GEOTHERMAL DEVELOPMENT IN THE U.S.A. AND FUTURE DIRECTIONS

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ABSTRACT

The geothermal industry presently has an operating generation capacity of about 2,300 MWe, and generates about 17,000 billion KWH per year in the U.S. Although the domestic market is stagnant due to restructuring of the electricity industry and to the very low competing price of natural gas, the industry is doing well by developing geothermal fields and power plants in the Philippines and Indonesia. The industry strongly supports the DOE R&D program to develop new and improved technology and help lower the costs of geothermal power generation.

INTRODUCTION

The U.S. geothermal industry is composed of more than 50 companies headquartered in various states. The largest U.S. developers of geothermal fields are Caithness Corporation, CalEnergy Company, Inc., Calpine Corporation, Constellation Energy, Inc., ESI Energy, Inc., Ormat International, Inc., Oxbow Power Services, Inc., and Geothermal Division, Unocal Corp. U.S. utilities using geothermal power include Hawaiian Electric Company, Northern California Power Agency, PacifiCorp, Pacific Gas & Electric Co., Sierra Pacific Power Co., Southern California Edison, and Utah Municipal Power Agency. Direct employment in geothermal energy is estimated to be about 14,000 jobs, and using a multiplier of 2.5, the indirect effect is a minimum of 35,000 additional jobs (Meidav and Pigott, 1994). This industry maintains about 2,300 megawatts of operating generation capacity to produce about 17 billion kilowatt-hours/year, in four states -- California, Hawaii, Nevada, and Utah (DOE/EIA, 1995). States having excellent potential for near-term development of geothermal power include Alaska, Arizona, Idaho, Oregon, New Mexico, and Washington, all in the western U.S. Geothermal plants and reservoirs in the U.S. and throughout the world continue to function as planned, proving the reliability of geothermal power.

All U.S. geothermal power plants operate at very high capacity factors, some at 100% or higher. All plants also operate at very high availability factors. According to the DOE/EIA (1993), the average capacity factor for U.S. geothermal power plants in 1990 was 69%, composed of an average of 59% for utilities and 83% for non-utility generators (NUGs). By contrast, the average capacity factor for fossil was 45%, for nuclear was 66%, for hydropower was 41%, for biomass was 59%, for wind was 16%, and for solar was 28%. Because of its high capacity factor, 1 MWe of installed geothermal generating capacity can satisfy the domestic needs of 1,300 people in the U.S., more than for essentially any other generating source. By contrast, 1 MWe of installed wind generating capacity will only furnish the domestic needs for about 300 people.

Contrary to popular belief, geothermal power generation is indeed dispatchable over suitable time frames. PG&E currently dispatches generation at The Geysers field at certain times. Other fields could be dispatched if the need arose.

GEOTHERMAL PRODUCTION AND FURTHER POTENTIAL IN THE U.S.

Electrical Power Generation

Current geothermal electrical power production in the U.S. is about 2,300 MWe, generating about 17 billion kwh/y. Total geothermal use in the U.S. is equivalent to burning about 60 million barrels of oil annually. Sales of geothermally generated electricity in the United States amount to about $1 billion per year. In recent years, production from The Geysers field has declined from its peak in 1987 of about 2,000 MWe to a present value of about 1,300 MWe. This topic is discussed further below. At other fields, production has been maintained or has grown over the past several years. Geothermal energy furnishes about 6% of California's electricity, about 8% of northern Nevada's electricity, about 2% of Utah's electricity, and 25-50% of the electricity on the Big Island of Hawaii. Royalties and fees are paid by the geothermal industry to the Federal Government for production from Federal lands, amounting to $27 to 30 million annually.

Geothermal energy is the second largest grid-connected renewable electricity source in the United States, after hydropower. This plentiful energy source generates 200 times more electricity than solar energy and 5 times more than wind energy (DOE/EIA, 1995). The power produced from geothermal energy in the United States displaces the emissions of 22 million tons of carbon dioxide, 200,000 tons of sulfur dioxide, 80,000 tons of nitrogen oxides, and 110,000 tons of particulate emissions (whose adverse health effects are becoming more widely known) per year compared with the production of the same amount of electricity from an average U.S. coal-fired plant (GEA, 1995; DOE/EIA, 1996; Goddard et al., 1989; Goddard and Goddard, 1990). By contrast, utilities in 11 contiguous Western states that contain geothermal resources emitted 501 thousand tons of sulfur dioxide, 839 thousand tons of nitrogen oxides and 327 million tons of carbon dioxide in 1991 from burning of fossil fuels.

There are no recent, comprehensive and well documented assessments of the hydrothermal resource base in the United States. Brook et al. (1979) gave the estimate of 95,000 - 150,000 MWe for 30 years from known and undiscovered hydrothermal systems, but most people now believe this number is too high. Wright (1991) gave a rough estimate of 4,800 MWe of electrical power available for development, beyond current development, over the next 10 to 20 years from known hydrothermal systems in the contiguous 48 states. Hawaii could add 100 - 200 MWe and Alaska could add 50 - 100 MWe to the total in this time frame. Most of the large disparity between Brook's numbers and Wright's numbers originates from the widely held belief, based on sound geologic reasoning, that there are many hidden, undiscovered hydrothermal resources. New and significantly improved technology will be needed for discovery of these hidden hydrothermal systems. The amount of exploration work being conducted for discovery of new hydrothermal systems in the U.S. is small or none at the present time, owing to the low competing cost of power generation from natural gas. However, some exploration work is being conducted in known resource areas with the objective of being prepared for expansion when electricity demand increases.

Direct-Heat Uses

Direct uses of geothermal energy in the U.S. total about 14,000 TJ/y, and comprise such installations as district heating systems, geothermal heat pumps, agricultural drying, greenhouses, fish farming, and bathing spas (Lienau et al., 1995a). However, although the usable resource base of low- and moderate-temperature geothermal occurrences is very large, development of direct-heat uses is proceeding slowly. There is essentially no direct-heat geothermal industry or infrastructure in the same sense that there is an electrical-power generation industry. Each direct-heat system is a separate design, and few consultants or contractors are trained and experienced in the direct use of geothermal resources. With low costs for natural gas, this situation may not change soon.

In terms of future potential in the United States, we note that the most recent compilation of low- and moderate-temperature geothermal resources in ten western states contains information on 8,977 thermal wells and springs that are in the temperature range of 20 oC to 150 oC (Lienau et al., 1995b, Lienau and Ross, 1996). Data and maps are available for Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, and Washington. Resources with temperatures greater than 50 oC and located within 8 km of a population center were identified for 271 collocated cities, and 50 sites were judged high in priority for near term comprehensive resource studies and development. Older data are available for the rest of the United States in Reed (1983). Like the nation's high-temperature geothermal resources, the resources suitable for direct-heat application are wholly underdeveloped compared with their potential.

STATUS OF THE GEYSERS GEOTHERMAL AREA

Power generation at The Geysers field, which began in 1960, has been in decline in recent years. Accelerated steam pressure decline coincided with the rapid development of new power production in the mid 1980s (Barker et al., 1991). Between 1972 and 1981, new power development averaged 67 MWe/y. From 1982 to 1989, the average rate of development was 150 MWe/y. Beginning in 1985, a roughly 30%/y decline in pressure was noticed, whereas the previous decline rate had been about 6%/y. The cause of this rapid decline is that water is being mined from the reservoir at a significantly faster rate than recharge can replenish it. Approximately 75% of the condensate from the turbines is used in the cooling towers, leaving only 25% for injection. To this injected condensate is added some surface water captured in dams, but the total injectate still is far less than the water removed through production wells.

Injection experiments have been performed with mixed results in several parts of The Geysers field. In some cases, injection has either not increased available steam or has produced highly corrosive steam containing hydrochloric acid. A recent experiment was undertaken in the southeast portion of the field by Unocal, Calpine, Northern California Power Agency, Pacific Gas & Electric, and the U. S. Department of Energy (Voge et al., 1994) to test the effects in injection there. Injection into one well at rates of 400 to 800 gpm (25 to 50 l/s) resulted in increased steam production in some nearby areas. Within several days of the 6 January 1994 start of injection, enhanced steam production totaling 45 thousand pounds per hour (kph) (5.7 kg/s) was seen from the five producing wells on the injection well pad. The experiment, which ultimately lasted about 18 months, has indicated that injection of more water into the reservoir will help arrest the pressure decline, and enable the reservoir to produce power for many decades more (Enedy et al., 1991; Voge et al., 1994). However, it is recognized that injection will have to be done with care to avoid adverse effects on nearby production wells (Pruess and Enedy, 1993).

That a very significant thermal resource still exists in The Geysers field is beyond question. If the field is assumed to encompass a block of rock 100 km2 in extent and 3 km thick (very conservative estimates), the heat content above 15o C is roughly 1.7 X 1020 J, or 170 Quads (Q), equivalent to burning 28 billion barrels of oil or 6.2 billion short tons of coal. For comparison, the total energy consumption in the United States for all uses is about 85 Q/y. It can be shown that only a few percent of the thermal energy in the system has been produced at the surface since electricity generation began in 1960.

Construction of a 29-mile, 20-inch waste-sewage pipeline was started in October, 1995, running from the Lake County Sanitation District to the southeast part of The Geysers field (Dellinger, 1996). Completion is scheduled in August, 1997. This pipeline will carry 7.8 million gallons per day of water, which will be a mixture of waste water from the sewage treatment plant and water taken from Clear Lake. Reservoir engineers anticipate that the project will increase generation at The Geysers field by about 70 megawatts or more. With the success anticipated on this project, the City of Santa Rosa, which lies west of the field, is planning to undertake a project to determine the feasibility of building a pipeline from their waste-water treatment plants to the central part of the geothermal field. Even more waste water will be available from this source for injection in the geothermal field.

CHANGES IN THE U.S. ELECTRICITY INDUSTRY

Significant changes are underway in the electric utility industry as a result of the Energy Policy Act of 1992, with efforts on both the Federal and state levels to restructure this industry. Utilities and their customers are becoming ever more strongly motivated solely by short-term economics. In addition, natural gas prices have been very low in recent years, with the result that the vast majority of new power-plant installation is gas-fired combustion turbines. Tradition, regulation, and subsidies have favored the use of fossil fuels for electric power generation in the U.S. for decades. Because geothermal energy is not yet at the point of being able to compete in such a biased situation, its many advantages are at risk of being lost. The State of California is among the leaders in utility-industry deregulation and restructuring, and it_s public utility commission is actively working with all concerned sectors to devise a new industry structure in that state.

Deregulation will include the breakup of the vertically integrated utilities that now constitute monopolies controlled primarily by state regulation. Generation, transmission, and distribution functions will be separated in an effort to increase competition in each area and lower electricity prices to consumers without disrupting the excellent electrical-energy services Americans enjoy. As a result, many utilities will opt to sell their generating capacity to become transmission companies (transcos) or distribution companies (distcos). Generation companies (gencos) will comprise companies spun off from utilities, large independent power producers (IPPs) such as Enron, and the myriad of small IPP's currently operating under the Public Utilities Regulatory Policy Act of 1978 (PURPA), which created a market for renewable energy options such as geothermal energy. Gencos may possibly sell their power into a pool, from which distcos would make purchases on a long-term or a spot-market basis (or, more likely, a mixture of both), and the transcos would wheel the power to the distcos at an agreed transmission rate.

In order to preserve the benefits of clean, renewable energy supplies already in place, as well as to create a nourishing environment for further development, both federal and state law-makers are considering several options. For example, one option would be to require a specified amount of the overall electricity fuel mix to be renewable energy, such as geothermal energy -- the so-called "renewable-energy portfolio standard (RPS)." The requirement could be applied at either the distco or the power pool level. With an increasing RPS percentage, such an option would increase the amount of renewable electricity in the supply as time passes, ensuring a growth environment for geothermal energy. Another option, perhaps in addition to the RPS, would be to allow and encourage distcos to market a certain amount of their power as "green power", derived from clean sources, and charge their customers a marginally higher price for such power. More than half of Americans say they would buy green power, if it was offered to them at as much as one cent per kilowatt-hour above market prices. Such issues are being discussed in Congress and state legislatures as this volume goes to press, and we can anticipate that several years will be required before all aspects of deregulation and restructuring of the electricity industry will be ironed out.

All of this adds up to a very troubled, stagnant domestic geothermal market. The U.S. geothermal industry has had to curtail activities within U.S. borders and focus its efforts offshore to survive. While foreign development results in expanded export of U.S. goods and services, opportunity to develop domestic geothermal resources is being lost along with its contribution to fuel diversity, energy security, and environmental preservation. It is evident that we must lower the costs of geothermal power production to be able to compete in the domestic market. The conclusion is that better, more cost-effective technology must be developed.

GEOTHERMAL R&D IN THE U.S.

Highly successful programs have been and are now being carried out by DOE's Geothermal Division, working with the industry. The current geothermal R&D budget is about $30 million, and has remained stable even though budgets for other energy technologies have been cut significantly over the past four years. The primary reasons the geothermal budget has not been reduced are (1) the lobbying program in the Congress undertaken by the industry in support of the need for geothermal R&D, (2) the increasing recognition in Washington, DC of the benefits and enormous potential for further development of geothermal energy, especially for electrical power generation, and (3) the success of the R&D program in past years.

Technology Needs and R&d Priorities

The growth of geothermal energy development is not yet limited by resource availability. Rather, it is limited by inadequate technology. Only the very highest-grade geothermal resources can be economically used today. Development of the vast majority of geothermal resources is not possible because, at most resource sites, our power-generation costs are higher than those for competing fossil fuels, especially natural gas. Geothermal costs today range from 4 to 7 cents per kilowatt-hour for new power development at high-grade geothermal resource sites, whereas new generation capacity from natural gas, where it is readily available, produces power at 2.5 to 5 cents per kilowatt-hour. (Operation and maintenance costs at geothermal power plants whose capitalization has been paid may be as low as 0.9 cents per kilowatt hour). Power-generation costs at the much more plentiful lower-grade geothermal resource sites are absolutely unable to compete with natural-gas generation costs in the United States. A core R&D program aimed at improving existing technology and developing new, advanced technology is critical to enable to geothermal industry to compete in the domestic and global energy marketplaces.

During the past two years, the Geothermal Energy Association has conducted a series of workshops to discuss our needs for new technology and to recommend to the DOE cost-shared R&D programs based on our highest-priority needs (Wright, 1994, 1996b). Our workshops have resulted in the recommendation to DOE to concentrate in three program areas -- drilling, exploration and reservoir technology, and energy conversion.

Drilling. Because of the high temperatures and corrosive nature of geothermal fluids, geothermal drilling is much more difficult and expensive than conventional oil and gas drilling. Drilling costs account for one-third to one-half of the total costs for a geothermal project. Improvement in existing drilling techniques and development of new, advanced drilling techniques would significantly lower the cost of electricity generated from geothermal resources.

Exploration and Reservoir Technology. The major problem in exploration is how to remotely detect producing zones deep in the subsurface so that drill holes can be sited and steered to intersect these producing zones. Present exploration techniques are not specific enough, and lead us to drill too many dry wells, driving up development costs. Further, inadequate knowledge of the physical and chemical properties of the subsurface makes it impossible for us to mine the heat in the most efficient way and ensure the sustainability of geothermal reservoirs.

Energy Conversion. The efficiency in conversion of geothermal steam into electricity in the power plant directly affects the cost of power generation. During the past decade, the efficiency of dry- and flash-steam geothermal power plants was improved by 25%. We believe that geothermal power-plant efficiency can be improved at least 25% more over the next decade with a modest investment in R&D.

GEOTHERMAL ENERGY IN DEVELOPING COUNTRIES

Although the market for new geothermal power development in the United States is currently depressed, robust demand in several developing countries is driving aggressive markets for new electrical power using a variety of fuels, including geothermal energy. Among developing countries having notable geothermal resources suitable for use in electrical power generation are the Philippines, Indonesia, and China in Asia; Mexico in North America; Guatemala, Honduras, Costa Rica, Nicaragua, and El Salvador in Central America; Peru, Chile, Argentina, and Bolivia in South America; and Turkey in the Mediterranean. Many other countries also have geothermal resources capable of electrical power generation, but the potential for their development appears to be somewhat lower at the present time compared with those countries named above.

The most rapid development of geothermal energy for electrical power production is currently taking place in the Philippines and in Indonesia. There, projects under construction or planned by U.S. companies will bring about 3,000 megawatts of new power on line by the year 2000. Power demand is very high in both countries, and power plants fired by fossil fuels are also being built.

In developing countries, electrical power generation, distribution, and sales have been and still mostly are enterprises undertaken by the state, although this is changing. There is a wide variety of choices to be made and models a country might follow in revamping its legal and business structure to encourage private investment in its electrical power sector (Knapp, 1996; Wright, 1996a). The basic requirement is that a country's laws and regulations must be clear, comprehensive, consistent, and constant, enabling an investor to determine and allocate all project risks. Only then can the quality of a business investment be judged against others available to the same investor.

CONCLUSIONS

I conclude from all of the above considerations that the U.S. geothermal industry is healthy despite the stagnation of the U.S. market for new geothermal power. Robust demand for geothermal power in Asia and elsewhere is helping to support the industry. In the long term, geothermal energy remains a very viable option to furnish clean, reliable power worldwide.

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DISCLAIMER

REFERENCES

Barker, B. J., Gulati, M. A., Bryan, M. A., and Riedel, K. L., 1992, Geysers reservoir performance: in Monograph on The Geysers Geothermal Field, Claudia Stone, ed., Geothermal Resources Council Special Monograph 17, 167-177.

Brook, C. A., Mariner, R. H., Mabey, D. R., Swanson, J. R., Guffanti, Marianne, and Muffler, L. P. J., 1979, Hydrothermal convection systems with reservoir temperatures >= 90 oC: in Assessment of Geothermal Resources of the United States -- 1978, L. J. P. Muffler, ed., U.S. Geological Survey Circular 790, 163 p.

Dellinger, Mark, 1996, Turning community wastes into sustainable geothermal energy -- the S. E. Geysers effluent pipeline project: Transactions, Geothermal Resources Council, 20, 205-208.

DOE/EIA, 1993, Renewable resources in the U.S. electricity supply: Energy Information Administration Report, DOE/EIA-0561, 67 p.

DOE/EIA, 1995, Renewable Energy Annual -- 1995, U.S. Department of Energy, Energy Information Administration, DOE/EIA-0603(95), 158 p.

DOE/EIA, 1996, Emissions in Greenhouse Gases in the United States -- 1995, U.S. Department of Energy, Energy Information Administration, DOE/EIA-0573(95), 140 p.

Enedy, S. L., Enedy, K. L., and Maney, John, 1991, Reservoir response to injection in the Southeast Geysers: in Monograph on The Geysers Geothermal Field, Geothermal Resources Council Special Report No. 17, 1991, 211-219.

GEA, 1995, Geothermal Energy -- Clean, Sustainable Energy for the Benefit of Mankind and the Environment, brochure produced by the Geothermal Energy Association, 6 p.

Goddard, W. B., Goddard, C. B., and McClain, D. W., 1989, Future air quality maintenance and improvements through the expanded use of geothermal energy: Transactions, Geothermal Resources Council, 13, 27-32.

Goddard, W. B. And Goddard, C. B., 1990, Energy fuel sources and their contribution to recent global air pollution trends, Transactions, Geothermal Resources Council, 14, 643-649.

Knapp, G. M., 1996, Business and financial issues for international power projects: Transactions, Geothermal Resources Council, 20, 529-550.

Lienau, P. J., Lund, J. W., and Culver, G. G., 1995a, Geothermal direct use in the United States update -- 1990 - 1994: Proceedings, World Geothermal Congress, 1995, Florence, Italy, 1, 363-369.

Lienau, P. J., Ross, H. P., and Wright, P. M., 1995b, Low-temperature resource assessment: Geothermal Resources Council Transactions, 19, 63-68.

Lienau, P. J. and Ross, Howard, 1996, Low-temperature resource assessment program, Final report: Geo-Heat Center, Oregon Institute of Technology, 35 p. with additional tables and appendices.

Meidav, Tsvi, and Pigott, Jack, 1994, The impact of geothermal energy development on employment: Transactions, Geothermal Resources Council, 18, 55-60.

Pruess, Karsten, and Enedy, Steve, 1993, Numerical modeling of injection experiments at The Geysers: Proceedings, Eighteenth Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, CA, 26-28 January, 1996, 63-67.

Reed, M. J., editor, 1983, Assessment of Low-Temperature Geothermal Resources of the United States - 1982: U. S. Geological Survey Circular 892, 73 p.

Voge, Edward, Koenig, Brian, Smith, Bill J. S., Enedy, Steve, Beall, J. J., Adams, M. C., and Haizlip, Jill, 1994, Initial findings of The Geysers Unit 18 cooperative injection project: Transactions, Geothermal Resources Council, 18, 353-357.

Wright, P. M., 1991, Exploration potential for new hydrothermal resources for electrical power generation in the 48 contiguous states: Geothermal Resources Council Transactions, 15, 217-228.

Wright, P. M., 1994, A study of the geothermal industry's R&D priorities: Transactions, Geothermal Resources Council, 18, 139-148.

Wright, P. M., 1996a, Overview of business considerations for geothermal projects in developing countries: Transactions, Geothermal Resources Council, 20, 551-553.

Wright, P. M., 1996b, Geothermal Energy R&D -- Investment in America's Future: Statement of the Geothermal Energy Association, Presented before the Subcommittee on Energy and Water Development, Committee on Appropriations, U.S. House of Representatives, 29 February, 1996, 5 p.