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DOE GEOTHERMAL R&D PROGRAM FOCUSED ON FACILITATING LONG-TERM, COST-EFFECTIVE PRIVATE RESOURCE DEVELOPMENT

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ABSTRACT

Analyses conducted in support of the National Energy Strategy projected that as much as 22,000 megawatts of cost-effective, moderate-temperature geothermal energy are available to the U.S. over the long-term, or to the year 2030. Thus, the primary hydrothermal technology research goal of the Department's Geothermal Division is to facilitate the ability of the private sector to exploit competitively this large source of energy up to that capacity level or greater. The primary mechanism for implementing this goal is an R&D core program cost-shared with industry focused on major cost-sensitive technology areas: exploration technology, reservoir engineering and management, and drilling.

The NES analyses also indicated that electricity generated with energy derived from hot dry rock could be a geographically dispersed, logical follow-on to hydrothermal electricity in the longer term. In order to demonstrate whether energy at useful temperatures can be extracted over extended periods at competitive energy prices, a long-term flow test of an experimental HDR system will be conducted.

This paper describes DOE's current participation in R&D activities leading to the development of "cutting edge" technology that will serve the geothermal industry's interest well into the next century.

INTRODUCTION

National market-analysis models developed in support of the National Energy Strategy show that when reasonable assumptions are made about the characteristics of U.S. geothermal resources and technology, continued markets for, and economic benefits from, can be projected for geothermal energy. In a scenario which assumes continuation of today's national energy policy, the NES projects that 22,100 (net summer capacity) of hydrothermal electric capacity will be in use in 2030. To derive this projection, my staff and the Meridian Corporation developed special simulators using existing resource and cost data, including projected mid- and long-term effects of research on technology cost-effectiveness. The quantitative research objectives of the DOE geothermal R&D program were used as a basis for technology improvement up to 2010, after which a more optimistic "breakthroughs" scenario for technology improvement was applied. The resulting cost-supply curves for hydrothermal electricity were then used in the primary NES economics model, FOSSIL-2, which competes most energy supply technologies against incremental demands to the year 2030.

For hot dry rock, the DOE/Meridian economic supply model indicated that if 10 percent of the moderate-to-high thermal gradient area of the U.S. could be used for HDR applications, the technically feasible potential would be about 19,000 GWe for 20 years with about 3,800 GWe occurring at economically attractive sites. In 1990, the 3,800 GWe could have had an average break-even price of just over 8¢/kWh in 1990 dollars. By 2010, the price could drop to about 5.3¢/kWh, and the long-run cost could be as low as 4¢/kWh if all the postulated technology developments occur.

The NES provides for a climate in which geothermal energy can reach reasonable expectations of growth through its commitment to substantial diversification of U.S. sources of energy. Specifically, it is stated, the Strategy "will spur more...competition throughout the energy sector, expand the fuel and technology choices available to the Nation, [and] improve U.S. research and development...." What is needed in renewable energy, including geothermal, the Strategy concludes, "is the opportunity to translate R&D progress to practice, removal of market barriers, and continued *focused* R&D to realize the full potential of these technologies."

This, then, is the goal of the DOE R&D program -- to focus on activities that will facilitate long-term, cost-effective private geothermal development. If successful, the program will enhance the ability of the geothermal industry to compete within the NES policy framework of market reliance -- i.e., "wherever possible, markets should be allowed to determine prices, quantities, and technology choices."

HYDROTHERMAL PROGRAM IMPLEMENTATION

The primary mechanism for achieving the hydrothermal objectives of this goal is an R&D core program cost-shared with industry focused on major cost-sensitive technology areas: exploration technology, reservoir engineering and management, and drilling, the costs of which impact both exploration and reservoir engineering and management.

Exploration Technology

A number of the U.S. hydrothermal reservoirs that were explored by industry beginning in the late 1960's and through a cooperative government/industry exploratory drilling program are in commercial production today. However, further near-term development will be limited by the availability of proven reservoirs. William P. Short III of Kidder, Peabody, & Co. predicts that "if there is insufficient evidence to classify a geothermal field's resource as proven, that geothermal field will probably not be developed in the 1990's." He bases his prediction on several factors, not the least of which is the lack of risk capital to commit to geothermal exploration and development programs.

And with today's technology limitations which require the drilling and testing of at least one expensive deep well to determine the producibility of a reservoir -- at costs of $1.5 to $3.5 million each -- the up-front risk capital needed by an industry described by Dr. Jim Combs as one of "cash-short entrepreneurs" is very large. In calling for continued cost-shared geothermal exploration and reserves confirmation R&D by DOE, industry, and academia, Dr. Combs of Geo Hills Associates said this effort is needed to resolve the "Catch-22" situation in which the industry finds itself. That is, he said, "industry needs to prove a viable geothermal reservoir without spending much money in order to acquire a long-term power sales contract with a utility which can be used to finance the project in order to drill and test the wells that are needed to prove the efficacy of the power generation project."

In response to this critical industry need, our R&D program is undertaking to select the most innovative methods to locate and characterize undiscovered resources. We are investigating the range of optical, electromagnetic, geochemical, gravitational, and biological methods that may offer promise as exploration techniques. Industry is actively involved with us in technology development to produce the new generation of instruments necessary to discover hidden geothermal systems, and we are planning to conduct a cooperative venture designed to confirm the existence of a suspected hydrothermal system. An RFP will be issued asking industry to propose a favorable exploration target based on its information up to that point. An area will be selected for completing exploratory work that has not been done, and finally a deep hole will be drilled to confirm the findings of the less expensive technologies or to determine where those methods failed.

Our current planning anticipates that this innovative research into improved exploration techniques will be continued and expanded as future resources permit to meet industry's needs for this function during the next decade and beyond.

Reservoir Engineering and Management

The need for improved methods, equipment, and materials for geothermal reservoir engineering and management is demonstrated conclusively by the current problems at The Geysers. And the need can only become more critical as hot water fields begin to mature and new reservoirs are identified bringing their own sets of characteristics and complexities to be delineated and managed in developing and implementing exploitation strategies.

The successful performance of geothermal reservoirs in terms of meeting contractual requirements for production quantity, quality, and longevity have implications far beyond the economics of the particular producer and user in each case. Successful performance is vital to the survival of geothermal energy as a reliable and accepted alternative fuel within regulatory and energy planning communities -- as well as the investment community. Successful performance in terms of environmental quality is vital to the acceptance of this resource by every level of government and the public. Less than successful performance invites our critics, doubters, and competitors to challenge the validity of this resource in the marketplace.

Thus, a very high priority continues to be given to the development of new techniques for locating and characterizing fractures and reservoir boundaries, to assess fluid recharge, and to understand complex reservoirs. Many in this workshop audience are long time participants in this R&D program element and will be reporting on their activities in detail, so I will confine my remarks to a brief summary of our Fiscal Year 1992 approach.

Research related to a better understanding of The Geysers system is continuing to be emphasized to aid the industry in managing the field for sustained production. Geophysical and geochemical studies related to fractured geothermal systems are investigating phenomena unique to vapor-dominated systems and the generic need for injection of water into all fractured geothermal systems to efficiently recover the resource. The benefits of this effort will extend beyond The Geysers and provide field management guidance for other major U.S. producing fields which depend on fracture permeability.

The research will include studies for the identification of fracture systems early in the exploration and drilling stages, the development and refinement of methods to model flow of reservoir fluids and injected fluids in fractured reservoirs, and the development of tracers which can be used in high-temperature hydrothermal reservoirs.

Drilling

The successful accomplishment of a major objective of the FY 1992 drilling R&D will advance both exploratory drilling and field management techniques. This objective is the development of downhole memory instrumentation to improve logging of geothermal wells.

The drilling experts at Sandia National Laboratory report that downhole measurements are not commonly used in the geothermal industry even though they possess a demonstrated capability of providing data important to development and maintenance of geothermal fields. Log data, for example, can provide the basis for engineering and permitting decisions involving corrosion control and the design/evaluation of cement bonding operations. In addition, log data on parameters such as fracture density, size, and orientation can guide well placement.

The use of logs in geothermal fields has been inhibited by the lack of high-temperature tools as well as uncertainty as to their value. However, a Sandia review of the logging literature indicates that similar uncertainties initially existed with respect to hydrocarbon applications, but as the ability developed to make downhole measurements, the interpretation of the data often produced unexpected beneficial results. A similar experience is expected in regard to geothermal applications.

The Sandia approach to instrumentation for high-temperature wells is to use a downhole memory unit that stores the data in a computer system. This technique is potentially inexpensive and does not require extensive uphole equipment or an expert crew, attributes which may lead to applications beyond use in geothermal wells.

DOE is funding, in conjunction with industry, the design and construction of a high-temperature spectral gamma tool based on the downhole memory concept. It will be designed for 400°C operation and will be compatible with small diameter coreholes in response to industry's needs for reduced exploration costs. New higher temperature tools being developed for deep gas wells will be evaluated by a cooperative arrangement among Sandia, geothermal operators, and a logging company.

Another element in the FY 1992 drilling R&D directed toward reducing exploration costs is the consideration of advanced coring concepts utilizing high-speed coring rigs to drill small, less expensive holes. It will be determined whether an industry cost-shared field test can be developed to compare directly productivity from the same formation in large and small wells. The field test would include injectivity/productivity correlations and use downhole instrumentation to supplement the wellhead measurements for better definition of the flow conditions in the wellbore.

HOT DRY ROCK PROGRAM IMPLEMENTATION

As most of you know, the Geothermal Research, Development, and Demonstration Act of 1974 mandated that the production and use of all forms of geothermal energy be investigated. At about the same time, a patent was issued to researchers at the Los Alamos Laboratory for the HDR extraction concept, and work began on the first HDR reservoir at Fenton Hill, New Mexico. Experimental work has continued from that time, and now we are examining the commercial prospects of this technology.

The first reservoir was tested successfully for about one year and demonstrated that the concept "works" -- i.e., it demonstrated that heat could be extracted from rock at reasonable rates without insurmountable technical problems or serious environmental effects. A deeper, hotter reservoir was constructed, and, after corrections to connect the two well bores, tested for 30 days in 1986. The production flow rate, fluid temperature, and, consequently, the thermal power increased throughout the test. The flow impedance continually declined as did the rate of water loss. By the end of the test, about 70 percent of the injected water was being produced at a temperature of 190°C. The power level reached about $10MW_t$.

More recently, preparations have been made to conduct a long-term flow test, which, if successful, will provide an example of the potential of the HDR concept over long periods of time and a benchmark for the development of commercial HDR systems. The objectives of the long-term flow test fall into three categories:

- Technical goals
    - Evaluating the useful lifetime of the reservoir, quantifying water consumption rates, measuring production fluid flow and temperatures, and determining the power production of the reservoir.
- Operational goals
    - Understanding the important operating parameters of the system including maintenance requirements, ongoing costs, and other relevant information.

- Scientific goals

  Increasing the levels of understanding in seismology, tracer technology, and underground reservoir engineering.

In a preliminary system checkout in December prior to actual start-up in January 1992, all major components of the plant performed adequately with a production temperature of 154.3°C.

This initial stage was observed by representatives attending a renewable energy conference conceived by former U.S. Secretary of the Interior Stewart Udall, and co-sponsored by the Center for Resource Management, Los Alamos National Laboratory, the Electric Power Research Institute, Southern California Edison, and Bechtel. The meeting heard reports on international HDR projects by representatives from Japan, the European Community, and the United Kingdom. Dr. Paul Kruger of Stanford University presented a summary of the Russian HDR effort. A panel was then convened to discuss the economics of HDR and the factors necessary for commercialization of the technology. The meeting concluded with the reading of a statement urging increased support for HDR development and proposing a series of concrete steps to move the technology forward. As has traditionally been the case with respect to the recommendations of industry and other sectors of the geothermal community regarding the conduct of hydrothermal R&D, the views of these distinguished individuals will be considered in planning for future research program activities.

CONCLUSION

While legislation needed to implement certain aspects of the National Energy Strategy is still under consideration by Congress, we do not really need new legislation to continue our effort to meet the NES goal of more competition in the energy sector and expansion of the available fuel and technology choices. We also do not need legislation to *use* the NES goals in support of geothermal energy. We should never waste an opportunity to remind decision-makers that this resource is "made-to-order" for implementing the strategy developed at the highest levels of government.

I believe that the geothermal R&D program I have highlighted here supports the recent call of the President for "an energy future that opens the door to new and diverse energy sources" and provides "the responsible leadership of industry and government."