GEOTHERMAL RESOURCE UTILIZATION

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ABSTRACT

Man has utilized the natural heat of the earth for centuries. Worldwide direct use of geothermal currently amounts to about 7,000 MW_t, as compared to 1,500 MW_e, now being used for the generation of electricity. Since the early 1970s, dwindling domestic reservoirs of oil and gas, continued price escalation of oil on the world market and environmental concerns associated with coal and nuclear energy have created a growing interest in the use of geothermal energy in the United States. The Department of Energy goals for hydrothermal resources utilization in the United States, expressed in barrels of oil equivalent, is 50 to 90 million bbl/yr by 1985 and 350 to 900 million bbl/yr by the year 2000. This relatively clean and highly versatile resource is now being used in a multitude of diverse applications (e.g., space heating and cooling, vegetable dehydration, agriculture, aquaculture, light manufacturing), and other applications requiring a reliable and economic source of heat.

SUMMARY OF UTILIZATION

The direct use of geothermal resources has been practiced internationally for centuries. Recorded history shows uses by Romans, Chinese, Japanese, Turks, Icelanders, Central Europeans, and the Maori of New Zealand for bathing, cooking and space heating. Today, worldwide, more than 7,000 MW_t (thermal) of geothermal energy are used for residential and commercial space heating and cooling, agriculture and aquaculture, and industrial processing.

Space heating generally utilizes temperatures in the range of 150 to 212°F, with 100°F being used in some marginal cases and heat pumps extending this range down to 55°F. The leading user of geothermal energy for space heating is Iceland, where over 50 percent of the country is provided with geothermal heat. The only known cooling is in Rotorua, New Zealand, at the International Hotel; however, many other applications are presently being considered.

Typically, the agriculture-related uses utilize the lowest temperatures, with values for 80 to 180°F being typical. Use of wastewater has wide applications here. The amount and types of chemicals and dissolved gases, such as boron, arsenic and hydrogen sulphide, are a major problem for this use. Heat exchangers and proper venting of gases may be necessary in some cases to solve this problem. Almost all of the agricultural-related energy utilization is in the Soviet Union where over 5,000 MW_t is reported being used.

Industrial processing typically requires the highest temperature, using both steam and superheated water. Temperatures up to 300°F are normally desired; however, lower temperatures can be used in some cases, especially for drying of various agricultural products. Though there are relatively few examples of industrial processing use of geothermal energy, they represent a wide range of applications, from drying of wool, fish, earth and timber, to pulp and paper processing, and to chemical extraction. The two largest industrial uses are the diatomaceous earth drying plant in Iceland, and the paper and wood processing plant in New Zealand.

Examples of Current Utilization

Traditionally, direct use of geothermal energy has been on a small scale by individuals. Surface hot springs were utilized and shallow wells could be justified with on-the-spot use or short transmission distances in uninsulated pipes or channels. However, at today's prices for development and hardware, the cost savings of these individual uses are often marginal. Large-scale use demands require more production and can, thus, justify deeper wells, longer transmission distances, more sophisticated utilization, and lower temperatures.

Most of present-day developments involve large-scale projects, such as district heating (Iceland), greenhouse complexes (Hungary), or major industrial use (New Zealand). Heat exchangers are also becoming more efficient and better adapted to geothermal use, allowing the use of lower-temperature waters and highly saline fluids. Heat pumps are extending geothermal development into traditionally non-geothermal countries, such as France, Austria, and Denmark, as well as the eastern United States.

Space Conditioning. The most famous space-heating project in the world is the Reykjavik municipal heating project, serving about 97 percent of the 113,000 people in the capital city of Iceland. At present, a total of 1.0×10^{10} gallons of geothermal fluid are used annually to supply 16,000 homes with space heating. One field supplies water through two 14-inch and one 28-inch diameter pipeline over a 12-mile distance. Insulated storage tanks (6.9×10^6 gallons) are used to meet peak flows and provide an emergency supply in the event of breakdown in the system. A fossil fuel-fired peaking station is used to boost the 176°F water to 230°F during 15 to 20 of the coldest days of the year. The city is served by nine pumping stations, distributing fluid through 200 miles of pipelines. The entire system provides 1,840 GW_h per year or 420 MW_t (including the peaking stations)(Zoega, 1974).

An example of individual home space heating is in Klamath Falls, Oregon, where over 400 wells are used for space heating, using waters from 100 to 230°F. The principal heat-extraction system is the closed-loop downhole heat exchanger utilizing city water in the loop. Larger examples of space heating in Klamath Falls include the Oregon Institute of Technology campus, where three wells up to 1,800 feet deep, produce up to 450 gpm of 192°F water and heat approximately 700,000 ft^2 of floor space. The geothermal water is pumped from the well using deep-well turbine pumps and, in most cases, is used directly in the heating system for each building. The annual operating cost of the campus system is approximately $30,000, a savings of almost $250,000 per year when compared with the cost of heating with conventional fuel. Other notable uses in the community include the 311-bed Merle West Medical Center hospital and nursing home, where the present worth of a 20-year savings due to a geothermal-retrofitted heating system is over one million dollars, and Maywood Industries, where 118°F water is used for heating a large manufacturing building.

Agriculture and Aquaculture. In Hungary, a greenhouse heating is second only to the USSR, with over 13 million ft^2 being geothermal heated. Many of these greenhouses are built on rollers, so they can be pulled from their location by tractors, the ground cultivated with large equipment, and then the greenhouse returned to its location. In addition, to minimize cost, much of the building/structure pipe-supporting system also acts as the supply and radiation system for the geothermal fluid. About 60 wells are used for animal husbandry projects, mainly for heating and cleaning of animal shelters. Priority is given to agricultural use of geothermal energy in Hungary, as this increases the volume and variety of production.

Some experimental work is being performed with grain, hay, tobacco, and paprika drying. In these cases, hot water supplies heat to forced-air heat exchangers and 120 to 140°F air is blown over the product to be dried.

In Japan, greenhouses cover about 157,000 ft^2, where a variety of vegetables and flowers are grown. Many large greenhouses are operated as tropical gardens for sightseeing purposes. Raising poultry through the use of geothermal energy has been a very successful enterprise. Here, under-the-floor heating is utilized in sheds where 40,000 chickens are raised annually. Another successful business is breeding and raising carp and eels. Eels are the most profitable and are raised in 10-inch diameter by 20-foot long earthenware pipes. Water in the pipes is held at 73°F by mixing hot spring water with river water. The adult eels weight from 3-1/2 to 5-1/4 ounces, with a total annual production of 8,400 lb. Alligators and crocodiles are also raised in geothermal water. These reptiles are being bred purely for sightseeing purposes In combination with greenhouses offering tropical flora, alligator farms are offering increasingly large inducements to the local growth of the tourist industry.

Excellent examples of greenhouse operation exist in the United States, the largest being Geo-Products Corporation complex near Susanville, California. Cucumbers and tomatoes are grown in a hydroponic system. Heat is provided to the greenhouses by geothermal fluid. At present, 30 greenhouses have been constructed, with expansion planned to over 200 units. Channel catfish are raised by Fish Breeders of Idaho near Buhl, using geothermal water. Using 6,000 gpm of 90°F water, approximately 500,000 lbs of fish are raised annually.

Industrial Processes. An example of industrial processing is the use of geothermal steam for the Tasman Pulp and Paper Company in New Zealand. Here, from 100 to 125 MW_t (18 tons/hr steam) of thermal energy is used for the timber drying, black liquor evaporation, and pulp and paper drying. The total investment cost for geothermal is $6.8 million, the majority of which is for well development. This amounts to approximately $70 per kW_t and will reduce the price of energy to 70 percent that of conventional fuels for an annual savings of $1.3 million. The annual maintenance costs are 2 percent of the capital cost.

In northern Iceland, a diatomaceous slurry is dredged from Lake Myuata. This slurry is transported through a pipeline and held in storage ponds. The 80 percent moisture is then removed in large rotary-drum driers using high temperature geothermal steam. The plant produces 27,000 tons of diatomite filteraids per year, most of which are used in beer processing in Germany.

Two industrial processing uses of geothermal energy are of note in the United States: Medo-Bell Creamery in Klamath Falls, Oregon, where low-temperature fluid is used for pasteurizing milk, and Geothermal Foods Processors at Brady Hot Springs, Nevada, where high-temperature fluid is used for dehydration of onions and other vegetables.

A major direct-thermal project in the USA, in the development stage, is the conversion of the Ore-Ida Foods, Inc., plant located in Ontario, Oregon. The Ore-Ida project involves drilling three production wells to a depth of 6,000 feet to obtain 800 gpm at a temperature of 300°F. The geothermal energy would replace 55 percent of the energy now supplied by natural gas and fuel oil for potato processing.

A summary of the present worldwide direct use of geothermal energy is as follows:

Table 1
Worldwide Direct Use of Geothermal Energy

Country	Space Heating / Cooling (MW_t)	Agriculture/ Aquaculture (MW_t)	Industrial Processes (MW_t)
Iceland	680	40	50
New Zealand	50	10	150
Japan	10	30	5
USSR	120	5,100	---
Hungary	300	370	---
Italy	50	5	20
France	10	—	---
Others	10	10	5
USA	75	5	5
Total	1,245	5,570	235

DOE DIRECT-HEAT APPLICATIONS PROJECTS

To simulate development in the direct-heat area, the Department of Energy, Division of Geothermal Energy, issued two Program Opportunity Notices. These solicitations are part of DOE's national geothermal energy program plan, which has as its goal the near-term commercialization by the private sector of hydrothermal resources. Encouragement is being given to the private sector by DOE cost, sharing a portion of the front-end financial risk in a limited number of demonstration projects.

The twenty-two projects are a direct result of the Program Opportunity Notice solicitations. These projects will: 1) provide visible evidence of the profitability of various direct-heat applications in a number of geographical regions; 2) obtain technical, economic, institutional, and environmental data under field operating conditions that will facilitate decisions on the utilization of geothermal energy by prospective developers and users, and 3) demonstrate a variety of types of applications.

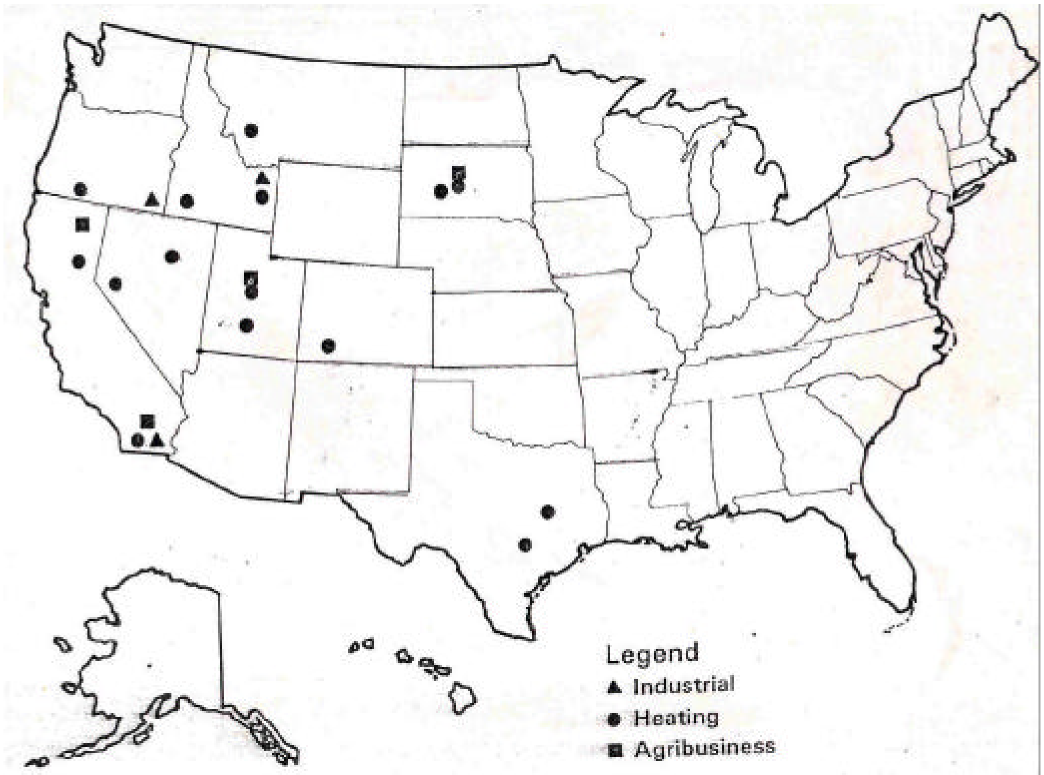

Figure 1, DOE Cost-Shared Direct-Heat Application Projects.

Conservatively, the energy savings from the projects amount to about one million barrels of oil per year on stream by 1981. Location of the projects is shown on Figure 1 and savings on Table 2.

The goals of the U.S. Department of Energy for hydrothermal resources utilization by 1985 and the year 2000 are shown on Table 3.

CASE STUDY - KLAMATH FALLS GEOTHERMAL DISTRICT HEATING PROJECT

The city of Klamath Falls, Oregon, is constructing a geothermal district heating project that will supply 314 x 10^9 Btu/yr (40 MW_t peak demand) of heat to commercial buildings on 54 blocks. Initially, that system will heat 14 government buildings (Phase 1) in the downtown area, subsequently expanded to heat 11 blocks (Phase II), and then to heat the entire 54-block central business district (Phase III).

Production wells will be drilled along the east boundary of the city, estimated to supply over 220°F water. A primary 10-inch diameter insulated steel pipeline, placed in a concrete duct, will supply

Table 2
DOE Hydrothermal Applications Projects
Annual Energy Savings

Category	No. Projects	Btu/Yr
District Heating	9	3,478 x 10^9
Unit Space Heating	7	238 x 10^9
Agriculture/Aquaculture	4	490 x 10^9
Industrial Process Heating	2	1,635 x 10^9
~ 1 Million Bopy On-Stream by 1981		5,841 x 10^9

Table 3
U.S. Goals for Hydrothermal
Resources Utilization

	1985	2000
Electric Power (MW_e)	3,000 - 4,000	20,000 - 40,000
Direct-Heat Application	0.1 - 0.2	0.5 - 2.0
Total Thermal Energy (q/yr)	0.3 - 0.5	2.0 - 5.0
Barrels of Oil Equivalent (10^6 bbl/yr)	50 - 90	350 - 900
*q/yr = 10^{15} Btu/yr		

geothermal fluid to a central heat exchange facility located 4,060 feet from the production wells. An injection well is located adjacent to this facility. Two frame-and-plate heat exchangers will provide the necessary load for the initial 14 buildings by means of a closed-loop secondary pipeline (5,780 feet) supplying heated water to the buildings at 200ºF. This line will consist of buried insulated fiberglass, reinforced plastic pipe.

Figure 2 shows the district heating distribution network.

The capital cost of the project (Phase I) will be $1.4 million, giving an equivalent annual capital, operation, and maintenance cost over a 20-year period of $150,000. Phase II cost of geothermal energy is estimated at $2.90 per million Btu; whereas, the equivalent annual fossil fuel cost is estimated at $9.40 per million Btu.

CONCLUSION

Direct utilization of geothermal energy for space and process heating, for the most part, utilizes known technology. Basically, hot water is hot water whether from a boiler or from the earth. The utilization of geothermal energy requires only straightforward engineering progress rather than revolutionary advances and major scientific discoveries. The technology, reliability, economics, and environmental acceptability have been demonstrated throughout the world.

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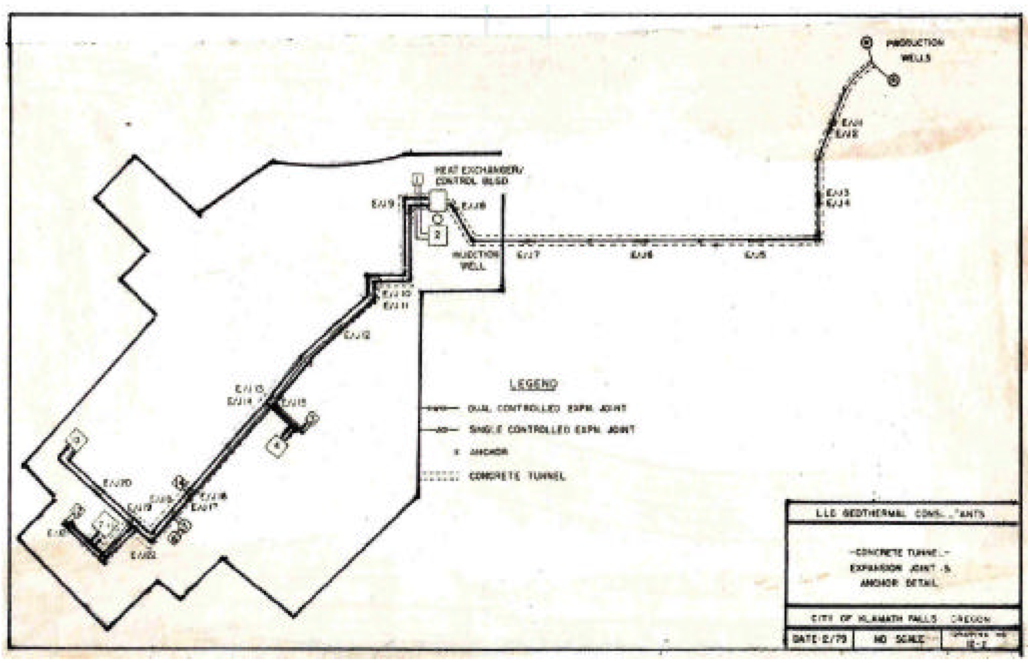

Figure 2. Klamath Falls Distribution Network.