DOE/EE-0091

Geothermal Progress Monitor

Report No. 17

December 1995

U.S. Department of Energy
Assistant Secretary for Energy Efficiency and Renewable Energy
Geothermal Division
Washington, D.C. 20585

Prepared in Cooperation with the
Interagency Geothermal Coordinating Council
with the Assistance of
DynCorp I&ET, Alexandria, Virginia

DISCLAIMER

CONTENTS

COVER PHOTO: The geothermally-heated campus of Oregon Institute of Technology at Klamath Falls. The campus also includes experimental geothermal aquaculture ponds and greenhouses and is home to the Geo-Heat Center which is celebrating its 20th year of operation.

The 1995 World Geothermal Congress (WGC) in Florence, Italy, highlighted the increasing role of geothermal energy as a world energy contributor. The Honorable Hazel O'Leary, Secretary, U.S. Department of Energy (DOE), delivered the keynote address to the WGC. In her address, she said, "This reliable, abundant, and environmentally-friendly resource which has been hugely successful in the U.S. is rapidly becoming a competitive source of energy worldwide." She added that "geothermal energy is ready to be put to practical use in many countries, and through cooperation between governments and with industry, we can accomplish this quickly."

More than 1,000 energy policy-makers and experts from 80 countries attended the WGC. The chairman of the Italian National Electricity Board noted that some of the delegates represented:

> "...Countries with the resources and other countries with technology and capital ... If we've managed to activate some synergies by the end of the Congress, we will have answered one of the important expectations with which the Congress-goers arrived in Florence... Only international cooperation makes it possible to optimize (geothermal) resources and move on to new horizons."

The technical sessions of the Congress explored state-of-the-art technologies and the innovative research which will create the methods of the future. The role of governmental policies and regulations and the impact of public/government/utility understanding of the resource were also considered at the WGC.

Secretary O'Leary also met with a roundtable of U.S. delegates, emphasizing her desire to hear of challenges facing industry and asking, specifically, how can the DOE support and assist the industry? Secretary O'Leary's responses to the delegates' suggestions and the results of follow-up meetings are described in the FEDERAL BEAT.

DOE is particularly concerned with reducing the costs of geothermal power generation, especially with the abundant moderate- to low-temperature resources in the U.S. This concern is reflected in DOE's support of a number of energy conversion projects. Projects which focus on the costs and performance of binary cycle technology include a commercial demonstration of supersaturated turbine expansions, which earlier studies have indicated could increase the power produced per pound of fluid. Other binary cycle projects include evaluations of the performance of various working fluid mixtures and the development and testing of advanced heat rejection systems which are desperately needed in water-short geothermal areas.

DOE is also investigating the applicability of flash steam technology to low-temperature resources, as an economic alternative to binary cycle systems. A low-cost, low-pressure steam turbine, selected for a grant, will be constructed to utilize fluid discharged from a flash steam plant in Nevada. Another project addresses the efficiency of high-temperature flash plants with a demonstration of the performance of the Biphase turbine which may increase the power output of such installations with no increase in fluid flow.

Field experiments are comparing data from slimholes with data from more expensive production-size wells. The aim is to reduce drilling costs by substituting slimholes for production-size wells for tests and data gathering during exploration and confirmation. The slimhole technology would not only reduce costs, but reduce the environmental impact of drilling as well.

Perhaps the most noteworthy feature of this issue of the GPM, the 17th since its inception in 1980, is the high degree of industry participation in federally-sponsored geothermal research and development (R&D). An active partnership between government and industry in geothermal development was envisioned at the inception of the federal program, and, today, this partnership is stronger than ever.

In addition to joint participation in research projects, DOE and industry have recently become partners in the development of additional commercial power generation capacity. The Department is offering financial incentives to offset industry's risks of installing new plants (or retrofitting existing ones) through its Geothermal Power Market Mobilization Initiative.

In response to the Program Review XIII (San Francisco, March, 1995) theme, "The Role of Cost-Shared R&D in the Development of Geothermal Resources," Ron A. Walter of Calpine Corp. told the audience:

> "I believe this method of funding to be one of the most effective ways that DOE can help industry to improve its product. Most of the projects I'm supporting today ... can be undertaken on a cost-shared basis since the focus is on near-term results ... The biggest mistake we could make is to ignore the present, and lose our existing hold on the market" while seeking long-range results for application "after the industry has disappeared."

SECRETARY O'LEARY OFFERS GEOTHERMAL INDUSTRY A HELPING HAND

In response to concerns expressed by geothermal industry spokesmen during the U.S. Roundtable at the 1995 World Geothermal Congress (WGC), U.S. Energy Secretary Hazel O'Leary stressed the importance of geothermal industry specialists taking their case to authorities and framing priority lists to which the federal government can respond. "The best advocates on behalf of the business are business people," she said, adding, "you are the ones who have to make up your minds what's needed in the long term, and take concerted action."

The Roundtable, held in Florence, Italy, on May 25, was attended by 40 representatives of the U.S. geothermal industry, 10 representatives of other U.S. organizations, including the national laboratories and several universities, and four representatives from the Department of Energy (DOE). In addition to Secretary O'Leary, DOE was represented by: Richard Rosenzweig, Chief of Staff, Office of the Secretary; Jeffrey Hahn, Geothermal Program Manager, Golden Field Office; and Allan Jelacic, Director of the Geothermal Division. The meeting was sponsored by the Geothermal Energy Association (GEA).

O'Leary emphasized her desire to hear the challenges facing the industry, including attempts in Congress to reform or repeal the Public Utilities Regulatory Policy Act of 1978 (PURPA), and industry recommendations on how to balance the various components of DOE's geothermal research program. Specifically, how can DOE support and assist the industry? This question, coupled with four brief industry statements, sparked further discussion.

Secretary O'Leary responded to industry recommendations by committing to:

- work with the industry in strengthening its competitive position through more technology R&D and helping to open foreign markets to U.S. products and services
- continue to fight for improved environmental conditions worldwide using clean energy technologies
- work with the Bonneville Power Administration to sustain its commitment to purchase power from two geothermal pilot projects in the Pacific N.W.
- spur completion of DOE's externalities study mandated by the Energy Policy Act of 1992.

She also called for a subsequent industry/DOE meeting to discuss research priorities and related issues. At the Secretary's request, the industry representatives continued discussions after the Roundtable in order to provide the Secretary with input on how DOE can be of greater assistance. Industry discussions during the Roundtable follow-up meeting elaborated on areas such as:

- the need to create a stable domestic power market as deregulation of the utility industry proceeds and to insure the security of existing power contracts

- the means to provide incentives to utilities to make long-term power purchase agreements

- a strong advocacy for implementing the results of the externalities study

- the continuation of high-level foreign trade missions including one or more persons from the industry to countries with significant geothermal potential such as Indonesia, the Philippines, and Latin America

- a study of U.S. tax laws to determine changes that could foster export of U.S. geothermal products and services

- the promotion of extended cooperation between the U.S. geothermal R&D program and the programs of other countries

- a more flexible and timely process for funding industry/DOE cost-shared R&D.

GEA SPONSORS WORKSHOPS IN RESPONSE TO O'LEARY'S SUGGESTION

In July, 1995 the GEA sponsored two subsequent workshops in response to Secretary O'Leary's Roundtable suggestion at the World Geothermal Congress. Attendance at the first workshop was restricted to representatives of the private sector. They were joined in the second by representatives of DOE, the national laboratories, and universities. The industry group identified and prioritized its chief technical priorities as itemized in Table 1. The industry's recommendations for the DOE geothermal R&D program are listed in Table 2.

During Workshop II, separate groups were formed to discuss research approaches in four areas:

- drilling and completion

- exploration, subsurface mapping, and fracture and permeability detection

- reservoir engineering and detection

- power plant systems, corrosion and scaling, and materials.

In addition to individual group meetings, several plenary sessions were conducted for all participants to discuss working group recommendations. A report covering the two workshops is available by contacting the GEA at (202) 383-2676.

FEDERAL FUNDING AVAILABLE TO OFFSET RISKS OF NEW GEOTHERMAL POWER CAPACITY

As reported in GPM No. 16, industry/government consortia were formed by DOE's Geothermal Division in response to the President's Climate Change Action Plan. The focus of these collaboratives is to promote the use of geothermal energy as a strategy for reducing greenhouse gas emissions, the objective of the President's plan.

Under the Geothermal Power Market Mobilization Initiative the federal govern-

Table 1. R&D Priorities Identified by Industry

Technical Area	Priority
Drilling—Conventional drilling, slim holes, and advanced technologies	**High**
Exploration and Subsurface Mapping—Permeability and fracture detection, reservoir mapping, conceptual models	**High**
Reservoir Assessment—Reservoir simulation, chemical control of permeability, tracer development, injection modeling	**High**
Corrosion and Scaling Prevention—Materials and coatings for subsurface and surface equipment	**High**
Energy Conversion—Dry steam, flash and binary cycles, heat rejection, noncondensible gas rejection	**High**
Cost-Shared Exploration Drilling—Industry-coupled drilling program	**Moderate**
Geothermal Heat Pumps—Stimulation of geothermal heat pump installations in residences, schools, commercial buildings (The Geothermal Heat Pump Consortium was not represented at these meetings)	**Low**
Heat Mining—Conventional hot dry rock, deep crustal heat, similar systems	**Low**

Table 2. Recommendations for DOE Geothermal R&D

Recommended Action
Program Focus—Focus the DOE research program more sharply on the goals of the component projects and the efforts of individual researchers. Focus R&D on items having large cost impact and large front-end costs. Use economic modeling as one guide to budget allocation. Perform systems studies where needed to determine highest-cost items.
Industry Oversight—Provide more industry input into and oversight of DOE R&D programs. • Make more effective use of advisory groups for technical programs in (1) drilling, (2) exploration, (3) reservoir mapping, and (4) energy conversion. • Provide recommendations on overarching priorities through institution of a GEA-sponsored advisory committee.
Controversial R&D—Establish effective industry review of and recommendations on controversial programs-hot dry rock, National Advanced Drilling and Excavation Technology program, laboratory involvement in export programs, others on a case-by-case basis.
Cost Sharing—Strengthen and provide more funding for the Geothermal Drilling Organization (GDO), the Geothermal Technology Organization (GTO), and the Geothermal Power Organization (GPO) as mechanisms for cost-sharing R&D work with industry.

ment will encourage: 1) additional geothermal capacity by providing financial incentives that help offset the initial drilling and plant installation risks associated with opening new hydrothermal fields, or 2) retrofitting existing plants. Proving new fields will encourage further investment in geothermal power generation and increase market share. This, in turn, will persuade companies to take greater risks in opening new hydrothermal fields and installing the first power plant. These field opening plants, known as ice breaker plants, range in size from 0.5 to 2 MWe and can be used as testing grounds for innovative technologies. Step-outs within existing fields are also targeted with power plant sizes up to 15 MWe, in order to minimize the investment risk of expanding a productive geothermal field. Further, efficiency improvements to existing plants using available and viable technologies are encouraged.

Fiscal year 1995 funding for this initiative was $800,000. The first award went to Earth Power Resources, Inc., for a geothermal binary plant at Lee Hot Spring in Nevada. The federal funds are earmarked specifically to offset power plant and transmission line costs and cannot be applied to the costs of developing a reservoir. The plant is described in detail in INDUSTRY SCENE.

Groundbreaking for the S.E. Geysers Pipeline and Injection Project, (Figure 1) another Power Market Initiative Project, was held on October 6, 1995, and the project is expected to become operational in early 1997. As described in GPM Issue No. 15, a 29-mile pipeline will carry up to 7.8 million gallons per day of treated wastewater effluent from the communities of Clearlake,

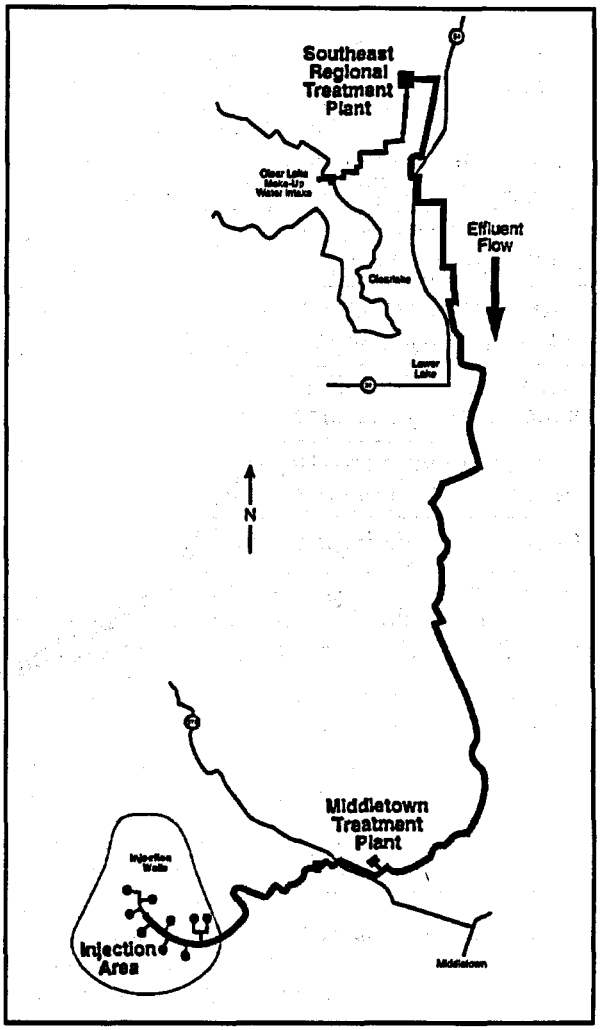
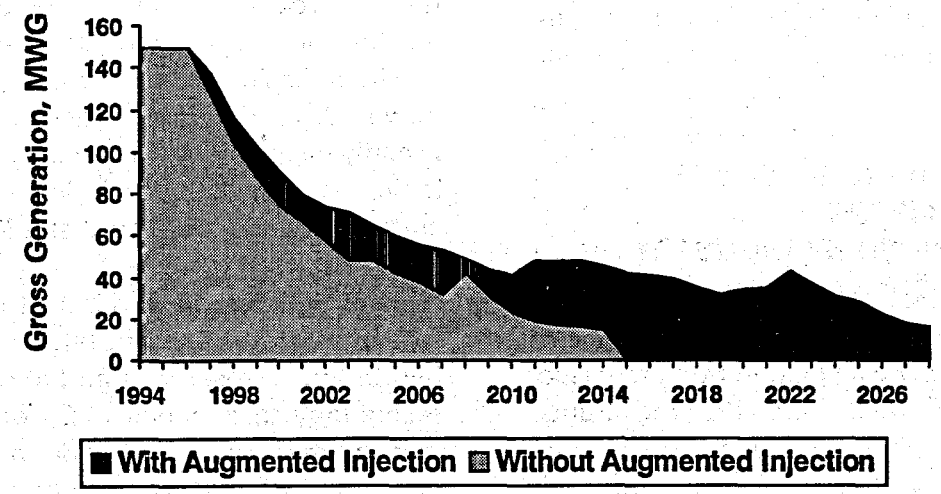


Figure 1. Southeast Geysers Effluent Pipeline

Lower Lake, and Middletown for injection into the southeast sector of The Geysers steam field. The project will serve both to sustain steam production at the field, producing an additional 70 MWe of generating capacity at existing plants, and to provide a publicly-acceptable method of wastewater disposal.

In addition, it may increase the royalty income of the federal government by about $71 million over the next 25 years. A royal-

ty of 12.5 percent on the value of the steam produced on federally-owned land at The Geysers, which accounts for about 55 percent of the total acreage in the SE portion, is paid to the federal government. Half of the total royalty income returns to the State of California which in turn distributes it among the California Energy Commission (CEC), a state royalty account, and the two counties of origin. CEC uses a portion of its share to fund loans and grants for innovative geothermal projects (See related article in STATE AND LOCAL.) Production in the SE area of the field represents a little less than 40 percent of the total Geysers production. Figure 2 presents the projected increase and sharing of royalties. (Source: Northern California Power Agency)



Source: Northern California Power Agency

Projected Impact of Augmented Injection on Royalties

	Augmented Injection		
Government Entity	**With**	**Without**	**Increase**
Bureau of Land Management	$75,400,000	$39,500,000	$35,900,000
CA State Account	$22,620,000	$11,850,000	$10,770,000
CA Energy Commission	$22,620,000	$11,850,000	$10,770,000
Lake County	$15,080,000	$7,900,000	$7,180,000
Sonoma County	$15,080,000	$7,900,000	$7,180,000
Totals	**$150,800,000**	**$79,000,000**	**$71,800,000**

Note: Royalties calculated on basis of entire field, including PG&E units. Gross generation projections are only for NCPA units, to represent the magnitude of improvement expected.

Figure 2. Projected Increases in NCPA Production and Royalty Payments Attributable to Cost-Shared S.E. Geysers Pipeline Project

A distinguishing hallmark of the project is its public/private financing plan that reflects the wide spectrum of interests impacted by the project. Construction costs are being shared by the geothermal industry, Lake County, California Energy Commission, the U.S. Departments of Energy, Interior, and Commerce, and the Environmental Protection Agency. The construction cost is approximately $42 million, including treatment plant improvements. Annual operating costs are estimated at about $2 million.

13TH ANNUAL GEOTHERMAL PROGRAM REVIEW WELL ATTENDED BY INDUSTRY

DOE's 13th Annual Geothermal Program Review was held in San Francisco March 14-16, 1995. The 120 registrants included a number of industry representatives as well as representatives of interested federal, state, and local agencies. Executives from Calpine Corporation, Northern California Power Agency (NCPA), Unocal Geothermal, and Pacific Gas & Electric Company (PG&E) discussed the public/private research that they consider important to the geothermal community. A number of industrial participants expressed interest in strong government support for their expansion in overseas markets. The GEA conducted a seminar on the status and direction of geothermal development in conjunction with the program review. See articles in INDUSTRY SCENE and TECHNOLOGY DEVELOPMENT for reports on presentations by various speakers.

USGS TO RESUME BASIN AND RANGE GEOTHERMAL INVESTIGATIONS; SEEKS INDUSTRY PARTNERS

After a hiatus of 10 to 15 years, the U.S. Geological Survey (USGS) is re-visiting geothermal prospects in the Basin and Range Province. The renewed study is focused on the northern Basin and Range, or Great Basin, where current geothermal power development is concentrated. The broadly based study includes plans for geologic, heat flow, hydrologic, and various surface-based geophysical studies.

The USGS is seeking industrial partners to investigate the potential for new hydrothermal reservoirs and to develop the technology to enhance the productivity of existing reservoirs. Its earlier studies of the area, conducted in collaboration with DOE's National Laboratories during the 1970's and early 1980's, were complementary to both regional and site-specific industry exploration, and were conducted without industry assistance. This independent approach to the studies was instituted in reaction to intense competition among geothermal operators and the uncertain status of land holdings, coupled with the lack of an appropriate mechanism for industry/government cooperative research.

More recent federal legislation has provided both a mandate and a mechanism for including industry in the USGS investigations. In particular, the USGS has been instructed by P.L. 102-486 (the Energy Policy Act of 1992) to enter into partnership with

industry and other governmental agencies to assess the potential of heat mining (or hot dry rock) on federal lands. In addition, the Technology Transfer Act (P.L. 99-502) provides for the establishment of Cooperative Research and Development Agreements (CRADAs) between federal laboratories and industrial or other non-governmental parties. The chief advantages of CRADAs over previous cooperative agreements exist in the specific safeguards to proprietary data and intellectual property that the non-government partner brings into the agreement. Such data and property are exempt from Freedom of Information Act requests by actual or potential competitors. There is also considerable flexibility and negotiating room regarding patents, copyrights, licensing, and disclosure of information developed jointly under the agreement.

The objectives of the USGS-industry partnerships are twofold—to assess and delineate the potential for additional hydrothermal systems in the Basin and Range Province and to assist in the design of reservoir-enhancement strategies. The potential for reservoir enhancement can be visualized in a qualitative manner by considering a spectrum of reservoir rocks as in Figure 3.

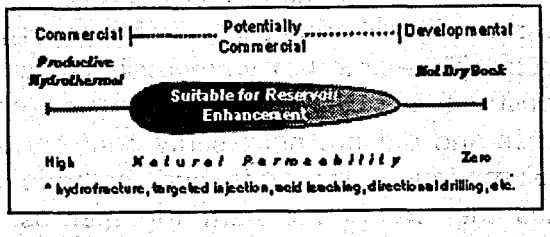


Figure 3. Permeability Levels for Commercial, Potentially Commercial, and Developmental Geothermal Reservoir Technology (Sass, 1995)

If reservoir enhancement strategies similar to those pioneered by the petroleum industry could be developed (for example, targeted injection and hydrofracture), the productivity of existing fields might be increased significantly, and currently uneconomic prospects could be brought on-line.

To date, one joint project has been developed with Oxbow Geothermal Corporation at its Dixie Valley, Nevada, power plant. The primary focus of the project is the investigation of stress, laterally and with depth. In addition, industry has provided considerable thermal data for the Great Basin, and the USGS is negotiating for additional data.

Those interested in teaming up with experienced Basin and Range geologists, geophysicists, hydrologists, and heat-flow specialists should contact the Geothermal Program Manager:

Manuel Nathenson
U.S. Geological Survey, Mail Stop 910
345 Middlefield Road
Menlo Park, CA 94025
Phone:(415) 329-5228
Fax:(415) 329-5203
Internet:mnathnsn@mojave.wr.usgs.gov

DOE CANCELS SOLICITATION TO CONSTRUCT FIRST COMMERCIAL HDR FACILITY

In October 1995, DOE canceled its December 1994 solicitation that sought partnership with private industry to construct and operate a facility producing and

marketing energy from a hot dry rock (HDR) resource. In conjunction with this decision, the hot dry rock research project at Fenton Hill, New Mexico, will be decommissioned. "Rather than pursue a commercialization goal," the Division's Director Allan Jelacic said, "the Department will refocus the geothermal hot dry rock program to work with industry and other interested parties to resolve the key technical issues." He added that Los Alamos National Laboratory is expected to play a continuing role in hot dry rock technology development.

Based on the results of the most recent flow testing at the Fenton Hill site, DOE first issued a Notice of Program Interest (NOPI) in 1993 to assess the potential for developing an industry-led project demonstrating that HDR technology can produce energy at competitive costs. This demonstration would set the stage for fully-privatized development of HDR projects by early in the next century. Forty-one responses to the NOPI were received from a wide variety of organizations, with 29 expressing a definite interest in participating in the project.

A follow-on solicitation was issued, which offered DOE funding of up to 50 percent of the total project installation cost, up to a limit of $30 million and a further $1.5 million per year in verification funding during the first three years of operation. When DOE participation ended, the private operator would have been free to take full possession of the project assets and to continue its operation indefinitely.

In order to facilitate DOE's revision of the hot dry rock program, a panel of industry experts met in December 1995 with members of the geothermal community at a workshop sponsored by the Geothermal Energy Association in Santa Rosa, California. They assessed the current status of the HDR program and developed recommendations which will be presented to DOE representatives. A report of the proceedings is anticipated in early 1996.

GEOTHERMAL ENERGY INCLUDED IN NATIONAL ENERGY MODELING SYSTEM

For the first time, U.S. energy policymakers have access to projected energy futures based on a single, comprehensive National Energy Modeling System (NEMS). The NEMS is a computer-based policy analysis tool which projects energy supply, demand, and prices based on assumptions about the state of the economy, energy markets, resources, technology, and demographics. DynCorp of Alexandria, Virginia, developed the Geothermal Electric Submodule (GES) for the system.

In the past, U.S. energy policy makers were limited to basing their decisions on alternative energy futures constructed from the outcomes of numerous models, each representing different aspects of the energy sector. These models were designed and constructed by various parties at different times and did not necessarily conform to assumptions, constraints, and methodologies that would tie them together as a coherent whole. The U.S. Energy Information Administration (EIA) developed the NEMS to remedy this shortcoming.

In the future, government policies affecting the geothermal industry, both directly and indirectly, will be based, in part, on multiple scenario analyses using NEMS. For this reason, it is important that the representation of geothermal energy within the NEMS is accurate and complete in order to facilitate rational decision-making in policy formulation. The EIA, in 1993, asked DynCorp to conceptualize the GES within a general framework outlined by NEMS developers. DynCorp prepared a component design report which laid the foundation for the creation of the geothermal submodule. EIA subsequently contracted with DynCorp to refine the design and construct the model code during 1993 and 1994. Although full integration of the GES within the NEMS was not possible in 1994, output from a stand-alone PC version of the GES was used as input to the NEMS to support EIA's preparation of the Annual Energy Outlook 1995 (AEO). The AEO-95 analysis projected U.S. geothermal electric capacity of about 4,500 megawatts by 2010.

DynCorp's efforts during 1995 have been focused on fully integrating the GES into NEMS. Results of the revised model will be published by EIA in the Annual Energy Outlook 1996 in early 1996. Copies of the document can be obtained from:

The Energy Information Administration
1000 Independence Avenue, SW
Washington, D.C. 20585

In 1994, $6 billion in contracts for 3,000 MWe of new geothermal projects was awarded by developing countries to the U.S. geothermal industry, on top of 1,200 MWe already being generated overseas as a result of equipment and services provided by U.S. companies. These foreign projects create jobs for Americans and help maintain a clean worldwide environment.

Secretary O'Leary
U.S. Department of Energy

GEOTHERMAL CAN "SURVIVE AND FLOURISH" SAYS CALPINE'S WALTER; NEED TO FOCUS ON KEEPING INDUSTRY ALIVE THROUGH TURBULENT PERIOD

"I believe in geothermal. I believe it can survive and flourish," Ron A. Walter of Calpine Corporation told the Geothermal Program Review XIII audience in March 1995. He added,

> "We need to focus our resources on keeping the industry alive while we go through this turbulent period...put our limited private and public resources into weathering the storm and bringing the industry through to a future time when geothermal is solidly planted in the country's mix."

Walter defined the "storm" as a world of deregulation, increased competition in electric generation, and low gas prices, as well as very limited federal R&D funds. He urged DOE's Geothermal Program to undertake only the highest impact projects. He suggested that DOE focus its efforts, with industry support, on three elements:

- extending the life of existing facilities and associated resources
- directly lowering the cost of geothermal power
- the near term.

Walter focused on extending reservoir life by suggesting the importation and injection of water into fields where only a small fraction of the heat has been consumed, but water for heat transfer is limited, such as The Geysers (See related article in FEDERAL BEAT). He thanked DOE for its support of the Lake County Wastewater Project, and noted that Calpine is considering another wastewater project with the City of Santa Rosa which is five times the size of the Lake County project.

In addition, he stressed that DOE can make a difference in future productivity in all reservoirs by finding ways to make injection more efficient and by adapting cost-effective heat rejection techniques that reduce the amount of water lost to evaporation. The development of lower cost dry cooling and wet-dry cooling systems, he added, can extend reservoir life and reduce costs of power generation. Walter suggested that DOE's continued support of the following will further reduce the incremental cost of power:

- R&D to reduce drilling costs
- effective corrosion control and mitigation systems
- material testing and identification.

Walter noted that the theme of Program Review XIII was "The Role of Cost-Shared R&D in the Development of Geothermal Resources," and said,

> "I believe this method of funding to be one of the most effective ways that DOE can help industry to improve its product. Most of the projects I'm supporting today...can be undertaken on a cost-shared basis, since the focus is on near-term results."

INDUSTRY URGES "SECOND LOOK" AT GEOTHERMAL RESERVOIR TECHNOLOGY

In response to geothermal market conditions created by continuing low natural gas prices, Dick Benoit of Oxbow Power Services told the Program Review XIII audience that,

> "This is a questionable time to be spending any research dollars in specifically discovering new reservoirs for which power sales agreements are unavailable ... Instead, now may be the optimum time to catch our breath and take a look around existing fields and start to clean up some unfinished business."

Benoit stated that the unfinished business is to assess the value of the various techniques in both locating reservoirs and defining the margins of known resources. He noted that the latter is particularly important, since the bulk of drilling is within the known reservoirs as makeup production wells are drilled and injection strategies are fine tuned. To minimize dry holes, "the game for the next few years," requires confidence that the reservoir margins or the limits of permeability can be reliably determined.

Benoit also stressed that the geothermal industry is continuing to undergo consolidation resulting in fewer geologic studies by experienced geologists. Geologic studies are, in Benoit's view, "one of the essential components of the available exploration tools." Therefore, their validity and limits must be double checked especially as, in his words, "we are staking our future" in international exploration and development over the next several years. "International projects also have dry hole risk," he said, "and over time other technologies will force geothermal to reduce its foreign exploration costs (dry holes) as is happening at home."

DOE GRANT AWARD TO OFFSET COSTS OF NEW BINARY PLANT

An $800,000 grant to offset power plant and transmission line costs was awarded to Earth Power Resources, Inc., in support of a 5 MWe geothermal binary plant at Lee Hot Spring in Nevada. The model plant has a power sales contract in place, as required by DOE in its solicitation for cost-sharing under DOE's Energy Partnerships for a Strong Economy program. The plant's initial output will be transmitted 18 miles north to the Sierra Pacific Power Company Fallon Substation. The 69 kV transmission line will be constructed as part of the DOE-supported project. A plant expansion of 15 MWe is planned, and may require rerouting of the northernmost 12 miles of the line to Sierra's Fort Churchill facility.

Two (or three) shallow geothermal production wells pumping approximately 1,875 gallons per minute of 138°C (280°F) fluid will be required for the first, and each succeeding 5 MWe unit. Based on previously drilled wells at Lee Hot Spring, neither the production wells nor the injection wells should exceed 2,500 feet. The injection wells will be located several thousand feet from the producing wells.

The plant will employ generic binary power technology with overall process flow and engineering services provided by Earth Power. The company will adapt or use technological improvements such as a new, less expensive downhole pump. Five 1 MWe output turbine generators will be used, rather than a single 5 MWe turbine expander.

The objectives of the DOE solicitation under the Geothermal Energy Partnership program are to:

- promote the commercialization of geothermal energy for the production of electrical power
- reduce the emission of greenhouse gases in the U.S. by offsetting the use of fossil fuels.

The accomplishment of these objectives will create jobs and better position the nation's geothermal industry to compete and win in the global marketplace.

CALPINE CORPORATION REPORTS RECORD EARNINGS FOR 1994; RAINFALL AFFECTS BOTTOM LINE

On April 10, 1995, Calpine Corporation, the San Jose-based independent power producer, reported record earnings for 1994. Net income for 1994 was up 60 percent, to $6 million, compared with $3.8 million in 1993. Revenue in 1994 was $94.8 million, an increase of 36 percent over 1993 revenue of $69.9 million. Calpine's 1994 earnings reflected the success of the geothermal and gas-fired facilities in performing at peak efficiency, averaging 99 percent availability, and from a favorable year for geothermal power in California, where low rainfall limited the production of hydroelectric power.

An abundance of low-cost hydropower in the first quarter of 1995, due to heavy rainfall, led PG&E to curtail its steam purchases from Calpine at The Geysers. However, the company reported quarterly revenue of $22 million, up some $2 million over the first quarter of 1994. The increase was attributed primarily to income from Thermal Power Company (TPC), which Calpine acquired in September 1994. TPC owns a 25 percent interest in 550 MWe in The Geysers steam field. Net income for the quarter was $59,000, compared with $858,000 in 1994, reflecting expected curtailment in the company's geothermal operations.

Source: GRC Bulletins 5/95 and 6/95

GEOTHERMAL COMPANY PRESIDENT WINS AN ENERGY PIONEER AWARD

On May 4, Dr. Tsvi Meidav, President of Trans-Pacific Geothermal Corporation of Oakland, California, received an Energy Pioneer Award from DOE for his outstanding work in the development of geothermal energy. Under Dr. Meidav's direction, Trans-Pacific has developed geothermal energy projects for power generation in Dixie Valley, Nevada, and Wendel-Amedee, California, and has a contract with the Bonneville Power Administration for power generation in the Pacific Northwest. In addition, Trans-Pacific is developing a geothermal energy project in Nicaragua. Dr. Meidav served as President of the National Geothermal Association in 1993.

GEA OPENS WASHINGTON OUTREACH OFFICE

The Geothermal Energy Association (GEA) has established a new office in Washington, DC to better assist its members in addressing issues affecting the business environment in which it operates. Located just a few blocks from the U.S. Capitol, the GEA is housed with the U.S. Export Council for Renewable Energy and several of its other member associations, including the American Wind Energy Association, the National Hydropower Association, and the Solar Energy Industries Association. From this office, the GEA conducts activities which focus on:

- strengthening the domestic market
- providing education and outreach
- facilitating the export of U.S. geothermal and related goods and services
- interacting with federal and state government offices, lending institutions, environmental and advocacy groups.

A separate organization directed by the GEA Board, the Geothermal Resources Association, was created to solicit and receive contributions from companies and individuals for lobbying activities authorized by the GEA.

The domestic market program supports activities vital to the existence and future of geothermal power production in the U.S. These include:

- preserving the provisions of PURPA that stimulate the development of renewable energy sources
- policies that will enable geothermal energy to remain a viable option as the electric utility industry restructures
- tax reform
- royalty issues
- export legislation.

To increase awareness of the benefits and potential of geothermal energy, the education and outreach program is developing written and audio-visual materials. These will be distributed to a variety of audiences including utility executives, federal and state government representatives, environmental groups, and the general public. Seminars and workshops are also conducted as part of this effort.

The export program compiles and distributes information on foreign geothermal resources, prospects, and projects to facilitate the U.S. industry's participation in the rapidly expanding export market. Other aspects of the export program include:

- tracking and assessing legal, financial, and political situations abroad that may affect geothermal development
- defining export barriers
- providing guidance to GEA member companies seeking project funding from domestic and foreign government agencies, multilateral banks, and various other lending institutions.

The office is currently staffed by Perle Dorr, Director, Outreach and Ann McKinney, Director, Export Programs. It is located at:

122 C Street, N.W., Suite 400
Washington, D.C. 20001
Phone: (202) 383-2676
Fax: (202) 383-2678

CYCLING OF UNITS AT THE GEYSERS PROVIDES FLEXIBILITY IN OPERATIONS; REDUCES STEAM DECLINE RATES

The Geysers Power Plant of PG&E has operated as a baseload resource except for infrequent, relatively short periods of loading curtailments during its 30-year history. However, in August 1994, PG&E and its largest steam supplier, Unocal-Thermal, executed new steam sales agreements which permit PG&E to cycle (vary) generation. Steam field operators view cycling as a means of reducing overall average steam flow production and generation output, which should result in lower rates of steam pressure decline. Since generators cycle other resources to meet customer electric demand, they see this practice as a means of providing more flexibility in geothermal operations. In fact, the Northern California Power Agency began cycling its Geysers units in 1988 and has reported that:

> The well decline rates, and the decline of total steam field potential, have been reduced in severity and actually temporarily reversed in trend when reductions have been made ... in the amount of power being generated.

PG&E has curtailed its geothermal units approximately 2,500 times since the new sales agreement was signed, deferring over two million MWh of electrical production when customer demands (e.g., minimum system conditions) did not require as much generation as The Geysers was capable of producing—such as early morning hours from 1:00 to 5:00 a.m.—or when power could be purchased cheaper elsewhere.

Cycling generally occurs on a daily basis or during a weekend (when commercial and some industrial load demand is reduced compared to daily demands), but can occur during weekdays as well. PG&E has shut down as many as eight of its twelve Unocal-Thermal supplied units for up to five months at a time.

There are several benefits of cycling operations. From a utility standpoint, cycling helps keep customer utility bills lower by allowing the utility to defer geothermal generation when lower cost power is available. Cycling should also extend the life of geothermal resources since steam not used to generate electricity is left in the reservoir to be used in the future. A third benefit is a short term increase "puff" in generation after the curtailed phase of the cycle. The amount of "puff" varies depending on the size and duration of the curtailment preceding it and on the characteristics of the steam reservoir, but in some cases can exceed 10 percent of the prior base generation level.

The problems associated with cycling operations include:

- decreased revenues to geothermal developers and generators
- thermal cycling of steam well bores
- water collection in steam gathering systems
- water carryover to separators and turbines
- possibly, an increase in noncondensible gases when generation is increased following a period of curtailment or restrained operation.

PG&E and Unocal are working to determine what changes in operating procedures and practices and what physical changes to equipment are needed at The Geysers to mitigate or eliminate these problems.

Source: Personal communication, Dean Cooley, Senior Engineer, PG&E Geysers Power Plant.

RESULTS OF SUCCESSFUL MODEL BIPHASE TURBINE TEST TO BE VALIDATED IN FULL-SIZE DEMONSTRATION; OTHER ENERGY CONVERSION TESTS UNDERWAY

A test of a model rotary separator turbine—the Biphase turbine—on a low-pressure geothermal well indicated a turbine efficiency range from about 10 percent at the lowest enthalpy to 46 percent for the highest enthalpy (dry, saturated steam). The turbine efficiency is defined as gross shaft power divided by enthalpy difference from inlet to exit.

The turbine, invented in 1975, generates power from mixtures of steam and brine, and internally pressurizes the separated brine. After developmental testing, a full-size unit was installed and demonstrated with the full flow from a geothermal well at Roosevelt Hot Springs, Utah. A schematic of a full-size system is shown in Figure 4. The unit generated 1600 kWe and demonstrated a 20 percent increase in power output above a single flash turbine. As a result of this 4,000 hour demonstration, the Electric Power Research Institute deemed the Biphase turbine to be a viable commercial technology. Subsequently, an advanced Biphase turbine has been developed to overcome two limitations in the original technology. This advanced equipment reduced the number of rotors from three to one to reduce costs, and steam blading was incorporated to permit conversion of the kinetic energy of the separated steam.

DOE, the CEC, and Douglas Energy Company (the developer), are cost-sharing a program to demonstrate the commercialization of the advanced Biphase turbine. The test site for the sub-scale model was provided by the California Energy Company at Coso Hot Springs, California, and the installation site for the full-size demonstra-

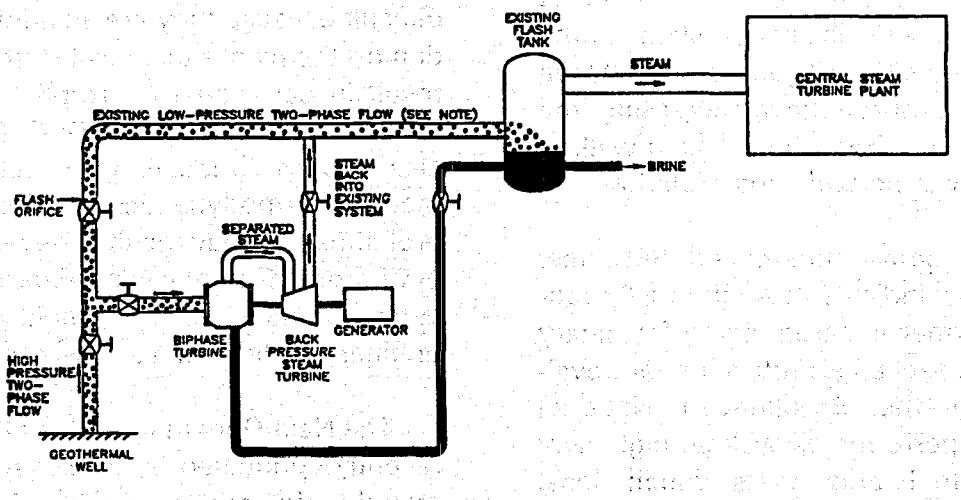


Figure 4. Arrangement of Biphase Wellhead Power Plant

tion is Cerro Prieto, Mexico, where the Comision Federal de Electricidad is providing a well which supplies steam to a 180 MWe power plant.

The well used at Coso had been inactive for a period of time and was very unstable when activated for the test. The wide fluctuations in flowrate, steam fraction, and pressure produced a wide range of operating conditions, virtually all of which were off-design for the turbine. However, analysis of the off-design performance agreed fairly closely with the predicted results. The most significant result of the sub-scale demonstration was the validation of a steam blading performance model which will be used to design the full size Biphase turbine.

The full-sized turbine is designed for operation in a wide range of geothermal well conditions. Variations in pressure, steam quality, and flowrate are accommodated by changing simple nozzle inserts. It is predicted that the Biphase system, as designed for the wellhead conditions of the demonstration site, will generate 4,150 kWe from the two-phase flow, increasing the power produced from the selected well by 45 percent with no additional well flow.

In other conversion-related R&D, test results to date indicate that a thermally conductive polymer concrete lining for binary system heat exchanger tubes, under development by the Brookhaven National Laboratory, performs as well as high-alloy stainless steel and costs much less. Eventually, this material could permit the use of a binary bottoming cycle which would increase energy extraction from high saline brines. Tests of the lined tubes have been conducted at a Magma Power Co. plant. The lining material is also being evaluated at The Geysers for use in conjunction with caustic injection systems.

NREL ESTABLISHING GEOTHERMAL CONVERSION FACILITY

The Geothermal Program at the National Renewable Energy Laboratory (NREL) in Golden, Colorado, is establishing a Geothermal Energy Conversion (GEC) Facility. The objective of the new facility is to develop a strong in-house technical capability in geothermal energy conversion technology where innovative ideas can be tested, evaluated, and demonstrated on a small scale. It will provide an opportunity for the geothermal industry to experiment and evaluate ideas that have sound theoretical basis but require proof of concept. Conducting such tests in existing geothermal power plants is usually expensive and difficult because they are an additional burden on the plant's technical staff and might result in occasional interruption or power capacity reduction. The GEC facility will also serve as a location for testing fundamental thermodynamics and heat transfer problems that may result in development of new, more efficient cycles. Examples of the latter potential are metastable expansion, or binary cycles with various working fluids.

The Next Generation Power Plant study, recently conducted by NREL, showed that mixed-hydrocarbon working fluid binary systems are one of the best systems with low levelized cost of electricity production which can be applied to low-temperature

geothermal resources. However, more information about working fluid choice is needed to permit more rapid commercialization of the concept. In addition, since water conservation is a major environmental issue in most geothermal areas, advanced heat rejection systems need to be developed and tested to improve the performance of binary cycles based on their location and specific needs, especially for cycles using working fluids with two or more components.

NREL is inaugurating the GEC Facility by conducting experiments on dry and wet/dry cooling systems and on boiling/condensation of mixed hydrocarbons. These special experiments will identify considerations that might be required for heat rejection systems, and the penalties associated with fractional condensation of the mixed working fluids.

All dry cooling systems will be tested, followed by wet heat rejection systems using surface condensers with working fluid on the shell side and water in the tube. These tests will complement the dry cooling test results and provide a background for a set of experiments on staged wet/dry systems. These systems will be set up in series, enabling careful examination of the split between the wet and dry portions. Various staged systems will be tested to identify the most efficient system for condensing the mixed hydrocarbon working fluid. Strategies such as addition or removal of high volatile working fluid to or from the heat rejection system will be considered.

NREL will also carry out tests to characterize different boiling domains and the attendant heat transfer mechanisms for convective boiling in a horizontal tube. The effects of fluid composition, flow rate and boiling surface on the boiling incipience, heat transfer coefficient, and the critical heat flux will be investigated. The data obtained for a number of binary mixtures will be used to test the validity of the models and correlations in the existing literature so that plant designers can optimize heat transfer and avoid dryout conditions. All tasks are scheduled to be completed by September, 1997.

Initial support for operation of the GEC Facility will be provided by DOE, although NREL is seeking to attract industry participation and collaboration by publicizing the facility's capabilities and by directly contacting the U.S. geothermal industry.

COMMERCIAL DEMONSTRATION OF SUPERSATURATED TURBINE EXPANSIONS UNDERWAY

Studies at the Idaho National Engineering Laboratory (INEL) have indicated that the performance of binary geothermal power cycles could be improved by utilizing metastable, supersaturated turbine expansions. One study indicates that an optimized cycle for a 173°C (350°F) brine would have a nine percent increase in the brine effectiveness (power produced per pound of fluid), if these expansions are allowed. However, industry has avoided these operating conditions because of the possible presence of condensate which might adversely offset performance or damage turbine internals. INEL studies and short-term testing suggested that the condensate might not form, and that if it did, the droplets would be too small to create problems.

Further tests are underway at Mammoth Pacific's Unit 100 (MPI) plant in the Mono-Long Valley of California to determine the commercial feasibility of extended operation with metastable turbine expansions. Results from Phase I of these tests indicate that it is feasible to operate the turbine at Unit 100 for an extended period with inlet conditions that will produce the desired degree of supersaturation during the expansion process. By monitoring the performance of the turbine over extended testing periods and examining the turbine internals at the conclusion of testing, the long-term effects of these expansions can be determined.

The rotor and nozzle set in the MPI Unit 100 turbine was replaced with new parts of the same design as those previously used. Prior to the installation of the new parts, their critical dimensions were measured and recorded, and the pre-operation condition of the surfaces that will be exposed to the expanding vapor was documented with photographs.

Next, the turbine was brought to typical inlet conditions—nominally 400 psia and 123°C (253°F)—and operated until it was determined that its operation was "normal." Performance at this point provides the reference baseline point for future data collection at 12-hour intervals. The operating condition for the extended test will be established at the highest turbine inlet pressure that does not produce a degradation in turbine efficiency by more than five percentage points from the efficiency at the baseline condition—i.e., a drop in efficiency from 80 percent to 75 percent. At the conclusion of the test, or in the event that the operation is prematurely terminated because of a degradation in performance, the turbine rotor and nozzle set will be examined and the post-test condition of each component recorded.

During the off-peak winter period, generation at the other plants can be increased to make up for any reduction in performance at Unit 100. At the start of the next peak period—summer 1996—Mammoth and INEL will decide, based on Unit 100 performance, whether to continue in the metastable expansion mode. Results of the extended testing will be reported to the geothermal industry at forums like the annual meeting of the Geothermal Resources Council.

LOW-TEMPERATURE FLASH STEAM GEOTHERMAL POWER PLANT TO BE DEMONSTRATED

High cost, equipment-intensive binary plants are currently required to produce power with low-temperature geothermal fluids. However, a DOE-supported project is designed to demonstrate that, with a new steam turbine design, a low-temperature flash steam plant can produce lower cost power than a binary plant.

A flash steam plant will be constructed to produce a nominal 4,690 kW of electrical power from 110°C (230°F) fluid that is currently discharged from the Dixie Valley, Nevada, 50 MWe plant of Oxbow Geothermal Corporation. If the project is successful, it may lead to a market for domestic and international geothermal power plants used in bottoming applications or with low-temperature resources. In addition, it may increase the portion of U.S.

resources at temperatures lower than has been traditionally considered for flash steam technology that can be developed economically. The installed cost of the proposed flash plant will be less than $1,100 per kWe, compared to an installed binary cost greater than $1,760 per kWe. It is also expected that the flash plant operating and maintenance costs will be lower.

While the flash plant maintains a cost advantage for the heat addition and heat rejection systems, there are currently no steam turbines on the market that can handle the steam flow rate for a low-temperature flash plant. Existing low-pressure turbines are designed for higher pressures than typical of low-temperature resources. They can be modified to handle lower inlet pressures by removing the higher pressure stages. However, this approach increases the cost of the turbine (on a $1 per kWe basis), and the resulting cost of power is not competitive.

Therefore, the critical component of the demonstration project is a low-cost, low-pressure steam turbine (see Figure 5). It will be designed and supplied by Barber-Nichols, Inc., which has considerable experience in developing turbines for a wide range of applications.

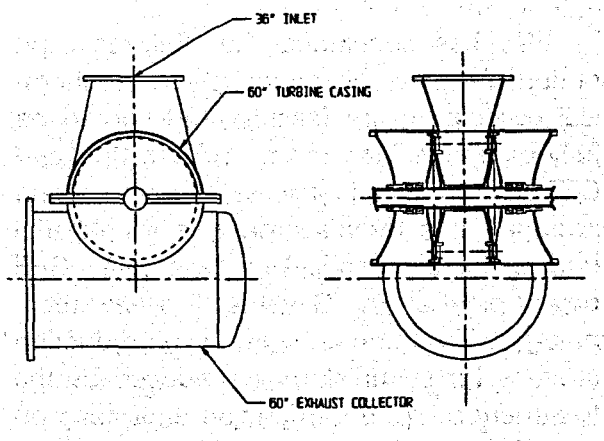


Figure 5. Low Pressure Steam Turbine

PROCESS FOR PRODUCING A REVENUE - GENERATING FEEDSTOCK TO OFFSET OPERATING COSTS IS PRIMARY TASK IN CONTINUING GEOTHERMAL WASTE TREATMENT R&D

Development of cost-efficient biochemical processes for the treatment of geothermal brines and sludges has led to the identification of several options which may allow the conversion of geothermal wastes into useful products, while reducing waste volume. Interphasing metal and metal salts recovery options with the initial waste detoxification process may generate revenues that can offset the cost of the initial investment in the process.

The Advanced Biochemical Processes for Geothermal Brines program at Brookhaven National Laboratory (BNL) has determined that the most efficient primary process utilizes two biocatalysts. The production and rate of recovery of these biocatalysts influences the size and number of bioreactors needed for operation. The fact that the rate of Biocatalyst 1 production is fast, and that of Biocatalyst 2 is slow, influences the cost of production; further, whether a 50:50 or 85:15 mix of the two is used significantly influences the economics of the process. However, three additional factors have to be taken into consideration: 1) recycling of the biocatalysts; 2) recovery

Table 3. Cost Comparison for Different Biocatalyst Mixes and Corresponding Total Bioprocess Costs per Metric Ton of Sludge

	*BC1:BC2	BC1:BC2	BC1:BC2
	50:50	85:15	85:15 (3 recycles)
	250 gal/h: 250 gal/h	425 gal/h: 75 gal/h	106.25 gal/h: 18.75 gal/h
BC1			
Capital Cost (CGR)	1,838,000	2,556,000	1,196,000
Annual Treatment Fee	1,097,000	1,778,000	820,000
Unit Treatment Fee ($/metric ton)	145	138	255
BC2			
Capital Cost (CGR)	7,017,000	2,573,000	1,002,000
Annual Treatment Fee	3,683,000	1,687,000	736,000
Unit Treatment Fee ($/metric ton)	486	743	1,298
BC1 + BC2			
Capital Cost (CGR)	8,855,000	5,129,000	2,199,000
Annual Treatment Fee	4,449,000	3,466,000	1,556,000
Unit Treatment Fee ($/metric ton)	316	229	411
Total Bioprocess Costs Including Biocatalyst Production			
Capital Cost (CGR)	10,195,000	6,493,000	3,415,000
Annual Treatment Fee	5,882,000	4,578,000	2,614,000
Unit Treatment Fee ($/metric ton sludge)	316	246	140
*BC = Biocatalyst			

of valuable metals; and 3) recovery of salts such as sodium chloride and potassium chloride. Significant savings are possible when using different biocatalyst mixes and recycling, as evident in Table 3.

The combination of the biocatalyst mixes and a potash recovery option shows the net monetary gain that may be accomplished by combined processing (see Table 4).

While the recovery process is being further optimized, the current cost estimates, based on an estimated 80 percent metal removal, are calculated as follows:

Table 4. Total Biochemical Process Cost Estimates Including Potash Plant Option for a 50 MWe Power Plant

BC1:BC2	Net Gain in $millions/year
50:50	1.83
85:15	2.74
85:15 3 recycles	5.51

- BNL costs of $500/ton of wastes processed
- non-regulated waste disposal cost of about $100/ton
- sludge containing sodium in addition to chromium and lead
- shipment at a cost of $400/cubic foot.

On the other hand, removal of the metals to isolate radium produces waste with disposal cost of $76/cubic foot, or $10,800 and $2,052 per ton, respectively. These costs represent a fivefold savings already achievable at the current scale of operations.

BNL has concluded that full recycling options for materials generated by biochemical processing are feasible and should be fully explored. Through a CRADA, BNL and CET Environmental Services, Inc. are making arrangements for placement of a field trial unit of the biochemical process at a PG&E power plant at The Geysers. The new technology will be applied as a waste reduction strategy for sulfur slurries produced by the treatment of hydrogen sulfide emissions on one of The Geysers plants. The unit has been selected, with groundbreaking expected in the spring of 1996.

RECENT DEVELOPMENTS IN FLUID CHEMISTRY AND PHENOMENOLOGICAL EQUATIONS INCORPORATED IN GEOTHERMAL BRINE CHEMISTRY MODELS

The Chemistry Department at the University of California at San Diego is continuing its program under an ongoing contract with DOE to improve the productivity of geothermal resources by developing modeling tools for predicting and mitigating associated chemical problems. For this purpose, they have incorporated recent developments in their computer models. For example, the updated models accurately predict the measured chemical behavior of brines (e.g., scale formation), the solubility and liquid-vapor coexistence of gases, and other thermodynamic properties (e.g., heat content) by using recent developments in chemistry of fluids and gases, especially parameterization. In addition, gas modeling utilizes recently developed phenomenological equations which can utilize PVT properties in both the liquid and gas phases, liquid-vapor coexistence, and other useful thermodynamic functions.

Recent results of the research include a final model of the H_2O - CO_2 - NaCl system that can predict properties such as the PVTX behavior, gas phase solubility, and multiple phase equilibria for the solid, liquid, and gas phases. This equation of state (EOS) is possibly the first EOS that can predict phase equilibria and volumetric properties in a system containing salt, liquid, and gas. Another product of this research is a model for predicting H_2S solubilities in NaCl-bearing

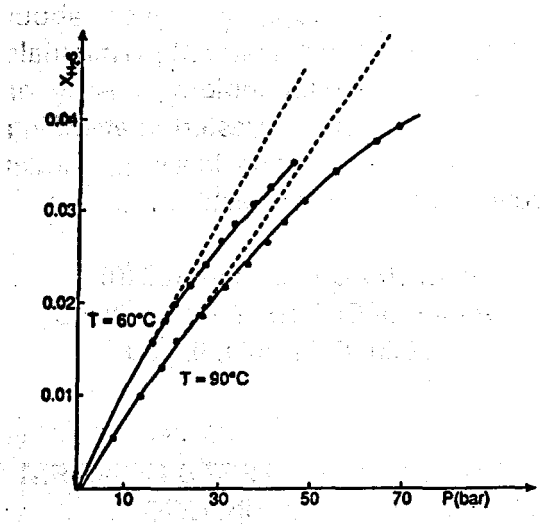


Figure 6. The Solubility of H_2S in H_2O As a Function of Pressure

aqueous solutions at higher pressures than previously published H_2S solubility models (Figure 6). Current activities include: testing of a seawater model, which includes parameterization to high temperatures and very high ionic strength; and initiation of a combination of the variable temperature seawater and carbonate model.

The models are compared to laboratory and field data for validation. Therefore, they provide an effective means of summarizing, comparing, and validating the geothermal chemical data presently available. They are included in user-friendly application packages called TEQUIL, GEOFLUID, and GEOHEAT (under development) which can be copied from diskettes to personal computers. User oriented graphical interfaces are developed and updated to facilitate the use of the software.

Periodic workshops are given about these programs and instruction manuals are updated as new technology is ready for application. Anyone interested in attending a workshop or presenting ideas for model improvement should contact:

Chemistry Department (0340)
University of California at San Diego
La Jolla, California, 92093

BEOWAWE TRACER TESTS CONFIRM EXCELLENT COMMUNICATION BETWEEN INJECTION AND PRODUCTION WELLS

To assess the effects of recent changes in the injection strategy at the Beowawe geothermal field in north-central Nevada (Figure 7), a DOE-funded interwell tracer test using fluorescein and tinopal CBS was initiated in 1994. Fluorescein return curves (Figure 8) established injection-production flow patterns and verified that produced water is being injected into a region of the reservoir that is in excellent communication

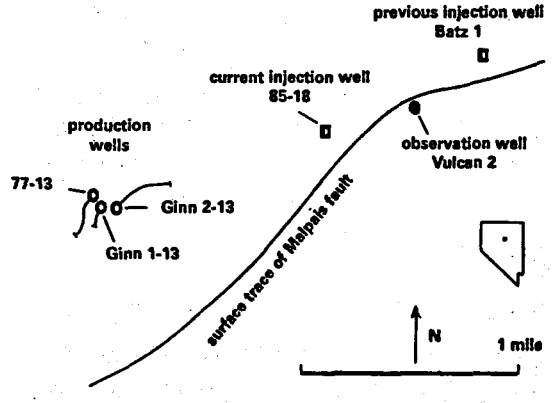


Figure 7. Location Map of the Beowawe Geothermal System

with the production wells. A tracer return of 38 percent was calculated.

Plots of fluorescein vs. time are as follows for each of the three production wells monitored:

- The maximum concentration in the first well in which the dyes were observed was detected only 17 days after tracer injection. In contrast, peak concentration in the other two wells were detected at 30 days and 35 days, respectively, indicating a much shorter and/or direct path between the injection well and the first production well than that between the injection well and the other two producers.

- By contrast, the curve shows that tinopal CBS was detected at only the first well, and only a 1.6 percent return of the tinopal CBS was calculated. This result, and the fact that the compound had been shown to be resistant to thermal decomposition under laboratory conditions, led to the conclusion that tinopal CBS was absorbed on the reservoir rock. Absorption would also serve to explain the fact that tinopal CBS was not detected at the two more distant wells—the path to which would expose the compound to greater rock surface area and, consequently, a greater opportunity for absorption.

- When the results of the 1994 test were compared with one conducted in 1990, the effects of the use of distinctly different injection strategies were revealed. In 1990, an injection well was used that had been shown through interference

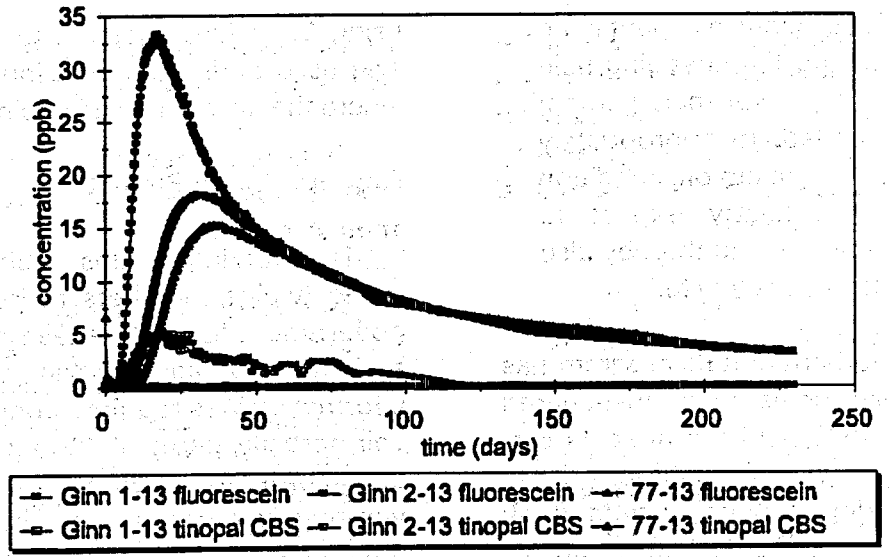


Figure 8. Beowawe Tracer Test: 1994

testing to be unconnected to the main reservoir, providing a rare opportunity to inject produced reservoir water without the risk of prematurely cooling the reservoir. However, the return curves were broad and flat, with only 8 percent of the tracer being returned. By contrast, in the 1994 test, an injection well that had been shown by interference testing to be strongly connected to the main reservoir was used, and the return curves revealed strong conductivity between the injector and the producers.

An analysis of the cumulative tracer return curve was used to estimate the overall (fractures and matrix) Beowawe reservoir volume at 2.4 billion gallons. Recently, a significant increase in reservoir pressure was observed, in contrast to the pressure decline which occurred after the addition of a third production well in 1991. Details of the test are described in a paper jointly presented at Geothermal Program Review XIII by representatives of the Earth Sciences and Resources Institute (ESRI), University of Utah, and Oxbow Power Services, Inc.

COST-SHARED R&D CONTINUES AT THE GEYSERS

The preliminary results of four cost-sharing projects at The Geysers were reported to Geothermal Program Review XIII in San Francisco in March 1995. When introducing these projects, J.L. Bill Smith of the Northern California Power Agency, said: "One might reasonably ask after 35 years of continuous production and expanded operations, what more remains as a necessity for research." He said:

> "It is the very fact of The Geysers' long history of use which has resulted in an evolving sequence of changing reservoir conditions that creates the continuing need for our further

research efforts. Only by identifying and implementing the changing field operation and reservoir management techniques needed, to appropriately respond to these reservoir condition changes, can industry expect to increase generation, and thereby also prolong the field's useful life."

The DOE geothermal R&D program has supported these goals with cost-shared research since 1990, and the projects currently in progress were selected for priority action by Working Groups convened by DOE's Geothermal Division and a consortium of geothermal companies in late 1992. Three of the four 1994 projects are currently active. Their funding sources, and industry partners are listed in Table 5.

The fourth cost-sharing program is the highly successful microearthquake (MEQ) monitoring studies in the S.E. Geysers field. It has been temporarily suspended, but it will be resumed when the S.E. Geysers Pipeline is completed to monitor the performance of the injection project. The MEQ array will be started up before the injection well begins using Clear Lake water. The MEQ array is also used during the injection to determine where the injected fluid is going.

Geysers Coring Project

The Working Groups, each consisting of six to twelve members representing both government-funded research institutions and industry, agreed that more detailed information was required concerning reservoir porosity, permeability, and fluid saturation in order to better understand the reservoir-pressure declines at The Geysers, to maximize injection strategies, and to improve forecasts of long-term reservoir behavior. The Groups further concluded that much of this information could only be obtained from a more significant length of core than had been retrieved from the field—none more than 26 feet with an aggregate length of 260 feet, all air drilled.

The coring operation took place in the northwest-central Geysers (Figure 9). The drilling phase of the project was completed by Tonto Drilling Services. It used a Universal 5000 coring rig equipped with a triple-tube

Table 5. Geysers Projects Cost-Shared by DOE and Industry

FUNDING SOURCES			
PROJECT	DOE	INDUSTRY	INDUSTRY PARTNERS
Geysers Coring, Core Preservation	$595,000	$320,000	Unocal, (Calpine)
Unit 18 Injection Test (3 years)	$588,000	$1,069,500	Unocal, PG&E, NCPA, Calpine
Isotope Geochemistry	$15,000	$15,000	CCPA, PG&E, NCPA, Calpine

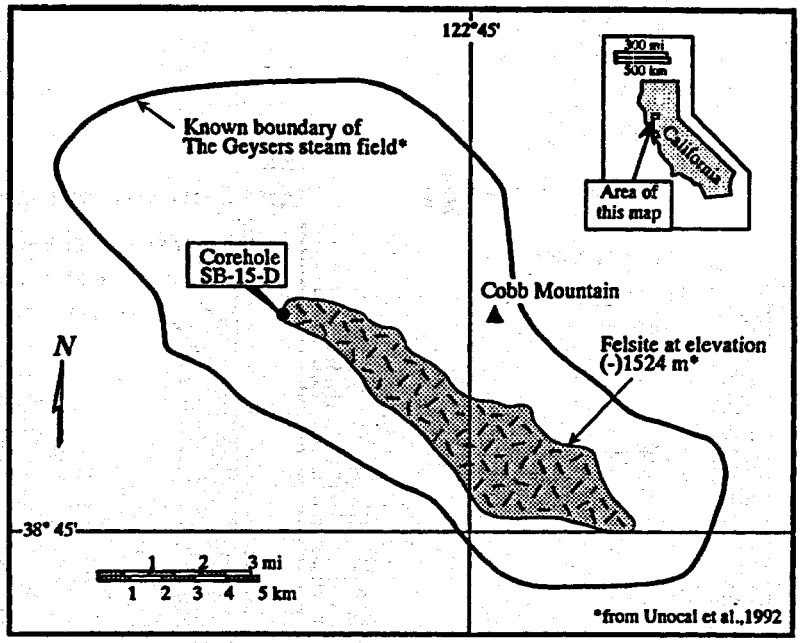


Figure 9. Location Map of the Geysers Coring Project

wireline coring and core-retrieval system. This system permitted recovery of texturally delicate core features which might otherwise have been obliterated. The system also allowed for collection of representative suites of sealed samples, including two retrieved and frozen under pressurized conditions, in support of detailed core studies being conducted by the project's 28 collaborating geoscientists. The project has demonstrated that wireline coring in vapor-dominated systems like The Geysers can be a very effective exploration and research tool.

The initial design for The Geysers corehole called for commencing coring operations at the bottom of production well SB-15. Adverse drilling conditions forced a major modification of this plan, and a new sidetrack was initiated and utilized for coring (Figure 10).

Baseline geologic studies of the retrieved core have already furnished new insight into the nature and evaluation of The Geysers' upper steam reservoir and its caprock. These studies should be essentially complete, with results distributed to the project investigators by the end of 1995, presented subsequently at one or more special symposia, and ultimately published as collected papers in a special issue of an appropriate technical journal.

The core is stored at the ESRI Geothermal Sample Library in Salt Lake City where it can be sampled judiciously in support of legitimate research projects. Those wishing to study the samples should contact ESRI at (801) 584-4422.

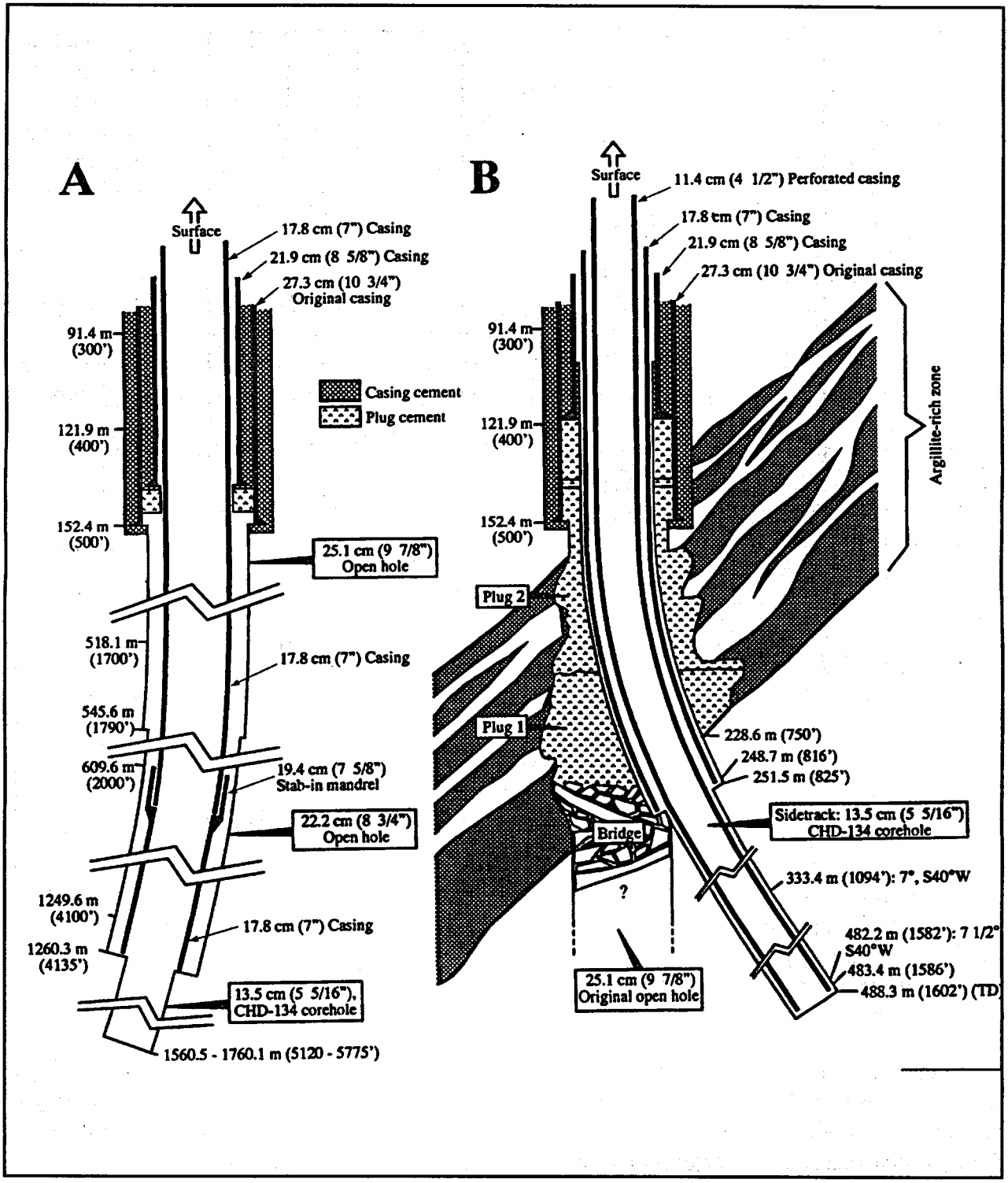


Figure 10. Corehole SB-15-D: A-Original Design; Modified Configuration and Completion

Unit 18 Injection Test

Unocal, PG&E, NCPA, and Calpine have initiated a three-year cooperative injection project with DOE. While 1989 tests of steam condensate injection into productive intervals of NCPA well C-11 and Calpine well 956A-1 (Figure 11) caused an adjacent area to experience both steam production and reservoir pressure increases. Further definition of reservoir characteristics contributing to this positive response is desirable to help reduce the risk and expense of future injection projects. Thus, the goals of the Unit 18 Cooperative Project are to monitor and define reservoir response to steam production interval water injection, and develop vapor phase tracers for application in geothermal reservoirs.

Injection into Unocal's DV-11 well at rates of 400 to 880 gpm have resulted in steam production increases primarily on the Unocal and NCPA leases. Calpine wells showed a combined 10 kph decrease in steam production, but this was attributed to production interference and water injection of nearby Calpine wells. Later tracer data indicated a minimal influence of DV-11 water injection on the Calpine wells. Considering the Unocal and NCPA gains in steam production, 81 kph and 42 kph respectively, 40.7 percent of the injectate is being recovered.

Responses in the steam geochemistry suggest a range of processes from total flashing of injected condensate to elimination of production interference as a result of the injection.

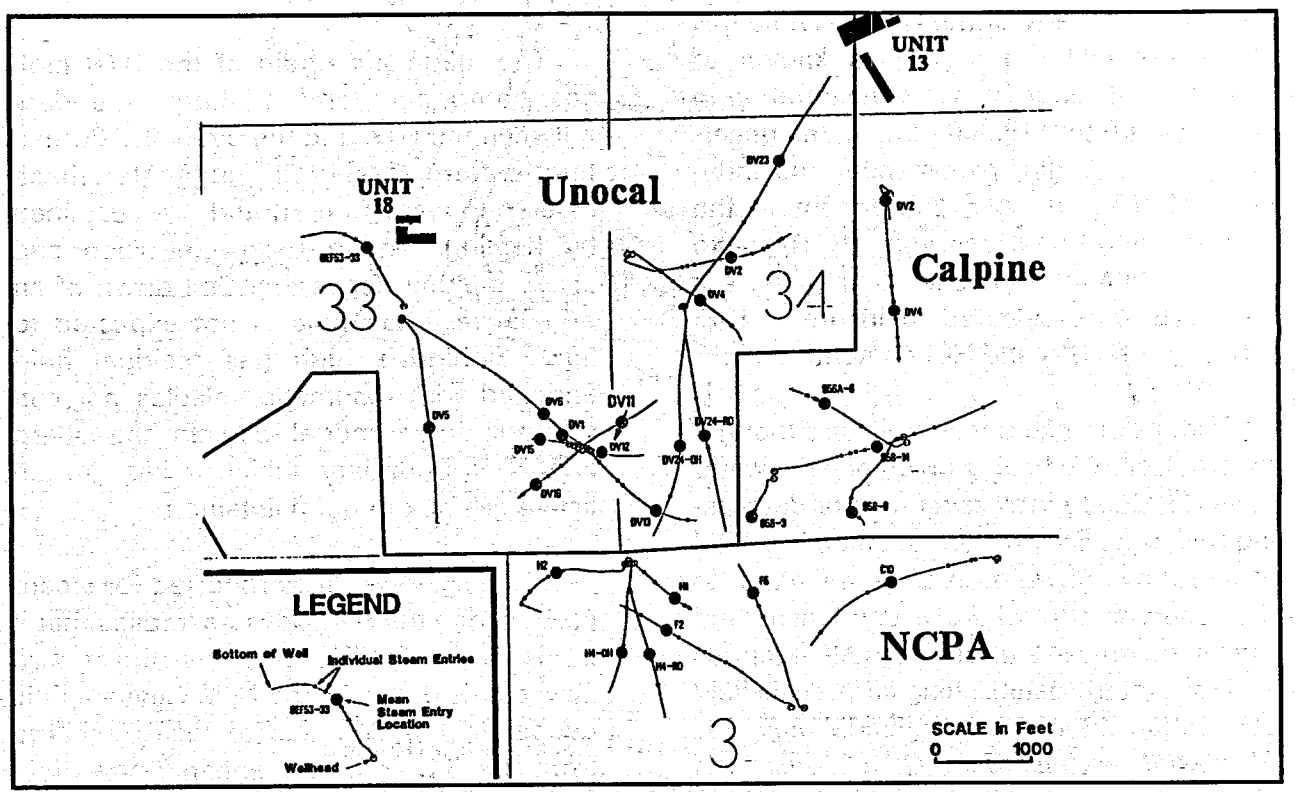


Figure 11. Unit 18 Cooperative Injection Project Study Area, Showing Monitored N-N-T, Calpine, and NCPA Wells. (Base map provided by NCPA)

SF6, R-13, and tritium were used to compare the behavior of multiple tracers in a geothermal environment. The tracer returns produced by the DV-11 test displayed a broad range of concentrations, confirming geochemical response by implying that immediate flashing of condensate was occurring and that wells were being supplied by this source. Results from the tracer test continue to be analyzed in an effort to correlate increased steam productivity, changes in gas chemistry, and the responses of the different tracers.

Isotope Geochemistry

A survey of the noble gases in the N.W. Geysers geothermal field was recently completed by Lawrence Berkley Laboratories (LBL) in consultation with A.H. Truesdell, formerly of the USGS. While this vapor dominated reservoir is known to have a wide range of gas concentration in steam (~100 to >75,000 ppmw), the uncertainty as to origin, persistence, and influence of the high gas component in the high-temperature reservoir (HTR) have made exploitation difficult. Thus, the wells surveyed were selected to insure a wide range in total gas and HCl content.

Vapor dominated reservoirs are thought to form from the boiling down of a hot water reservoir due to increasing heat or decreasing recharge. Steam from deep boiling fluid (brine) flows upward, in large fractures, to the reservoir top where it condenses and drains downward through small fractures and rock matrix establishing large scale fluid convection. (See paper entitled *Noble Gas Elemental and Isotopic Geochemistry in Geothermal Research, the N.W. Geysers: A Case Study* presented to Geothermal Program Review XIII for references.)

At The Geysers, direct evidence of deep boiling brine has not been found. Its presence in the Central and S.E. areas of the field is inferred from patterns of steam/gas and isotope compositions. Steam/gas and 18O/16O ratios decrease towards the margins of the field forming "bulls eye" patterns consistent with lateral movement of a condensing plume and therefore, large scale fluid convection. However, in the N.W. Geysers steam/gas ratios decrease dramatically towards the center of the field and low steam/gas ratios are associated with fluid produced from the high-temperature reservoir. In addition, steep lateral gradients in composition preclude large scale convection such as that in the Central and S.E. Geysers.

The magmatic origin of the HTR high gas component and a sharp boundary between the HTR and the overlying normal temperature reservoir suggests these reservoirs were formed and are sustained by heating due to recent intrusion and active magma degassing. Boil down of an original reservoir fluid is not expected to leave behind a high gas residual fluid enriched with magmatic volatiles nor can the boil-down model explain the sharp HTR-NTR boundary which relies on an active gas flux to be maintained.

High 3He/4He ratios reported for steam produced in the S.E. Geysers implies that it is likely the HTR underlies the entire Geysers field. Unlike the N.W. Geysers, it is deeper in the S.E. due to local recharge from the S.E., possibly enhanced by fracture networks associated with Cobb

Mountain volcanics. Appearance of HCl in steam with declining reservoir pressures in the S.E. and Central Geysers may indicate infiltration from an underlying HTR.

EFFECTS OF WATER ADSORPTION ON VAPOR-DOMINATED RESERVOIR PERFORMANCE UNDER STUDY

Other studies of primary benefit to The Geysers were also reported to Program Review XIII during the reservoir engineering session. Two of these studies focus on the phenomenon of adsorbed water on the rock surfaces in vapor-dominated reservoirs which has long been thought to provide a major source of fluid within the reservoirs. The production and mitigation of acid chlorides in geothermal steam are the subject of another study reported.

Over the past several years, the Stanford Geothermal Program has conducted a series of experimental, theoretical, and numerical investigations into the phenomena of water adsorption in geothermal systems and their effects on reservoir performance. More recently, the INEL has initiated a study on the effects of adsorption and capillary condensation in the exploitation of vapor-dominated systems.

The inclusion of capillary condensation as a separate issue affecting reservoir performance in the INEL study is a major difference between the two. At Stanford, a 1994 investigation into the theoretical aspects of adsorption in a porous medium estimated the conditions under which adsorption and capillary condensation occur. It concludes that:

- for geothermal reservoirs, pure adsorption is an effect that takes place at low pressure whereas capillary condensation occurs at pressures close to the saturation pressure

- at intermediate pressures, the adsorption phenomenon is a combination of both physical adsorption and capillary condensation

- for the purposes of discussing reservoir performance there is no real need to distinguish between the two effects.

However, INEL researchers have evaluated the two effects separately in studies aimed at understanding these mass storage mechanisms and how best to implement such processes in a geothermal simulator. In both preliminary simulations and an evaluation of adsorption and condensation by injection and subsequent production of a tracer in a 5-spot pattern, capillary condensation was seen to be the more dominant mechanism. Currently, the engineering literature in adsorption and capillary condensation is being reviewed and an improved conceptual model is being analyzed.

The Stanford researchers presented a detailed paper on the recent results of their adsorption studies to Geothermal Program Review XIII. In summary, they have found that the amount of (liquid) water adsorbed in vapor dominated fields is considerable, even at pressures below the boiling point pressure. Thus, reservoir engineering design of production and injection schemes must take proper account of adsorption. To estimate the extent of its support of production, it is necessary to measure the adsorption

isotherms of the particular reservoir rocks—a task that can fortunately be accomplished using well cuttings rather than cores. Theoretical studies indicate that adsorption should increase with temperature at a given relative pressure—a conclusion confirmed in laboratory measurements. Also based on experimental results, it can be inferred that allowing reservoir pressure to rise during injection may result in a substantial reduction in the effectiveness of injection—a factor that should be taken into account in the overall efficiency of an injection scheme.

Including the effects of adsorption and desorption into a reservoir simulator produces results different from those of traditional flat-interface geothermal simulators. Pressures may actually decline sooner in the presence of sorption; however, the rate of pressure decline moderates more than with flat interface thermodynamics. Without sorption, most simulators would compute a sudden rise in pressure on cessation of production. Including sorption produces a more moderate rise, as seen in the field.

Acid chloride contaminants in geothermal steam have caused significant corrosion problems, particularly in the high-temperature (>300°C >572°F) reservoir of the N.W. Geysers. A recent study has found that laboratory measurements of the distribution of relatively nonvolatile solutes between liquid water and steam can be used to establish the thermodynamic properties of these partitioning reactions over wide ranges of temperature and brine composition. The new data developed can be used to estimate the composition of a source brine in equilibrium with steam, based on an assumed equilibrium temperature and available analyses of wellhead condensate samples. Regardless of the source of chlorides in steam, the partitioning thermodynamic can be used to guide the design of processes for decreasing the levels of harmful impurities in steam, including desuperheating to partial condensation. The study was conducted by Oak Ridge National Laboratory.

DOE INITIATES NADET RESEARCH THROUGH SOLICITATION OF SBIR GRANTS FOR ADVANCED DRILLING TECHNOLOGY

The first research-related activity under the auspices of the National Advanced Drilling and Excavation Technologies (NADET) program was initiated in late 1994. It included an advanced drilling category in DOE's solicitation through the Small Business Innovation Research (SBIR) program. Two awards in the category have been announced. One is to develop acoustic sensors and associated electronics using silicon carbide, that can survive harsh downhole environments. The other award is for a project to investigate the feasibility of drill bit instrumentation that will provide downhole measurements of conditions ahead of the drill bit.

The solicitation for grant applications for SBIR projects for 1996 focuses on hard rock drilling technologies. The closing date for applications is February 13, 1996. The SBIR program awards grants to small businesses (500 employees or less) in two phases. Phase I provides up to $75,000 for researchers to conduct feasibility studies of proposed concepts. About one-third to one-half of these projects continue into Phase II, the principal R&D effort. Awards for this phase can be up to $750,000 for a two-year period.

NADET is a cost-shared research and development effort founded at the behest of DOE's Geothermal Division to create an integrated, efficient, and economic drilling and excavation system for the next century. It incorporates the interests of the several industries who require access to the subsurface and whose economics would be greatly improved by more efficient, cost-effective, and environmentally acceptable methods for getting such access. The industrial areas of interest and the federal agencies involved in these activities are shown in Table 6.

The direction of the overall NADET effort was established by a report, Drilling and Excavation Technologies for the Future, issued in June 1994 by the National Research Council, commissioned by the Geothermal Division and the Gas Research Institute. The Council concluded that development of a "smart" drilling system should be the principal emphasis of the NADET research and development program, but recommended pursuit of incremental improvements to current drilling technology.

Table 6. Federal Agencies Interested in Drilling and Excavation Technologies

Agency	Office	Areas of Interest
Energy	Geothermal Division Fossil Energy Energy Research Civilian Radioactive Waste Environmental Management	Geothermal development Gas exploration Earth science Radioactive waste disposal Waste handling
Transportation	Federal Highway Administration Federal Transit Administration	Tunneling Tunneling
National Science Foundation	Ocean Drilling Program Earth Sciences Division Geomechanical, Geotechnical and Geoenvironmental Systems	Deep water operations Earth science Tunneling; excavation; construction
Environmental Protection Agency	Oil & Gas Industry Underground Injection Control Office of Solid Waste	Regulation Waste disposal Waste disposal
Interior	Bureau of Mines U.S. Geological Survey	Mining; excavation Earth science
Defense	Army Research Laboratory Defense Nuclear Agency	Projectile drilling Drilling; tunneling
Nuclear Regulatory Commission	Nuclear Regulatory Research	Radioactive waste disposal
National Aeronautics & Space Administration	Planet Earth Study Office	Drilling; excavation
Commerce	National Institute of Science and Technology	Drilling; excavation

A Coordination Agreement for Research, Development, and Demonstration in Advanced Drilling Technologies has been signed, to date, by DOE's Office of Energy Efficiency and Renewable Energy, Energy Research, and Civilian Radioactive Waste Management, and Environmental Management. This agreement established NADET as a vehicle for coordinating individual research activities while enabling each federal office to retain programmatic control over any project that it supports exclusively. Other offices within the federal government are invited to participate.

EFFORTS TO DEMONSTRATE VIABILITY OF SLIMHOLE DRILLING CONTINUES

The necessity to drill production-size holes in order to identify and evaluate geothermal reservoirs contributes to the relatively high cost of developing this resource. Thus, industry places a very high priority on demonstrating that far less costly "slimholes" can adequately define and prove the resource, and is participating in the slimhole drilling project of Sandia National Laboratories.

The most recent project in this effort was an exploratory slimhole near Vale, Oregon, cost-shared with Trans-Pacific Geothermal Corp. Although the slimhole showed low-temperatures and permeability that preclude development at that location, there was a direct cost comparison with a conventional rotary-drilled exploratory well two miles away. Drilled to almost identical depths, the slimhole produced test data equivalent to data from the larger hole at approximately 65 percent of the cost. Much greater savings should be realized where lost circulation problems are severe.

During FY96, an additional slimhole will be cost-shared with the California Energy Co., at Newberry, Oregon. The location of these test holes is important because the use of slimholes reduces the environmental impact as well as the cost of exploration. In environmentally sensitive areas such as the Pacific Northwest, the technology may be crucial to development.

Sandia is also collecting and analyzing slimhole and production well data from Japanese fields. They are also seeking cost-sharing partners with leases in new resource areas that have been identified as potential reservoirs, but require additional exploration to justify production drilling.

California Energy and Sandia are also cooperating in a Geothermal Drilling Organization project at the Newberry field. The relative effectiveness of Halliburton's new cementitious mud, or cementitious lost-circulation material (CLCM), will be determined as well as the time and cost savings attainable with the CLCM. Sandia's lost circulation program also focuses on loss-zone diagnostic techniques as well as downhole tools and materials such as the CLCM for lost circulation control.

ALASKA

HIGH-TEMPERATURE GEOTHERMAL RESERVOIRS IDENTIFIED IN ALASKA'S ALEUTIAN ARC; DETAILED MAPS AVAILABLE

The Alaska Division of Geological and Geophysical Surveys (ADGGS) conducted studies that have identified 14 sites with high-temperature—greater than 150°C (300°F)—hydrothermal reservoirs in the Aleutian arc. One of two wells drilled during the study successfully produced 195°C (380°F) water from a depth of 1,936 feet at Makushin. This confirmed reservoir lies near Unalaska, a major fish processing port that serves as a base of operation for Bering Sea and Gulf of Alaska fishing fleets. According to other sources, a 15 MWe power plant is planned for this area.

Three other sites located near population centers have excellent potential for future development. These include northern Adak Island near the Adak Naval Station, northern Atka Island near the village of Atka, and Hot Springs Bay near the village of Akutan. Geyser Bight, although remote, also warrants consideration because of its size, accessibility, and high temperatures. Most other sites in the Aleutian arc will probably remain undeveloped because of their remoteness or their location within national conservation units.

In addition to the 14 high-temperature sites, four intermediate systems—90 to 150°C (194-300°F)—and six low-temperature—less than 90°C (194°F)—systems were identified.

The sites studied are mapped in Figure 12, and Figures 13 and 14 include photos at two of the sites. The studies were conducted by ADGGS between 1980 and 1988, frequently in collaboration with investigators at the University of Alaska, Fairbanks.

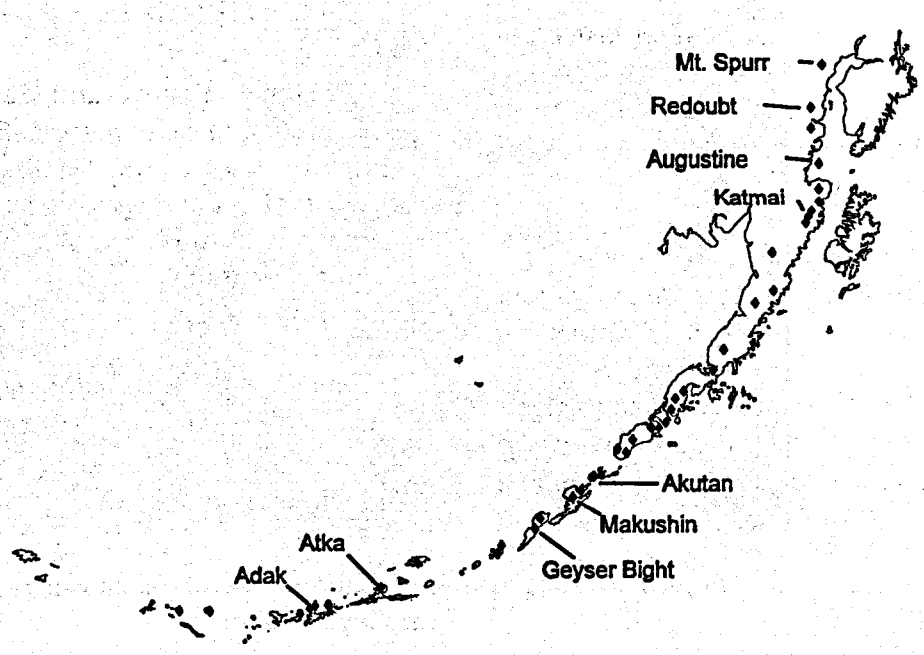


Figure 12. Geothermal Sites in the Aleutian Arc

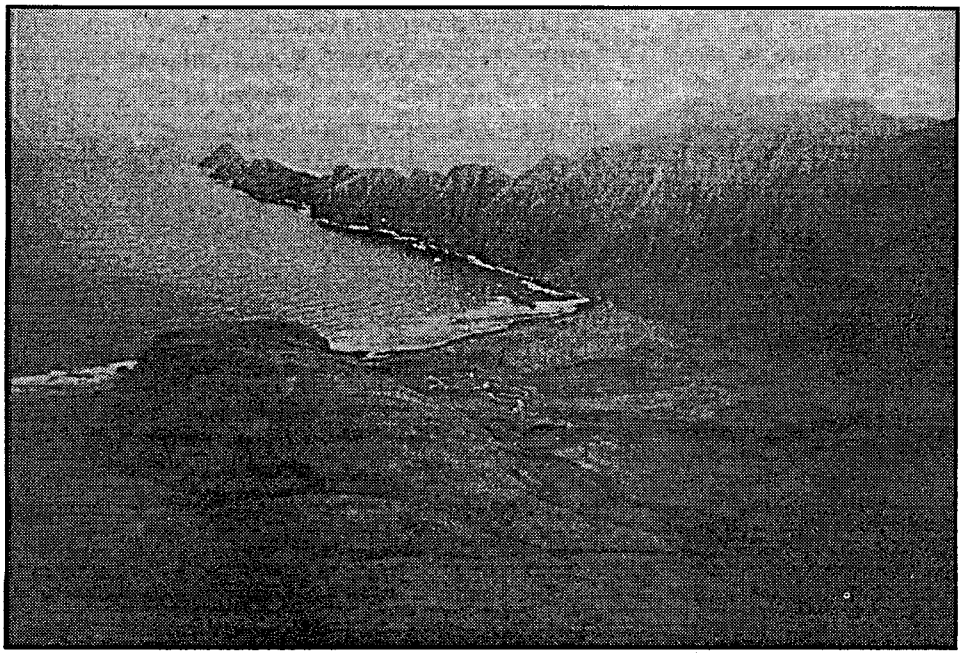


Figure 13. Hot Springs Bay Valley in Alaska's Aleutian Arc—A Potential Site for Geothermal Development

Figure 14. Alaska Geological and Geophysical Survey Team at Geyser Bight

The studies included:

- drilling two wells
- reconnaissance geochemistry of thermal spring waters and fumarole gases throughout the arc
- several site-specific studies including geological and geophysical studies
- additional fluid geochemistry investigations.

The report on the studies entitled, "Publication PR-114, Geothermal Resources of the Aleutian Arc," consists of four plates with accompanying descriptions. Three of the plates are annotated maps at a scale of 1:1,000,000 showing the location and providing brief descriptions of geothermal resources; the fourth contains tables of data on fluid geochemistry, site locations and type of geothermal activity, and Holocene volcanoes. The report covers a region stretching westward from Mount Spurr to Buldir volcano, the farthest volcano in the arc. It is available from:

ADGGS
794 University Avenue, Suite 200
Fairbanks, AK 99709-3645

CALIFORNIA

CEC BEGINS NEW FUNDING CYCLE FOR GEOTHERMAL PROJECTS

The California Energy Commission (CEC) announced in September that it had initiated a new funding cycle of its Geothermal Program. This program enables the CEC to provide funding to private and public entities for projects that promote the development of new geothermal resources and technologies.

Nearly $6 million are available for Fiscal Year 1995 - 1996 which ends on June 30, 1996. This is an open and continuous solicitation so application can be made at any time. Funding is awarded to approved proposals in the order that complete applications are made.

Most types of geothermal projects in California qualify for this funding; but research, development, and commercialization proposals are particularly encouraged. Private and public entities may apply. Universities, national laboratories, and state and Federal agencies can participate when in partnership with an eligible local jurisdiction or private entity. There is no predetermined limit on the funding that can be requested for each project.

This round of the CEC's activities promoting geothermal development is supported by the 1994 California Energy Policy's conclusion that, "New geothermal technologies such as flash steam and binary cycle liquid geothermal await a more competitive situation as a result of low natural gas prices."

A major contribution in cash, equipment, and/or in-kind services is required for project award. Details on repayment of awards converted to loans and conditions necessary for conversion to a grant and/or an application packet may be obtained from the CEC at (916) 654-5129 or fax (916) 653-6010.

NEVADA

NEVADA ENERGY TO BUY YERINGTON PLANT

Nevada Energy Company of Reno, NV has acquired a geothermal power generation and non-operational ethanol plant at Yerington, about 40 miles S.E. of Reno, by assuming a $125,000 note and paying $875,000 in stock. The purchase includes Tad's Geothermal, Inc. and its long-term sales contract with Sierra Pacific Power Company of Reno.

Nevada Energy Company holds interests in renewable energy facilities including geothermal and wind power applications.

Source: GRC Bulletin 5/95

NEW JERSEY

SALEM COMMUNITY COLLEGE GOES GEOTHERMAL

Salem Community College, a state-supported school in Carney's Point, anticipates savings to exceed $60,000 in annual energy costs with the installation of two large geothermal heat pump systems. In addition to the economic and environmental benefits, the installation provided hands-on training experience for students enrolled in the college's two-year Heating, Ventilating, and Air Conditioning (HVAC) Mechanics course of instruction.

Each system comprises sixteen geothermal units totalling 80 tons of capacity, and serves one of two buildings. The buildings are 32,000 and 31,000 square feet respectively. A closed loop system, composed of high density polyethylene piping, encompasses fifty 200 feet deep wells in a field next to the building. This closed loop serves as a heat exchanger, absorbing heat from the earth in the winter and transferring heat to the earth in summer months. In addition to supplying heating and cooling, three of the units in one building are equipped with desuperheating coils which capture waste heat from the unit's condenser for use in water heating. This additional feature provides over half the facility's hot water needs by using this "free" heat source.

Further benefits and features of the new geothermal system include uniform temperature levels, more precise comfort control, and virtually soundless operation. Projected annual savings are 365,000 kWh and nearly 400,000 kWh for the two buildings, respectively. This results in a $30,000 annual savings in operating costs for each building while reducing annual maintenance costs by $8,000.

More information on the system is available from Barb Wieging of Water Furnace International, which supplied all of the units, at (219) 478-5667, ext. 218.

Source: Geo-Heat Center Quarterly Progress Report 1/3/95

NEW MEXICO

NEW MEXICO OFFERS GEOTHERMAL GREENHOUSES FAVORABLE POLITICAL AND ENVIRONMENTAL CLIMATE, ENGINEERING AND HORTICULTURAL ASSISTANCE

The state of New Mexico and New Mexico State University are encouraging the development of geothermal energy for greenhouse applications in the state. The

state offers growers favorable political, environmental, and economic conditions. Southern New Mexico contains several locations that have all or most of the following advantages:

- good quality water source for irrigation
- access to a market and a transportation network
- available labor
- somewhat level land.

Growers enjoy more than 320 days of sun per year and a dry climate that reduces disease control problems and allows for very effective cooling with evaporative cooling systems.

Two of the largest geothermal greenhouses in the U.S. are located in southern New Mexico. Burgett Floral operates a facility of approximately 27 acres in the Animas Valley. Masson's Radium Springs is located in the Rio Grande rift zone, a promising location for additional geothermal development.

New Mexico State University provides technical engineering and horticultural assistance to potential developers. For more information about its assistance programs contact:

The Southwest Technology
Development Institute
New Mexico State University
Las Cruces, NM 88003
Phone: (505) 646-0846

Source: Geo-Heat Center Quarterly Bulletin 11/94

OREGON

HOSPITAL EXPANDS GEOTHERMAL HEATING SYSTEM TO AVOID GAS USE

The Merle West Medical Center in Klamath Falls has expanded the capacity of its geothermal heating system to provide heat and hot water for an 85,000 square foot assisted-living retirement facility on the hospital grounds. The system will also provide heat for the facility's swimming pool and sidewalks to prevent icing. A new, variable-speed drive controlled by new building automation equipment is the centerpiece of the retrofit.

The expanded geothermal capacity will offset the use of backup gas-fired heating equipment and will save approximately 6,800 million Btu of natural gas per year. Including the expected decrease in electricity use, a total annual energy cost reduction of $34,000 is expected. The project, at a total cost of $215,000, is predicted to pay for itself in 6.3 years. Other details of the retrofit are available in Energy User News, Vol. 20, No. 2, February 1995.

Source: Geo-Heat Center Quarterly Progress Report 1/3/95.

GEOTHERMALLY HEATED WHEELCHAIR RAMP INSTALLED AT OIT

The construction of a new wheel chair ramp on the Oregon Institute of Technology (OIT) campus incorporating a geothermally heated snow and ice melting system, pictured in Figure 15, was recently completed. The system utilizes geothermal fluids in a

brazed plate geothermal-to-glycol exchanger with a small pump in the glycol loop. The tubing used in the system is 5/8-inch diameter cross-linked polyethylene tubing manufactured by the Wirsbo Company. There are four reverse return loops in the system (one not shown at the upper landing), the longest being about 230 feet with 10-inch spacing between tubes. A manifold with balancing valves is provided to adjust flows in each of these return loops. With an entering 50/50 propylene glycol/water temperature of 60°C (144°F), the system should maintain a slab surface temperature of 3.3°C (38°F) at 20.6°C (-5°F) air temperature and 10 mph wind. Output is 166 Btu/ft^2 requiring a flow of 2.4 gpm in the longest loop.

No electric controls were installed and a manual system is turned on and off according to season. The system performed well during its first winter in operation.

Source: Geo-Heat Center Bulletin 11/94; personal communication 9/14/95

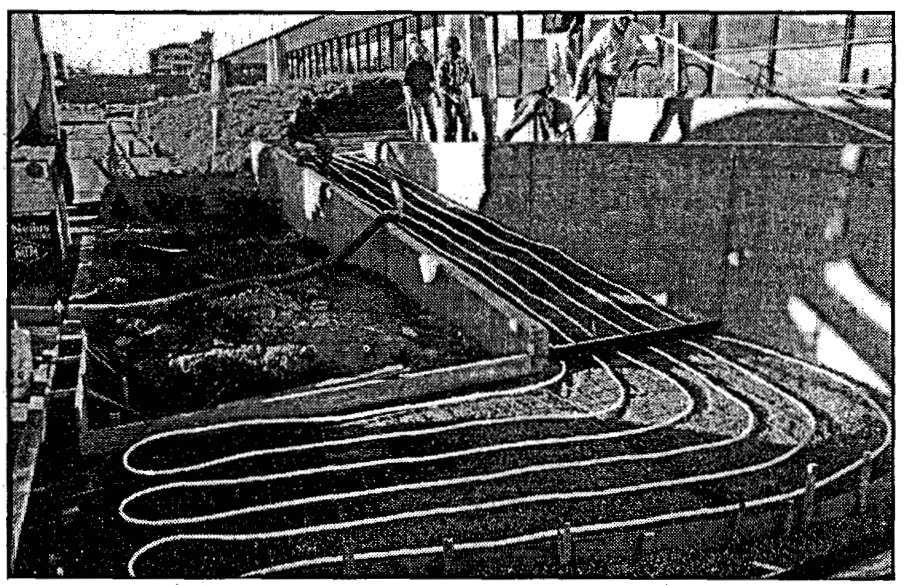


Figure 15. Concrete being poured for new geothermally heated wheelchair ramp on the OIT campus

GEOTHERMALLY HEATED SIDEWALKS FEATURE OF KLAMATH FALLS REDEVELOPMENT

The city of Klamath Falls is developing a downtown redevelopment streetscape project for Main Street. The project includes brick crosswalks, antique-style light fixtures, park benches, and geothermally heated sidewalks and crosswalks. The project is planned to extend ten blocks.

In an effort to conserve water for buildings on the system, heat for the project's snowmelt system will be provided from the return main of the city's geothermal district heating system. The district return water will be pumped from the return main at 60°C (140°F), through a plate-and-frame heat exchanger and back into the return main downstream. The snowmelt loop will contain a propylene glycol/water mix, supplied at a maximum temperature of 54°C (130°F). Supply temperature will be reduced at higher than design air and sidewalk slab temperatures. The district heating water and snowmelt loop pumps will be controlled by adjustable frequency drives. A single service vault containing the heat exchanger and pumps will supply the entire ten block project.

Source: Geo-Heat Center Quarterly Project Progress Report 4/6/95

WORLD GEOTHERMAL CONGRESS—A REPORT

When asked what results he expected from the 1995 World Geothermal Congress held in Florence, Italy, Franco Viezzoli, Chairman of ENEL, the Italian National Electricity Board said:

> "Research and development in geothermal energy requires very heavy commitment. Only international cooperation makes it possible to optimize resources and move on to new horizons.... There are delegates (here) from countries with the resources and others from countries with technology and capital. If we've managed to activate some synergies by the end of the Congress, we will have answered one of the important expectations with which the Congress-goers arrived in Florence."

Regardless of whether any such "synergies," developed as a direct result of the Congress, the large number (over 1,000) of participants from throughout the world certainly generated exchanges of knowledge needed to ensure technological progress and stimulate new initiatives. "For further development," Viezzoli said, "we are counting on new technologies, new drilling techniques for great depths, and reinjection techniques."

The technical sessions of the WGC explored both today's state-of-the-art technologies and the research needed to develop the innovations of tomorrow's methods. In addition, the five-day program of 27 sessions and over 500 papers assessed the role of governmental policies/regulations in worldwide geothermal development and the impact of public/government/utility understanding of geothermal energy.

The events of the Congress were summarized as they unfolded by a full-blown newspaper called The WGC 95 Daily News. The six issues provided the details of the Congress highlights used in this brief report.

Role of Government Policy/Regulation

The role of government in geothermal development varies from country to country in a number of significant ways. The most basic differences are that power generation and ownership of subsurface rights in some countries is by the state while in others are by private industry and individuals.

In spite of these differences, speakers emphasized commonalities in the impact of governmental policies. For example, Robert Skinner of the International Energy Agency suggested that the future role of geothermal energy:

> "will depend both on technological caprice and on industry adaptations to a declining and changing role by government, which has stopped `picking winners' and has started to open up (power) generation to competition... The industry should not count on policy changes improving the relative economic merits of geothermal."

"But the future of renewable energy," according to Italian industry ministry Energy Chief Ettore Rossoni, "also depends

(in addition to new types of technology) on the maintenance of central planning programs. The process of liberalization taking place in energy markets must not lead to an abandonment of planning by public authorities."

A number of country-by-country reports indicate that many countries have implemented policies/regulations in support of geothermal development and provide incentives in one form or another. The types of incentives reported at the Congress include:

- publicly available resource data bases
- subsidies for developers
- low interest rates on loans
- grants
- tax credits
- settlement of divisive resource ownership disputes
- risk-shared R&D and exploration
- creation of an accessible market
- attracting foreign capital through "Build-Own-Operate-Transfer" contracts.

Need for Educating Public/Government/Utilities on Benefits of Geothermal Energy

A number of speakers noted that the benefits of geothermal energy use are frequently not well understood by the public (including the investment community), governmental agencies, and/or electric utilities. This is especially true, they suggested, in the environmental attributes of the resource.

For example, Christos Papoutsis, European Union Energy Commissioner, remarked that one remaining barrier to wide-scale deployment of geothermal "can be removed by getting the message across to the general public." Japan sees the opportunity for "getting around strict laws on new sites—many in or near national parks—by the use of new technology."

Giuseppe Potestio of ENEL reported, "excessive red tape and pressure from environmental regulations have meant that the effects were not as full as they might be," despite Italy's strong support for geothermal programs through its National Energy Plan, the Italian Geothermal Inventory and generous incentives.

Jim Combs, Chairman of the International Geothermal Association (IGA) noted,

> "For many years, there has been little understanding of geothermal energy and the problem has been one of educating people. Unfortunately, in most nations, the electrical utilities and power companies, which developed electrical power networks, chose oil-fired, coal-fired, and nuclear projects. Geothermal failed to get a lick in."

On a more positive note, he said that while utilities have become accustomed to buying fuel on the commodities market, "the mentality at utilities is changing now" and they are grasping the importance of having their fuel resource right at the power plant location. This takes advantage of

geothermal's big environmental plus by avoiding off-site mining, petroleum or natural gas production, and a major transportation operation. "Everything is on the same site," Combs noted, "and all you have are the electric lines running out of the plant."

Another barrier blocking more rapid growth in geothermal use is due to the "rather poor job of assessing our own potential," according to Mike Wright of ESRI, and failure "to communicate effectively." He called for steps to correct deficiencies in the assessment of the long-term production potential of reservoirs that lead non-specialists "to make inaccurate evaluations of geothermal's potential."

WORLDWIDE STATUS AND PROSPECTIVE FUTURE OF GEOTHERMAL DEVELOPMENT

Gerald W. Huttrer, of Geothermal Management Co., Inc., Frisco, Colorado, Rapporteur of the WGC95 sessions on the status of worldwide geothermal power production noted,

> "It is difficult, in a Rapporteur's Summary, to do justice to the detailed in-country reports as eloquently presented by their authors. Too often, interesting side topics must be briefly mentioned or ignored while dry statistics tend to dominate."

This comment explains his attempt to retain and convey some of the enthusiasm and optimism regarding future geothermal development that is typical of most in-country reports. Table 7 summarizes the installed geothermal capacity and lists future geothermal plans for each country.

WORLDWIDE GEOTHERMAL DIRECT USE STATUS AND OUTLOOK OUTLINED AT WORLD GEOTHERMAL CONGRESS

The May 22, 1995, WGC session on regional prospects opened with Derek Freeston's worldwide perspective on direct uses of geothermal energy, including additional information on heat pumps and investment.

The evidence from draft reports, Freeston said, shows a large potential for the development of low-to-moderate temperature direct use, not yet exploited because of financial constraints and the low costs of competing energy. Installed thermal power at the end of 1994 was roughly 8,207 MWt compared to 8,064 in 1990, using 35,998 kg/s of fluid, compared to 31,800 in 1990. Thermal energy used was 105,745 TJy, compared to 61,747 in 1990.

An estimate of the total investment worldwide between 1985 and 1994 was 1,325 million U.S. dollars, including 580 million in France, 240 in Iceland, 177 in Switzerland, 73.5 in Slovenia, 68.4 in the United States, 60 in Poland, 54 in Italy, 35 in Georgia, 26.7 in Macedonia, 5.5 in Denmark, 4.4 in Argentina, and 0.5 in Belgium.

The average cost per thermal MW and average manpower per thermal MW also showed a very large variation in cost from 0.04 for the United States to 1.88 for Slovenia, and in personnel from 0.1 for the United States to 10.6 for Poland.

Table 7. Current Worldwide Installed Geothermal Power Generation Capacities and Plans/Projections for Future Development

Country	1995 Installed Capacity (MW_e)	Plans/Projections
Argentina	0.67	None for power generation; direct use at 2 of 4 identified areas with potential high enthalpy projects.
Australia	0.17	After 4-year demonstration period in 1996, plant's future will depend on its performance.
Canada	0	Drilling at Meager Creek; additional exploration at Pebble Creek is encouraging, a 10 MW_e pilot plant followed by 100 MW_e working plant.
Chile	0	Legislation to make geothermal franchiseable to "for-profit" entities with annuity payments to the government after successful development; costs will have to compete with imported natural gas.
China	28.78	81-104 MW_e on line by 2000, 210-295 MW_e by 2010, and 400-590 MW_e by 2020.
Costa Rica	55	170 MW_e by 2000
Croatia	0	Dependent on current detailed evaluations; two potential reservoirs.
El Salvador	105	165 MW_e by 2000; 250 MW_e by 2010.
Ethiopia	0	30 MW_e in 3 phases by 1997 at Aluto; 1405 MW_e countrywide by 2010 including export of 200 MW_e
France	4.2	Power development on 2 islands with potential stagnant due to environmental concerns; officials hope to overcome objections with factual information and resume development.
Greece	2.0 pilot plant closed	No information available.
Guatemala	24 (under construction)	Funds committed for 70 MW_e; 94 MW_e projected installed by 2000.
Hungary	0	Many years' experience in direct use and knowledge of country's resources should soon permit power development.
Iceland	49.4	80 MW_e at Nesjavallir when foreseen demand exceeds supply; power development continues "unhurried."
India	0	Plans to build a 20 kW and a 1 MW_e binary in Tatapani and Puga-Chhumathang in NW Himalaya yet to be realized; international financial assistance needed to compete with abundant cheap coal; technical assistance also needed.

Country	1995 Installed Capacity (MW_e)	Plans/Projections
Indonesia	309	2000 MW_e total by 2000.
Iran	0	Drilling of deep wells at Mishkin Shaha recommended next step although other drill sites may be considered.
Italy	631.7	856 MW_e by 2000.
Japan	413.705	600 MQw by 2000.
Kenya	45	A total of 448 MW_e, or 30% of annual demand, by 2012.
Lithuania	0	Actively seeking financial assistance for demonstration projects from international lending and private investment communities.
Mexico	723	960 MW_e by 2000.
Mozambique	0	Generally positive structural environment for geothermal, but significant increases in intensity of geothermal studies are needed to realize potential.
Nepal	0	Calculated temperatures too low for power generation; national inventory planned to support direct uses.
New Zealand	286	440 MW_e by 2000.
Philippines	1227	1978 MW_e by 1998.
Portugal (Azores)	5	Three more 2.6 MW_e plants on Sao Miguel; initiation of exploration and exploitation of the Terciera Island prospects.
Russia	11	A 7 MW_e addition at Pauzhetskaya in Kamchatka by 2010; 80 MW_e under construction at Mutnovsky in 20 MW_e increments to be completed by 2010; 30 MW_e on Iturup Island in the Kuril Archipelago; and a 3 MW_e pilot plant at Kayasulinskaya in the Northern Caucasus which may be abandoned due to resource problems.
Slovenia	0	1 MW_e in the Pannonian Basin; cautious optimism about development but financial assistance needed.
Thailand	0.3	If deep test wells along the Pai River confirm a resource, power generation with binary units will be planned for near future.
Turkey	20.6	125 MW_e from several fields by 2000; 150 by 2005, and 258 by 2010.
U.S.	2816.7	3395 MW_e by 2000.

Space heating was again the biggest sector of use, thanks to some major district heating operations, comprising 33 percent of total energy utilization. Following is a list of use sectors ranked by percent total energy utilization:

- space heating—33%
- bathing—15%
- fish farming—13%
- greenhouses—12%
- heat pumps—12%
- industry—10%
- agricultural drying—1%
- snow melting and air conditioning—1%
- sundry small applications— 3%.

According to Freeston, Switzerland and the United States are the major users of heat pumps. New Zealand and Iceland the leaders for industrial uses, and China and the United States the front-runners for fish and other animal farming.

Source: World Geothermal Congress Daily News 5/23/95.

U.S. AND INDONESIA SIGN $3.46 BILLION GEOTHERMAL POWER DEAL

Four American-Indonesian joint ventures won contracts to explore and develop geothermal fields in West and Central Java and to establish power plants with a total capacity of up to 1,420 MWe over 15 years. These "build, own, operate, transfer" contracts were awarded to :

- PT Mandala Magma Nusantara BV, for 400 MWe (Magma's 90 percent stake subsequently acquired by California Energy International, Ltd.)
- PT Karaha Bodas Company for 220 MWe (90 percent owned by New York based Caithness Resources, Inc.)
- PT Patuba Power Ltd., for 400 MWe (90 percent owned by California Energy) and
- PT Himpurna California Energy Ltd. for 400 MWe.

After negotiations of almost a year, the government—the state oil company Pertamina for exploration and the state electricity company PLN for power plants—and the contractors agreed on sale prices based on a three-tiered rate for their electricity within 30 years. These rates average 7.76 cents for the first 14 years, 5.67 cents for the following eight years, and 4.96 cents for the remaining eight years. Pertamina previously contracted with Unocal Geothermal Indonesia to build and operate three 55 MWe plants at Gunung Salak in West Java. A PLN spokesman said that his organization is now offering new geothermal power plants in Surulla of North Sumatra and in Lampung to private firms—each with a capacity of 110 MWe.

Source: GRC Bulletin 1/95

HDR STUDY IN AUSTRALIA INDICATES ELECTRICITY COST OF 9¢/KWH ACHIEVABLE IN POWER PLANT DEMONSTRATION

An economic model for a 20 MWe power plant based on a study of hot dry rock resources in Australia indicates that an electricity cost of $.09/kWh is achievable at the plant demonstration stage. The estimate

includes the costs of drilling, stimulation, logging, and seismic monitoring and assumes a capacity factor of 80 percent and an annual rate of return of 15 percent over 30 years.

The study, conducted by the Australian Geological Survey Organization (AGSO), found that a large HDR resource exists at depths shallower than 16,000 feet, 80 percent of which is beneath the Eromanga Basin. The resource in this area alone is enough to supply Australia's energy needs for 870 years at present energy usage rates.

The stress regime for most of the Australian Crust indicates crustal shortening, with a vertical axis for minimum principal stress. This means reservoir development would be horizontal, rather than vertical, as has been the case in all previous HDR programs. The AGSO envisions a series of stacked stimulation cells (perhaps five in all) in a vertical well, each 656 feet (200 m) high and extending 1,640 feet (500 m) horizontally out from the well, creating a stimulated reservoir volume approaching 1 cubic kilometer from a single vertical well.

The AGSO plans to drill a well for pumping experiments. It will be located either in the Cooper Basin, where the best HDR resources are found, or in the Sydney Basin where a gravity low with a high gradient is located. The AGSO hopes the test will prove that the reservoir will develop in a horizontal direction, which would be the most favorable geometry for generating large reservoirs from single vertical wells, and that stacking horizontal cells up the well is a viable method of enlarging the reservoir volume.

The January, 1995 Geothermal Resources Council (GRC) Bulletin contains more detail on the study and future plans in a letter written by Doone Wyborn of the AGSO.

MEAGER CREEK PROJECT DELAYED BY DRY HOLE

The first large-diameter, deep geothermal well in Canada was drilled in British Columbia in June 1995 by Nabors Drilling, Ltd. for Pacific GeoPower (PGP). PGP is a joint venture between Canadian Crew Energy Corp. and Guy F. Atkinson Holdings Ltd. The majority of the proposals received by B.C. Hydro were for natural gas-fired projects. Cost-per-kWh will be a key factor in its selection of suppliers. However, social factors as well as technical and financial risks will influence the decision under a process called Multiple Account Evaluation. PGP submitted the only geothermal proposal—for 63.5 MWe—in response to B.C. Hydro's request for proposals to acquire electricity from the private sector. Late in the year, PGP learned that its proposal was not included on B.C. Hydro's "short list" of bidders.

The well was intended to provide data for developing a reservoir model to determine future drilling programs at the South Meager geothermal project--Canada's first. Its location was based on an exploration and research program conducted by B.C. Hydro from 1973 to 1983, however, the well was a dry hole at 11,200 feet. PGP may possibly drill another well in the summer of 1996, to the north and in rougher terrain. The reservoir is estimated to have a potential for 260 MWe.

PGP's preliminary power plant design is based on the use of the Kalina Cycle System, a patented product of Exergy, Inc. The system has the potential for up to a 40 percent improvement in efficiency over more conventional binary cycles. The first commercial Kalina Cycle power plant is being demonstrated at a 12 MWe unit at Steamboat, Nevada.

PGP initiated a public consultation program more than two years ago. The Community Advisory Committee, consisting of members from the community, government agencies, and PGP, has since become the focal point for distribution of information and review of community concerns. PGP management believes that such involvement is vital to the success of the project.

Source: GRC Bulletins 2/95, 3/95, 5/95, and 6/95; personal communication

U.S. GEOTHERMAL COMPANY TO DEVELOP UP TO 105 MWE IN NICARAGUA

The Ministry of Energy of Nicaragua (INE) issued its first geothermal concession to Trans-Pacific Geothermal Corporation (TGC) of Oakland, California, in December 1995. The concession covers 114 square km in the E1 Hoyo-Monte Galan area, about 50 km north of Managua. This follows an Agreement in Principle that TGC negotiated with INE in December 1994. TGC expects to convert the Agreement in Principle into a full-fledged power purchase agreement within the first quarter of 1996, and is gearing up to carry out additional geoscientific studies in the concession area. The Agreement in Principle commits Nicaragua to buy the output of a geothermal project, up to 105 MW, which will be constructed in two stages.

GEOTHERMAL POWER EXPANDS TO WEST INDIES

On February 23, 1995, Caribbean Power Enterprises Limited (a U.S. owned company), the government of the Commonwealth of Dominica, and the Dominica Electricity Services Company Limited (DOMLEC) signed a contract which created the Dominica Geothermal Power Company owned by the government and Caribbean Power Enterprises Limited. A power sales contract was also signed between Dominica Geothermal Power Company and DOMLEC. The document stipulates that 10 megawatts will be sold by the geothermal company to DOMLEC from four powerplants (2.5 megawatts apiece) that will be built between 1998 and 2004. The total value of the project will be in excess of $20 million (U.S.). This will be the first geothermal development in the Commonwealth of Dominica.

GEO-HEAT CENTER CELEBRATES ITS 20TH ANNIVERSARY; CONTINUES TO OFFER TECHNICAL SERVICES

The Geo-Heat Center (GHC), located on the geothermally heated campus of Oregon Institute of Technology in Klamath Falls, celebrated it 20th anniversary this year. Its beginning is traced to an international conference, held on campus in October 1974 on geothermal energy. It was organized to review nonelectric, multipurpose uses of the resource in Hungary, Iceland, New Zealand, the United States, and Russia. The GHC (formerly the Geo-Heat Utilization Center) was established in 1975 as a result of the conference and interest in the need to exchange and disseminate information on low- to moderate-temperature resources and their utilization. Initial funding was provided by the Pacific Northwest Regional Commission (PNRC), a branch of the Executive Department of the Governors of the states of Oregon, Washington, and Idaho. The $3,000 contribution supported publication of the conference proceedings titled *Multipurpose Use of Geothermal Energy–Proceedings of the International Conference on Geothermal Energy for Industrial, Agricultural, and Commercial/Residential Uses.*

Since 1975 the GHC's activities have been funded primarily by DOE. In addition to PNRC, other study and project sponsors include the California Energy Commission, USGS, Bonneville Power Administration, Electric Power Research Institute, EG&G, and various communities.

The primary functions of the Center are to disseminate information to potential users of geothermal resources, perform applied research on the utilization of low-temperature resources, and to publish a quarterly newsletter on the progress and development of direct-use geothermal energy in the United States and other countries. It has recently published a brochure to advise consultants, developers, potential users, and the general public of the services it can provide through DOE support of its activities. The information it has developed, through first-hand experience with numerous projects and extensive research, is provided to individuals, organizations, and companies involved in geothermal development.

Technical assistance for geothermal projects involving direct and heat pump space heating, industrial processes, and low-temperature wellhead electric power generation is allocated based on merit. Assistance is available at the outset of a project—e.g., economic analysis, technical feasibility, equipment and materials selection—or for follow-up trouble shooting for operational systems. In addition to technical assistance, the services offered include:

- Resource Information—data is available for a specific area of a city or county in Arizona, California, Colorado, Idaho, Montana, Nevada, Oregon, Utah, and Washington (The inventory of the nation's low- and moderate-temperature geothermal resources has been updated by a recent DOE-sponsored resource assessment.)

- Advising and Referrals—technical information is provided by meeting with

groups and answering telephone inquiries and letters

- Speaker's Bureau—center staff are available to make presentations to both lay and technical audiences

- Tours—individual and group tours of the Klamath Falls district heating system and other geothermal applications in the area

- Publications—a quarterly bulletin featuring domestic and foreign reports is available free of charge and technical material may be obtained by writing for the GHC Publication Request Form

- Library—a geothermal library of over 5,000 volumes is maintained for lay and technical readers. Volumes are available for loan by writing the GHC librarian, and a GHC library subject matter listing is available along with a computer reference search.

The GHC address is:

Geo-Heat Center
Oregon Institute of Technology
3201 Campus Drive
Klamath Falls, OR 97601-9978
Phone: (503) 885-1750
Fax: (503) 885-1754
E-Mail: lienaup@oit.osshe.edu
lundj@oit.asshe.edu

MAPS SHOWING CO-LOCATION OF GEOTHERMAL RESOURCES AND POTENTIAL USER COMMUNITIES AVAILABLE FOR NINE STATES

Maps of nine western states showing the co-location of geothermal wells and springs with communities that represent potential users of the resource are available to the public. For example, the map of California in Figure 16 indicates that 70 cities and towns are located within 4.8 miles (8 km) of identified geothermal wells and springs with temperatures in excess of 50°C (122°F). The other states for which similar maps have been prepared are listed in Table 8.

The accompanying data tables identify:

- city/county
- latitude/longitude
- population
- reservoir temperature
- number of wells
- typical depth
- flow
- total dissolved solids
- current use
- heating degree days
- design temperature
- distance of resources from city

Table 8. States for Which Co-Location Sites Are Mapped (except CA)

	No. Sites		No. Sites
Colorado	15	New Mexico	12
Idaho	51	Oregon	32
Montana	18	Utah	23
Nevada	30	Washington	6

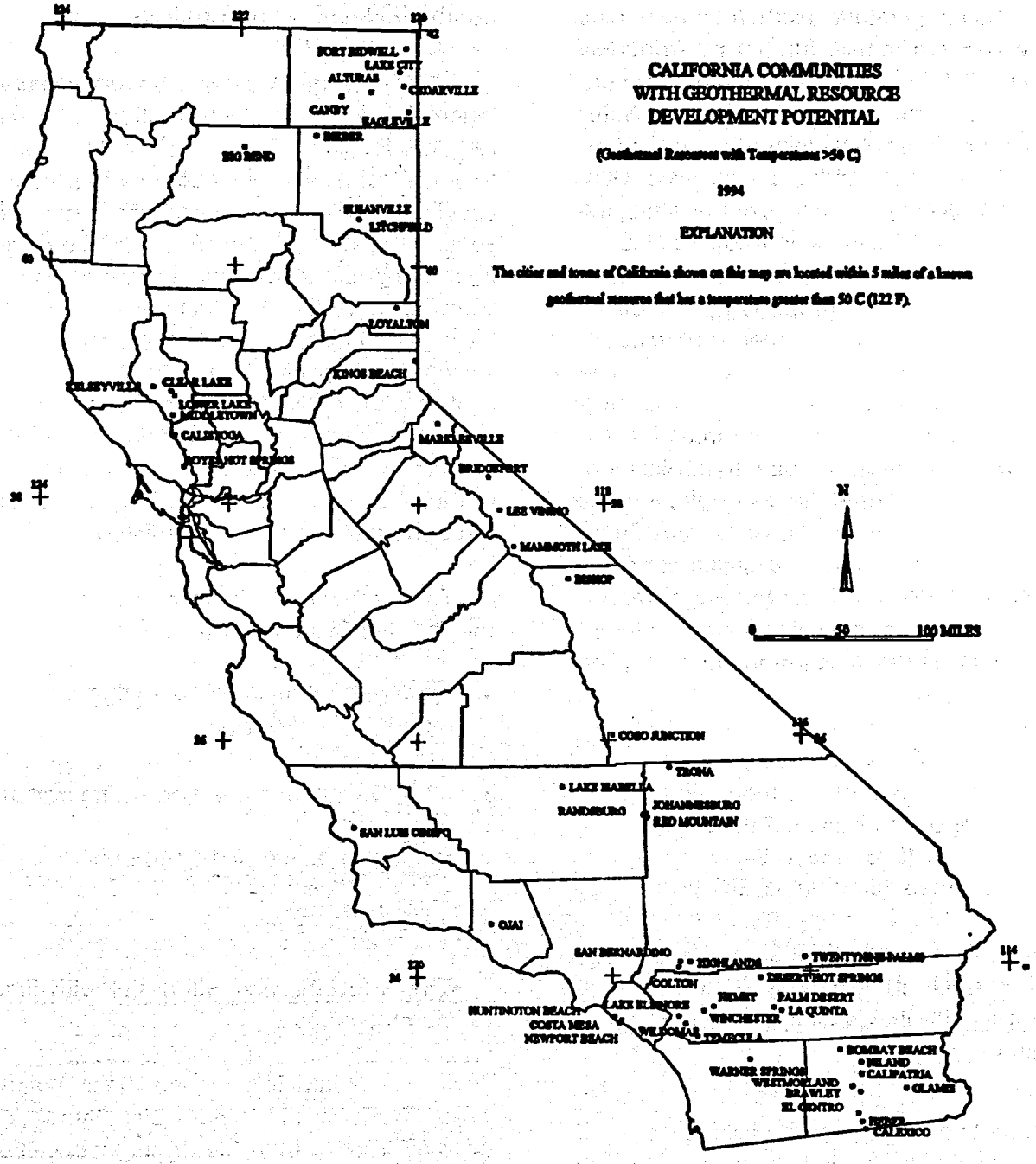


Figure 16. California Communities with Geothermal Resource Development Potential

The maps and data were developed as part of an updated assessment of low- and moderate-temperature geothermal resources in the western states, funded by Congress through DOE in 1991. The program was conducted by the GHC, the Idaho Water Resources Research Institute, the Earth Science Laboratory at the University of Utah Research Institute, and teams representing the cognizant agencies in the individual states.

Letters and accompanying resource data, for each area, have been sent to county economic development agencies. The GHC will provide assistance to those interested in developing their resources for district heating or an industrial application. This assistance could, for example, involve brokering—arranging contracts with financial institutions, resource assessment companies if needed, and engineering firms.

Copies of the maps and data may be obtained from:

Geo-Heat Center
Oregon Institute of Technology
Klamath Falls, OR 97601
(503) 885-1750
Fax (503) 885-1754

A SECTION OF GRC'S ON-LINE INFORMATION SYSTEM AVAILABLE AT NO COST

Effective February 1, 1995, the GRC made available a section of its On-Line Information System at no cost. Geothermists worldwide, through computer access, will be able to use the system's Message Areas and search the system's comprehensive list of vendors who supply geothermal goods and services.

The Message Area is a special section where those in need of information can make requests for general or specific data on how to solve technical problems, how to procure specific goods or services, and whom to send Requests For Proposals. In addition, the Message Area is available to vendors who want to advertise products and services. Listings of limited size will be carried on the system for a specified amount of time at no cost. Until recently, the Vendor List data base consisted only of U.S. companies. Presently, any company involved in geothermal exploration, development, and production throughout the world may be listed.

The hardware requirements for using the On-Line System are as follows:

- IBM compatible computer ('386 or better recommended)
- MS-DOS 5.0 (or higher) operating system
- modem of 9,600 or 14,400 bps
- a phone hook-up.

The GRC Librarian will assist with first-time connections.

If you would like to use the Message Area, to search the Vendor List Data Base, or to advertise in the Message Area, call or fax the GRC office at (916) 758-2360, fax (916) 758-2839, for an information packet.

Source: GRC Bulletin 1/95

GRC EMPHASIZES IMPORTANCE OF GEOTHERMAL SUSTAINABILITY

GRC presented a session at its 1994 Annual Meeting emphasizing the importance of sustainable geothermal production for the future of the industry. Two of the papers presented, printed in the GRC's September/October 1994 Bulletin, address sustainability strategies for two vastly different reservoirs and applications: 1) a field long used for power generation, and 2) an aquifer only recently employed in heating greenhouses.

Larderello

At the Larderello field in Italy, which has been used for commercial power production since 1926, two sustainability strategies have been employed - drilling of deep wells and injection. These applications followed a decade of stabilizing production, after it reached its peak in the 1960's, by drilling wells over increasingly large areas. When the boundaries of the productive area were reached, experiments began on extracting steam from deeper, undrained or only partially drained levels and producing new steam by injecting water into the more permeable and exploited areas of the field.

The deep drilling experiments were positive in the south-central zone and at the margins of the field. High productivity and reservoir pressures at approximately 5,000 to 8,000 feet made it possible to increase production and to offset the decline of the wells already in production. To the north, in the Larderello-Valle Secolo zone, the additional fluid was insufficient to offset the production decline of the area. See Figure 17 for a geologic cross section of the area. Wells drilled at the east, south, and west reached sufficient production and pressure levels, at approximately 10,000 and 11,500 feet, to allow construction of additional power plants in the future. The number of deep wells will be reduced, through optimum well spacing once analyses of the entire potential productive area is completed.

The first injection experiments were conducted in the Larderello-Valle Secolo

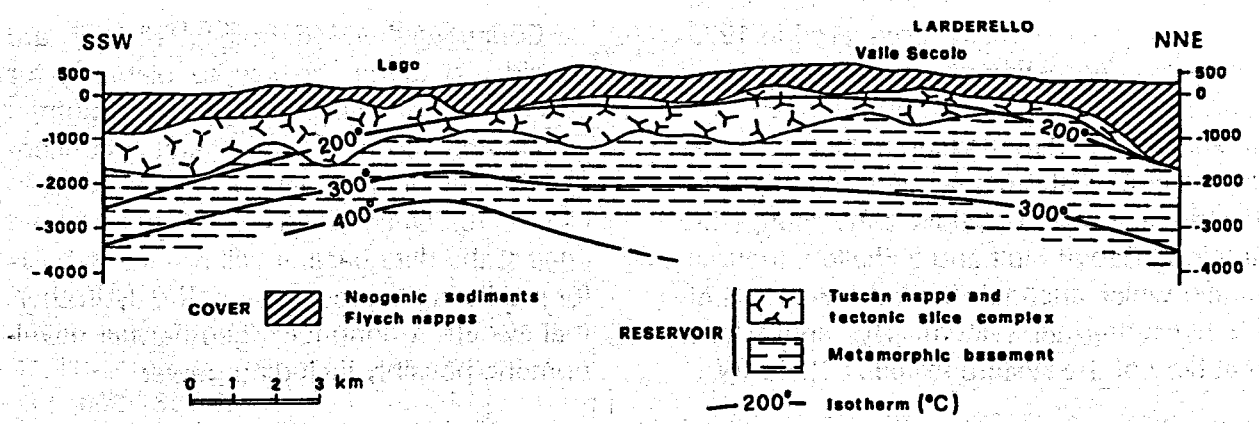


Figure 17. Geologic Section of Larderello Field

zone, which was the most favorable due to the extensive distribution of fractures and the presence of highly super heated steam. The tests at the top of the reservoir proved to be positive in the area of the fractured metamorphic formations. On the contrary, where the metamorphic formations are not fractured, there is breakthrough between the injection and production wells since the injectate does not penetrate to depth. Deep injection did not yield positive results.

Beginning in 1993, the condensate from the power plants was injected at the top of the reservoir in the most favorable area (Valle Secolo). A 15-year experimental period made it possible to define the limits and modes of injection. On-going injection experiments, in poorly fractured zones with high temperatures, have already achieved positive results by alternating individual wells for injection and production.

Newcastle, Utah

The Newcastle, Utah geothermal reservoir, located along the southeastern edge of the Escalante Desert, lies in a rural farming community. The concealed hydrothermal system was accidentally discovered in 1975 during aquifer testing at a newly drilled irrigation well. Subsequent studies by the University of Utah Research Institute, the Utah Geological Survey, and others have defined a covered upflow zone along the Antelope Range fault and a shallow thermal aquifer which channels the outflow plume of the hydrothermal system. The anomalous heat flow of the system exceeds 12.4 MW.

In 1988, three relatively small greenhouses and a church were producing thermal fluid for space heating and disposing of the cooled fluids in shallow evaporation/infiltration pits. No substantial change in fluid temperature or depths to warm water have been reported. However, in 1993, a 4-acre greenhouse was constructed, the first of seven planned. Since further expansions in greenhouse operations are economically desirable in southwestern Utah, it is important to resolve current uncertainties about the reservoir and to plan for sustainable (long-term) development which will provide continued employment and protect the capital already invested.

A limited program of temperature monitoring was initiated in August 1993, followed by a fluid level measurement program. Although significant temperature changes have been observed, neither temperature nor water level changes impacted users during the relatively mild 1993-94 heating season. However, since increased production levels during a colder winter may impact closely spaced production wells, additional monitoring wells are needed in areas anticipating substantial added development. Efforts are underway to obtain funding.

Conceptual and numerical models are considered to be the key to planning for additional development with minimal adverse effect on existing users. A conceptual model of the system is presented in Figure 18. Once it has been fully tested against the data base, it will provide a basis for predicting the response of the hydrothermal system to long-term geothermal development, possibly including power.

Source: GRC Bulletin 9/10/94

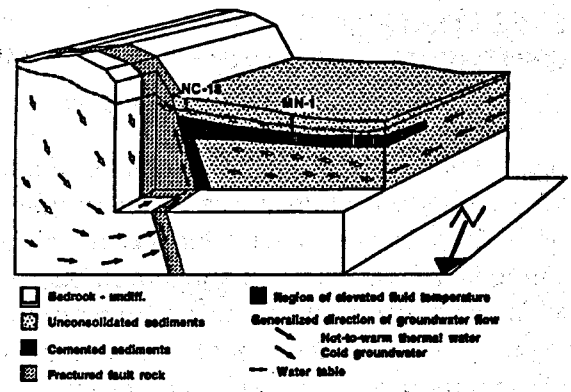


Figure 18. Conceptual Model for Groundwater Flow in Newcastle System

GEO-HEAT CENTER SPREADSHEET AVAILABLE FOR EVALUATING COSTS OF GEOTHERMAL SYSTEMS

The wide variety of heating equipment available for geothermal greenhouses, growers' preferences, and resource temperature can make the selection of equipment a complicated process. As with any project, equipment cost is a primary consideration. Manually evaluating the cost of five or six alternative systems for each project is too time consuming.

As a result of these issues, the Geo-Heat Center has developed a spreadsheet entitled, "Greenhouse Heating Equipment Selection" (GHS). It is a tool for evaluating the cost (both capital and operating) of six types of greenhouse heating systems:

- unit heaters
- finned pipe
- bare tube
- fan coil
- combination base tube/fan coil
- low-temperature unit heaters.

A future modification of the spreadsheet will allow a propane unit heater peaking system to be added to any of these systems.

Similarly, a spreadsheet, "Geothermal Energy Cost Evaluation," has been developed to compare two basic approaches to producing heat - a geothermal system and a gas boiler plant. This information is particularly useful at the conceptual stage of a project, when developers typically make decisions about fuel sources.

In addition, a data base, easily accessible and maintained on personal computers presents the results of findings from 253 case studies of ground source (or geothermal) heat pump (GSHP) installations. The data base contains information on the monitored (metered) and simulated (modeled) data used to establish patterns of energy savings, peak demand reductions, and economics for residential and commercial applications. The information also summarizes the status of GSHP demand-side management programs for the following:

- almost 60 electric utilities and rural electric cooperatives
- marketing, incentives, barriers to market penetrations
- number of units installed in service areas
- benefits.

More detail on the greenhouse spreadsheet and an example of its use are provided in the Center's Quarterly Bulletin of November 1994. Or information may be obtained from Kevin Rafferty at the Center on (503) 885-1750.

EXPANDED LOW TEMPERATURE GEOTHERMAL DATA BASE FOR OREGON NOW AVAILABLE

The Oregon Department of Geology and Mineral Industries (DOGAMI) has produced a digital inventory of Oregon's low-temperature and moderate-temperature geothermal resources - up to 150°C (300°F). This inventory is now available on a computer diskette. It lists 2,193 geothermal wells and springs; more than doubling the number (from the 1982 inventory) of known geothermal resources in the state.

The inventory of geothermal sites is part of the nationwide low-temperature Geothermal Resources and Technology Transfer Program funded by DOE's Geothermal Division. It is administered in Oregon by the GHC at the Oregon Institute of Technology.

The data base is now available to the public as DOGAMI Open-File Report O-94-9, Digital Data and Selected Texts from Low-Temperature Geothermal Data Base for Oregon. The price for the 3 1/2 inch high-density diskette is $12.00. It may be obtained from:

Nature of Oregon Information Center
Suite 177, State Office Building
800 N.E. Oregon Street, #5
Portland, OR 97232-2109
Phone: (503) 731-4444
Fax: (503) 731-4066

Orders may be charged to Visa or Mastercard. Orders under $50 require prepayment except for credit-card holders.

Source: GRC Bulletin 9-10/94; Geo-Heat Center Quarterly Bulletin 11/94

FREE POSTER ON GEOTHERMAL ENERGY

A colorful and comprehensive poster on geothermal energy has been prepared primarily for use as an educational tool in schools. In both art work and simplified text, all facets of the resource and its uses—ranging from the origins of heat and a brief history of man's use of natural hot water to power generation and the operation of heat pumps and other direct uses—are described. The environmental preferability of geothermal energy over competitive fuels is documented with comparative data on air emissions, land use, and handling of waste water.

The poster was prepared by the GRC and the Geothermal Education Office and funded by the Department of Energy. Copies may be obtained free-of-charge from:

The GRC
2001 Second Street, #5
Davis, CA 95616
Phone: (916) 758-2360

or

The GEO
644 Hilary Drive
Tiburon, CA 94920
Phone: (415) 435-4544

USGS PUBLICATION LOOKS AT PAST, PRESENT, AND FUTURE OF GEOTHERMAL ENERGY

The USGS publication Tapping the Earth's Natural Heat is both an attractive and informative "text book" on geothermal energy. The introduction presents its primary purpose as providing information that will help the reader understand how, where, and to what extent this resource can contribute to our Nation's needs. The publication does the following:

- describes the distribution and nature of geothermal energy
- reviews the common types of geothermal systems that provide useful energy using current technology
- considers potential geothermal resources that could be tapped with new technologies
- summarizes the role of earth-science information in assessing and tapping the geothermal resources of the U.S.
- providing technical assistance to developing countries' studies of their geothermal fields.

Identified as USGS Circular 1125, the publication is free from:

USGS Map Distribution
Box 25286, MS 306
Denver Federal Center
Denver, CO 80225

GEOTHERMAL INFORMATION AVAILABLE ON DOE CD-ROM

According to Infotech Update, a quarterly newsletter published by DOE's Office of Scientific and Technical Information, geothermal energy is one of many topics covered by Energy Science and Technology—a multidisciplinary file containing nearly 3 million worldwide references to basic and applied scientific and technical literature in all fields of energy. Other subject areas of potential interest to the geothermal community include:

- energy conversion
- environmental effects of energy usage-relative to greenhouse gas effects and global climate change
- pollution mitigating activities
- electric power engineering.

On average, about 50 percent of the data base is from foreign sources.

For subscription prices and information about local-area-network or wide-area-network changes, please contact:

Knight-Ridder Information, Inc.
Dialog On Disk
2440 El Camino Road
Mountain View, CA 94040
Phone: (800) 334-2564
Fax: (415) 254-8000

ASTM STANDARD FOR TWO-PHASE FLUID DEVELOPED

The American Society for Testing and Materials (ASTM) has developed a standard ensuring consistent and reliable data on the chemical composition of geothermal fluids from different worldwide sources. According to Paul Hirtz, chairman of the ASTM Task Group that developed standard E1675, the Practice for Sampling Two-Phase Geothermal Fluid for Purposes of Chemical Analysis provides users with the ability to obtain representative samples of the known quality of liquids and steam in a pipeline.

E1675 is available from ASTM Customer Services, (215) 299-5585. For information about E1675 or to suggest new standards development activities, contact Hirtz at:

Thermochem Inc.
5347 Skylane Blvd.
Santa Rosa, CA 95403
Phone: (707) 575-1310

Source: GRC Bulletin 6/95

MAJOR SOURCES OF GEOTHERMAL INFORMATION

This section of the GPM presents a representative sample of geothermal literature that has been reported since the last issue. Wider coverage of the literature may be found in a bimonthly publication of current abstracts, titled "Geothermal Energy," published by DOE's Office of Scientific and Technical Information. The publication may be obtained from the National Technical Information Service (NTIS), Springfield, VA 22161 as PB95-914700. The annual subscription price for six issues is $90.00 (domestic) and $180.00 (outside the North American continent). The publication typically lists each paper, article, or report derived from another publication, such as conference proceedings, as separate entries. Space does not permit separate listings in the GPM; thus, the following are recommended:

Geothermal Resources Council Bulletin, Monthly Publication of GRC, P.O. Box 1350, Davis, California 95617-1350.

Geothermal Resources Council Transactions, Proceedings, GRC Annual Meetings.

Stanford University Annual Workshop on Geothermal Reservoir Engineering, Stanford Geothermal Program, Dept. of Petroleum Engineering, Stanford, California 94305.

Proceedings of the Annual Geothermal Program Review, Geothermal Division, U.S. Department of Energy. Available from the National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia 22161.

Federal Geothermal Research Program Update, Volumes 1 and 2, U.S. Department of Energy.

Geo-Heat Center Quarterly Bulletin, Oregon Institute of Technology, Klamath, Falls, Oregon.

Water-Rock Interaction; Proceedings, Vol. 1, Low-Temperature Environments, Vol. 2 Moderate and High-Temperature Environments, Netherlands, 1992; Seventh Water-Rock Interaction Conference, Park City, Utah, July 9-22, 1992.

World Geothermal Congress, Florence, Italy, May 1995.

Sixth International Conference on Thermal Energy Storage, Espoo, Finland, Aug. 15-17, 1995. (In CALORSTOCK '94, Order No. DE95772422, OSTI; NTIS)

Note: Copies of the publications listed below should be obtained from NTIS at the address provided at the beginning of this article, or from one of the other sources listed. Those marked "GPO Dep." are available for inspection or interlibrary loan at Government Printing Office regional depository libraries. DOE and DOE contractors may order from the DOE Office of Scientific and Technical Information (OSTI), P.O. Box 62, Oak Ridge, TN 37831. Where given, the "GPO Dep. Order No." is the accession number for all locations; an NTIS number only is given when the document is not available at GPO. ITIS is the Integrated Technical Information System maintained by OSTI for contractor accession to DOE online data bases.

RESOURCE STATUS AND ASSESSMENT

Dickson, M.H. and M. Fanelli, "Smalol Geothermal Resources: A Review," Italian National Research Council (Pisa, Italy), International Institute for Geothermal Research, *Energy Sources,* 16(3) (Jul. 7-Sept. 1994).

Hicks, T.W., et al., *HDR Resources and Technology,* CSM Associates, Ltd., Camborne (United Kingdom) Sponsored by Energy Technology Support Unit, Harwell; available from the British Document Supply Centre, Boston Spa, Wetherby, West Yorks, LS 23 7BQ (1994)

Phair, K.A., "Getting the Most Out of Geothermal Power," Stone and Webster Engineering Corp., Denver, *Mechanical Engineering,* 116(9): 76-80 (Sept. 1994).

Rummel, F. and O. Kappelmeyer (eds.), *Geothermal Energy: Future Energy Source? Facts-Research-Future,* C.F. Mueller, Karlsruhe (Germany) 1993.

Salazar, J. and M. Brown (eds.), *Hot Dry Rock Energy: Hot Dry Rock Geothermal Development Program. Progress Report,* Fiscal Year 1993, Los Alamos National Laboratory, Order No. DE95009525, OSTI; NTIS; GPO Dep. (March 1995).

Willis-Richards, J., et al., *Site Comparison Study for the European Scientific Prototype HDR System,* Ibid.

GEOLOGY AND HYDROLOGY OF GEOTHERMAL SYSTEMS

Anovski, T., et al., "Possibility Determination for Reinjection of Used Geothermal Waters," Skopje University, Yugoslavia, *Renewable Energy* (United Kingdom); 5(5-8) (Aug. 1994).

Bjornstad, S.C., et al., *Coso Monitoring Program,* October 1992 through September 1993, Naval Air Weapons Station, China Lake, CA, NAWS-CL-TP003, NTIS prices: PCA07/MFA02 (Jan. 1994).

Brown, D.W., and K.L. Burns, *Designs of an HDR Reservoir at Clearlake California,* Las Alamos National Laboratory, Conference, EPRI/HDDR Geothermal Power for U.S. Electric Utilities, Irwindale, CA, OSTI; NTIS; GPO Dep.; Order No. DE94016199 (May 23-24, 1994).

Jewell, P.W., et al., "Hydrology and Chemistry of Thermal Waters Near Wells, Nevada," University of Utah, Department of Geology and Geophysics, *Ground Water,* 32(4) (July-Aug. 1994).

Klee, G. and F. Rummel, "Hydrofrac Stress Data for the European HDR Research Project Test Site Soultz-sous-Forests as a Part of the HDR Feasibility Study," in *Rock Mechanics in the 1990s: Proceedings:* Vol. 2, OSTI; NTIS; order No. DE94014602 (1993).

Matsuki, K. and K. Takeuchi, "Three-Dimensional In-Situ Stress Determination by Anelastic Strain Recovery of a Rock Core," Ibid.

Steefel, C.I., and A.C. Lasaga, "A Coupled Model for Transport of Multiple Chemical Species and Kinetic Precipitation/Dissolution Reactions with Application to reactive flow in Single Phase Hydrothermal Systems," Yale University, *American Journal of Science* 294(5), (May 1994).

Wallroth, T., *Status of HDR Research with Special Emphasis on Design Issues,* Chalmers University of technology, Dept. of Geology, Geothenburg, Sweden; Swedish National Board for Industrial and Technical Development (NUTEK) Stockholm, OSTI; NTIS; Order No. DE94783405 (1994).

Watanabe, K. and H. Takahashi, "Fractal Geometry Characterization of Geothermal Reservoir Fracture Networks," *Journal of Geophysical Research,* 100(B1) (Jan. 1995).

GEOTHERMAL EXPLORATION AND EXPLORATION TECHNOLOGY

Conca, J.L., *Transport in Porous and Fractured Media of the Creede Formation,* Washington State University, OSTI; NTIS; GPO Dep; Order No. DE95004260 (1995).

Finger, J.T., et al., *Steamboat Hills Explanatory Slimhole: Drilling and Testing,* Sandia National Laboratories, OSTI; NTIS; GPO Dep; Order No. DE94002956 (Oct. 1994).

Kutasov, I.M., "Empirical Equation Estimates Geothermal Gradients," *Multi Spectrum Technologies,* Santa Monica, CA, Oil and Gas Journal, 93(1) (Jan. 2, 1995).

Witcher, J.C., *Alpine 1/Federal: Executive Summary Final Report,* New Mexico State University, Southwest Technology Development Institute, Arizona Energy Office, Phoenix, OSTI; NTIS; GPO Dep; Order No. DE94017948 (April 1994).

Witcher, J.C., et al., *Alpine 1/Federal: Drilling Report: Final Report, Part 1,* Ibid, Order No. DE94017949 (June 1994).

Ibid, Part 2, Order No. DE94017950.

ECONOMIC, INDUSTRIAL, AND BUSINESS ASPECTS

Bonneville Power Administration, *Newberry Geothermal Pilot Project,* U.S. Department of Energy, OSTI; NTIS; GPO Dep; Order No. DE95001766 (Sept. 1994).

Dickson, M.H., and M. Fanelli, "Electricity from Geothermal Energy: Analysis of the Trend to the Year 2000, "International Institute for Geothermal Research, CNR, Pisa, Italy, *Renewable Energy* (United Kingdom), 5(5-8) (Aug. 1994).

Doherty, P. and R. Harrison, *Economics of HDR Systems,* Sunderland University, Renewable Energy Center and Energy Technology Support Unit, Harwell (United Kingdom), Sponsored by Dept. of Trade and Industry, London; available from the British Library Document Supply Center, Boston Spa, Wetherby, West Yorks, LS237BQ (1994).

"Geothermal in the Philippines," *Independent Energy,* 24(6) (July-Aug. 1994).

Wright, P.M., "Status and Potential of the U.S. Geothermal Industry;" University of Utah Research Institute, *AAPG Bulletin (American Association of Petroleum Geologists),* 77(8) Aug. 1993).

ENVIRONMENTAL ASPECTS

Evaluation of Options for Reduction of Noncondensible Gas Content and Hydrogen Sulfide Emissions at the Bacman I Geothermal Power Plant: Final Report, funded by the U.S. Trade and Development Agency on behalf of the Philippines' National Oil Co., Energy Development Corp., AEA Environment and Energy Harwell (United Kingdom), NTIS Prices: PCA07 (Jan. 1994).

Evans, K., et al., *A Survey of Endangered Waterbirds on Maui and Oahu and Assessment of Potential Impacts to Waterbirds from the Proposed Hawaii Geothermal Project Transmission Corridor: Final Report,* U.S. Fish and Wildlife Service, OSTI; NTIS; GPO; Dep. Order No. DE94017946 (Aug. 1994).

Miller, S.E., and J.M. Burgtt, *Hawaii Geothermal Project Annotated Bibliography: Biological Resources of the Geothermal Subzones, the Transmission Corridors, and the Puna District, Island of Hawaii,* U.S. Fish and Wildlife Services, OSTI; NTIS; GPO Dep; Order No. DE94017944 (Oct. 1993).

Reynolds, M., et al., *Surveys on the Distribution and abundance of the Hawaiian Hoary Bat (Lasiurus cinereus semotus) in the Vicinity of Proposed Geothermal Project Subzones in the District of Puna, Hawaii: Final Report,* U.S. Fish and Wildlife Services, OSTI; NTIS; GPO Dep; Order No. 94017943 (Aug. 1994).

Reynolds, M., et al., *Surveys of Distribution and Abundance of the Hawaiian Hawk within the Vicinity of Proposed Geothermal Project Subzones in the District of Puna, Hawaii: Final Report,* U.S. Fish and Wildlife Service, OSTI; NTIS; GPO Dep. Order No. DE94017947 (Aug. 1994).

Sorey, M.L. and E.M. Colvard, *Potential Effects of the Hawaii Geothermal Project on Ground-Water Resources on the Island of Hawaii,* U.S. Geological Survey, Denver, OSTI; NTIS; GPO Dep. Order No. DE94014680 (1994).

Surveys of the Distribution of Seabirds Found in the Vicinity of Proposed Geothermal Project Subzones in the District of Puna, Hawaii: Final Report, Ibid, Order No. DE94017945.

Willis-Richards, J., *Report of Phase 4 HDR 1993/1994 Work Program,* CSM Associates, Ltd., Ibid.

GEOTHERMAL POWER PLANTS

Alicilar, A., et al., "Optimization of a Double Stage Flash System," Dept. of Chemical Engineering. Gazi University, Ankara, Turkey, *International Journal of Energy Research,* United Kingdom, 19(2) (March 1995).

Lazzeri, L., et al., "GRAPE: A Preengineered Standard for Geothermal Application," Ansaldo, Proceedings: Vol. 56-1, *Illinois Institute of Technology,* CONF-940445-: 56. Annual American Power Conference, Chicago (April 25-27, 1994).

Pilot Reboiler System for the 20 MW Botong Geothermal Power Plant: Final Report, Ibid., NTIS Prices: PCA04.

GEOTHERMAL ENGINEERING

Allan, M.L. and L.E. Kukacka, *Lost Circulation Control Materials. Progress Report,* Brookhaven National Laboratory, Order No. 95010441, OSTI; NTIS; GPO Dep.

Forsha, M.D. and K. Lankford, "Turbine-driven Compressors for Noncondensible Gas Removal at Geothermal Steam Power Plants," Barber-Nichols Inc., Arvada, CO, Ibid.

Geothermal Power: Corrosion and Material Development (Latest citations from the NTIS Bibliographic Data Base) Published Search, NERAC, Inc., Tolland, CT, NTIS Prices: PCN01/MF NO1, PB-94-884061/XAB (June 1994).

Geothermal Power: Drilling Technology and Hardware, Ibid.

Hughes, E.E. and H.K. McCluer, "Present and Future Geothermal Power Plants in the United States," Electric Power Research Institute, *29th Intersociety Energy Conversion Engineering Conference: Technical Papers. Part 4,* Monterey, CA, American Institute of Aeronautics and Astronautics, Washington, D.C. (Aug. 7-12, 1994).

Lea, C.M., et al., *Reservoir Engineering Studies of the Glays McCall Geopressured-Geothermal Resources,* Texas University, Center for Petroleum and Geosystems Engineering, OSTI; NTIS; GPO Dep. Order No. DE94015521 (Sept. 1993).

Matsunaga, I., et al., "Studying Hydraulic Fracturing Mechanism by Laboratory Experiments with Acoustic Emission Monitoring," National Research Institute of Resources and Environment (Japan) and Wisconsin University, *U.S. Symposium on Rock Mechanics, Madison, Wisconsin, in Rock Mechanics in the 1990s: Proceedings: Vol. 2,* OSTI; NTIS; Order No. DE94014602 (June 27-30, 1993).

Oikawa, Yasuki, et al., "Study for Differential Strain Curve Analysis to Estimate Stress\State of the Hijiori Hot Dry Rock Field, Japan," Ibid.

Tso, C.P., and J. Zhao, "A Study in Forced Convection of Water in a Single Uneven Planar Rock Fracture for Geothermal Application," Nanyang Technological University, Singapore, *Renewable Energy* (United Kingdom), 4(4) (1994).

DIRECT ENERGY UTILIZATION

Ayala, R., et al., "Experimental Assessment of an Ammonia/Lithium Nitrate Absorption Cooler Operated on Low-Temperature Geothermal Energy," Institute de Investigaciones Electricas, Mexico, *Heat Recovery Systems and CHP* (United Kingdom), 14(4) (July 1994).

Davis, G.W. and Chih Wu, "Optimal Performance of a Geothermal Heat-engine Driven Heat-pump System," U.S. Naval Academy, *Energy* (United Kingdom, 19(12) (Dec. 1994).

Latrofa, E.M., et al., "Geothermal Convector Design: Solutions, Design Criteria, and Calculation Methods," University di Pisa, Italy, *Energy Sources,* 16(4) (Oct-Dec. 1994).

Marinez, G.M. and W.N. Sullivan, "Geothermal Heat Pump Research and Development Studies at Sandia National Laboratories," *29th Intersociety Energy Conversion Engineering Conference: Technical Papers. Part 4,* Monterey, CA, American Institute of Aeronautics and Astonautics, Washington, D.C. (Aug. 7-12, 1994).

GEOTHERMAL DATA AND THEORY

Anovitz, L.M. *Electrochemical Determination of the Gibbs Free Energies of Rock - Forming Minerals. Final Report,* Arizona University, Dept. of Geoscience, Order No. DE95009682, OSTI; NTIS; GPO Dep.

Compton, R.G., and C.A. Brown, "The Inhibition of Calcite Dissolution/ Precipitation: Mg2+," Oxford University (United Kingdom), *Journal of Colloid and Interface Science,* 165(2) (July 1994).

Horita, J., et al., "Salt Effects on Stable Isotope Partitioning and Their Chemical Implications for Geothermal Brines," Oak Ridge National Laboratory, 19th Workshop on Geothermal Reservoir Engineering, Stanford University, OSTI; NTIS; GPO Dep. Order No. DE94012341 (Jan. 1994).

Kenyon , W.E. and J.A. Kolleeny, "NMR Surface Relaxivity of Calcite with Absorbed Mn2+," Schlumberger-Doll Research, Ridgefield, CT, *Journal of Colloid and Interface Science,* 170(2) (March 15, 1995).

Murty, V.D., et al., "A Numerical Study of the Stability of Thermohaline Convection in a Rectangular Box Containing a Porous Medium," University of Portland, *International Communications in Heat and Mass Transfer,* 21(2) (March-April 1994).

Pruess, K., "Liquid-Phase Dispersion During Injection into Vapor-Dominated Reservoirs," Lawrence Berkeley Laboratory, 19th Workshop on Reservoir Geothermal Engineering, Stanford University, OSTI; NTIS; GPO Dep. Order No. DE94011355 (Jan. 1994).

Simmons, S.F. and B.W. Christianson, "Origins of Calcite in a Boiling Geothermal System," University of Auckland (New Zealand), *American Journal of Science,* 294(3) (March 1994).

WASTE MANAGEMENT

Peralta, G.L., et al., "Characterization of the Solid Residues from Geothermal Power Generation," University of Toronto, Dept. of Chemical Engineering and Applied Chemistry, CONF-940204-: 124 Annual Meeting of the Minerals, Metals and Materials Society, San Francisco (Feb. 27-March 3, 1994).

Premuzic, E.T. and M.S. Lin, "Biochemical Solubilization of Toxic Salts from Residue Geothermal Brines and Waste Waters," U.S. Patent 5,366,891/A/, issued to Associated Universities, Inc., Washington, D.C., Patent and Trademark Office, Box 9, Washington, D.C. 20232 (Nov. 22, 1994).

The following tables present data on the facilities of the U.S. geothermal power industry, past, present, and planned. The information was assembled from published sources and direct contact with industry spokesmen. It is believed to be accurate as of the end of 1995.

The key to the abbreviations used in the following power plant tables is as follows:

DDS	-	Dry Steam
DF	-	Dual Flash
SF	-	Single Flash
B	-	Binary

Utilities

BPA	-	Bonneville Power Administration
HELCO	-	Hawaii Electric Light Co.
IID	-	Imperial Irrigation District
LADWP	-	Los Angeles Department of Water and Power
NCPA	-	Northern California Power Agency
PG&E	-	Pacific Gas and Electric Co.
PP&L	-	Pacific Power and Light Co.
PSP&L	-	Puget Sound Power & Light Co.
SCE	-	Southern California Edison
SDG&E	-	San Diego Gas and Electric Co.
SPP	-	Sierra Pacific Power Co.
SMUD	-	Sacramento Municipal Utility District
UPD	-	Utah Power Division of Pacific Corp.

GEOTHERMAL ELECTRIC POWER PLANTS OPERATIONAL, UNDER CONSTRUCTION, AND PLANNED IN THE UNITED STATES
(Dry Steam Plants at The Geysers)

PLANT NAME	FIELD DEVELOPER	PLANT OWNER	UTILITY	RATED CAPACITY (MW)	YEAR ON LINE
PG&E Unit 1[a]	UNOCAL/Magma/Thermal	PG&E	PG&E	11	1960
PG&E Unit 2[a]	"	"	"	13	1963
PG&E Unit 3[a]	"	"	"	27	1967
PG&E Unit 4[a]	"	"	"	27	1968
PG&E Unit 5	"	"	"	53	1971
PG&E Unit 6	"	"	"	53	1971
PG&E Unit 7	"	"	"	53	1972
PG&E Unit 8	"	"	"	53	1972
PG&E Unit 9	"	"	"	53	1973
PG&E Unit 10	"	"	"	53	1973
PG&E Unit 11	"	"	"	106	1975
PG&E Unit 12	"	"	"	106	1979
PG&E Unit 15[a]	Geothermal Resources International	"	"	59	1979
PG&E Unit 13	Santa Rosa Geothermal Co.[b]	"	"	133	1980
PG&E Unit 14	UNOCAL/Magma/Thermal (Natomas)	"	"	109	1980

[a] Retired

[b] Formed by Calpine Corp. and Freeport-McMoran as new owner of leases and steam supply operations; originally Aminoil properties

GEOTHERMAL ELECTRIC POWER PLANTS OPERATIONAL, UNDER CONSTRUCTION, AND PLANNED IN THE UNITED STATES
(Dry Steam Plants at The Geysers)

PLANT NAME	FIELD DEVELOPER	PLANT OWNER	UTILITY	RATED CAPACITY (MW)	YEAR ON LINE
PG&E Unit 17	UNOCAL/Magma/Thermal (Natomas)	PG&E	PG&E	110	1982
PG&E Unit 18	UNOCAL/Magma/Thermal (Natomas)	PG&E	PG&E	110	1983
SMUDGEO No. 1	Santa Rosa Geothermal Co.[b]	Sacramento Municipal Utility District	SMUD	72	1983
NCPA No. 1[c]	Northern Calif. Power Agency (originally Grace Geothermal)	NCPA	NCPA	110	1983
Santa Fe Geothermal 1	Santa Fe Geothermal (originally Occidental)	Santa Fe Geothermal	PG&E	80	1984
Bottle Rock[d]	NCPA	Calif. Dept of Water Resources	Calif. Dept of Water Resources	55	1984
NCPA No. 2[c]	NCPA	NCPA	NCPA	110	1985
PG&E Unit 16	Santa Rosa Geothermal Co.[b]	PG&E	PG&E	110	1985
PG&E Unit 20	UNOCAL/Thermal (Diamond Shamrock)	PG&E	PG&E	110	1985
Cold Water Creek	Cold Water Creek Operating Co.	CCPA[e]	CCPA[e]	124	1988
Bear Canyon Creek	Santa Rosa Geothermal Co.[f]	Santa Rosa[f]	PG&E	22	1988

[c] Originally NCPA Nos. 2 and 3

[d] Closed

[e] Plant ownership divided among Sacramento Municipal Utility District (SMUD), Modesto Irrigation District (MID), and the City of Santa Clara

GEOTHERMAL ELECTRIC POWER PLANTS OPERATIONAL, UNDER CONSTRUCTION, AND PLANNED IN THE UNITED STATES
(Dry Steam Plants at The Geysers)

PLANT NAME	FIELD DEVELOPER	PLANT OWNER	UTILITY	RATED CAPACITY (MW)	YEAR ON LINE
West Ford Flat	Santa Rosa Geothermal Co.[f]	Santa Rosa[f]	PG&E	29	1988
Joseph W. Aidlin Power Plant	Geothermal Energy Partners[g]	Geothermal Energy Partners/Cloverdale Geothermal Partners[h]	PG&E	20	1989

f The new partnership of Calpine Corp. and Freeport-McMoRan owns both field and power plant operations; originally Geysers Geothermal properties

g A subsidiary of Mission Power is general partner

h Calpine Corp. and Metlife Capital Corp. (affiliate of Metropolitan Life Ins. Co.)

GEOTHERMAL ELECTRIC POWER PLANTS OPERATIONAL, UNDER CONSTRUCTION, AND PLANNED IN THE UNITED STATES (Hot Water Plants)							
LOCATION (State and Site)	**PLANT NAME**	**TYPE**	**FIELD DEVELOPER**	**PLANT OWNER**	**UTILITY**	**RATED CAPACITY (MW)**	**YEAR ON LINE**
ALASKA							
	Unalaska	TBD	Exergy	Alaska Energy Authority	TBD	12	1996
CALIFORNIA							
Coso Hot Springs	Navy Plant No. 1, Units No. 1, 2, & 3	DF	California Energy[a]	California Energy[a]	SCE	80	1987-1988
	BLM East (Units 1&2)	DF	California Energy[a]	California Energy[a]	SCE	48	1988
	BLM West	DF	California Energy[a]	California Energy[a]	SCE	28	1989
	Navy Plant No. 2, Units No. 4, 5, & 6	DF	California Energy[a]	California Energy[a]	SCE	80	1989
East Mesa	GEM 1 (formerly B.C. McCabe)	B	GEO Operator/Mission[b,c]	GEO/Mission[c]	SCE	12.5[d]	1980
	Ormesa I	B	OESI	OESI	SCE	24	1986
	Ormesa II	B	OESI/Harbert International	OESI/Harbert	SCE	17	1988
	Ormesa IE	B	OESI	OESI	SCE	8	1988

[a] Various venture partners are involved in all California Energy Coso plants

[b] Magma Power original owner

[c] Mission Energy, a subsidiary of SCE

[d] Enlarged from 10 MWe

GEOTHERMAL ELECTRIC POWER PLANTS OPERATIONAL, UNDER CONSTRUCTION, AND PLANNED IN THE UNITED STATES (Hot Water Plants)

LOCATION (State and Site)	PLANT NAME	TYPE	FIELD DEVELOPER	PLANT OWNER	UTILITY	RATED CAPACITY (MW)	YEAR ON LINE
CALIFORNIA (Cont'd)	Ormesa IH	B	OESI	OESI/Harbert	SCE	6	1989
	GEM 2	DF	GEO/Mission[c]	GEO/Mission[c]	SCE	37	1989
Glass Mountain	BPA Pilot II[e]	DF	Calpine	Trans-Pacific	BPA	30	1998 (est.)
Heber	Heber Dual Flash Power Plant	DF	Chevron Resources Co.	Calpine Corp./ERC International[f]	SCE	47	1985
	Heber Binary Project[g]	B	Chevron	To be sold by SDG&E	SDG&E	45	1985
	Second Imperial	B	Second Imperial Geothermal Co.	GE Capital	SCE	37	1993
Mono-Long Valley	Mammoth Pacific (MP) Unit 1	B	Pacific Energy[h]	Pacific Energy[h]/Constellation	SCE	7	1984
	MP Unit II	B	Pacific Energy[h]	Pacific Energy[h]/Constellation	SCE	10	1990
	MP Unit III	B	Pacific Energy[h]	Pacific Energy[h]/Constellation	SCE	10	1998 (est.)

e Bonneville Power Administration Geothermal Pilot Project

f Partnership of Dravo Corp. and Centennial Energy original owner

g Demonstration plant supported by the U.S. Department of Energy; currently not in operation

h Subsidiary of Pacific Enterprises

GEOTHERMAL ELECTRIC POWER PLANTS OPERATIONAL, UNDER CONSTRUCTION, AND PLANNED IN THE UNITED STATES (Hot Water Plants)							
LOCATION (State and Site)	**PLANT NAME**	**TYPE**	**FIELD DEVELOPER**	**PLANT OWNER**	**UTILITY**	**RATED CAPACITY (MW)**	**YEAR ON LINE**
CALIFORNIA (Cont'd)	Pacific Lighting Energy Systems (PLES) Unit I	B	Pacific Energy[h]	Pacific Energy[h]/Constellation	SCE	10	1990
Salton Sea	Salton Sea Unit 1[i]	SF	California Energy	California Energy	SCE	10	1982
	Salton Sea Unit 2[i]	SF	California Energy	California Energy	SCE	18[k]	1990
	Vulcan	DF	California Energy/Mission[c]	California Energy/Mission[c]	SCE	30	1985
	Del Ranch	DF	California Energy/Mission[c]	California Energy/Mission[c]	SCE	34	1988
	Elmore I	DF	California Energy/Mission[c]	California Energy/Mission[c]	SCE	34	1988
	Leathers I	DF	California Energy/Mission[c]	California Energy/Mission[c]	SCE	34	1989
	Salton Sea Unit 3	DF	California Energy	California Energy	SCE	48	1989
	Salton Sea Expansion[j]	DF	California Energy	California Energy	SCE	34	1996
Wendel-Amedee	Wineagle Project	B	Wineagle Developers	Wineagle Developers	PG&E	.7	1985

[i] Formerly developed by Unocal

[j] A renegotiated power purchase agreement combined the Salton Sea I expansion and Fish Lake projects.

GEOTHERMAL ELECTRIC POWER PLANTS OPERATIONAL, UNDER CONSTRUCTION, AND PLANNED IN THE UNITED STATES (Hot Water Plants)							
LOCATION (State and Site)	**PLANT NAME**	**TYPE**	**FIELD DEVELOPER**	**PLANT OWNER**	**UTILITY**	**RATED CAPACITY (MW)**	**YEAR ON LINE**
CALIFORNIA (Cont'd)	Amedee Geothermal	B	Trans-Pacific Geothermal Inc. (TPG)/U.S. Energy Corp.	TPG/U.S.	PG&E	2	1988
	Honey Lake Power Facility	B[k]	GeoProducts Corp.	HL Power Co.	PG&E	30	1988
HAWAII							
	Puna Geothermal Venture I	SF/B	OESI	OESI	HELCO	25	1993
NEVADA							
Beowawe	Beowawe	DF	California Energy (originally Chevron)	California Energy/Crescent Valley Geothermal[l]	SCE	15	1985
Brady-Hazen	Desert Peak	DF	California Energy (originally Phillips; more recently Chevron)	California Energy (originally Chevron)	SPP	9	1985
	Brady Hot Springs I	DF	Brady Power Partners	Brady Power Partners	SPP	20	1992
Dixie Valley	Oxbow	DF	Oxbow Geothermal (originally Sunedco; then Trans-Pacific)	Oxbow	SCE	50	1988
Lee Hot Springs	Lee Hot Springs I	B	Earth Power Resources	Earth Power Resources	SPP	5	1998 (est.)

[k] A hybrid plant using wood waste and geothermal heat; geothermal fluid used only to preheat boiler feedwater

[l] SCE Subsidiary

GEOTHERMAL ELECTRIC POWER PLANTS OPERATIONAL, UNDER CONSTRUCTION, AND PLANNED IN THE UNITED STATES (Hot Water Plants)							
LOCATION (State and Site)	**PLANT NAME**	**TYPE**	**FIELD DEVELOPER**	**PLANT OWNER**	**UTILITY**	**RATED CAPACITY (MW)**	**YEAR ON LINE**
NEVADA (Cont'd)							
San Emidio Desert	Empire Geothermal Project	B	OESI	Empire Geothermal	SPP	3	1987
Steamboat Springs	Steamboat Geothermal I	B	Geothermal Development Associates (GDA/OESI)	Far West Electric Energy Fund, Ltd.	SPP	6.8	1986
	Steamboat Geothermal IA	B	OESI/GDA	Far West	SPP	1.2	1989
	Yankee/Caithness	SF	Caithness/Sequa	Caithness/Sequa	SPP	12	1988
	Steamboat 2	B	Steamboat Development	Steamboat Development	SPP	12	1992
	Steamboat 3	B	Steamboat Development	Steamboat Development	SPP	12	1993
Stillwater/Soda Lake	Soda Lake Geothermal Project	B	Chevron	Institutional Investors (OESI Operator)	SPP	2.7	1987
	Stillwater Geothermal I Project	B	OESI	OESI/Constellation Development/Chrysler Capital	SPP	13	1989
	Soda Lake II	B	Amor	OESI	SPP	13	1990
Wabuska[m]	Wabuska	B	Tad's Enterprises	Tad's Enterprises	SPP	1.5	1984

[m] Declassified KGRA

GEOTHERMAL ELECTRIC POWER PLANTS OPERATIONAL, UNDER CONSTRUCTION, AND PLANNED IN THE UNITED STATES (Hot Water Plants)							
LOCATION (State and Site)	**PLANT NAME**	**TYPE**	**FIELD DEVELOPER**	**PLANT OWNER**	**UTILITY**	**RATED CAPACITY (MW)**	**YEAR ON LINE**
OREGON							
Newberry Crater	BPA Pilot I[e]	DF	California Energy	California Energy	Eugene Water & Electric; BPA	30	1998
UTAH							
Roosevelt Hot Springs	Blundell I	SF	California Energy Co. (originally Phillips; subsequently Chevron)	Utah Power Div. (UPD) of PacificCorp	UPD	20	1984
Cove Fort-Sulphurdale	Cove Fort Geothermal No. 1	B	Mother Earth	City of Provo	Utah Municipal Power Agency	2	1985
	Cove Fort Steam Plant	DS	Mother Earth	City of Provo	Provo Power Co.	2	1988
	Cove Fort Steam No. 2	DS	Mother Earth	City of Provo	Provo Power Co.	7	1989

DOE HEADQUARTERS

U.S. Department of Energy
Geothermal Division, EE-122
1000 Independence Ave., SW
Washington, DC 20585
Phone (202) 586 - (ext.)

Allan Hoffman	9275	Deputy Assistant Secretary, Office of Utility Technologies
Ronald R. Loose	8086	Acting Assistant Deputy Secretary, Office of Utility Technologies
Allan J. Jelacic	6054	Director, Geothermal Division
David B. Lombard	4952	Team Leader, Energy Applications
Raymond Fortuna	1711	Manager, Geysers Pipeline Project and Direct Use
Gladys J. Hooper	1146	Manager, Advanced Brine Chemistry, Hot Dry Rock
Raymond J. LaSala	4198	Manager, Energy Conversion and Materials
Lew W. Pratsch	1512	Manager, Drilling and Geothermal Heat Pumps
Marshall Reed	8076	Manager, Hydrothermal Reservoir Technology and International Programs

DOE FIELD OFFICES (GEOTHERMAL PROGRAM MANAGEMENT)

U.S. Department of Energy
Albuquerque Operations Office
P. O. Box 5400
Albuquerque, NM 87112

Dan Sanchez
Energy Project Manager
(505) 845-4417

U.S. Department of Energy
Golden Field Office
1617 Cole Boulevard
Golden, CO 80401

Robert L. Martin
Senior Project Manager
(303) 275-4763

Jeffrey Hahn
Geothermal Project Manager
(303) 275-4775

U.S. Department of Energy
Idaho Operations Office
785 DOE Place
Idaho Falls, ID 83402

Peggy Brookshier
Senior Program Manager
(208) 526-1403

Robert Creed
Geothermal Project Manager
(208) 526-9063

NATIONAL LABORATORIES (GEOTHERMAL PRINCIPAL INVESTIGATORS)

Brookhaven National Laboratory
Process Materials Group
Building 526
Upton, NY 11973

Lawrence E. Kukacka
Advanced Materials Research
(516) 282-3065

Eugene T. Premuzic
Biochemical Processes
(516) 282-2893

Idaho National Engineering Laboratory
P. O. Box 1625
Technology
Idaho Falls, ID 83415

Joel Renner
Hydrothermal Reservoir
(208) 526-9824

Greg Mines
Energy Conversion
(208) 526-0260

Lawrence Berkeley Laboratory
Earth Sciences Division
Building 50E
Berkeley, CA 94720

Marcelo J. Lippmann
Reservoir Research
(510) 486-5035

Los Alamos National Laboratory
P. O. Box 1663, MS-D443
Los Alamos, NM 87545

David V. Duchane
Hot Dry Rock Research
(505) 667-9893

National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, CO 80401

John V. Anderson
Energy Conversion
(303) 231-1022

Sandia National Laboratories
P. O. Box 5800, Division 6252
Albuquerque, NM 87185

James C. Dunn
Drilling R&D;
Geothermal Heat Pumps
(505) 844-4715

STATE GEOTHERMAL CONTACTS

STATE	NAME	PHONE NUMBER
ARIZONA	Jack Haenicken Arizona Department of Commerce Energy Office 3800 North Central Suite 1200 Phoenix, AZ 85012	Tel: (602) 280-1402 Fax: (602) 280-1445
CALIFORNIA	Kelly Birkinshaw California Energy Commission 1516 Ninth Street - MS-43 Sacramento, CA 95814	Tel: (916) 654-4542 Fax: (916) 654-4676
COLORADO	Marc Roper Renewable Energy Coordinator Governor's Office of Energy Conservation 1675 Broadway #1300 Denver, CO 80202-4613	Tel: (303) 620-4292 Fax: (303) 620-4288
HAWAII	Maurice H. Kaya Energy Program Administrator Energy Division 335 Merchant Street, Room 110 Honolulu, HI 96813	Tel: (808) 587-3812 Fax: (808) 586-2536
	Dean Nakano State of Hawaii Geothermal Project Office 335 Merchant Street, Room 110 Honolulu, HI 96813	Tel: (808) 586-2352 Fax: (808) 586-2536
NEW MEXICO	Roy Johnson Chris Williams New Mexico Energy, Minerals and Natural Resources Department 2040 South Pacheco Street Santa Fe, NM 87505	Tel: (505) 827-8198 Fax: (505) 827-8177
NORTH DAKOTA	Joe Murphy Program Administrator Office of Intergovernmental Assistance SECP State Capitol - 14th Floor 600 East Boulevard Avenue Bismarck, ND 58505-01701	Tel: (701) 328-2094 Fax: (701) 328-2308

OREGON	John White Oregon Department of Energy 625 Marion, N.E. Salem, OR 97310	Tel: (503) 378-3194 Fax: (503) 373-7806
UTAH	John Solum Utah Department of Natural Resources Division of Water Rights 1636 West North Temple Salt Lake City, UT 84116	Tel: (801) 538-7406 Fax: (801) 538-7315

STATE RESERVOIR ASSESSMENT PROGRAMS

STATE	NAME	PHONE NUMBER
ALASKA	Roman Motyka Department of Natural Resources Division of Geological and Geophysical Surveys 794 University Avenue, Suite 200 Fairbanks, AK 99709	Tel: (907) 451-5028 Fax: (907) 451-5050
	Eugene Wescott Geophysical Institute University of Alaska P.O. Box 757320 Fairbanks, AK 99775-7320	Tel: (907) 474-7576 Fax: (907) 474-7290
CALIFORNIA	Richard Thomas California Division of Oil, Gas and Geothermal Resources Geothermal Section 801 K Street, MS 21 20th Floor Sacramento, CA 95814-3530	Tel: (916) 323-1787 Fax: (916) 323-0424
IDAHO	Warren J. Weihiny Idaho Department of Water Resources 1301 North Orchard, Statehouse Mail Boise, ID 83720	Tel: (208) 327-7961 Fax: (208) 327-7866
MONTANA	Georgia Brensdal Montana Department of Environmental Quality Energy Division 1520 6th Avenue, E Helena, MT 59620-2301	Tel: (406) 444-6697 Fax: (406) 444-6721
	William Sill Department of Geophysical Engineering Montana Tech 1300 West Park Street Butte, MT 59701	Tel: (406) 496-4216 Fax: (406) 496-4133
	Chuck Widemand Hydrothermal Division Montana College of Mineral Science and Technology Butte, MT 59701	Tel: (406) 496-4209 Fax: (406) 496-4211

NEVADA	Dennis Trexler Division of Earth Science 100 Washington Street, Suite 201 Reno, NV 89503	Tel: (702) 784-6151 Fax: (702) 784-4549
NEW MEXICO	Rudi Schoenmackers Southwest Technology Development Institute New Mexico State University P.O. Box 30001 Department 3-SOL Las Cruces, NM 88003-8001	Tel: (505) 646-1846 Fax: (505) 646-2960
OKLAHOMA	Ken Luza Oklahoma Geological Survey University of Oklahoma 100 E. Boyd, Room N-131 Norman, OK 73019-0628	Tel: (405) 325-3031 Fax: (405) 325-3180
OREGON	Ian Madin State Department of Geology and Mineral Industries 1831 First Street Baker City, OR 97814-3442	Tel: (541) 523-3133 Fax: (541) 523-5992
UTAH	Robert Blackett Utah Geological Survey 2363 S. Foothill Drive Salt Lake City, UT 84109	Tel: (801) 467-7970 Fax: (801) 467-4070
WASHINGTON	Eric Schuster Department of Natural Resources Division of Geology and Earth Resources P.O. Box 47007 Olympia, WA 98504-7007	Tel: (206) 902-1451 Fax: (206) 902-1785