Geothermal technologies
U.S. Department of Energy

Vol.4 Issue 3
July 1999

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DOE Welcomes More Competition for Funds

As you may know, significant changes are afoot in how the U.S. Department of Energy (DOE) spends its budget dollars. In particular, DOE has committed to achieving greater competition among recipients of federal funds. Consequently, DOE has issued solicitations in a number of areas to create more competitive opportunities for interested stakeholders.

One such recent opportunity concerned a broad-based solicitation in education and outreach for geothermal energy. DOE has awarded a grant under this solicitation to a team of bidders led by the Oregon Institute of Technology. Among other things, the team will provide training and design support to potential users of geothermal energy; maintain technical libraries and other information references; disseminate various types of geothermal information to interested members of the public; develop educational materials; and analyze market opportunities.

DOE's Golden Field Office has issued another broad-based solicitation looking for innovative concepts and methods in geothermal technology that would benefit from research and development (R&D). Initially, the awards would be small, about $75,000, and designed to verify the potential of ideas. At a later date, a decision would be made whether to support further development, which would require a larger funding commitment.

In addition, the Geothermal Energy Program offers several other solicitations on a cyclic basis to those interested in specific areas of geothermal technology, such as reservoir analysis and energy conversion. DOE will consider proposals for competitive funding in these areas three times a year at specified intervals through the Idaho Operations Office (IDO). For more information visit the IDO Web site at *www.id.doe.gov/doeid/psd/proc-div.html.*

Finally, we should not forget the unique and highly successful method established some years ago to foster closer, cost-shared cooperation between the government and industry in geothermal technology development. I refer, of course, to the industry-led consortia: the Geothermal Drilling Organization, the Geothermal Technology Organization, and the Geothermal Power Organization. These groups will continue to use competitive bidding as a way of accelerating the commercialization of technology needed by industry in the near term.

The move toward more open competition for federal dollars gives us added flexibility to fund research of the best quality at the least cost. By doing so, we are taking a positive step toward accomplishing the goals of the geothermal R&D program as laid out in our strategic plan.

Allan J. Jelacic, Director
DOE Office of Geothermal Technologies

You're Invited to International Geothermal Days—Oregon 1999

The Geo-Heat Center (GHC) at the Oregon Institute of Technology (OIT) invites you to attend its International Geothermal Summer School program: "**International Geothermal Days—Oregon 1999.**" The conference will be held in Klamath Falls, Oregon, from October 10–16. It will feature a series of workshops, courses, seminars, and field trips on many aspects of geothermal energy.

The International Summer School of Macedonia and GHC are co-sponsoring the conference, which is the latest in a series of such conferences that have been held in Europe

The Oregon Institute of Technology campus.

since 1990. Dr. Kiril Popovski of the International Summer School and Dr. John Lund with GHC will serve as conference co-chairs. In addition to speakers from the United States and Europe, there will be presentations by geothermal experts from Latin American and Pacific Rim countries

Klamath Falls is an ideal setting for colleagues from all over the world to meet and discuss the development and use of geothermal energy. With more than 500 geothermal wells and many examples of geothermal utilization, the area provides an excellent field laboratory for teaching and demonstrating the uses and advantages of this sustainable energy resource.

This year's conference will cover three main subject areas: small-scale power projects, geothermal heat pumps (GHPs), and direct utilization of geothermal energy. Two evening workshops on specialized computer programs—software for GHPs, and HEATMAP© (district heating design software)—will supplement these topics.

In addition, there will be three field trips: one to Medicine Lake (Glass Mountain) in northern California to view the sites of the proposed Calpine Corp. and CalEnergy Co. power plants; another to direct-use sites in the Klamath Falls area, including OIT's heating system and the city's district heating/snow melting system, greenhouses, and an aquaculture project; and a final one to visit the district heating systems and binary and hybrid electric power generation projects on the way to Reno, Nevada. This last field trip will occur on Saturday, October 16, after the conference has officially ended. It will end up in Reno just in time for the Geothermal Resources Council (GRC) Annual Meeting at the Reno Hilton Hotel. Participants can then take GRC's Sunday field trip to local power plants (Steamboat and Brady Hot Springs), returning in time for that evening's opening reception at the hotel. (The costs of the GRC events are not included in the Klamath Falls conference.)

GHC is well known for its contributions to the development of geothermal energy through teaching, technical assistance, information dissemination, and international cooperation. It also publishes the *Geo-Heat Center Quarterly Bulletin*, which is recognized as the major journal in the field of geothermal direct-use.

For further information on the Klamath Falls conference and to obtain a registration form, contact GHC at (541)885-1750 (phone) or (541)885-1754 (fax). The entire program can also be viewed on GHC's Web site at www.oit.edu/other/geoheat/iss/issindex.htm.

DOE Developing Systems Approach ell Construction

The U.S. Department of Energy's (DOE) Office of Geothermal Technologies (OGT) has funded Sandia National Laboratories (SNL) to plan a comprehensive systems approach to geothermal well construction that goes far beyond conventional efforts to improve well drilling. Dubbed "Diagnostics While Drilling" (DWD), the system development plan springs from industry and laboratory workshops that focused on ways to reduce costs and improve performance of this crucial component of geothermal energy development.

Funding for this effort comes from OGT's Advanced Drilling Technology Program (ADP). SNL's plan will call for research and development (R&D) in six areas: DWD tools; high-speed data links; drilling advisory software; drilling personnel training; drill rig and pipe design; and surface controllable downhole tools. Building on the successful partnerships formed under NADET (the National Advanced Drilling and Excavation Technology Institute), ADP continues to provide SNL's R&D expertise to private researchers who are developing a variety of new technologies under separate funding vehicles.

BACKGROUND

To tackle the problem of high drilling costs, SNL in 1997 convened a workshop of drilling experts at Berkeley, California, to study concepts for advanced drilling systems. Discussions ranged widely, seeking solutions applicable to geothermal, which could also apply to other industries that drill. The experts identified 10 discrete functions in the drilling process (see sidebar below), pinpointed specific problems in each function, and selected possible solutions for those problems to study.

Following the Berkeley workshop, the Geothermal Research Department at SNL applied a systems approach to planning the research effort, hoping to identify a matrix of new technologies that would integrate and improve all 10 functions. This would create a revolutionary new drilling system.

SNL put its engineering experience to work, and, drawing on expertise in many fields across the laboratory, developed DWD —an amalgam of new technologies that will provide system-wide benefits to the drilling process. It promises huge savings.

PROPOSED APPROACH

Emphasis on a systems approach differs from almost all previous work on advanced drilling, which focused primarily on the rock reduction process, i.e., on the drill bit itself rather than on the entire well construction process. Although more efficient rock reduction remains an important element

The 10 Essential Functions of Drilling

- Rock reduction
- Downhole energy transfer
- Rock removal
- Bore stabilization and fluid containment
- Control of formation pore fluids
- Permanent borehole preservation
- Sensing, communication, and process control
- Directional drilling and control
- Production stimulation
- Well maintenance and workover

of improved drilling, truly cost-effective drilling also requires that the other nine functions within the overall process operate optimally. Even the best drill bit will not significantly reduce the costs of a well if it is not compatible with, or does not enhance, the complete drilling system. What SNL seeks is an enabling technology that links all 10 of the drilling functions and improves all component parts of the drilling process.

At the Berkeley workshop, participants agreed that while drilling, the single greatest hindrance is a lack of real-time knowledge and control of what is actually happening downhole. If a feedback capability could somehow be realized, all functions could be optimized for highest efficiency and lowest cost, creating a great potential for significantly reduced costs of geothermal wells. Participants believed this capability would also serve as a motivating factor for developing other tools to take advantage of real-time data and control.

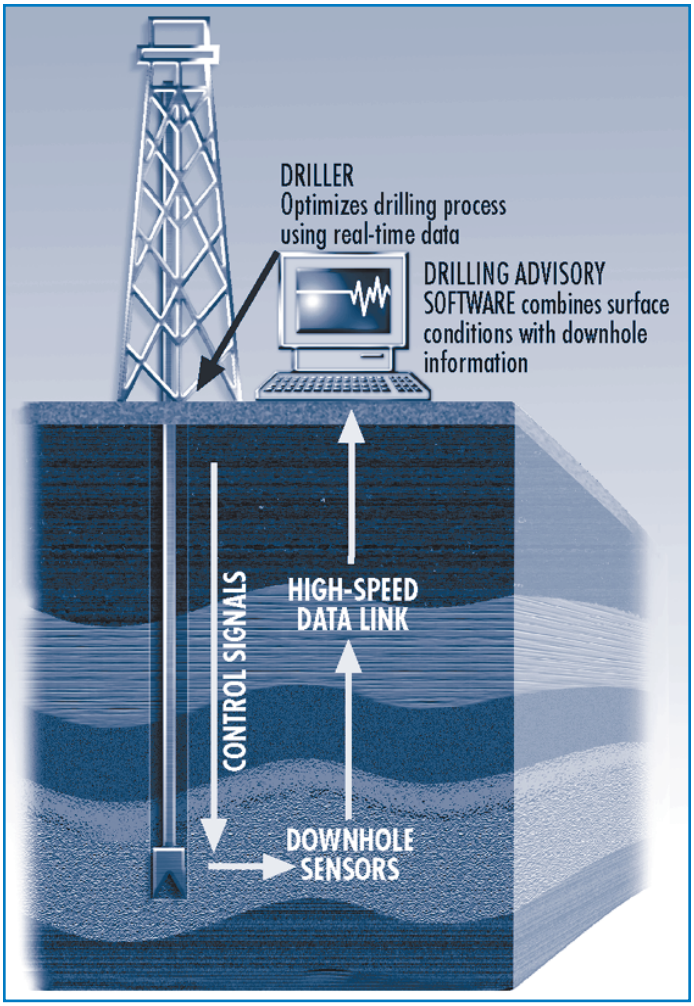
The DWD system will be built on sensing, communication, and control, which the workshop experts identified as the key elements required for overall improvement. These elements will make other downhole and surface tools possible, including improved drill bits. The first priority in research will be to develop a high-speed data link from the drill bit to the rig platform. The workshop also specifically identified drilling advisory software and surface-controllable downhole tools as high priority components, which will make the DWD system a reality.

ANTICIPATED BENEFITS

DWD's central concept is a closed information loop—carrying data up and control signals down—between the drilling platform at the surface and tools at the bottom of the hole. When data travels upward, it gives a real-time report on drilling conditions, bit and tool performance, and on imminent problems. Drilling personnel can then use this information to either change surface parameters (e.g., weight-on-bit, rotary speed, and mudflow rate) with immediate knowledge of their effect, or to return control signals to active downhole components.

DWD will reduce costs, even in the short-term, by improving drilling performance, increasing tool life, and avoiding trouble. Some recent work by Baker Hughes INTEQ (BHI) illustrates this potential. BHI used surface-mounted equipment to monitor downhole vibration while drilling, cutting 33 days off of a 90-day drilling job.

The longer-term potential of DWD includes variable-damping shock subs for smoother drilling, reservoir characterization for locating the pay-zone while drilling, bit wear diagnostics while drilling, and self-steering directional drilling. Ultimately, DWD will lead naturally to autonomous "smart" drilling systems that analyze data and make drilling decisions downhole, without the driller's direct control.



By carrying data up and sending control signals down, the Diagnostics While Drilling (DWD) system gives a real-time report on drilling conditions, bit and tool performance, and on any imminent problems.

Cost reductions will be realized through improved penetration rate, increased bit life, diminished tool failures, and reduced completion cost. The sum of the projected near-term savings is 25%, but advanced technology, that can only be dimly visualized now, has the potential to drive the savings even higher. SNL is currently planning proof-of-concept tests that will demonstrate the inherent value of DWD for optimizing drilling.

OGT initiated ADP, but it collaborates with DOE's Office of Oil and Gas on R&D efforts. Cost-shared research between the two offices and the U.S. private sector provides potential benefits for all the extractive industries.

For more information, contact Paul Grabowski, U.S. DOE, (202)586-0478, paul.grabowski@hq.doe.gov; Mike Prairie, SNL, (505)844-3154, mrprair@sandia.gov; or Chip Mansure, SNL, (505)844-9315, ajmansu@sandia.gov. SNL is a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin company, for DOE.

Geothermal Heat Pumps for EnergySmart Schools—Seven unding

Under DOE's State Energy Programs Special Projects Initiative, seven state energy offices (SEOs) received funding in support of GHPs for EnergySmart Schools. Those SEOs were Arkansas, Iowa, Nebraska, New Jersey, New York, Virginia, and Wisconsin. The total funding is about $345,000. These projects will assist education officials, SEOs, and non-profit organizations to provide schools with information and resources needed to apply GHP technology.

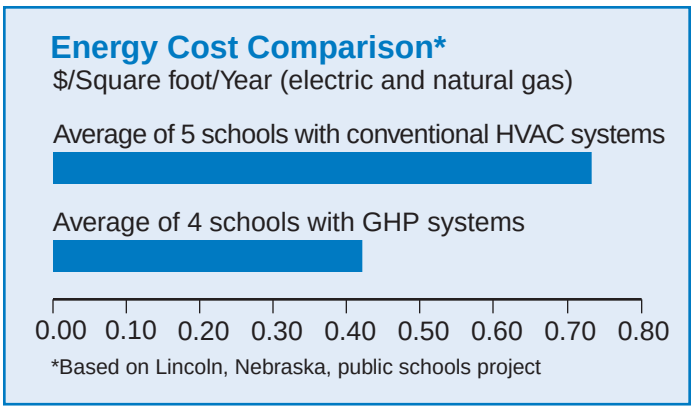
"These grants underscore the productive relationship between the Department of Energy and state energy offices across the country," said Secretary of Energy Bill Richardson.

Nearly 500 schools and colleges in the United States have installed geothermal heat pump (GHP) systems, as numerous facility managers have recognized the overall comfort, reliability, economy, and energy efficiency of these systems. Schools choose GHP systems for many reasons, some of which include aesthetics, zone control, lower maintenance costs, decreased space requirements, and safety.

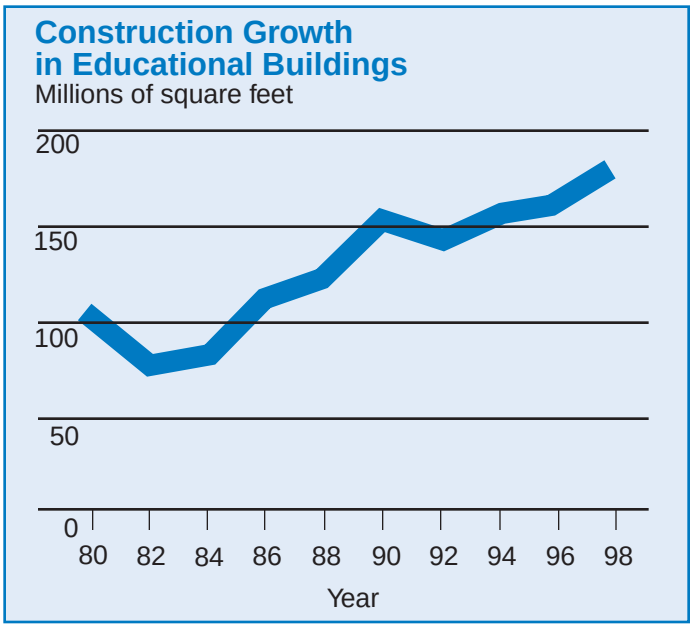
The Geothermal Heat Pump Consortium (GHPC), also funded by DOE, provides design assistance to schools. Over 50 schools have received such assistance so far. Of those that made a decision, 92% have decided to use GHP systems.

Case Study- Nebraska Schools Find Benefits

In Lincoln, Nebraska, not only is the school district benefiting from the savings of GHP systems, but the taxpayers are too. With cooperation from Lincoln Electric Systems and Lincoln Public Schools, four elementary schools recently installed GHP systems. The heating and cooling costs are about $144,000 a year less (from 1996-1997) than they would have been if those schools installed more traditional HVAC systems. These savings will reach about $3.8 million over just 20 years, allowing for other capital improvements to be realized.



Source: Lincoln Electric Systems



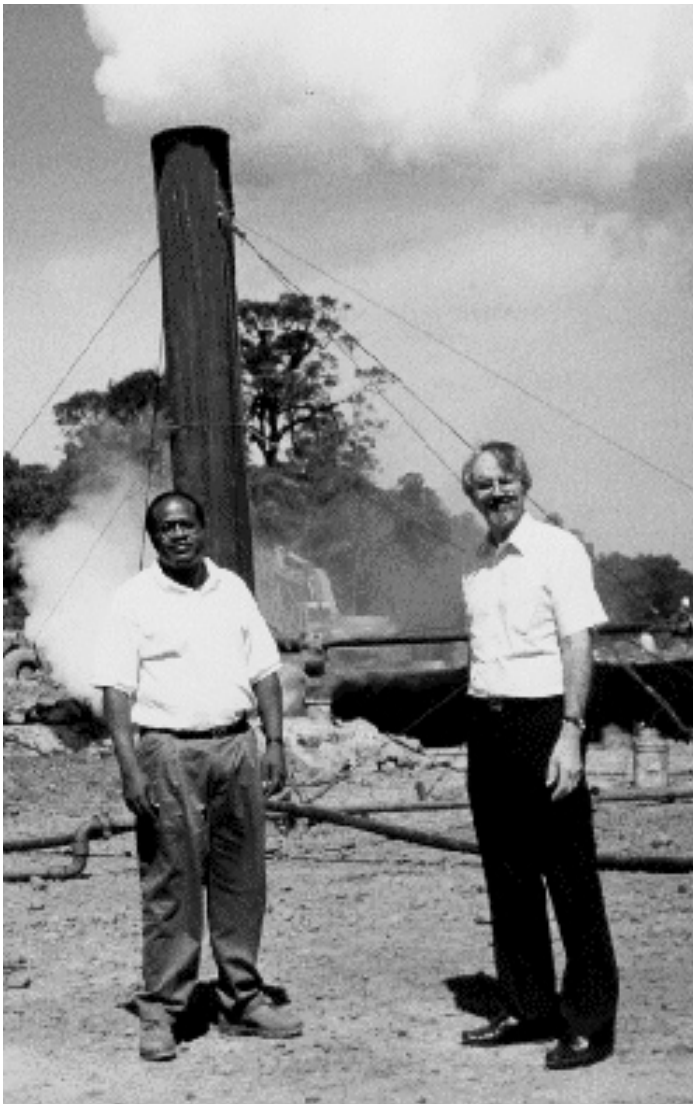
Source: Geothermal Heat Pump Consortium

For more information, contact Lew Pratsch, U.S. DOE, at (202) 586-1512 or lew_pratsch@hq.doe.gov; or the call the GHPC, toll free, at (888) ALL-4-GEO, or visit its Web site at: www.geoexchange.org.

Dr. Roland N. Horne truly has had a lifetime of involvement in geothermal energy. He started when he was nine-years-old.

In the early 1960s, Roland emigrated from England to New Zealand when his father, a civil engineer, moved the family to join a company involved in the construction of the Wairakei B geothermal power station. From early visits to the Wairakei field as a youngster, Roland went on to study engineering at the University of Auckland. In 1973, he earned his PhD under Mike O'Sullivan, with a focus on geothermal reservoir simulation and convection in porous media. He then spent two years as a postdoctoral research fellow before coming to the United States to take a position as acting assistant professor of chemical engineering at Stanford University.

After five years of research on numerical simulation in New Zealand, Roland had become a skeptic on using simulation for geothermal reservoir analysis and looked forward to the move to Stanford as a chance to get out of geothermal energy and follow his first love of natural convection studies. (At the time, this was actually his second love, after mountaineering!) But to raise the money to support him, the chemical engineering department "sold" part of his time to the Petroleum Engineering Department, and Roland found himself back in geothermal engineering again.



Dr. Roland Horne (right) in 1997 with one of his students at the Kahara geothermal field in Indonesia.

He soon made firm friendships with people in the Stanford Geothermal Program, including such well-known geothermalists as Hank Ramey, Paul Kruger, Paul Atkinson, and Bill Brigham. He also discovered new interests in geothermal reservoir engineering, which focused more on the practical and conceptual aspects of reservoir development. After one year at Stanford, he became program manager of the Stanford Geothermal Program, and transferred full time to the Petroleum Engineering Department. He never did succeed in getting out of geothermal research, and continues his renewed interest to the present day.

Roland returned to New Zealand in 1978, where he lectured at the University of Auckland's Geothermal Institute, when it was created in 1979. However, he soon returned to Stanford, and became an assistant professor of petroleum engineering in 1980. During the 1980s, his geothermal research focused on the impact of reinjection returns through fractured rock, as the importance of premature thermal breakthrough caused by rapid flow in fractures became evident from tracer studies in several Japanese fields.

In the 1990s, Stanford's geothermal research shifted in response to the immediacy of interest in the reservoir decline at The Geysers, and Roland worked on analyzing water injection into vapor-dominated reservoirs and the influence of adsorption on this process.

More recently, his focus has changed again to fundamental properties of steam-water flow in porous and fractured rocks. He was influential in obtaining a CAT-Scan (Computer Aided Tomography-Scanner) for the Petroleum Engineering Department to observe fluid flow under experimental conditions.

Roland also carries on a long-established tradition called the Stanford Workshop on Geothermal Reservoir Engineering. Held in Palo Alto, California, every winter for the past 24 years, the workshop brings together experts from around the world who are working with and solving the major challenges in geothermal reservoir development and management. The workshop is self-supporting, and continues to constitute a major source of scientific and technical information for the geothermal industry. The National Science Foundation started funding geothermal research at Stanford in 1975. The U.S. Department of Energy (DOE) then took it over in 1977.

As director of the Stanford Geothermal Program, as well as a professor and chairman of the Petroleum Engineering Department at Stanford, he makes major contributions to our understanding of geothermal reservoirs, particularly at The Geysers steam field in California. During his 27 years of geothermal research (not counting visits to Wairakei at age nine), Roland has supervised 33 geothermal graduate students, which include 27 master's candidates and six doctoral candidates. He and his team of researchers form the core of the Office of Geothermal Technologies Reservoir Technology Research Program, headed by Dr. Marshall Reed at DOE's Washington headquarters. He is also the author of an exciting, best-selling book, *Modern Well Test Analysis,* that is now in its second edition. (Bidding for motion picture rights could start any day now!)

So we can be glad that, despite his best efforts, Roland never succeeded in getting out of geothermal energy.

Year

artnership with Industry

The U.S. Department of Energy's (DOE) Office of Geothermal Technologies (OGT) held its 17th annual Geothermal Program Review in Berkeley, California, on May 18-20, 1999. The conference promotes the greater development and use of geothermal energy worldwide by providing a real-time, interactive forum for sharing recent technical advancements, field data, and research and development results between and among technology researchers and deployers.

Daniel Adamson (left), deputy assistant secretary of DOE's Office of Energy Efficiency and Renewable Energy, and Allan Jelacic (right), director of DOE's Office of Geothermal Technologies, at the 17th annual Geothermal Program Review.

This year's theme was "Building on 25 Years of Geothermal Research Partnership with Industry," marking the anniversary of the Geothermal Research and Development Act. "The U.S. Congress exercised great wisdom and foresight in recognizing that geothermal energy embodied huge potential to help the nation with its energy problems," said OGT Director Allan Jelacic. DOE and the U.S. geothermal industry are working together to develop technologies that will enable the industry to take maximum advantage of electric utility deregulation and "green energy" promotion in this country, as well as the trend toward privatization of state-owned utilities in a number of foreign countries.

The program review opened with keynote speeches by influential executives and senior managers from industry and government. Many of them described the long-term plans and policy directions of their respective organizations. A panel of experts then discussed environmental issues as they relate to geothermal energy, especially the large contribution it can make in reducing greenhouse gas emissions. "With its greenhouse gas reduction benefits and relatively low cost among renewables, geothermal can clearly play a major role in resolving this huge problem (global climate issue) hanging over us," said Daniel Adamson, deputy assistant secretary of DOE's Office of Energy Efficiency and Renewable Energy.

Richard Campbell, consultant and former president of the Ben Holt Company, speaks at the Geothermal Program Review.

During the technical sessions that followed, 38 researchers —in the areas of geothermal exploration, well drilling, reservoir engineering, and energy conversion technologies— presented technical papers describing the objectives, results, and future plans of their DOE-funded projects. On a trial basis this year, six experts from industry and academia provided peer reviews of all technical presentations. OGT is now evaluating the peer review process for possible incorporation into all of its future program reviews.

The meeting concluded with a long-term planning session, which covered a draft document entitled, *Activities to Meet the Goals of the Geothermal Strategic Plan*. In June 1998, OGT issued the Strategic Plan for the Geothermal Energy Program, an important component of DOE's Comprehensive National Energy Strategy. The plan stems from a series of workshops convened by the Geothermal Energy Association, on behalf of OGT, to identify areas of research that are particularly relevant to the industry's actual projects and needs.

For more information, contact Pat Pickering, U.S. DOE, at (202) 586-8166 or patricia_pickering@hq.doe.gov. The OGT strategic plan is available online at www.eren.doe.gov/geothermal/public.html.

Announcement

The U.S. Department of Energy's (DOE) Office of Geothermal Technologies (OGT) has published a Notice of Program Interest (NOPI) regarding research and development projects for its Enhanced Geothermal Systems (EGS) Program. OGT is presently seeking expressions of interest and comments on the NOPI, which interested parties can review at *www.doeal.gov/cpd/readroom.htm*. The comment period ends August 31, 1999.

Summary

The purpose of the NOPI is to obtain a preliminary indication of interest from utilities, independent power producers, and industrial concerns in cost-sharing the development and operation of a domestic EGS that significantly augments electric power production from an

existing geothermal field. If the level of interest is sufficient, the Albuquerque Operations Office will issue a formal solicitation for research, development, and demonstration proposals for EGS projects. The initial solicitation will be for research that is directed toward EGS development at an existing site. A possible follow-on solicitation may be directed toward new technologies for EGS, such as site identification, creation of fractures, development and enhancement of fracture permeability, and EGS reservoir engineering.

The overall objective of the EGS Program is to develop the technology, knowledge, and information necessary for the implementation of operational EGS that augment the power production of existing geothermal fields. DOE expects all proposals to illustrate how the expected results will eventually lead to a cost-shared, industry-led EGS project.

Research Areas

Projects may ultimately be sought within two interrelated research areas.

1. Project Development—research, development, and demonstration to verify EGS at existing hydrothermal reservoirs. Proposals may include rework and characterization of existing dry and/or low permeability wells, as long as they show how the effort will lead to an EGS that will augment power production.

2. Technology Development—research, development, and demonstration of tools, methods, and data that will help EGS become commercially viable within an eight-year time frame. Research geared toward a specific EGS project —future or current—will be given primary consideration, as will research to reduce the risks associated with EGS site development and project implementation.

For additional information, contact Dan Sanchez with U.S. DOE's Albuquerque Operations Office at (505)845-4417 or dsanchez@doeal.gov. The DOE Headquarters Program Manager, Paul Grabowski, can be reached at (202)586-0478 or paul.grabowski@hq.doe.gov.

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"The Geysers geothermal field responds favorably to recharging." That was the consensus among speakers at the May 17 seminar in Berkeley, California, on sustaining power production at The Geysers, which was held prior to the U.S. Department of Energy's (DOE) Geothermal Program Review XVII.

DOE's Office of Geothermal Technologies (OGT) and the California Energy and State Lands commissions jointly sponsored the seminar. Its purpose was to review data from the Southeast Geysers Effluent Project (SEGEP), a pipeline from the Lake County Sanitation District's (LACOSAN) treatment plant that carries wastewater to the southeast portion of The Geysers steam field. Discussions also covered research results that have provided a better understanding of how the steam reservoir responds to large-scale liquid injection, and of the proposed effluent pipeline from Santa Rosa and neighboring communities.

Tom Box, Geysers resource manager for Calpine Corporation, organized the seminar and acted as its moderator. His opening remarks focused on the unique partnership developed during the planning, construction, and operation of SEGEP, as well as the fact that despite differing interests of the participants, the project was completed within budget.

Ben Barker, formerly with UNOCAL and now an independent consultant, then reviewed The Geysers injection history. As a result of greatly increased steam production and low injection rates in the 1980s, the reservoir pressure declined through most of The Geysers geothermal field. Steam production declined rapidly in 1989 and 1990, and industry requested DOE assistance to reverse the decline.

Barker reported that the field is "doing well" and is successfully responding to increased injection. He said the mass replaced by injection is about 65% of the steam produced, and that power generation has stabilized at an average of 950 MW over the last two years. Sixty percent of this capacity is now used for load-following, as opposed to its former use as base-load capacity. Capacity peaked in 1989 at 2000 MW, but it decreased with the retirement of old PG&E power plants 1, 2, 3, and 4. Installed capacity now stands at 1602 MW. Barker said that besides contributing to arresting the decline of power production, increased injection at The Geysers reduces production of hydrogen sulfide and carbon dioxide (a greenhouse gas) through the dilution by injection water of the natural fluid.

Barker gave credit to OGT for funding several significant research projects, such as the 1994 coring of well SB14 and the 1995 DV-11 injection tracer test. These projects, along with earlier research, gave UNOCAL the confidence to join other operators in the SEGEP agreement.

Mark Dellinger, a LACOSAN official, reviewed the 18-month operating history of SEGEP. Injection averaged 5700 gallons per minute (gpm) in April 1999. The district has plans to increase the pumping rate to 6200 gpm when Phase II of SEGEP (which will bring effluent from LACOSAN's northwest treatment plant) is connected to the present system. This project will require further industry commitments, which are being evaluated. He also stressed the environmental benefit of injection—it reduces contaminants in the produced steam.

Northern California Power Authority (NCPA) is the operator of SEGEP. NCPA Official Steve Enedy reviewed the results of increased injection since SEGEP came on-line 18 months ago. Injection in the southeast section of the reservoir has more than doubled to where it now replaces 80% of the mass produced. It accounts for one-third of The Geysers total steam production. The section's production is 40 MW greater than NCPA's earlier projections, which assumed an annual decline rate of 4.5%. Moreover, there is, in fact, an absolute increase in production of 9 MW. No decline in

reservoir superheat has been detected, but the amount of hydrogen sulfide in the produced steam has been reduced by 18%. Overall, Enedy expects SEGEP to extend the economic life of the field significantly.

Marshall Reed, a senior OGT program manager, followed with a review of DOE-sponsored Geysers research projects, which began in 1990. These included reservoir rock coring; laboratory water adsorption studies on minerals; documentation of the thermal and chemical geologic history of the system; evaluation of new injection water tracers; microseismic monitoring; and research on vapor-dominated systems. This research has resulted in the publication of numerous joint (industry/national, laboratory/university) technical reports and papers.

Miles Ferris, an official with the City of Santa Rosa Utilities Department, reviewed 1986 discussions with UNOCAL on piping Santa Rosa's reclaimed wastewater to The Geysers for injection. These discussions were the genesis of what came to be called The Geysers Recharge Project (GRP). A year earlier, the city's environmental impact report (EIR) on wastewater discharge was challenged in court and was found to be inadequate with respect to discharge alternatives. Subsequently, the city prepared an expanded EIR that offered four alternatives and selected the GRP as the preferred option.

The GRP, if fully developed, would increase injection by 7600 gpm into the central portion of The Geysers reservoir. Since additional water is available in the winter for pond storage, up to one-half of the wastewater could go to irrigation projects north of Santa Rosa. The dual usage of the treated effluent provides greater flexibility (weather-independency) and operational control.

Brian Koenig, formerly with UNOCAL and now a consultant, discussed future research and development programs for The Geysers. First, he detailed the differences between SEGEP and GRP. The latter proposes a 40% greater injection rate into the central portion of the reservoir where the non-condensable gases in the steam are considerably higher, ranging from 0.5% to 5%. The increase would allow operators to optimize large-scale injection by modifying operations based upon the results of experiments conducted with a comprehensive monitoring system. Increases in steam production, which are similar to those resulting from SEGEP, could occur, as well as possible augmentation from underlying regions at temperatures above the normal reservoir.

In some portions of The Geysers reservoir, primarily to the northwest, the steam has a higher non-condensable gas component and may locally also contain corrosive hydrogen chloride. At greater depths to the north and northwest, and possibly also under the central corrosive region, the steam may have significantly elevated temperatures (275° to 300°C or 527° to 572°F). Koenig called here for more research and field experiments to evaluate the potential for enhancing the geothermal system. The rewards from this effort would be increased production by mining the heat of unsaturated rock, while reducing corrosiveness due to chemical mitigation and curtailing non-condensable gas content in the steam by dilution.

Mike Wright, deputy director of the Energy & Geoscience Institute at the University of Utah, followed up by describing the potential of an Enhanced Geothermal Systems Program. He said that most convective and fractured geothermal reservoirs are thought to be underlain by a ductile intrusive body with temperatures of at least 700°C (1292°F), between which there is a conductive transition zone. The rocks in this transition zone tend to change from ductile (where there are no lasting fractures) to brittle properties below 370°C (698°F). Mining the heat (up to 340°C or 644°F) of the transition zone rock beneath The Geysers reservoir could yield the energy equivalent of a 12-billion barrel oil reservoir, which would rank this system among the top five fields in the world.

Mike Morrison, with the California State Lands Commission, explained the ownership rights of the geothermal resources at The Geysers. They are divided approximately into thirds between private, federal, and state ownership. All state royalties from steam production, and a portion of the federal royalties, supplement the state's Teachers Retirement Fund. "We support all projects that will enhance revenue," Morrison concluded. "The Geysers is one of them."

Box then summarized the positive prospects for The Geysers by reviewing Calpine's commitment to the field, as evidenced by its investments there since 1989, including its recent purchases of the UNOCAL and PG&E interests. Calpine now owns and operates both wells and power plants totaling 800 MW capacity, representing an investment of approximately $690 million. The company supports the GRP, which it expects will increase steam production while also reducing corrosion and non-condensable gases. He reported that preliminary injection tests in the northwest have resulted in a 40% drop in chlorides and non-condensable gases in the steam produced from offset wells. Increased production from shut-in wells is also anticipated, if corrosiveness and non-condensable gas levels can be reduced.

For more information about the seminar, contact Marshall Reed, U.S. DOE, at (202) 586-8076 or marshall.reed@hq.doe.gov.

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