DOCUMENT RESUME

ED 270 291 SE 046 436

TITLE Geothermal Energy.
INSTITUTION Conservation and Renewable Energy Inquiry and Referral Service (DOE), Silver Spring, MD.
REPORT NO DOE/CE-0117; FS-188
PUB DATE Jun 85
NOTE 7p.; For other bulletins in this series, see SE 046 433-441 and SE 046 444.
PUB TYPE Reports - General (140)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Alternative Energy Sources; Electricity; Energy; *Energy Education; *Geothermal Energy; Intermediate Grades; *Power Technology; Science Education; Secondary Education

ABSTRACT

An introduction to geothermal energy is provided in this discussion of: (1) how a geothermal reservoir works; (2) how to find geothermal energy; (3) where it is located; (4) electric power generation using geothermal energy; (5) use of geothermal energy as a direct source of heat; (6) geopressured reservoirs; (7) environmental effects; (8) institutional and legal problems associated with geothermal energy; (9) economic considerations; (10) hot dry rock; and (11) future prospects. Eight resources available from the National Technical Information Service (NTIS) are listed. Each entry includes title, author(s), annotation, publication date, and current cost. (JN)

DOE/CE-0117

INFORMATION

U.S. DEPARTMENT OF ENERGY

CONSERVATION AND RENEWABLE ENERGY INQUIRY AND REFERRAL SERVICE

Geothermal Energy

Introduction

Geothermal energy is heat generated by natural processes beneath the earth's surface. It occurs at great depths everywhere on earth but in some places can be found close to or even at the surface. Active volcanoes like Mount Kilauea in Hawaii and geysers such as "Old Faithful" in Yellowstone National Park are well-known examples. Those who have seen an erupting volcano or a spouting geyser come away with a sense of the tremendous power that lies beneath the earth's surface.

In many places around the world, developers have drilled down, extracted hot water or steam and used it to heat and cool buildings; process food and other consumer goods; heat cattle barns, greenhouses and fish ponds; and, since 1904, generate electric power.

Geothermal power plants 60 miles north of San Francisco now generate 1,453 megawatts (MW) of electric power. (A megawatt is a million watts and serves the electrical needs of about 1,000 customers.)

Homeowners in Klamath Falls, Oregon, and in Boise, Idaho, have been using geothermal hot water to heat their homes inexpensively since the 1890's. Communities in several other parts of the United States are now beginning to use modern methods of distributing their underground heat to homes and office buildings. Private companies are also developing ways to use geothermal energy instead of other fuels. Hot springs that once were popular sources of medical therapy and recreation now serve as indicators of underground resources.

From an experimental beginning in 1960, Pacific Gas and Electric Company's generating units at The Geysers have produced increasing quantities of electricity from geothermal steam. Source: Pacific Gas and Electric

FS 188, 1st Edition, June 1985

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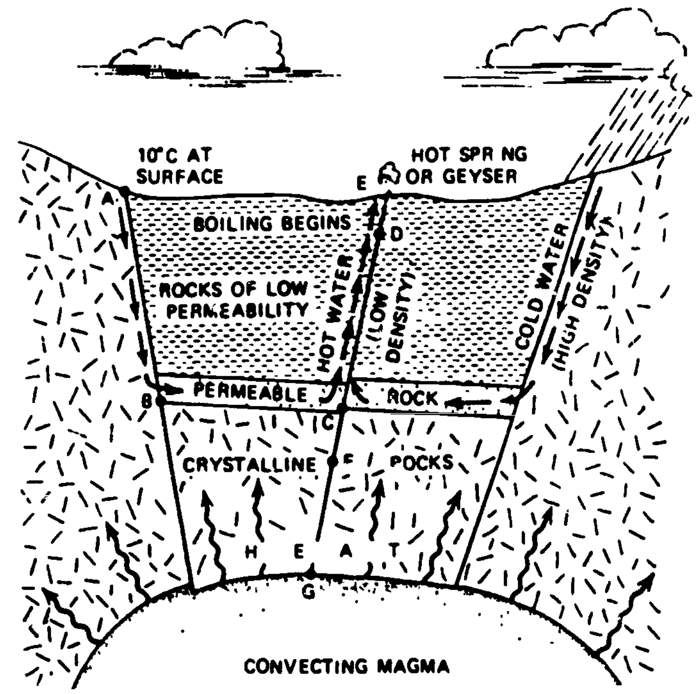


Diagram of a geothermal reservoir. Source: "Sourcebook on the Production of Electricity From Geothermal Energy" U.S. Department of Energy

Scientists and Government officials believe that geothermal energy can be put to far greater use and are studying ways in which it might supplement or replace scarce fossil fuels.

How A Geothermal Reservoir Works

The outer layer of cool rock surrounding the earth is called the crust and is relatively thin - 24 to 48 kilometers (15 to 30 miles). Below this is a layer of semi-molten rock called the mantle; and beneath that is a hypothesized liquid iron and nickel core.

Scientists now generally believe that the crust is not one continuous sheet of rock but consists of continental "plates" floating on the mantle. These plates move and interact with one another. In places where two or more plates are colliding or drifting apart and at isolated thin spots in the crust, molten rock (called magma) may come quite close to the surface, and occasionally break through to form a volcano.

If magma comes within a few miles of the surface, it may transfer heat to underground water. The hot water may come to the surface spontaneously as a hot spring or geyser, or it may be trapped under a layer of solid rock and lie undetected thousands of feet underground. By drilling into geologic formations that contain this hot water, it can be pumped to the surface and its heat recovered.

Finding Geothermal Energy

Some geothermal sources are easy to identify. Steam rising up through a crack in the ground or from a hot spring indicates that there is hot water below, although it may not indicate how much heat is available.

It is hard to find geothermal energy and to deterimine the size of the resource without these surface signs. A variety of techniques, some borrowed from the oil and gas industry, are being used, and new ones are being developed. These include studying geologic maps and satellite photos, measuring the density of the rock by gravitymeters, measuring patterns by which electricity or sound waves travel through the earth, and drilling shallow holes to take temperature and heat flow measurements. If an area seems promising, prospectors then drill deep exploratory wells to confirm that the resource is there and whether it contains enough heat to justify further work.

Rock formations associated with geothermal energy are not only hotter but usually much harder than those in oil and gas reservoirs. Minerals dissolved in the hot water form a brine that is highly corrosive. Oil and gas drilling methods, therefore, are not well suited to geothermal drilling. Tougher drill bits and novel approaches are being devised for the special needs of geothermal formations. One new concept is a flame jet that fractures the rock by creating thermal stresses. Special measuring instruments that can withstand the high underground temperatures are also being developed.

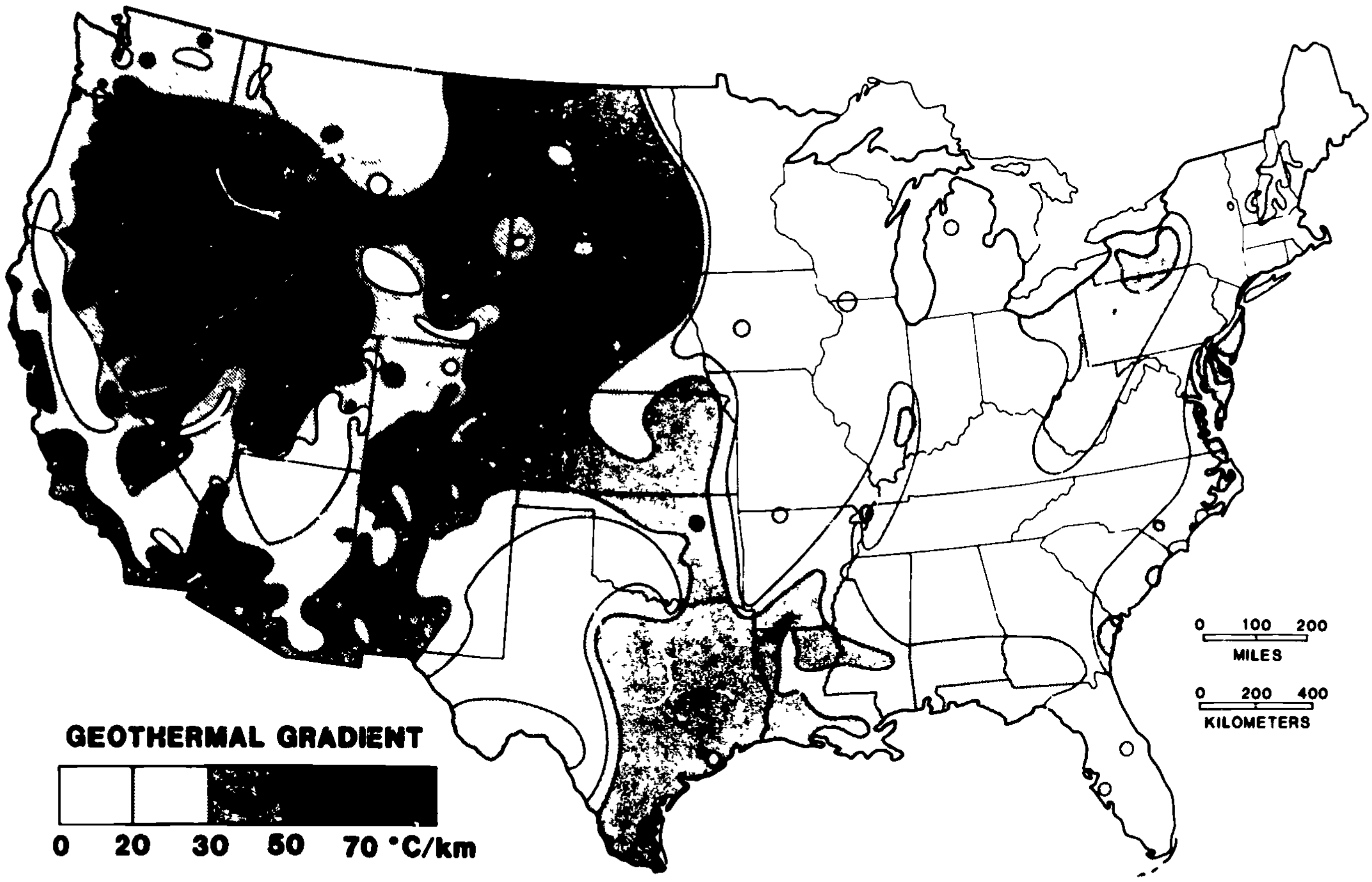
Where It Is

Hot water geothermal resources, which are also called hydrothermal resources, are located in many areas of the United States but are most plentiful in the West. A somewhat different kind of resource, called the geopressured zone, is found along the Texas and Louisiana Gulf Coast. Recent studies suggest that moderately hot geothermal resources which lie under regions of the Dakotas, along the Atlantic Coast, in Arkansas and in central Texas, may be quite useful. Similar resources may exist in many other states but have yet to be discovered.

Generating Electric Power

Geothermal energy was first used to generate electric power in 1904 at Larderello near Pisa, Italy. Today, electricity is produced from geothermal resources in China, El Salvador, Iceland, Indonesia, Italy, Japan, Kenya, Mexico, New Zealand, Nicaragua, the Philippines, Portugal, the Soviet Union, Taiwan, Turkey and the United States.

The largest commercial geothermal electric power plant complex is The



Geothermal gradient map of the United States based on gradients measured where the terrestrial heat flow is by conduction through the rock.
Source: Los Alamos National Laboratory

Geysers, in northern California, operated largely by Pacific Gas & Electric (PG&E) Company. At this facility, steam is collected from a number of wells and passed through turbines that drive electric generators. This type of installation costs less to build than conventional fossil fuel or nuclear power plants, and the overall cost of electricity production is competitive with other sources of electric power in California.

Pacific Gas and Electric now has 17 geothermal steam-powered units operating at The Geysers, and four other operators have similar units. The combined capacity of all the units is now 1,453 megawatts. This is enough capacity to meet the normal electric needs of the cities of San Francisco, Oakland and Berkeley.

By 1988, PG&E expects to have 22 units operating which would generate 1,645 megawatts of electricity. This will be about 10 percent of PG&E's total generating capacity. Other operators will bring the total to about 2,355 megawatts.

The resource at The Geysers is "dry steam" (in a "vapor dominated" reservoir) that contains little or no water. Unfortunately, this is very rare. Much more common are resources that contain mixed steam and hot water in "liquid dominated" reservoirs. Several countries, including the Philippines, New Zealand, Mexico and Japan, are already using hot water resources extensively for electric power generation. Industry is planning several installations totalling over 400 megawatts in this country within the next few years, and eight small plants totalling 54 megawatts are already in operation.

onventional equipment for generating electric power from hot steam does not work well with water at lower temperatures, so special systems are being developed for geothermal power plants. One system, already tested in California and Idaho, is called the binary system because it uses two different fluids circulating in separate pipe loops. A 45 megawatt binary plant is under construction in California under a cost-sharing agreement between several utilities and the Federal Government.

Direct Use

It is often very efficient and economical to use geothermal energy as a direct source of heat.

Examples of Geothermal Direct Use Applications

In San Bernardino, California, the Water Department has placed a low temperature geothermal heating system on line. The geothermal fluid is used to heat an anaerobic digester at the city's wastewater treatment plant. The well supplies fluid flows at the rate of 2,500 gallons per minute and a temperature of 134° F.

A geothermal space heating project is under construction in Boise, Idaho. The city of Boise will purchase the production from the geothermal wells and act as the distributer. The city will negotiate with residential, commercial and institutional customers for the supply of geothermal fluids to be used for space heating.

In 1982 the Elko Heat Company began supplying hot water to downtown buildings of Elko, Nevada. Water is produced at a rate of 400 to 600 gallons per minute at a temperature of 175° F. After most of the heat is extracted, the geothermal water is used by the city for irrigation and other municipal purposes.

Navarro College in Corsicana, Texas, has recently begun a

System for extracting energy from a dry geothermal reservoir.
Source: Los Alamos National Laboratory

multiple use geothermal research project. Heat from geothermal water is used to grow shrimp, tropical fish and catfish. The water is also used to grow plants and to irrigate farmland.

Only a few geothermal resources have been identified in the Eastern United States, but a recent geologic study of the Mid-Atlantic states indicates that many may contain geothermal resources suitable for use in local poultry and seafood processing plants, grain drying operations and industrial parks.

Hot Dry Rock

So far, we have been discussing uses of water that have been naturally heated by contact with hot underground rock formations. In time, the largest geothermal energy source may be hot rock formations that have not come into contact with underground water because it is not porous enough for water to filter through it.

Researchers in New Mexico have succeeded in creating an artificial geothermal system. They drilled one hole deep into a hot dry rock formation, then fractured the rock by pumping water down the hole under very high pressure. They then drilled a second hole to connect with the fracture. Cold water was pumped down one hole and hot water, which had been heated by its passage through the fracture, was recovered from the other. The system ran for nine months with about five thermal megawatts recovery.

Much more experimental work is needed before hot dry rock can become a practical source of energy because the technology is expensive and there are a number of unknown factors. It is not known, for example, how long a particular system will continue to supply heat before the rock cools. If this research is successful, hot dry rock could become a major energy source in the future.

Geopressured Reservoirs

Geothermal reservoirs are found in deep sedimentary rocks beneath the Texas and Louisiana Gulf Coasts. Deposits of oil and natural gas are sometimes found in the same rock formations, but usually the pores of the rock are filled with hot salty water that contains dissolved natural gas. This water is contained under very high pressures (5,000 to over 20,000 pounds per square inch), and when produced through a well that is open at the top it emerges with great force. It may be possible to capture not only the heat energy but the natural gas and hydraulic energy as well. We know about the geopressured zones because for many years oil and gas developers have been drilling through these zones. Researchers are now determining the number, location and size of geopressured reservoirs. Wells drilled into some of these reservoirs are being tested to determine if their energy can be recovered at competitive cost. If so, the geopressured reservoirs may prove to be a substantial source of energy.

Environmental Effects

Geothermal energy has many ecological advantages. For example, it produces little atmospheric pollution or solid waste, and these are readily handled.

The use of geothermal resources is environmentally benign when compared to conventional nonrenewable energy resources. However, some problems could delay exploitation or expansion at some sites. As a result, methods are being developed to mitigate the effects of hydrogen sulfide emissions, subsidence, noise and disposal of brines. Environmental effects are minimal and consistent with the national need for additional domestic energy. At the same time, appropriate environmental regulations have been worked out that will support development of geothermal resources. Fortunately, most of the adverse environmental impacts can be controlled or eliminated.

Institutional and Legal Problems

Much of the technology needed to use geothermal energy effectively has been perfected, but there are other problems connected with its ownership and use. Various laws governing mineral and water rights often overlap or conflict with its development and use. Satisfying legal requirements and obtaining the necessary permits for use of geothermal energy can take many years. If sections of cities are to be heated or if the same water is to be used for several purposes, different industries and levels of government need to work closely together, sometimes in ways not often tried before in the United States. The Department of Energy is working closely with other Federal agencies, with state, county and municipal governments and with industry to bring geothermal energy into production.

Economics

Every geothermal resource is different - below and above ground. Water temperatures, mineral content and flow rate vary, as do local laws, population densities, industries and proximity to other sources of energy. At present, only a fraction of the total geothermal energy resource is competitive with other forms of energy. The Federal Government has a program to develop lower-cost technologies so that much more of the resource can be used. Because geothermal energy must be used close to its source, direct application of heat will require planning and bringing industry and other users to the geothermal sites.

Future Prospects

The contained heat energy within the United States could, in theory, provide all the future needs of this Nation. Yet a modest goal of 9,000 to 12,000-megawatts is the anticipated geothermal contribution by 1990.

The actual contribution will be determined by the effort - time, people and funding - devoted to a broad research, development and demonstration program with participation by Federal, state and local governments in cooperation with industry, universities, laboratories and the American people.

Reading List

Candidate Sites For Future Hot Dry Rock Development In The United States... F. Goff and E.R. Decker; Los Alamos National Laboratory, 1982, 39 pp, $8.50. Report No. LA-9625-HDR, available from NTIS (see Source List). Generalized geologic and other data are tabulated for 24 potential hot dry sites in the U.S. Potential reservoir rocks at each site are described and each system is categorized according to inferred heat sources.

Direct Utilization Of Geothermal Energy For Space and Water Heating At Marlin, Texas... M.F. Conover et al.; Radian Corporation, 1983, 320 pp, $25.00. Documents the Torbett-Hutchings-Smith Memorial Hospital geothermal heating project, which is one of nineteen direct-use geothermal projects funded principally by DOE.

Geothermal Energy As A Source Of Electricity... R. DiPippo; Southeastern Massachusetts University, 1980, 377 pp, $29.50. Report No. DOE/RA/28320-1, available from NTIS (see Source List).

Geothermal Power Plant R&D. An Analysis of Cost Performance Tradeoffs And The Heber Binary-Cycle Demonstration Project...

T. Cas[illegible]el et al.; Technecon Analytic Research, Inc., 1983, 160 pp, $16.00. Report No. DOE/CS/30674-2, available from NTIS (see Source List). Report documents an analysis of Federal research and development of technologies for producing electric power from 300-400° F geothermal resources.

Geothermal Technology Development Program, Annual Progress Report, October 1981 - September 1982... J.R. Kelsey; Sandia National Laboratories, 1983, 259 pp, $22.00. Report No. SAND82-2690, available from NTIS (see Source List). This report describes the status of ongoing research and development within the Geothermal Technology Development Program. The program emphasizes research in rock penetration mechanics, fluid technology, borehole mechanics, diagnostics technology and permeability enhancement.

Hot Dry Rock Geothermal Energy Development Program... M.C. Smith et al.; Los Alamos National Laboratory, 1982, 127 pp, $14.50. Report No. LA-9780-HDR, available from NTIS (see Source List). During 1982, emphasis in the Hot Dry Rock Program was on development of methods to produce the hydraulic fractures required to connect the deep, inclined wells of the Phase II system at Fenton Hill. Environmental surveillance, instrument development, laboratory and modeling studies and other supporting activities were continued as well.

Sourcebook On The Production Of Electricity From Geothermal Energy... J. Kestin et al.; (ed.); Brown University, 1980, 1,013 pp, Report No. DOE/RA/4051-1, available from NTIS (see Source List).

Workshop On Exploration For Hot Dry Rock Geothermal Systems... G.H. Heiken et al.; Los Alamos National Laboratory, 1983, 88 pp, $11.50. Report No. LA-9697-C, available from NTIS (see Source List). Hot Dry Rock resources lack the sharp physical and chemical contrasts produced by geysers and hot springs and thus present unusual exploration problems. The subject of this workshop is exploration for Hot Dry Rock.

Source List

NTIS
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