceptance, vested interests, historical precedents, existing regulations not directly resulting from geothermal operations, overlapping jurisdictions, and economic factors.

These problems are often more difficult to resolve than are engineering obstacles and they may in the long run be the major constraints to an orderly, rapid, development of geothermal resources.

The solution to such problems may require broad public interaction, changes in laws and regulations, and perhaps changes in traditional investment and marketing procedures.

Many lists of real, potential, and imaginary environmental impacts have been published over the past few years. Potential environmental impacts have been identified as gaseous emissions, liquid waste disposal, and geophysical effects, among others. What is needed now are not more lists, but objective evaluations of the actual severity and magnitude of the important potential environmental impacts and baseline data and advanced technology for monitoring the potential impacts and controlling the actual hazards.

In addition to the extensive capability of the environmental resources staff in the RANN program, the NSF geothermal program seeks competent investigators to undertake research projects to evaluate these impacts and to develop methods for monitoring and control where needed. To initiate this phase of the program NSF will support a Workshop on Environmental Aspects of Geothermal Resources Development. The results of this workshop will be widely distributed to ensure its maximum utilization by industry and regulatory agencies.

Evaluation of the legal aspects of geothermal energy is another major objective of the NSF FY 1975 program. Many basic questions remain unresolved; such as the definition of a geothermal resource, its classification as water, mineral, or energy, application of various tax incentive policies, effects of alternate bidding and leasing arrangements, investment assistance to promote early exploration, and simplification of regulatory and licensing procedures at three levels of government - federal, state, and local. The NSF program will also support a workshop to investigate the critical legal constraints inhibiting the commercial utilization of geothermal resources. The results of this workshop will also be distributed rapidly and broadly to provide a general basis for the resolution of these problems as recommendations for administrative and legislative actions.

Institutional problems involve social and economic questions. They involve land use planning, especially complex when geothermal resources span Federal, State and private lands. They involve capital investment, especially when private investment institutions may be reluctant to undertake high-risk, long-delay time geothermal projects. They involve interindustry arrangements, especially when multipurpose utilization is needed to support economic development. And they involve multigovernment arrangements, especially in the realms of regulation, licensing, and utilization.

Research is needed in each of these problem areas. The NSF program is supporting intergovernmental programs to evaluate and incorporate the impact of geothermal development in local and regional planning. The objective of these programs is to provide state and local regulatory agencies with sufficient expertise in geothermal technology to avoid major regulatory conflict

and to smooth the way for acceptable development and utilization of geothermal resources on a local and state-wide basis.

VI. THE NSF FY 1975 BUDGET

To accomplish this many faceted advanced research and technology program in geothermal energy, the NSF has budgeted for FY 1975 a total of \$22,300,000, divided among the four program objectives as follows:

Resource Exploration and Assessment	\$ 3,000,000
Advanced Research and Technology	7,500,000
Resource-type Research Facilities	9,500,000
Environmental, Legal, Institutional Aspects	<u>2,300,000</u>
Total	\$22,300,000

The FY 1975 budget represents a marked challenge to accelerate the NSF program supported by the FY 1974 budget of \$3,700,000. The National Science Foundation actively seeks research proposals in each and all of these program objectives. The Program Managers of the Advanced Geothermal Energy Research and Technology section are ready to assist qualified researchers in obtaining NSF support.