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DOE's GEOTHERMAL PROGRAM: NEW EMPHASIS ON INDUSTRIAL PARTICIPATION

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ABSTRACT

In line with industry's traditional strong role in targeting research priorities for the Department of Energy's geothermal program, the new policy thrust toward industry-driven R&D will complement our existing planning processes. Cost-sharing and leveraging of DOE's limited research resources remain critical elements, especially at The Geysers where DOE-funded research must have a very strong potential for yielding early industrial application.

Upcoming geothermal reservoir engineering program initiatives respond to industry's expressed need for new exploration technologies to find undiscovered geothermal resources where there are little or no surface manifestations and for drilling innovations to reduce the costs of exploration for such resources. In accord with the Department's policy of focusing on research supported by industry, long-term research on geopressured and hot dry rock resources has been reduced in scope or deferred.

INTRODUCTION

As the geothermal community gathers once again here at Stanford, we are supporting a new Department of Energy policy emphasis on industrial participation in renewable energy technology development. We have, in fact, been the vanguard of governmental/industry cooperation in technology development since the early 1970's, with industry playing a strong traditional role in targeting research priorities for the Department's geothermal program. Thus, the new focus on industry-driven R&D will complement our existing planning process. Cost-sharing and leveraging of DOE's limited research resources remain critical elements, and my remarks this morning will address these aspects of our program implementation with respect to the elements with which this audience is primarily concerned -- reservoir technology, with special emphasis on research at The Geysers and the potential commercial benefits to be derived.

FAVORABLE TRENDS FOR GEOTHERMAL DEVELOPMENT

First, however, I would like to review briefly trends in energy supply and demand and emerging environmental principles that appear to be healthy for geothermal development for the present, and optimistic and promising for the future. While all of you are no doubt generally aware of these trends, they bear repeating as a boost to our determination to continue to develop needed cost-effective hydrothermal technology.

I use the term "healthy" to describe both DOE's geothermal R&D program and industry's posture at the moment. California Energy Co., for example, has announced record third quarter 1990 revenue and earnings at the Coso installation that surpassed over 85 percent of its entire earnings for fiscal year 1989. Electricity output rose nearly 80 percent over the same period in 1989, and the Coso facility operated at 91.5 percent of capacity in the third quarter of 1990, compared to 83.5 percent for the first half of the year.

Magma Power continues to report quarter after quarter of record earnings generated by its plants at the Salton Sea and royalty payments from other plants. Its 1989 net income increased 140 percent over 1988, even before the last Salton Sea plant was completed in January 1990.

Richard J. Stegemeier, president of Unocal, has called Unocal's new Salton Sea geothermal facility the company's "crown jewels," and announced that Unocal's geothermal sales reached $188 million in 1990. Unocal is planning, he said, "to spend several hundred million dollars over the next several years for further exploration and development along the Pacific Rim's geologic 'ring of fire.' Currently the company is constructing a 110 MWe plant in Indonesia which culminates nearly a decade of exploration, field development, and negotiations with the Indonesian government.

I salute all of these industry successes as well as the many others that have come to fruition in recent years. Each of them has been reached via unique developmental pathways and with varying sources and amounts of financial support, but always with the vision

that geothermal energy is a highly efficient and cost-effective resource that, properly managed, can reap profits for industry's stockholders.

I believe that DOE's geothermal program is "healthy" for several reasons. Renewable energy technologies received a great deal of visibility and acceptance during the National Energy Strategy process. As a result, while the Department continued throughout 1990 to analyze and evaluate the many other energy options proposed, Secretary Watkins early in the year designated renewable energy for "fast track" consideration among the policy choices available. This action, combined with greater budgetary support from Congress, indicates an enhanced emphasis on renewable energy programs.

The direction of the geothermal R&D budget has been reversed for the first time in recent years. As shown in Table 1, appropriated funds for FY 1989 were $23.7 million, $17.8 million for FY 1990, and $27.9 million for this year, or FY 1991. I am pleased with this improvement, and feel that it is more than justified by the proven attributes of geothermal energy and the continuing participatory performance of industry in the R&D program.

The Department's leadership in establishing the concept of Integrated Resource Planning, or IRP, also supports a healthy climate for geothermal development. As you know, this utility planning process -- also known as Least Cost Utility Planning or LCUP -- includes the consideration of demand reduction and alternative energy sources in planning for the supply of future energy sources. This concept not only offers geothermal power a brighter future among supply-side alternatives, but can rapidly increase the market for direct use applications of this resource, as both a supply- and demand-side alternative. Utilities in this country and abroad are recognizing this phenomenon, or have already done so, primarily through the demonstrated benefits of geothermal heat pumps. By replacing electric resistance heating as the primary heat source for thousands of residences and commercial establishments, this technology has the potential to eliminate or postpone construction of costly power plants. In addition, the load leveling potential of geothermal heat pumps complements the base load strength of geothermal power, significantly reducing the seasonal demands on utilities. While the Geothermal Division has no mandate to support improvement in heat pump technology, we are looking at relatively quick and inexpensive methods for drilling shallow vertical (and horizontal) heat exchanger wells.

Another exciting prospect for geothermal's future is inherent in projections of increased power demand in regions where geothermal energy is available to pursue these markets along with competing fuels. According to a forecast adopted by the California Energy Commission last year, the peak demand for electricity by California's consumers, businesses, and industries will grow over the next 20 years by more than 23,000 MWe, the equivalent of providing energy to power 23 million additional homes. This represents a growth rate of 2.7 percent per year and is approximately a 50 percent increase over peak 1989 demand. The forecast shows a demand increase of more than 2,000 MWe compared to the Commission's 1988 projection.

Similarly, the highest of the annual power demand growth rate projections for the Pacific Northwest is placed at 2.5 percent. This forecast contrasts to a period of substantial electricity surplus at the lowest costs in the nation, a period in which new energy technologies had little, or no, opportunity to develop. According to the 1990 Annual Report of the Northwest Power Planning Council, the joint interim forecast of the Council and the Bonneville Power Administration indicated that, with very high economic growth, the region's need for power could climb by 13,000 MWe by the year 2010, up from the 16,620 MWe consumed in 1988. A more likely medium-low to medium-high economic growth would translate into a 2,400 MWe to 7,800 MWe increase in regional demand compared with 1988.

These statistics relate to <u>overall</u> power demand in key geothermal regions, but I believe the most exciting prospect inherent in these numbers is the potential for <u>specific</u> geothermal power demand. In California, according to CEC, the largest bulk of the additional demand will occur in areas served by Pacific Gas and Electric Co., Southern California Edison, and San Diego Gas and Electric. Untapped geothermal resources are available to all of these utilities, and all of them have substantial experience and expertise in geothermal operations. And, significantly, these utility service areas are populated by the world's most knowledgeable and capable independent geothermal power producers!

In the Pacific Northwest, the power surplus provided a grace period in which those responsible for the region's power needs -- both in planning and providing power -- could learn how to deal with uncertainty and evaluate and select resources in a manner that would be the least costly to the regional electrical power system. As a result of comprehensive studies of various scenarios critiqued by technical advisory committees and energy and environmental organizations, the NPPC decided to include 350 MWe of geothermal power in its resource portfolios analysis and evaluate another 1,000 MWe to determine its role in the Power Plan. Specifically, for the near term, the Council is recommending the acquisition of three geothermal demonstration projects at separate sites in the Cascades, producing at least 10 MWe each. Who would have thought,

even two years ago, that this market would soon be opened this fully to geothermal development.

The geothermal industry's ability to respond expeditiously to this challenge in the Northwest is enhanced greatly by the results of the DOE/industry cost-shared drilling projects at promising prospect areas in the Cascades. This is but one more example of the commercial benefits that derive when government and industry pool their limited resources to reach a common goal.

To me, however, of equal importance to the opportunities opened to geothermal operations through increased demand is the shift toward incorporating "external" costs and benefits -- or externalities -- into the energy decision making process by using least-cost or integrated resource planning as described above. The Northwest Power Planning Council, for example, in preparing its 1991 power plan defines "least-cost" and "cost-effective," to refer "to total costs to society, including environmental, labor, and other capital costs." In California, CEC's adopted demand forecast "for the first time explicitly takes into account the impacts of air quality rules adopted by the South Coast Air Quality Management District." The rules adopted include measures for reducing emissions from fuel combustion, some of which would require the use of electricity instead of other fuels in industrial facilities. In its evaluation of ways that utilities can meet future power demands, the Commission has announced that it will determine the best mix of these alternatives balancing environmental, energy security, and economic concerns and goals. How can geothermal lose under this set of criteria?

The outlook abroad is also promising. A compilation of statistics provided to the World Bank indicate that developing countries plan to more than double their geothermal power capacities during the 1990's from 2 GW to 5 GW. Our U.S. geothermal industry, with the assistance and support of DOE, has established an Export Trading Company to enhance its ability to tap this large overseas market. We wish the companies every success in their venture. With each successful geothermal project, wherever it is located, the perception of geothermal energy as a reliable and desirable fuel grows in those places where its reputation counts -- at the energy policy- and decision-making level, whether local, regional, national, or international.

CURRENT R&D PROGRAM

To answer my rhetorical question above, geothermal energy can "lose" even under very favorable circumstances if technology development does not advance sufficiently rapidly to help find new resources to support long-term industry growth and to facilitate economic definition of known resources. These objectives are the focus of this workshop and DOE's Reservoir Technology Task. The Department's current budget for reservoir R&D has increased over allocations for recent years; I wish to emphasize, however, that while the trends are healthy, the funds committed remain "limited" in light of today's costs and the broad needs in terms of technology innovations, improvements, and remedial measures needed for geothermal energy to achieve its full potential. Thus, the continued commitment of industry support to various R&D projects is essential, first, to DOE approval of specific projects, and, second, to the successful conclusion of approved projects. Nowhere is this participation more necessary than at The Geysers where both federal and private interests are at stake.

I am happy to report this morning that industry is not only supporting DOE-sponsored research at The Geysers, its contributions are quite substantial. Estimates are that industry spent $3.5 million in FY 1990 and that it has committed $4.5 million this year. Most of last year's expenditures were for the injection tests performed jointly by the Northern California Power Agency and Calpine Corp., with instrumentation assistance from Unocal. The data developed are being provided to DOE for use in additional research, a major milestone in government/industry cooperation. DOE's expenditures at The Geysers for the same two years are $1.2 million and $2.5 million, respectively.

Proposals for DOE-supported research are reviewed by a "Steering Committee for Geysers Research" consisting of representatives of the Unocal Geothermal Division, Calpine Corporation, Northern California Power Agency, and Coldwater Creek Operator Company, with Marcelo Lippmann of the Lawrence Berkeley Laboratory (LBL) acting as coordinator. At this writing, 41 proposals have been reviewed for FY 1991 funding. Contract awards are expected this month after some proposers provide more information on specific milestones and deliverables. In the case of the proposals that did not meet the requirements of the Steering Committee, it was suggested that their authors communicate with industry to better discern industry's needs. This approach is in line with the policy that research funded at The Geysers must have a very strong potential for yielding results that have early industrial application and will benefit industry. In addition to DOE, the major non-industry participants in The Geysers research are:

- Idaho National Engineering Laboratory
- Lawrence Berkeley Laboratory
- Lawrence Livermore Laboratory
- Oak Ridge National Laboratory
- Stanford University Geothermal Program
- University of Utah Research Institute

In addition, the Brookhaven National Laboratory is participating in corrosion mitigation, the U.S. Geological Survey is working with others to investigate the buildup of hydrochloric acid in the field, and the specialties of other widely diverse institutions are being tapped for specific research needs.

During FY 1990 significant progress was made on Geysers projects, but results are not yet quantifiable in all cases. The achievements are summarized in Table 2. Preliminary results indicate, for example, that the research correlating seismic velocity and attenuation images to geological and reservoir conditions demonstrated a methodology that can be used to locate steam and 2-phase zones. This in turn will lead to improved well siting and to better reservoir management policies.

Geysers projects for this year are summarized in Table 3 along with reservoir-oriented projects for wider application. The number of geophysical activities aimed toward improving this technology for geothermal application is too numerous to describe in detail here, but I want to point up one project that we expect to advance the exploration for as yet undiscovered resources. Numerical analysis will be performed to determine theoretical geophysical responses from fluid-filled fractures, and field tests of surface geophysical techniques will be designed and conducted to verify the responses to be expected. The use of new interpretation methods for these advanced geophysical techniques for locating fractured hydrothermal systems will be investigated, concentrating on electromagnetic and passive seismic exploration methods. The observed geophysical data will be combined with laboratory measurement of physical properties and existing geologic data to provide exploration plans for regions such as the Cascades volcanic province for which data sets are available. I feel sure that other speakers will provide the details of other on-going and anticipated geophysical projects.

In other R&D areas, work is continuing on improvements in technology to identify the location and extent of lost circulation zones and methods for plugging; advanced drilling and coring concepts are being explored with emphasis on high-temperature drilling systems for operation above 300°C; and downhole electronic memory tools for use in very harsh geothermal environments are in development.

The heat cycle research is continuing efforts to increase the net fluid effectiveness of binary technology and to reduce the consumptive cooling water requirements for geothermal power plants and still maintain heat rejection performance comparable to that of a conventional wet cooling system.

Corrosion mitigation at The Geysers involves development and testing of material for lining casing and installation of a lined casing string for downhole evaluation. Other materials developments include lightweight cements resistant to carbon dioxide, thermally conductive polymer concrete liners for heat exchangers, chemical systems for lost circulation control, and high-temperature chemical coupling systems. The equilibrium model of complex brine chemistry is being prepared for use with personal computers to enhance its usefulness in the field, and analysis of the first generation of modified bioreactors for the treatment of waste sludges will be completed.

In accordance with the Department policy of focusing on research supported by industry, long-term research on geopressured and hot dry rock resources has been reduced or deferred. However, industry and the State of California are now expressing interest in using geopressured brines for such purposes as thermal enhancement of oil recovery (TEOR) and supercritical waste treatment, and the Department is considering participation in these efforts. Where geopressured fluids are collocated with fields of medium and heavy oils, TEOR with the naturally heated fluid would provide an environmentally clean method of recovery and add millions of barrels of oil to the country's recoverable resources. Supercritical water oxidation (SCWO) of hazardous organic chemical wastes is an emerging self-sustaining technology. It is a low-temperature chemical reaction effective for contaminated water, concentrated organics, and complex mixtures in which the effluent is fully controlled.

The experimental hot dry rock reservoir at Fenton Hill, New Mexico, will be subjected to a long-term flow test beginning next year which will provide a basis for future commercial exploitation of hot dry rock resources worldwide. A generalized economic model recently developed by researchers at the Massachusetts Institute of Technology, Drs. Jefferson W. Tester and Howard J. Herzog, indicates that high-grade HDR resources (i.e., an average gradient of 80°C/km) are competitive with $18/barrel oil, and that mid-grade (50°C) would be competitive with oil at more than $30/barrel, and/or if environmental costs associated with fossil-fuel systems -- e.g., an acid rain or carbon tax -- were included. Thus the hot dry rock research performed over nearly 20 years has established the potential commercial viability of yet another form of geothermal energy.

CONCLUSION

In concluding these remarks I would like to quote a former U.S. senator from Nevada -- Senator Alan Bible. As early as 1973, the Senator wrote:

"What are the prospects for geothermal power? The answer depends on the willingness of the federal government and the willingness and capacity of private industry and the scientific community to get on with the task of ascertaining the technical and economic feasibility and environmental acceptability of the development of geothermal resources."

All three of the entities he charged with the responsibility for determining the course of the development of this "ageless phenomenon and challenging new frontier" are represented here, and we have met our responsibilities. The sessions this week will further our cooperative efforts to pursue even greater horizons for geothermal energy.

TABLE 1

DOE GEOTHERMAL PROGRAM BUDGET
($1,000)

	FY 1989	FY 1990	FY 1991
HYDROTHERMAL			
Hard Rock Penetration	2,250	2,205	2,385
Reservoir Technology	2,450	2,074	5,500
Conversion Technology	1,935	1,527	1,943
Other	0	0	7,800**
TOTAL	6,635	5,806	17,628
GEOPRESSURED	10,380	5,755	6,000
HOT DRY ROCK	1,635	5,039*	4,967***
MAGMA	3,500	*	***
OTHER			
Capital Equipment	795	444	405
Program Direction	826	814	900
TOTAL	**23,771**	**17,858**	**27,900**

* New category designation; "Advanced Systems" includes $3,390 for hot dry rock and $1,649 for magma.
** Includes activities in Hawaii, Boise, Oregon Institute of Technology, and other low-temperature projects.
*** Advanced Systems includes $3,967 for hot dry rock and $1,000 for magma.

TABLE 2

SIGNIFICANT FY 1990 ACCOMPLISHMENTS OF GEYSERS RESEARCH

- Preparation of a major subset as "MULKOM" modules for release of "TOUGH2"; documentation of code futures.
- Analysis of microseismic signals to produce seismic and attenuation images and their relationship to geological and reservoir conditions.
- Development of laboratory equipment for measuring HC between liquid and vapor phases.
- Expansion of existing algorithms to include calculations of trapping pressures from estimates of the CO_2 contents of inclusion fluids and to calculate pressure corrections for NaCl concentrations up to 26 weight percent.
- Numerical simulation of injection into superheated zones vs. injection into 2-phase vapor-dominated zones.
- Identification of hydrochlorofluorocarbons as suitable tracers for a vapor-phase environment and methodologies for injecting, sampling, and analyzing tracers in vapor-dominated reservoirs.

TABLE 3

SUMMARY OF FY 1991 RESERVOIR TECHNOLOGY RESEARCH AREAS FOR SPECIFIC APPLICATION AT THE GEYSERS AND/OR OTHER HYDROTHERMAL RESERVOIRS

- Development and testing of new advanced geophysical equipment and interpretive methods for locating fractures and permeable zones, determining fluid concentrations, and estimating reservoir generating capacity and longevity for use in exploration and field development.
- Refinement of predictive models and investigation of the applicability of existing numerical simulations to Geysers problems.
- Development of conceptual models for geothermal exploration.
- Development of cryogenic gravimeters to detect minute changes in mass within the earth.
- Development and testing of tracer materials and techniques for tracer injection, sampling, and interpretation.
- Analysis of the strength of seismic signals produced by fluid injection and production.
- Investigation of HCl formation at The Geysers.
- Incorporation of experimental data into brine chemistry equilibrium model.
- Investigation of relationship of adsorbed water on fracture surfaces to Geysers development.
- Evaluation of remote sensing and biogeochemistry as geothermal exploration tools.