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1993 STATUS REPORT — THE BONNEVILLE
POWER ADMINISTRATION'S GEOTHERMAL PROGRAM
PART II: RESEARCH, PROJECT SUPPORT, AND OTHER ACTIVITIES

George D. Darr
Jody C. Key

Bonneville Power Administration
P.O. Box 3621 (RMGB)
Portland, Oregon 97208

ABSTRACT

The Bonneville Power Administration's (BPA) Geothermal Program includes activities that support the geothermal pilot projects and that encourage the use of the Pacific Northwest's geothermal resources. Activities supporting the pilot projects include initiating environmental baseline monitoring programs and conducting environmental and economic impact studies. Research activities include efforts to better understand the cold water blanket phenomenon in the Cascades, a study to characterize the hydrothermal system in the Pueblo Valley, a geothermal exploration program in southeastern Oregon, and support for research to expand the use of slim-holes for resource confirmation. Efforts to address institutional issues include support for the Regional Renewables Project, which will help Northwest environmentalists become more knowledgeable about the role of conservation and renewables in the region's energy picture. A guide to geothermal permitting and licensing was prepared to help developers and utilities find their way through the regulatory maze. A geothermal curriculum is being developed for grades 4 through 8 in the Oregon schools. Data on the location and operating experience of existing U.S. geothermal plants has been collected in a database. Market penetration of geothermal heat pumps is being encouraged through a demonstration project in Montana and by helping BPA customers prepare proposals for geothermal heat pump projects that can compete successfully in BPA power acquisitions.

BACKGROUND

Geothermal is an environmentally desirable renewable resource that could contribute substantially to the Pacific Northwest's energy supply. Studies conducted by BPA and others show geothermal may be abundant in this region and has potential for being cost-effective in the near term (Bloomquist and others, 1985; Northwest Power Planning Council, 1991). To help initiate development at several high-temperature reservoirs — and to give utilities and the public the information they need to make informed decisions about issues related to development — BPA offered to participate in up to three demonstration power projects, and conducted a number of studies and other activities to support them. The demonstration projects are described in a companion paper (Darr, 1993).

BPA has also funded activities aimed at identifying new resources, solving technical problems related to resource development, and encouraging the use of low-temperature geothermal. This paper reports on the status of research and geothermal support activities undertaken during the last five years. These activities are summarized in Table 1.

PILOT PROJECT SUPPORT

Environmental Baselines

The regulations governing operations on Federal geothermal leases require the operator to collect at least one year of baseline environmental data prior to production. The purpose of the data is to characterize the existing environment so that impacts of development can be identified. Guidelines for acquiring baseline data are contained in Geothermal Resources Operation Order No. 4 (U.S. Geological Survey, 1975) and the Guidelines for Acquiring Environmental Baseline Data on Federal Geothermal Leases (U.S. Geological Survey, 1977). The baselines usually must include data on air quality, water quality, biology, noise, seismicity, and subsidence.

Early in the development of the geothermal confirmation program, we recognized that impacts on surface and ground water and other hydrologic features (such as hot springs) were likely to be an important issue in many areas. It was also apparent that one year of hydrologic data might be insufficient to adequately characterize the predevelopment hydrologic system. We did not want the pilot projects to be delayed if multiple years of data were deemed necessary by oversight agencies. We also wanted to be able to make informed judgments about possible environmental impacts of the projects. Collecting predevelopment environmental data was considered so important that it was included in the Northwest Power Planning Council's Geothermal Confirmation Agenda (Northwest Power Planning Council, 1991).

Inspired by the hydrologic monitoring program at Long Valley Caldera, California (Farrar and Lyster, 1990), BPA — acting together with the Bureau of Land Management and the Forest Service — requested assistance from the Water Resources Division of the U.S. Geological Survey (USGS) in designing hydrologic monitoring networks at Newberry Volcano and the Alvord Known Geothermal Resource Area (KGRA). In 1991, the USGS performed a literature search and designed monitoring programs for both areas, and began collecting data at Newberry. Up to 45 parameters are being measured or sampled at about 20 sites (sites have been added or dropped since we started). The Forest Service began cofunding the work at Newberry in 1992. Developers are expected to assume funding responsibility in 1994.

BPA focused on Newberry and the Alvord KGRA because recent developer activity indicated we would probably see pilot project proposals at those sites. When no proposal was submitted for the Alvord, efforts were limited to developing monitoring recommendations that could be implemented in the future. In 1992, the USGS designed hydrologic monitoring programs at Vale and Medicine Lake. Reports on all four sites should be available by late 1993.

It appeared likely that adequate baselines for air quality and biology could also require more than one year of data collection. Even if it turned out that one year was adequate, designing monitoring programs in advance would help to identify problems and potential "show stoppers." The Forest Service and BPA therefore cofunded the design of air quality and water quality baselines at Newberry. We thought noise, seismicity, and subsidence were not likely to be major concerns at Newberry, or at least could be adequately addressed with one year of baseline data. Our contractor designed two program levels, one a broad-based program covering all of the sites likely to be developed, the second level only covering a specific site. The resulting report (Ogden Environmental, 1993), intended to identify issues and promote informed discussion (rather than prescribe the Newberry monitoring program), gave the agencies a number of useful insights into monitoring priorities.

Economic Impact Studies

Even a 25-MW geothermal project is likely to be among a county's largest revenue contributors. This was a conclusion reached in each of a series of economic impact studies performed for BPA by the Oregon Department of Energy (ODOE) and the Washington State Energy Office (WSEO). The studies estimate direct and induced economic impacts, as well as impacts on employment and public service requirements, of a hypothetical 100-MW geothermal power project development. The projects are assumed to be built in 25-MW increments, one

per year for four years. The studies were done for Deschutes (Newberry Volcano, Bend Highlands), Harney (Alvord KGRA), and Malheur (Vale KGRA) Counties in Oregon, and for Skamania (Mt. Adams) and Whatcom (Mt. Baker) Counties in Washington. The locations of these counties are shown in Figure 2.

These reports have already been very useful to the pilot projects. For example, citizens in Bend, Oregon (near Newberry Volcano), are very concerned about impacts of rapid population growth in the area. Another concern is that reduced timber harvests in Federal forests, due to the spotted owl and other factors, may result in reduced county revenues. ODOE's Deschutes County study shows that geothermal development will generate about 100 short-term construction jobs and perhaps 20 permanent jobs, with much of the permanent work-force hired locally. Even a 25-MW project will probably be the largest property taxpayer in the county, and half of Federal royalties on production will also go to the county. Thus, economic benefits will be large, but population growth and "boom-town" effects should be small. For most local residents, this is welcome news.

Geothermal Impact Analysis — Bend Highlands, Pueblo Valley, Newberry Volcano

In an effort to identify potential land use and other conflicts in areas judged promising for development, BPA funded geo-

Table 1. BPA Geothermal Program Activities, 1988-1993

ACTIVITY	CONTRACTOR	PRODUCT
Hydrologic Baseline Monitoring - Newberry Volcano	U.S. Geological Survey	Hydrologic, Water Quality, and Meteorological Data for Newberry Crater and Vicinity, Deschutes County, Oregon, 1992-92. USGS Open-File Report No. 93-xx
Hydrologic Baseline Program Design - Alvord KGRA	U.S. Geological Survey	In Progress
Hydrologic Baseline Program Design - Vale KGRA	U.S. Geological Survey	In Progress
Hydrologic Baseline Program Design - Medicine Lake	U.S. Geological Survey	In Progress
Environmental Baseline Program Design - Newberry	Ogden Environmental	Environmental Baseline Report (Pub. No. DOE/BP-29028-1), Mar. 1993
Economic Impact Study - Deschutes County	Oregon Dept. of Energy	Economic Impacts of Geothermal Development in Deschutes County, Oregon (Pub. No. DOE/BP-07129-1), Dec. 1991
Economic Impact Study - Harney County	Oregon Dept. of Energy	Economic Impacts of Geothermal Development in Harney County, Oregon (Pub. No. DOE/BP-07129-2), Dec. 1991
Economic Impact Study - Malheur County	Oregon Dept. of Energy	Economic Impacts of Geothermal Development in Malheur County, Oregon (Pub. No. DOE/BP-07129-3), Jan. 1993
Economic Impact Study - Whatcom County	Wash. State Energy Office	Economic Impacts of Geothermal Development in Whatcom County, Washington (Pub. No. DOE/BP-2013), July 1992
Economic Impact Study - Skamania County	Wash. State Energy Office	Economic Impacts of Geothermal Development in Skamania County, Washington (Pub. No. DOE/BP-2014), July 1992
Geothermal Impact Analysis - Newberry Volcano	Oregon Dept. of Energy	Newberry Volcano Geothermal Impact Analysis (Pub. No. DOE/BP-2142) June 1992
Geothermal Impact Analysis - Pueblo Valley	Oregon Dept. of Energy	Pueblo Valley, Oregon, Geothermal Impact Analysis (Pub. No. DOE/BP-2143) February 1993
Geothermal Impact Analysis - Bend Highlands	Oregon Dept. of Energy	Bend Highlands Geothermal Impact Analysis (Pub. No. DOE/BP-2141) May 1993
Optioning Geothermal Resources (Slim-Hole Project)	GeothermEx, Inc.	Purchasing Options on Geothermal Power Generated within the BPA Service Area (Unpublished Report) Sept. 1990
	GeothermEx, Inc.	Feasibility of Applying Slim-Hole Technology to Option Purchases (Unpublished Report) August 1991
	GeothermEx, Inc.	Computer Program Documentation for Geothermal Resource Assessment Software Package (Unpublished Report) April 1992
Geology and Geochemistry of the Alvord Valley Geothermal System	Portland State University	Hydrogeochemical Characterization of the Alvord Valley Geothermal Resources Area
Cold Water Blanket Study	Oregon Dept. of Geology	In Progress
Oregon Cascades Resource Assessment Update	Oregon Dept. of Geology	In Progress
Geothermal Exploration Program in SE Oregon	Oregon Dept. of Geology/ Portland State University	In Progress
Environmental Issues in Geothermal Development	Geothermal Resources Council	Environmental Issues in Geothermal Development (not yet published)
Regional Renewables Project	Northwest Power Planning Council	In Progress
Permitting Guides for Renewable Resource Developers	Washington State Energy Office	Geothermal: A Regulatory Guide to Leasing, Permitting, and Licensing in Idaho Montana, Oregon, and Washington (Pub. No. DOE/BP-00425-2), Oct. 1991
Geothermal Curriculum for Grades 4-8	Oregon Dept. of Energy	In Progress
Geothermal Power Plant Database	Oregon Dept. of Energy	Database Files and Annual Report
Missoula Geothermal Heat Pump Demonstration Project	Missoula Electric Cooperative	In Progress
Technical Support for Geothermal Heat Pump Billing Credit Projects	Oregon Dept. of Energy	In Progress



Figure 1. Locations of Economic Impact Studies

thermal impact studies by ODOE for Newberry Volcano, the Pueblo Valley (Alvord KGRA), and the Bend Highlands areas. ODOE also produced maps that facilitate analysis of these conflicts. Parameters analyzed include:

- Air quality
- Archaeological/Cultural/Historical resources
- Geological, volcanic, and hydrothermal features
- Hydrologic resources
- Recreational resources
- Visual resources
- Wildlife and plant resources

The studies discuss how land use conflicts could affect geothermal development and identify measures that may be used to mitigate these impacts. Data for the digitized maps were provided by the Forest Service and the Bureau of Land Management.

RESOURCE EXPLORATION AND CHARACTERIZATION

Assessment of the Feasibility of Applying Slim-Hole Technology to Option Purchases

In a typical exploration program, geological reconnaissance and geophysical techniques are used in conjunction with small diameter exploration wells ("slim-holes") to pinpoint sites for full-size production wells. Production wells typically cost one to two million dollars, and can cost much more. A slim-hole to the same depth costs about one-third to one-half as much. Usually, a reservoir is not considered "confirmed" for the purpose of obtaining financing or a power contract until long-term flow tests have been performed on production wells. Even if flow testing from a slim-hole is possible, the data obtained may be considered insufficiently reliable to evaluate the reservoir (Entingh and Petty, 1992).

Recognizing the potential cost savings from expanded use of slim holes, the University of Hawaii initiated a Scientific Observation Hole (SOH) slim-hole drilling program in an effort to confirm at least 500 MW of resources on the Big Island

and Maui. This was needed to justify construction of a \$500 million underwater cable linking those islands to load centers on Oahu (Olson, 1988). The program included trying to develop techniques that would increase the extent to which slim-holes could be used to confirm resources.

Because the Pacific Northwest shares many of Hawaii's geothermal confirmation objectives, BPA and the Electric Power Research Institute (EPRI) cofunded studies that contributed to Hawaii's SOH project, took advantage of data developed through Hawaii's effort, and produced reports addressing specific BPA needs. One of these needs was information regarding the feasibility of purchasing options on geothermal power.

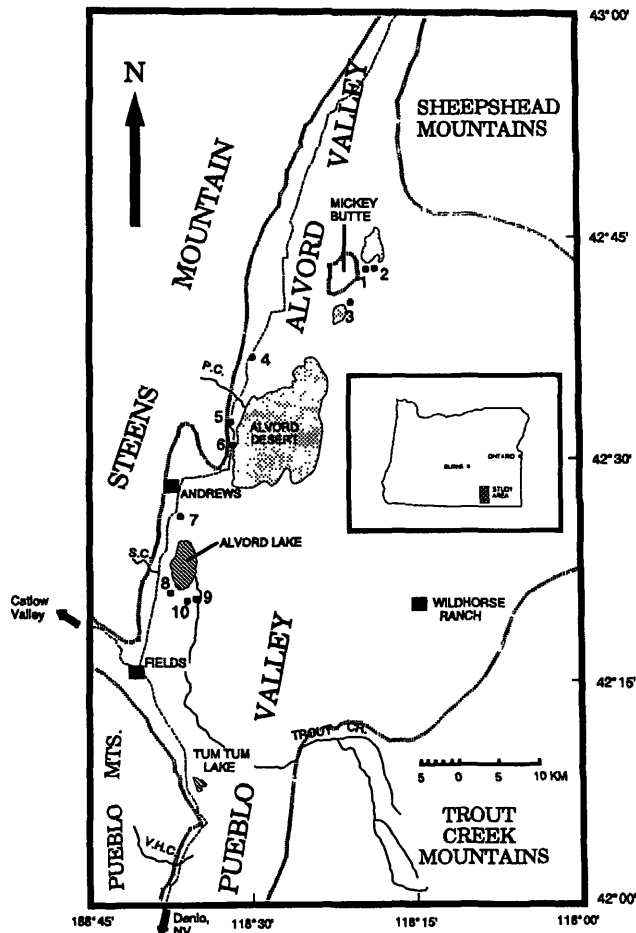
Utility planners in the Northwest have sought to reduce the lead time on power projects by performing as many pre-construction activities as possible, and then keeping the project "on-the-shelf" until needed. Project developers would be induced to do this through an option payment, and the concept is called "optioning." The idea seemed particularly applicable to geothermal development on Federal leases, especially if the environmental impact assessment for the initial development was sufficiently broad-based that subsequent projects could undergo a relatively short approval process. The environmental baseline programs described above were an outgrowth of trying to apply the optioning concept.

The University of Hawaii's consultant produced two reports for BPA. The first report examined the feasibility of purchasing options on geothermal resources (GeothermEx, 1990). The second report specified under what conditions slim-hole data could be used as the basis for an option purchase (GeothermEx, 1991). Studies funded by EPRI developed methodology for applying probabilistic methods to slim-hole data to estimate reserves and quantify risks. A personal computer-based resource assessment package using these methods was also produced (GeothermEx, 1992).

Geology and Geochemistry of the Alvord Valley Geothermal System

The geothermal resource potential of the Alvord KGRA has been estimated to be about 66 to 91 MW for 30 years (Bloomquist and others, 1985; Brook and others, 1979). Environmental groups and others are concerned that geothermal development may affect the endangered Borax Lake chub, a fish species inhabiting a hot spring pool less than a mile from proposed exploration drilling. Before development can proceed, the relationship, if any, must be established between the hydrothermal system and the water feeding Borax Lake, or a monitoring program must be designed that adequately protects the chub. In an effort to better understand these systems, a number of studies have been done, including work by the Bureau of Land Management, the Nature Conservancy, the U.S. Fish and Wildlife Service, and the USGS hydrologic monitoring study noted above.

BPA also funded a study by Portland State University (PSU) that examined hydrologic and geochemical data in order to develop a conceptual model of the Alvord KGRA (Cummins and St. John, 1993). The study area is shown in Figure 2. The study integrates geologic, geochemical, and isotopic data to estimate the temperature and extent of underlying reservoirs, evaluate reservoir rock types, define possible recharge zones, and determine if a hydrologic connection exists among Borax Lake, Alvord Hot Springs, and Mickey Hot Springs. Only preliminary results were available at the time of writing, but the final report should be done by mid-1993.



- DESERT/DEPRESSION
- COUNTY ROAD
- FLUID & GAS SAMPLE LOCATIONS
 - 1 CORRAL SPRINGS
 - 2 UNAMED SPRING N. OF MICKEY SPR.
 - 3 MICKEY SPRINGS
 - 4 ALVORD RANCH
 - 5 ALVORD HOT SPRINGS
 - 6 THOMAS PLACE
 - 7 KUENY RANCH
 - 8 BLM WELL
 - 9 FLOWING WELL N.E. OF BORAX LAKE
 - 10 BORAX LAKE AND ADJACENT SPRINGS TO NORTH
- V.H.C. = VAN HORN CREEK
 S.C. = SCOUDES CREEK
 P.C. = PIKE CREEK

Figure 2. Location of PSU Alvord Valley Study (Cummings and St. John, 1993)

Cold Water Blanket Study

In the Cascades, ground water may mask signs of geothermal activity to several thousand feet (the "rain curtain" or "cold water blanket" phenomenon), and require deep drilling even for reconnaissance (Swanberg and others, 1988). Since the thickness of the cold water blanket cannot be predicted and has not been mapped, temperature gradient wells are often either deeper than necessary (and thus excessively expensive) or not deep enough (yielding inadequate data). Mapping and methods that aid in predicting the thickness of the blanket will decrease exploration costs and tend to stimulate geothermal development in the Cascades.

With BPA funding, the Oregon Department of Geology and Mineral Industries (DOGAMI) is performing a study that will analyze and summarize existing temperature and geologic data from exploration drilling and other sources. An attempt will be made to use this data to devise techniques for predicting the cold water blanket's thickness and for better estimating minimum drilling depths needed to obtain necessary data. Results of this study are expected in mid to late 1993.

Oregon Cascades Resource Assessment Update

DOGAMI will also revise existing geothermal resource assessments for the Oregon Cascades. Efforts will concentrate on compiling temperature and thermal conductivity data for exploration wells drilled since the last assessment in 1985. New thermal conductivity data will be collected and tabulated where possible. The revised assessment is due in fall, 1993.

Geothermal Exploration Program in Southeastern Oregon

A joint effort headed by Michael Cummings at PSU and George Priest at DOGAMI will examine southeastern Oregon for undiscovered geothermal resources. The study area is shown in Figure 3. The project, which got under way in mid-1993, will use a recently developed statewide database of anomalously warm wells to search for blind geothermal systems (systems with no surface manifestations, such as hot

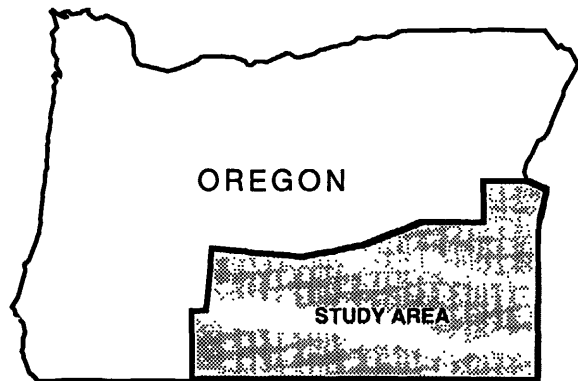


Figure 3. Study Area for Southeastern Oregon Geothermal Exploration Project

springs) and to identify targets for field measurement of temperature gradient and/or water sampling. Quaternary faulting will be identified through aerial photography as a guide to exploration targets. Field sampling will include soil mercury surveys, water sampling, and analysis of soil and rock materials for the presence of hydrothermal alteration.

A number of digital maps will be produced, which will summarize land availability (noting wilderness areas, wildlife refuges, etc.), heat flow, neotectonic features, and proximity to transmission lines. We expect the study to be completed in late 1994.

Environmental Issues in Geothermal Development Report

Long needed by the geothermal industry, this report will be an authoritative reference on the environmental impacts of geothermal development. Prepared — mostly with donated time — by experts in the industry, the report will provide a concise introduction to geothermal technology and a balanced treatment of environmental impacts and available mitigation measures. The report is sponsored by the Geothermal Resources Council with funding from BPA, and should be available by fall 1993.

INSTITUTIONAL

Regional Renewables Project

The Northwest's long-standing energy surplus is gone, and utilities are acquiring additional power. Relatively little of this power is coming from renewable resources, partly because the environmental community resists resource development in valued scenic and recreational areas. Unfortunately, most renewables — particularly wind, solar, hydro, and geothermal — must be exploited where they are found, which is often in one of these areas. If we are to build a sustainable energy future based on the use of renewable resources, the environmental community needs a better understanding of energy issues. In particular, they need to understand the role of conservation and renewables in the region's energy picture, and to realize what the alternatives will be if they oppose all development. The Regional Renewables Project hopes to overcome some of this opposition and facilitate development of environmentally responsible renewable resources.

The project is being conducted by a consortium of Northwest environmental groups, lead by the Solar Energy Association of Oregon and the Northwest Conservation Act Coalition. The \$140,000 budget came from utilities, developers (including the California Energy Company), and institutions (including the Northwest Power Planning Council). The U.S. Department of Energy and BPA provided about half the funding. The following activities took place as part of the project:

1. Compile Information Packets. A Resource Handbook was compiled, containing information about the Northwest energy situation, conservation, wind, solar, and geothermal. Biomass and hydro were also covered, but they were not a focus of the project. The handbooks were distributed to environmental group members.
2. Conduct Individual Information Sessions with Participants. One-on-one meetings between resource experts and environmental group leaders were meant to initiate constructive dialogue in a non-adversarial setting.
3. Develop and Convene Participatory Workshops. A series of workshops were held in Seattle, Port-

land, Bozeman, Missoula, Boise, Bend, and Spokane. The workshops provided a concentrated introduction to conservation implementation issues and renewable technology. Time was provided at each workshop for questions and discussion, again with the goal of promoting constructive dialogue.

4. Renewable Resources Conferences. All-day conferences were held in Seattle and Portland. Unlike the workshops, which were by invitation only and usually had 10 to 30 participants, the conferences were open to the public. They attracted 200 to 250 attendees at each site.
5. Site Visits. To give them a chance to see operating projects and thereby assess environmental impacts for themselves, two van-loads of environmental group leaders were taken to geothermal, wind, and solar sites in California and Nevada.
6. Development Criteria Workshop. A survey was taken to elicit from the environmental/public interest community their attitudes and concerns about renewable resource development. The survey was the basis for a development criteria workshop held in June at Carson Hot Springs, Washington. The workshop had not been held at the time of writing, but was expected to result in recommendations to decision-makers on development criteria. These criteria could include an assessment of what legal, regulatory, and other safeguards would be needed to protect against environmentally unsound development.

At this time, it is too early to judge the results of the project. At a minimum, it has resulted in an environmental community more knowledgeable about energy issues, and in a greater awareness among the developers and utilities who participated of the concerns of environmentalists.

Guide to Geothermal Leasing, Permitting, and Licensing in Idaho, Montana, Oregon, and Washington

The Washington State Energy Office — with assistance from state energy offices in Idaho, Montana, and Oregon — has written four guides to the Federal, state, and local permitting and licensing process in the four Northwest states for renewable resource power projects. One of the guides covers geothermal, and the others cover hydro, cogeneration, and wind and solar. The guides include tabular summaries of permit requirements, time lines for obtaining permits, flow charts of licensing processes, and agency addresses. A workshop devoted to geothermal permitting and licensing was held in Bend, Oregon, in November 1991. The guides are available (at no charge, presently) from BPA and the four state energy offices.

Geothermal Curriculum for Grades 4-8

With funding from BPA, ODOE is developing a geothermal energy curriculum and teaching materials for grades 4 through 8. After being tested, the curriculum will be distributed to teachers at one or more workshops to be held in summer 1994.

TECHNOLOGY TRACKING

Geothermal Power Plant Database

ODOE has compiled a database on operating geothermal power plants in the United States. It is described in detail in (Sifford, 1992). The database contains over 110 data fields,

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and currently covers 63 plants. Data is obtained through publications, other databases, questionnaires, and interviews with contractors and project managers. An annual report notes recent findings and trends.

GEOTHERMAL HEAT PUMPS

Demonstration Project in Missoula, Montana

The goal of BPA's Resource Supply Expansion Program (RSEP) is to confirm the availability of conservation and renewable resources to meet future needs by conducting demonstration projects. The projects are to be collaborations among electric utilities and other interested parties. Although they predate RSEP, BPA's geothermal pilot projects are in the same spirit and share its goal.

As part of RSEP, BPA will cofund, along with the Missoula Electric Cooperative, the Missoula Montana Ground Source Heat Pump Demonstration Project. The project involves installing individual vertical closed-loop geothermal heat pump systems in 40 homes. Construction will take place during the 1993-94 construction season. All of the homes will be built to Long Term Super Good Cents building efficiency standards. In addition to the usual whole house kilowatt-hour (kWh) meter, 20 of the homes will be equipped with a heat pump kWh meter, a water heater kWh meter, water flow meters, and data acquisition equipment to measure heat transfer in water flows through their ground loop and desuperheater. The remaining 20 homes will have an additional kWh meter for the heat pump only. Data collected over a two-year period will be used for thermal analysis, cost-effectiveness analysis, and performance evaluation of the system.

Technical Support to Help BPA's Customers Develop Geothermal Heat Pump Projects

Billing credits were created by the Northwest Power Planning and Conservation Act of 1980 as a way to encourage BPA's utility customers to develop their own resources. Billing credits remove the disincentive of always being able to buy power more cheaply from BPA. A customer may receive a credit on its power bill ("billing credit") for the difference between BPA's wholesale power rate and the cost of power from the resource, up to a prescribed limit. BPA periodically solicits billing credit proposals from customers as a way to "acquire" new resources. Both conservation and generation resources are eligible under these solicitations, and there are reasons to believe geothermal heat pump (GHP) projects could compete successfully.

ODOE will identify BPA customers in Oregon with high potential for developing cost-effective GHP projects. Feasibility studies will be done to find out under what circumstances GHP projects are feasible, and ODOE will identify and rank opportunities for implementing these projects through billing credits. If suitable projects are identified, BPA customers will be offered assistance in developing a billing credit proposal acceptable to BPA. If successful, this effort will encourage utility acceptance and market penetration of GHPs.

SUMMARY AND CONCLUSIONS

BPA's geothermal program includes efforts to identify and develop Northwest resources, both high and low temperature, and to improve technologies that promise benefits in the near term. We have worked to overcome institutional and public acceptance barriers through education and outreach projects, and to guard against environmental degradation by initiating environmental baseline monitoring efforts prior to development.

Future efforts will concentrate on ensuring the success of the pilot projects, on finding ways to make geothermal more competitive with other resources (by, for example, reducing capital costs and improving dispatchability), and increasing the use of low-temperature resources.

ACKNOWLEDGEMENTS

The BPA program has benefited from generous advice and assistance from Northwest state energy offices, the Forest Service, the Bureau of Land Management, developers, and a host of others, and their help is gratefully acknowledged.

The contributions of Alex Sifford of the Oregon Department of Energy deserve special thanks. This program would have died on the vine a long time ago without his help and support. The Geothermal Strategy Group (Bob Fujimoto, Dennis Davis, Larry Chitwood, Greg McClarren, George Chesley, Sally Collins, and, more recently, Mike Johnson, Alice Doremus, and Carolyn Wisdom) at the Deschutes National Forest have also been valued allies in helping to make sure geothermal is developed in a way we can live with.

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