



GEO-HEAT CENTER

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GEO-HEAT CENTER QUARTERLY BULLETIN

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A Quarterly Progress and Development Report
on the Direct Utilization of Geothermal Resources

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GEOHERMAL RESEARCH AT THE GEO-HEAT CENTER OREGON INSTITUTE OF TECHNOLOGY

**John W. Lund
Geo-Heat Center**

INTRODUCTION

The beginning of the Geo-Heat Center (GHC) can be traced to an international conference held on geothermal energy at the Oregon Institute of Technology (OIT) campus during October of 1974. The meeting was organized to review non-electric, multipurpose uses of geothermal energy in Hungary, Iceland, New Zealand, the United States and Russia (USSR). As a result of the conference and interest in the need to exchange and disseminate information on low-to-moderate temperature resources and their utilization, the Geo-Heat Center (first known as the Geo-Heat Utilization Center) was established in 1975. Initial funding was provided by the Pacific Northwest Regional Commission (PNRC), a branch of the Executive Department of the Governors of the states of Oregon, Washington and Idaho. A sum of \$3,000 was granted to distribute information to participants of the October 1974 international conference. The proceedings were published in a volume titled "Multipurpose Use of Geothermal Energy--Proceedings of the International Conference on Geothermal Energy for Industrial, Agricultural and Commercial/Residential Uses." The primary functions of the Center were to disseminate information to potential users of geothermal resources, perform applied research on the utilization of low-temperature resources, and to publish a quarterly newsletter on the progress and development of direct-use geothermal energy in the United States and other countries.

Over the years, a number of people were employed by the Center on a full-time basis or for special projects. Many of these individuals started their careers in geothermal with the Center and are still involved with geothermal energy today.

The transfer of technological information to consultants, developers, potential users, and the general public, is an important element in the development of geothermal energy. Through the USDOE, the Geo-Heat Center's resources are available to the public. Information developed through first-hand experience with hundreds of projects and through extensive research is provided to individuals, organizations or companies involved in geothermal development.

SERVICES OFFERED

Technical Assistance

The Geo-Heat Center provides technical/economic analysis for those actively involved in geothermal development. This assistance can be in the area of feasibility at the out-set of a project, equipment and materials selection during the design phase or follow-up troubleshooting for

operational systems. Geothermal projects involving direct and heat pump space heating, industrial process, and low-temperature wellhead electric power generation, will be allocated a limited number of man-hours for analysis (based on merit).

Resource Information

Based on recently developed databases for the states of AZ, CA, CO, ID, MT, NV, NM, OR, UT and WA, data can be provided on over 8,000 thermal springs and wells. Data is available for a specific area of a city or county and includes: location, temperature, flow rate, depth, water chemistry, current utilization and source references from which more detailed information can be obtained.

Advising and Referrals

The Geo-Heat Center acts as a clearinghouse providing technical information by meeting with groups and answering telephone inquiries, letters and e-mail from individuals, businesses, and local governments on geothermal resources, space heating, district heating, greenhouses, aquaculture projects, equipment, heat pumps, small-scale electric generation systems, and other related items.

Speaker's Bureau

Center staff are available to make presentations on topics such as system design, economic considerations, and project examples to both lay and technical audiences.

Tours

The Center will arrange individual and group tours of Klamath Falls district heating system, campus geothermal heating/cooling system, residential and local greenhouse applications

Publications

A quarterly bulletin featuring domestic and foreign research, development and utilization is available free of charge. Technical material on resources, direct-use equipment, design schemes, software, and feasibility studies may be obtained by writing or through e-mail for the GHC Publications Request Form.

Library

The Center maintains a geothermal library of over 5,000 volumes for lay and technical readers. Volumes can be reviewed at the Center. Computer reference search is also available.

FUNDING

Research is supported by the Office of Geothermal Technologies, under the Office of Utility Technologies of the U.S. Department of Energy, through a grant.

Since 1975, the GHC has been involved in a number of studies and projects, funded by a variety of sources, but primarily from the Department of Energy, to meet its goals. A summary of these projects and activities are recounted in Lienau and Lund (1995)

TECHNICAL ASSISTANCE PROGRAM

The Geo-Heat Center staff can provide up to eight hours of technical assistance, free of charge, to individuals, public organizations and private companies, in the form of a feasibility study for potential direct use developments. We can also provide “troubleshooting” support for existing systems.

During 1995 over 350 inquiries were handled; in 1996, 583 were responded to (Figure 1); and for 1997, 761 requests completed (Figure 2). The recent increases are due to our home page (<http://www.oit.edu/~geoheat>) on the World Wide Web. Approximately half of our requests are by e-mail, and our international requests are around 15%.

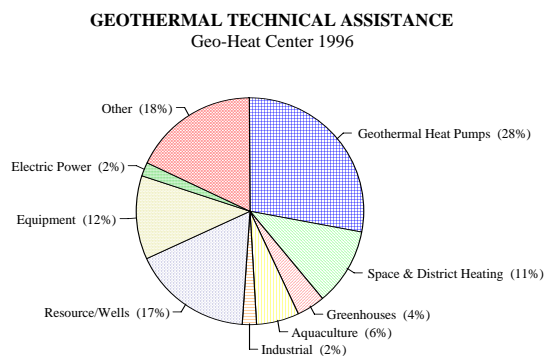


Figure 1. Geothermal technical assistance 1996.

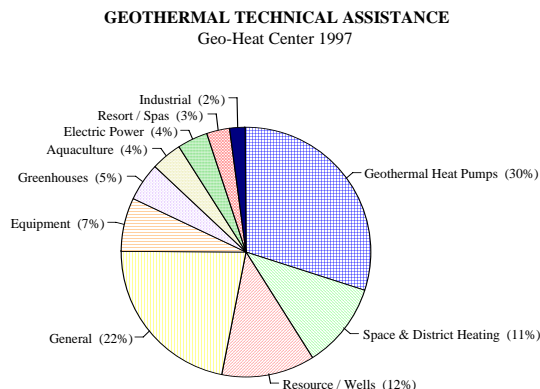


Figure 2. Geothermal technical assistance 1997.

MAJOR PUBLICATIONS

In addition to technical papers and research reports prepared by the staff, the Geo-Heat Center has developed and published a comprehensive “Geothermal Direct Use Engineering and Design Guidebook.” This guidebook, revised in 1998 in a 3rd edition, consists of 19 chapters covering all aspect of geothermal direct use, from exploration to greenhouse design to environmental considerations. We have also published a “Quarterly Bulletin” for over 20 years which contains domestic and international articles on direct-use projects and research.

DIRECT-USE PROJECTS

The Geo-Heat Center staff has preformed numerous research projects, seven of which are summarized in the following section.

Downhole Heat Exchangers (Lund, et al., 1975; Culver and Reinstad, 1978)

Since Klamath Falls has over 500 downhole heat exchangers in use, research in the area became one of the earliest priorities of the Geo-Heat Center staff.

The downhole heat exchanger (DHE) eliminates the problem of disposal of geothermal fluid, since only heat is taken from the well. The exchanger consists of a system of pipes or tubes suspended in the well through which “clean” secondary water is pumped or allowed to circulate by natural convection. These systems offer substantial economic savings over surface heat exchangers where a single-well system is adequate [typically less than 0.8 MWt (2.73×10^6 Btu/hr)] , with well depths up to about 150 m (500 ft) and may be economical under certain conditions at well depths to 450 m (1500 ft) .

Several designs have proven successful; but, the most popular are a simple hairpin loop or multiple loops of iron pipe (similar to the tubes in a U-Tube and shell exchanger) extending near the well bottom (Figure 3). An experimental design consisting of multiple small tubes with “leaders” at each end suspended just below the water surface appears to offer economic and heating capacity advantages.

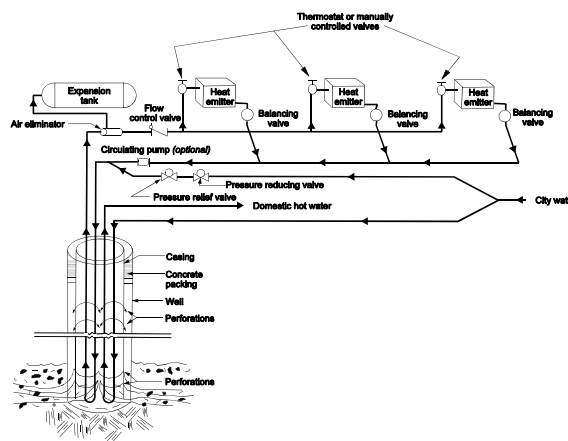


Figure 3. Typical hot-water distribution system using a downhole heat exchanger.

In order to obtain maximum output, the well must be designed to have an open annulus between the wellbore and the casing, and perforations above and below the heat exchanger surface. Natural convection circulates the water down inside the casing, through the lower perforations, up in the annulus and back inside the casing, through the upper perforations. If the design parameters of bore diameter, casing diameter, heat exchanger length, tube diameter, number of loops, flow rate and inlet temperature are carefully selected, the velocity and mass flow of the natural convection cell in the well may approach those of a conventional shell-and-tube heat exchanger.

The interaction between the fluid in the aquifer and that in the well is not fully understood; but, it appears that outputs are higher where there is a high degree of mixing indicating that somewhat permeable formations are preferred.

Considering life and replacement costs, materials should be selected to provide economical protection from corrosion. Attention must be given to the anodic-cathodic relationship between the exchanger and the casing since it is relatively expensive to replace the well casing. Experience in the approximately 500 downhole exchangers in use indicates that corrosion is most severe at the air-water interface at static water level and that stray electrical currents can accelerate corrosion. Insulating unions should be used to isolate the exchanger from stray currents in building and city water lines. Capping the top of the casing will also reduce the air-water interface corrosion.

A Capital Cost Comparison of Commercial Ground-Source Heat Pump Systems (Rafferty, 1995a)

Unitary ground-source heat pump systems for commercial buildings can be installed in a variety of configurations. The oldest and, until recently, most widely used approach was the groundwater system. In this design, groundwater from a well or wells is delivered to a heat exchanger installed in the heat pump loop. After passing through the heat exchanger (where it absorbs heat from or delivers heat to the loop), the groundwater is disposed of on the surface or in an injection well. The use of an injection well is desirable in order to conserve the groundwater resource.

A second and increasingly popular design is the ground-coupled heat pump system. In this approach, a closed loop of buried piping is connected to the building loop. For most larger commercial applications, the buried piping is installed in a grid of vertical boreholes 30 to 90 m (100 to 300 ft) deep. Heat pump loop water is circulated through the buried piping network absorbing heat from or delivering heat to the soil. The quantity of buried piping varies with climate, soil properties and building characteristics, but is generally in the range of 13 to 22 m/kW (150 to 250 ft/ton) of system capacity. Borehole length requirements are almost always dictated by heat rejection (cooling mode) duty for commercial buildings.

A third design for ground-source systems in commercial buildings is the “hybrid” system. This approach may also be considered a variation of the ground-coupled design. Due to the high cost associated with installing a ground loop to meet the peak cooling load, the hybrid system includes a cooling tower. The use of the tower allows the designer to size the ground loop for the heating load and use it in combination with the tower to meet the peak cooling load. The tower preserves some of the energy efficiency of the system, but reduces the capital cost associated with the ground loop installation.

Generally, the hybrid system is attractive in situations where ground loop costs per kW (ton) are high, and where the heating loop length requirement is low relative to the cooling loop length requirement.

Costs were developed for three groundwater/soil temperature 10°, 15.6° and 21.1 °C (50°, 60° and 70 °F) representing northern, central and southern climates. For brevity, only the results for the 15.6°C (60°F) cases are presented in Figures 4 and 5.

Figure 4 presents a comparison of the three types of systems for 15.6°C (60°F soil) (for the most favorable conditions). The ground-coupled system cost line is based upon \$16/m (\$5/ft) and \$284/kW (200 ft/ton = \$1000/ton). The two hybrid system curves are based upon loop length ratios (heating ÷ cooling) of 0.30 and 0.40, which is the most favorable for hybrid systems. This figure shows that the groundwater (GW) system has a capital cost advantage over the other systems.

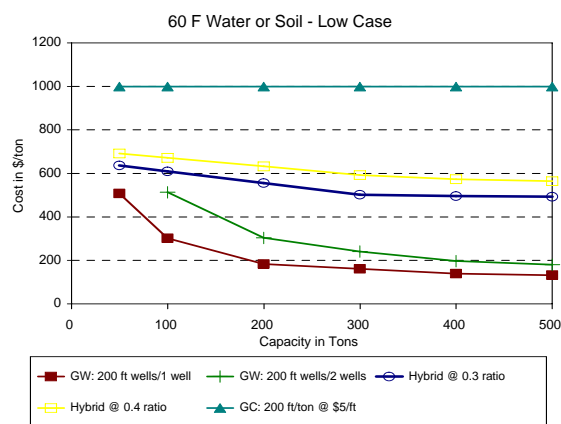


Figure 4. Ground-source system costs - low case.

Figure 5 presents additional data for the 15.6°C (60°F) soil case. The ground-coupled line is based on 17 m/kW (200 ft/ton) and \$16/m (\$5/ft). The two hybrid system curves are based upon loop length ratios of 0.50 (lower) and 0.60 (upper). These are the least favorable conditions for the hybrid systems covered in the paper. The two curves for the groundwater system are based upon a single production/injection well pair at 244 m (800 foot) depth (lower curve) and two production/injection well pairs at a 183 m (600 foot) depth. These are the least favorable conditions for the groundwater system covered in the paper.

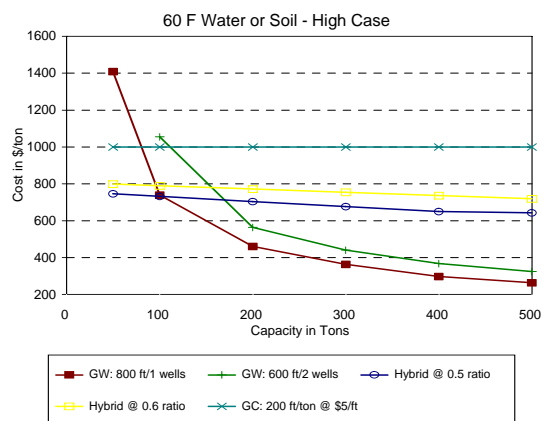


Figure 5. Ground-source system costs - high case.

At system capacities of 350 - 615 kW (100 - 175 tons) and above, the groundwater system has the capital cost advantage over hybrid and ground-coupled systems. Below this range, the hybrid system is the most attractive. It is only under conditions of less than 350 kW (100 tons) with well depths of 244 m (800 feet) that the groundwater system capital cost exceeds that of the ground-coupled system.

The article addresses only system capital cost. In the process of system selection, other issues should be considered as well. These would include operating costs such as electricity for pumps and fans, water treatment costs (tower) and regulatory issues with respect to groundwater. As a result, system capital cost provides only a portion of the information required for informed decision making.

A Spreadsheet for Geothermal Energy Cost Evaluation (Rafferty, 1995b)

The Geo-Heat Center developed a spreadsheet which will allow potential users to quickly evaluate the capital cost and unit energy cost of accessing a geothermal resource.

Using resource, financing and operating inputs, the spreadsheet calculates the capital cost for production well(s), well pump(s), well head equipment, injection well(s), and connecting pipelines. These capital costs are used along with the quantity of annual energy to be supplied and financing information to produce a unit cost of energy. Unit costs for operation (maintenance and electricity) are added to arrive at a total unit cost in \$per million Btu for geothermal heat. To put this value into perspective, similar costs for an equivalently sized gas boiler plant are also calculated. These values can then be compared to determine the relative economic merit of geothermal for any specific set of circumstances.

For the geothermal system, up to three production wells can be specified. Well casing is sized to accommodate a pump capable of supplying the required flow rate. Costs are included for drilling, casing, cementing, packers, bits and drill rig mobilization. An option is provided for open hole completion.

Wells can be equipped with production pumps at the users discretion. Pumps are assumed to be oil lubricated/

lineshaft type and can be equipped with electronic variable-speed drives. The spread-sheet calculates the total pump head (including injection pressure if applicable), bowl size, number of stages, lateral requirements, column size and length, and all costs.

Well head equipment includes piping, check valve and shut-off valve along with electrical connections and accessories for the motor. All of these items are assumed to be located in an enclosure.

Injection wells (up to 3) can be included in the system at the users discretion, along with a user defined casing depth. Cost components for the injection wells are similar to those described for the production wells; although, the drilling cost rates used for injection are higher than those used for production. This rate is 20% higher to allow for alternate drilling methods sometimes employed for injection wells.

Finally, piping connecting the production wells and injection wells to the building (or process) are included to complete the geothermal system. A 15% contingency is added to all major cost categories.

For the boiler plant, costs are calculated for a cast iron gas-fired boiler including: boiler and burner, concrete pad, breaching to flue, gas piping, combusting air louvers, expansion tank and air fitting, air separation, relief valve and piping, feed-water assembly, boiler room piping and shut-off valves. The spreadsheet is intended to compare geothermal to other conventional methods of supplying heat. As a result, it focuses upon the heat source only. Costs necessary for interface with a specific use, such as a heat exchanger, fan coil units or distribution system are not included.

Table 1 illustrates the output for a system similar to the one at Oregon Institute of Technology, which consists of three production wells and two injection wells. The system heats over (52,000 m² (560,000 ft²) of buildings.

Table 1. Sample Output for Cost Evaluation

OUTPUT		
1.	Required Flow	600 gpm (37.8 L/s)
2.	Production Well	\$ 281,698
3.	Well Pump	\$ 117,131
4.	Wellhead Equipment	\$ 25,913
5.	Injection Well	\$ 251,487
6.	Pipeline	\$ 46,182
7.	Total Geothermal Cost	\$ 722,410
8.	Boiler Plant Cost	\$ 96,509
9.	Unit Capital Cost	2.80 \$/MMBtu*
10.	Unit Maintenance Cost	0.49 \$/MMBtu
11.	Unit Electricity Cost	0.42 \$/MMBtu
12.	Total Unit Cost	3.71 \$/MMBtu
13.	Boiler Fuel Cost	5.73 \$/MMBtu
14.	Equipment Unit Cost	0.43 \$/MMBtu
15.	Maintenance Unit Cost	0.11 \$/MMBtu
16.	Total Unit Cost	6.27 \$/MMBtu
17.	Simple Payback	9.28 Years

* 1MMBtu = 293 kWh = 1.05 GJ

Utilization of Silica Waste From Geothermal Power Production (Lund and Boyd, 1996)

The Geo-Heat Center has been investigating the utilization of waste silica from the Cerro Prieto geothermal field for several years. The main objectives of the research were to combine silica with various additives to (1) form bricks for low-cost housing, and (2) to produce a suitable road surfacing material. The various additives that were tested included hydrated lime, portland cement, plastic fibers, asphalt cement and emulsified asphalt. The silica-cement combination produced the strongest bricks and had the best weather resistance; whereas, the silica-lime combination produced the bricks with the lowest thermal conductivity and specific gravity density. The addition of plastic fibers to the silica-lime mixture improved both strength and weather resistance. The combination of asphalt and silica is not suitable as a road surfacing material; however, silica-cement appears promising.

Figures 6 and 7 are test results illustrating the relationships between additive, thermal conductivity and specific gravity.

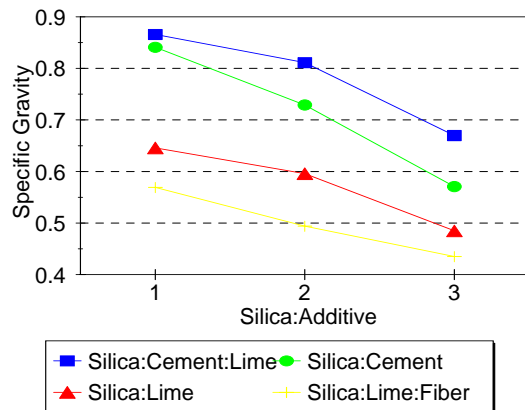


Figure 6. Silica additive vs. specific gravity.

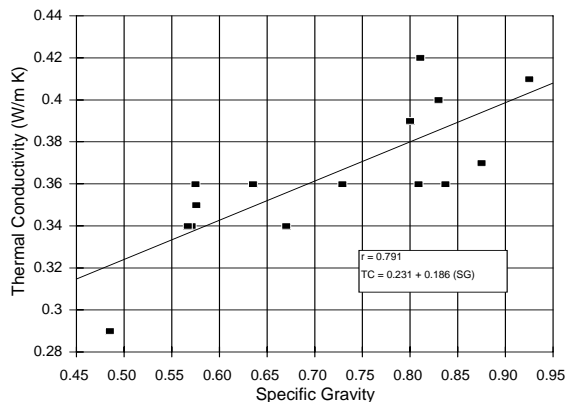


Figure 7. Specific gravity vs. thermal conductivity.

It is proposed to test several walls constructed of silica-lime and silica-cement mixtures in the Imperial Valley area. This will provide long-term field testing of the various types of bricks and determine if they need protective coatings, reinforcing, etc.

During the course of the investigation, it was determined that a lightweight roofing tile using portland cement, silica and cellulose fibers is presently being manufactured in Mexico City and sold through outlets in the U.S. Their advertised advantage is that

they are lighter weight [60 percent lighter than clay or concrete tile at 20 kg/m² (4 lbs/ft²)]. CFE is presently investigating the potential for use of the Cerro Prieto waste silica by this manufacturer.

Fossil Fuel-Fired Peak Heating for Geothermal Greenhouses (Rafferty, 1997)

Increasingly, greenhouse operations will encounter limitations in available geothermal resource flow due either to production or disposal considerations. As a result, it will be necessary to operate additions at reduced water temperatures reflective of the effluent from the existing operations. Water temperature has a strong influence on heating system design.

Due to temperature occurrences in most western geothermal locations, a base load system (geothermal) designed for approximately 60% of the peak load can actually meet 95+% of the annual heating requirement. As a result, a facility with limited geothermal flow can expand to provide a portion of the heating requirements with a conventionally-fueled peak heating system. Thus, they can use the heating system of choice and still achieve substantial energy savings with a base load/peak load heating system design. In addition, the fossil-fueled peak load system offers a no-cost emergency backup in the event of a failure in the geothermal system.

The report examines the economics of fossil-fuel peaking for three different climates (Helena, MT; Klamath Falls, OR and San Bernardino, CA) representing very cold, moderate and warm climates. Figure 8 presents the results for Klamath Falls. Cost shown are expressed in \$/ft² of greenhouse floor area and include capitalization of the equipment, fuel costs and maintenance for the fossil-fuel peaking system.

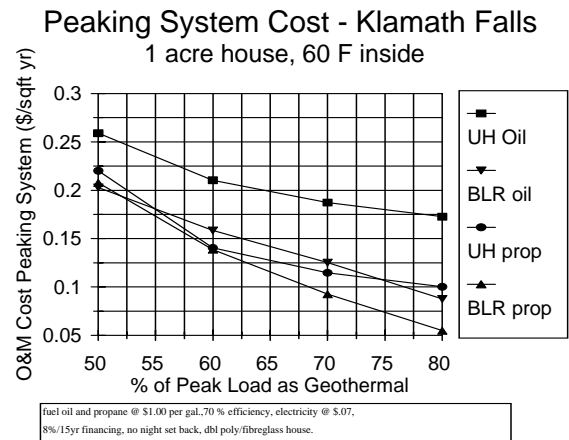


Figure 8. Peaking system cost - Klamath Falls.

As indicated, the propane boiler (BLR prop) is the least expensive peaking system for a wide range of conditions, with the propane unit heaters (UH prop), and oil boiler system (BLR oil) competitive up to the 65% base load level. These results are similar to the other climates with the exception that in the coldest climate, the oil unit heater system (UH oil) is the least cost design at less than 60% base load sizing.

In cases where there is limited geothermal flow available and the grower wishes to use a system which is difficult to apply at low water temperatures, the use of fossil fuel peaking permits the use of the growers preferred system for a reasonable increment in operating costs.

Selected Cost Considerations for Geothermal District Heating in Existing Single-Family Residential Areas (Rafferty, 1996)

District heating in existing single-family residential areas has long been considered to be uneconomical due to the low-heating load density. In comparison to the typical downtown business districts load density is low; however, there are some characteristics of residential areas which could serve to enhance the economics of district heating.

Among these are: (1) wide variety of heating fuels (and costs) which can result in a range of conventional heating costs of 3 or more to 1 for the same heating load density; (2) availability of unpaved areas for installation of the distribution system; (3) fewer utilities in the pipeline corridor; (4) less traffic control requirements during construction; (5) potential for the use of uninsulated piping, and (6) older, poorly insulated structures with high energy use.

The report explores some of the issues related to costs involved in the installation of geothermal district heating (GDH) in existing single-family residential areas. A summary of construction cost percentages for a 6-in. preinsulated ductile iron pipe installation is shown in Figure 9.

**Construction Costs - 6" Pre Ins DI
Condensed Cost Percentages**

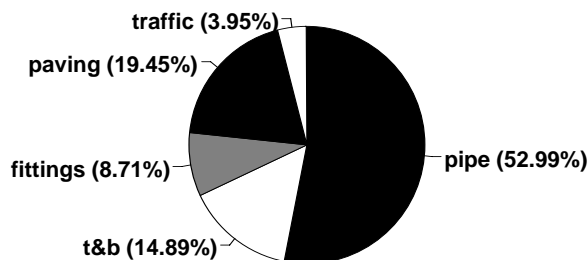


Figure 9. Sample construction costs.

Based on the example residential area evaluated in the paper, it appears that geothermal district heating in existing single-family residential areas could be feasible in situations where: (1) propane, fuel oil and electricity (or combination of these fuels with wood) dominate the conventional heating used; (2) small lot sizes (465 m²) (<5,000 ft²); (3) subdivisions where unpaved areas are available for installation of some or all of the distribution system, and (4) customer penetration rate is high (>=75%).

Collocated Resources Inventory of Wells and Hot Springs in the Western U.S. (Boyd, 1996)

Low- and moderate-temperature geothermal resources are widely distributed throughout the western and

central United States. Since the last major effort in assessing the national potential of these resources in the early 1980s, there has been a substantial increase in direct-heat utilization. However, the large resource base is greatly under-utilized. To help expand utilization of the direct-heat resource base, a current inventory of these resources has been developed.

A further breakdown of the current inventory, identifies 271 collocated communities with wells or springs 50°C (>=122°F) within 8 km (5 miles). These communities could benefit by utilizing the geothermal resource. The Geo-Heat Center has sent out information about the resources to the Economic Development Centers for the collocated communities in hopes of promoting geothermal use.

Figure 10 is the map of the 70 collocated communities in California, and Table 2 is an example database for five of these locations.

Table 2. Section of the Collocated Resource Database for California.

	Bombay Beach	Boyes Hot Springs	Brawley	Bridgeport	Byron
County	Imperial	Sonoma	Imperial	Mono	Contra Costa
Latitude	33.35	38.317	32.9833	38.25	37.8472
Longitude	115.7167	122.4833	115.5333	119.2333	121.63
Population	500	5937	19450	900	1100
Resource Temp. °C	88	53.1	138	82	51
Number of Wells	11	2	5	3	1
Typical Depth m	201	396	2545	300	75
Flow L/min	2660	757	500	450	600
TDS	3800	1287	28000	4320	
Current Use	Aquaculture	Baths/pools & space Heating		Power Plant	
HDD	925	3311	925	6022	2806
Design Temp.	38	30	38	10	30
Remarks	11 wells, located within 5 miles of Bombay Beach	1 spring/well, located within 0.5 miles of Boyes Hot Springs, and 2 miles of Sonoma	5 wells, located within 2 miles of Brawley	2 springs/1 well, located within 3 miles of Bridgeport	1 well, located within 1 mile of Byron

Rafferty, K., 1995b, "A Spreadsheet for Geothermal Energy Cost Evaluation," *Geo-Heat Center Quarterly Bulletin*, Vol. 16, No. 2 (February), Klamath Falls, OR, pp. 11-14.

Rafferty, K., 1996, "Selected Cost Considerations for Geothermal District Heating in Existing Single-Family Residential Area," *Geo-Heat Center Quarterly Bulletin*, Vol. 17, No. 3 (August), Klamath Falls, OR, pp. 10-15.

Rafferty, K., 1977, "Fossil Fuel-Fired Peak Heating for Geothermal Greenhouses," *Geo-Heat Center Quarterly Bulletin*, vol. 18, No. 1 (January), Klamath Falls, OR. Pp. 1-4.

THE SUSTAINABILITY OF PRODUCTION FROM GEOTHERMAL RESOURCES

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INTRODUCTION

In the strictest sense, the sustainability in consumption of a resource, of whatever kind, is dependent on its initial quantity, its rate of generation and its rate of consumption. Consumption can obviously be sustained over any time period in which a resource is being created faster than it is being depleted. If the rate of consumption exceeds the rate of generation, consumption can, nevertheless, be sustained over some time period dependent upon the initial amount of the resource available when consumption begins.

The term "sustainable development" was used by the World Commission on Environment and Development in a somewhat different way, to mean development that "meets the needs of the present generation without compromising the needs of future generations" (Brundtland Commission, 1987). To meet the Brundtland Commission's definition of sustainability for energy supply, we must consider the interactions among all available and reasonably foreseen energy sources. If one resource becomes depleted, we need only have an available substitute to ensure that future generations are able to meet their needs. Kozloff and Dower (1993) believe that whether or not consumption of a resource can said to be renewable depends on the time frame under consideration. They suggest that a perspective of 300 years or more of continuous production is adequate for an energy fuel to be considered as renewable, since technical advances during that time will have rendered today's perspective obsolete.

FACTORS AFFECTING HYDROTHERMAL SUSTAINABILITY

The total available amount of heat in any particular hydrothermal geothermal resource and its rate of resupply by conduction and fluid recharge from great depth are quantities potentially amenable to determination by geoscientific methods. The rate of consumption of the resource through production of geothermal fluids at the surface is most strongly dependent on financial, political, and regulatory factors, which we will together term "economic factors." Determination of the potential sustainability of production from a given hydrothermal resource therefore depends on both geoscientific and economic factors, and these factors can, in principle, all be determined.

INTRUSION AND COOLING OF PLUTONS IN THE EARTH

Intrusion of molten igneous rocks into shallow regions of the earth's crust (2 to 10 km depth) has occurred since the beginning of geologic time. Igneous intrusion brings up enormous quantities of heat from mantle depths and deposits this heat in the crust. There is little doubt that the larger, higher-temperature, and more vigorous hydrothermal systems are driven by igneous heat sources.

Numerical model studies of the cooling of magmatic-hydrothermal systems have been carried out by several investigators (Cathles, 1977, 1981; Norton, 1982; Cathles et al., 1997). Such studies as these allow their authors to reach several conclusions: (1) small intrusions can generate large surface heat fluxes and substantial reservoirs of hot rock with vapor- or liquid-dominated hydrothermal reservoirs; (2) the duration of the high surface heat flux, although short geologically, ranges from 5,000 to more than 1,000,000 years; and, (3) enormous volumes of water circulate through the system, with the most vigorous fluid convection taking place underground prior to arrival of the thermal anomaly at the surface.

These numerical modeling results are borne out by radioactive dating of the duration of hydrothermal activity. For example, Sims and White (1981) concluded that hydrothermal activity responsible for deposition of mercury at the Sulphur Bank mine, near The Geysers geothermal field, California, began 34,000 years ago and continues at the present time. White (1968) estimated that a magma volume of 100 km³ must have been cooling and crystallizing for 100,000 years to supply the convective heat losses at Steamboat, Nevada, at their present rates. The oldest hot spring sinter at that location was deposited 3 m.y. ago, documenting a very long history of hydrothermal activity, perhaps spawned by individual episodes of intrusion to shallow depth from a very large underlying magma body. Silberman (1983) suggested that "the most conclusive data from volcanic-hosted precious-metal vein and disseminated deposits, thermal spring systems, and porphyry-copper deposits suggest that on average, the total time span of hydrothermal activity is about 1 m.y., although the range of activity is between 0.6 and 2.5 m.y."

While all of these results are interesting and pertinent, the most important finding from our perspective is that the duration of typical hydrothermal systems ranges upward from 5,000 to more than 1,000,000 years. System duration depends on the amount of thermal energy input to the crust by the pluton, the permeability of the pluton and host rock, and whether or not free flow out the top surface occurs, among many other variables. High permeability and free flow out the top promote more vigorous fluid circulation and lead to shorter system lifetimes. We conclude that hydrothermal systems in the earth's crust meet any reasonable definition of the terms "renewable" and "sustainable". However, exploitation that exceeds natural recharge can greatly shorten the system lifetime.

Estimates of the rate of natural recharge of a system are available from two sources. The undisturbed natural system will produce a heat-flow anomaly at the earth's surface which, if defined well enough, may be integrated over its surface area to yield the natural rate of conductive heat loss from the top of the resource. To such determinations must be added the heat lost from hot springs, geysers and other surface features. This total heat loss at the surface is taken to equal the rate of heat input from deep convective and conductive thermal resupply. A second method of determining natural recharge rate is with detailed reservoir-simulation models. Starting from a known or assumed natural, pre-production state, these models attempt to match either (1) the known, pre-production temperature and pressure distribution in the subsurface, (2) the production history from available wells, or (3) both. The natural recharge rate is included as a parameter to help improve the model match to the field data. When a satisfactory match is achieved, the recharge parameter is taken as an estimate of the natural advective thermal recharge rate. A brief summary of published recharge values (Wright, 1995) indicates that the rate of natural recharge of known crustal hydrothermal systems ranges from a few megawatts to more than 1,000 MWt. The natural recharge rate represents the minimum rate at which hydrothermal systems could, in principal, be produced for thousands of years. However, when artificial production becomes intense, profound changes are made to the natural hydrothermal system and the lifetime may be considerably foreshortened.

ENERGY PRODUCTION FROM HYDROTHERMAL SYSTEMS

Hanano et al. (1990) give a helpful discussion of reservoir longevity for liquid-dominated systems. They use a simulation technique composed of a reservoir model, a well-flow model, and a system-management model to study reservoir pressure and temperature behavior in various development cases. Reservoir behavior is simulated under conditions of constant power-plant electric output, requiring a variable flow rate through periodic addition of new wells as temperature and pressure decline until abandonment conditions are reached. As might be expected, total recoverable electric energy and reservoir longevity are both

highest at small output rates. As the power-plant size increases, both parameters decline rapidly. In their example, the system longevity for 1 MWe is almost 200 times greater than for 100 MWe, and the recoverable electric energy from 1 MWe steady production is twice as large as that of 100 MWe. The authors state that six factors strongly influence longevity -- (1) output power, (2) well density, (3) injection strategy, (4) initial reservoir pressure, (5) initial fluid temperature, and (6) permeability in and around the reservoir. The first three factors can be managed artificially, but the last three are fixed by nature and are specific to the area. Economic and engineering influences affect the first three factors, with economics having perhaps the most profound consequences.

ECONOMICS AND SUSTAINABLE DEVELOPMENT

Traditional methods of economic analysis were inherited from an era when the carrying capacities of the earth's natural systems were large compared with the demands being made upon them. Today, this is no longer the case, and new methods of economic analysis are badly needed. In conventional analysis of projects, economists traditionally apply a discount rate to determine the present value of a future asset, say an income stream from geothermal production. When this is done for the relatively long time periods of interest in sustainability, the present value of future geothermal production becomes very small. For example, the present value of \$1,000 available 30 years hence discounted at a rate of 10% is \$57. If discounted over 100 years, the same \$1,000 is worth a mere \$0.07 today. According to this method of valuing a future asset, there is little economic incentive for a geothermal developer to extract energy from a resource in a sustainable way.

Pearce and Warford (1993) have introduced the concept of total economic value (TEV) as a way of bringing environmental and sustainability concerns into economic analyses on a project basis. The total economic value for a resource would consist of the direct-use value, the indirect-use value, the option-use value, and the intrinsic or existence value. Direct-use values for energy resources are fairly straightforward, and are given by current economic analysis if these analyses include external costs of using the resource. Indirect-use values consist mainly of values given by ecologists, and are important but may be difficult to quantify for energy resources. Option-use values relate to the amount that governments or individuals are willing to pay to conserve a resource for future use. Existence values relate to all other valuations of the natural asset, such as scenic beauty. The total economic value offers a comprehensive framework within which to value natural assets such as geothermal energy resources. If a system of analysis based on the TEV were implemented, it would be a significant departure from traditional economic analyses of geothermal resources and contribute to a more sustainable rate of production from them. However, much remains to be learned and accepted by governments and markets before modified systems of national

accounts and project analysis will be adopted that take the sustainability of the natural environment into full consideration.

GEOTHERMAL ENERGY AND SUSTAINABILITY

Sustainable development in the context of the Bundtland Commission (1987) does not imply that any given energy resource needs to be used in a totally sustainable fashion, but merely that a replacement for the resource can be found that will allow future generations to provide for themselves in spite of the fact that the particular resource has been depleted. Thus, it may not be necessary that any specific geothermal field be exploited in a sustainable fashion. Perhaps we should direct our geothermal sustainability studies toward reaching and then sustaining a certain overall level of geothermal production at a national or regional level, both for electrical power generation and direct-heat applications, for a certain period, say 300 years, by bringing new geothermal systems on line as others are depleted.

In this context, we should consider the extent of geothermal resources potentially available. The geothermal energy resource base is known to be very large. Table 1 shows an assessment of the geothermal resource base, which I recently compiled from analysis of many sources, compared with an estimate of oil reserves.

We are drawn to conclude that production of useful levels of energy from geothermal resources can be expected to be undertaken by humans for hundreds or thousands of years. If carefully managed, geothermal production can be sustained essentially indefinitely. New methods of economic analysis that account for the total economic value of a resource would help foster sustainable use of individual resources.

ACKNOWLEDGMENTS

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Table 1. Estimate of World Geothermal Energy Resource Base

GEOLOGIC REGIME	U.S. RESOURCES Joules bbl oil equivalent	WORLD CONTINENTAL RESOURCES¹ Joules bbl oil equivalent	TECHNOLOGY NEEDED FOR DEVELOPMENT
Magmatic Systems (surface to 10 km)	1×10^{24} $160,000 \times 10^9$	15×10^{24} $2,400,000 \times 10^9$	Hydrothermal (part) EGS ² (part)
Crustal Heat ³ (3 km to 10 km)	14×10^{24} $2,300,000 \times 10^9$	490×10^{24} $79,000,000 \times 10^9$	EGS
Thermal Aquifers	55×10^{18} 9×10^9	810×10^{18} 130×10^9	Hydrothermal
Geopressed Basins (surface to 6.9 km)	0.17×10^{24} $28,000 \times 10^9$	2.5×10^{24} $410,000 \times 10^9$	Oil Field plus Hydrothermal
Total Oil Reserves ⁴ (for comparison), bbl	890×10^9	$5,300 \times 10^9$	

1. Excluding Antarctica. Only a rough estimate is possible.
2. EGS = Enhanced Geothermal Systems (a.k.a., Hot Dry Rock).
3. Excluding heat in magmatic systems, thermal aquifers, and geopressed basins.
4. Includes crude oil, heavy oil, tar sands, and oil shale.

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CITY OF BOISE

GEOHERMAL INJECTION WELL PROJECT

JUNE 1998 UPDATE

Kent Johnson
Public Works Department
City of Boise

BACKGROUND

In 1998, the city of Boise signed a Cooperative Agreement with the Department of Energy which provides \$870,000 for the construction of an injection well for the city's geothermal heating system. The goal of the project is to hydraulically replenish the geothermal aquifer the city shares with the Boise Warm Springs Water District, the Veterans Administration hospital, and the state of Idaho Capital Mall buildings, and to reduce the discharge of spent geothermal water to the Boise River. If the injection well is successful, the moratorium that limits the geothermal production for the city's system could be lifted and the city could expand the city-owned geothermal heating district.

The first milestone of the Agreement was to jointly conduct a study of the aquifer with the Boise Warm Springs Water District (BWSWD) per the city's agreement with BWSWD. The study produced a model of the geothermal aquifer which predicated overall positive benefits if the spent geothermal fluid is injected back to the aquifer.

As a result of the recommendation of the modeling studies under the DOE agreement, the city attempted to negotiate an intertie of city and Capital Mall geothermal systems. This was thought to be a mutually desirable arrangement where the city would deliver its warmer geothermal water to the Capital Mall system in exchange for the use of the Capital Mall wells for injection for both systems. This arrangement would have saved the cost and risk of drilling an additional well and allowed the DOE funds to be used for other system enhancements. Negotiations with the state began in December 1993, with tentative agreement in June 1994; but ultimately, negotiations failed and were terminated in August 1995.

Efforts were then refocused on drilling a new injection well for the city's system. RFPs for engineering design work were advertized in August with design work begun by Montgomery Watson in December 1995. A separate RFP for developing the DOE's Environmental Assessment was advertized in October 1995 and awarded in January 1996 to Power Engineers.

Montgomery Watson completed a Phase I design report in March 1996 discussing five possible injection well locations and it was the impetus to conduct a seismic survey to provide a geological basis for selecting an injection well site. After a seismic survey was completed during April and

May of 1996, a preferred injection well site was selected and a Draft Environmental Assessment was published in July. Due to concern by the state of Idaho of adverse effects on their Capital Mall geothermal heating system, the environmental clearance process was delayed approximately 15 months, with DOE finally issuing a "Finding of No Significant Impact" in November of 1997.

A contract for drilling the injection well was then advertized and opened in December of 1997, the contract awarded to Holman Drilling of Spokane, Washington in January of 1998, and drilling of the well actually began in February. The well was completed in April to a total depth of 3,200 ft with better than anticipated results. We were thrilled to find that the well, with a little encouragement by air lifting water out of the casing for a couple of minutes, began flowing under artesian pressure. The well flows at about 900 gallons per minute (gpm) at a temperature of 168°F. An injection test was also conducted. Utilizing our supply water from the existing geothermal wells, we were able to inject 1,800 gpm for several hours. The final analysis of the well characteristics is still being conducted to determine the ultimate capacity. This well should meet our needs for many years to come. The hydraulics are such that under existing operating conditions, we will be able to inject into this well using normal system operating pressures (we will not need an auxiliary pump).

RECENT PROGRESS

With the basic well capacity determined, the final design of the pipeline connecting to the geothermal heating system, the well house, and injection pump is being completed and will be constructed this summer. It is anticipated to have the injection well in service for the 98-99 heating season.

SEISMIC MONITORING

An issue that was raised during the process of obtaining an injection well permit from the Idaho Department of Water Resources (DWR) was the possibility of causing seismic activity with injection. According to the literature, the probability of causing seismic activity appears to be low; but, since the injection well is being developed in a heavily populated area (within four blocks of downtown Boise), IDWR is requiring some basic seismic monitoring be conducted by the city, for at least the first few years of the operation of the injection well.

DEMONSTRATION GEOTHERMAL PROJECT AT RIBEIRA GRANDE (AZORES, PORTUGAL)

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INOVA - Institute for New Technologies of Azores
Ponta Delgada, Azores, Portugal

INTRODUCTION

The Azores Islands consist of nine volcanic islands in the middle of the Atlantic Ocean. Two of them are placed on the American Plate and others are aligned along a northwest-southwest tensional axis which runs from the mid-Atlantic ridge to Gibraltar after a directional change close to S. Miguel island. The youthfulness of the Azores archipelago makes it an attractive target for geothermal exploration and development. Of the discharging wells in operation, the liquid portion, are about 70-80% of the superheated geothermal fluid. Each 10-in. diameter borehole is able to produce 100-200 tons of fluid per hour. The amount of power which is available for direct heat uses is in the order of 9-19 MW per well. Up to now, only geothermal electricity production has been introduced. There are no direct application experiences on the islands.

Effluent water, from one of the existing power plants is 90°C (194°F) and flow of 8 L/s (127 gpm). The geothermal fluid is slightly aggressive and has a tendency to scale. The scaling problem is more characteristic at higher temperatures of the fluid (i.e., in the part used in the power production plant). The sustained heat potential of this energy source can be estimated for the temperature difference 90/25°C (194/77°F), which is technically feasible for many direct uses.

Since the islands are completely on the import of agricultural products from the continent and with the possibility to develop their own production based on the “free” geothermal energy, a demonstration project was proposed by INOVA- The Institute for Technological Innovation of Azores from Ponta Delgada in 1992. The proposal was accepted and financed by the EC Programme THERMIE of the DG-XVII and the Regional Government of Azores. It was completed in June 1997 and now measurements and investigations are being undertaken.

PROJECT COMPOSITION

The project consists of six (192 sq. m) + one (nursery of 96 sq. m) “family size” geothermally heated greenhouses for cultivation of the typically local crops, such as pineapple. Smooth Cayenne, Cape Gooseberry (*Physalis Peruviana* L) and melon, grown in different substrates of local origin (“bagacina,” pumice and a locally made compost) and have fully automatic control of the inside greenhouse climatic condition (Figure 1), such as:

- One of the greenhouses is for growing gooseberry in local substrates, bagacina and pumice (6);

- Two of the greenhouses are for growing pineapples in locally composed substrates (4 & 5);
- One of the greenhouses is for growing melon in local substrate (bagacina)(3);
- One nursery with “virus-” and “insect-free” conditions for rooting the stocks and young plants in preparation for planting (7);
- Mini micro-propagation laboratory for pineapple and Cape-Gooseberry crops;
- Cold store for plant stocks, young plants and post-harvesting treatment;
- Store rooms for raw materials and spare parts, geothermal distribution station; and
- Working area.

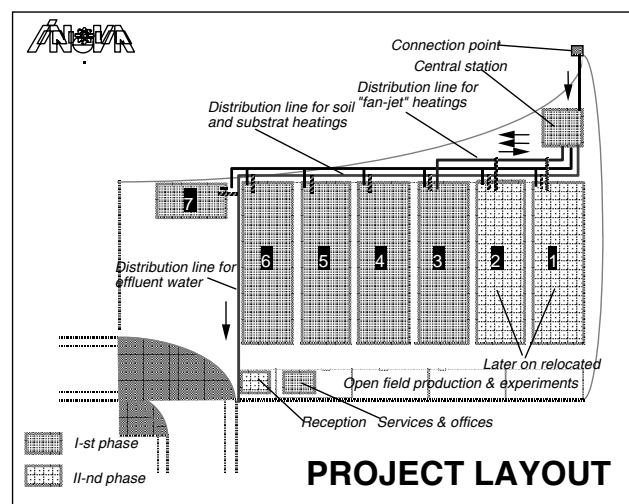


Figure 1. Planned project layout.

The second phase will consist of two additional greenhouses of 192 sq. m, for other cultures of interest for the Azorean agriculture development.

GREENHOUSES

The greenhouses are of rigid plastic covered construction of 8 x 24 m (26 x 79 ft), with foundations and design made of accommodated the local wind conditions. Both roof and side ventilation are provided (Figures 2 and 3) in order to provide strong ventilation of the greenhouses' interior, needed because of the small difference between the inside and outside air humidity.

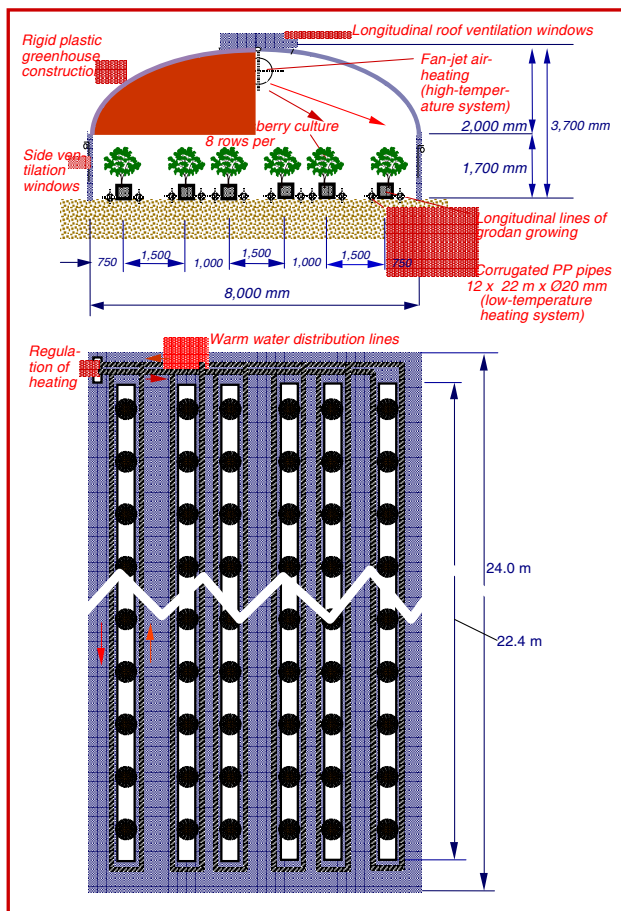


Figure 2. Greenhouse for growing of cape-gooseberry culture.

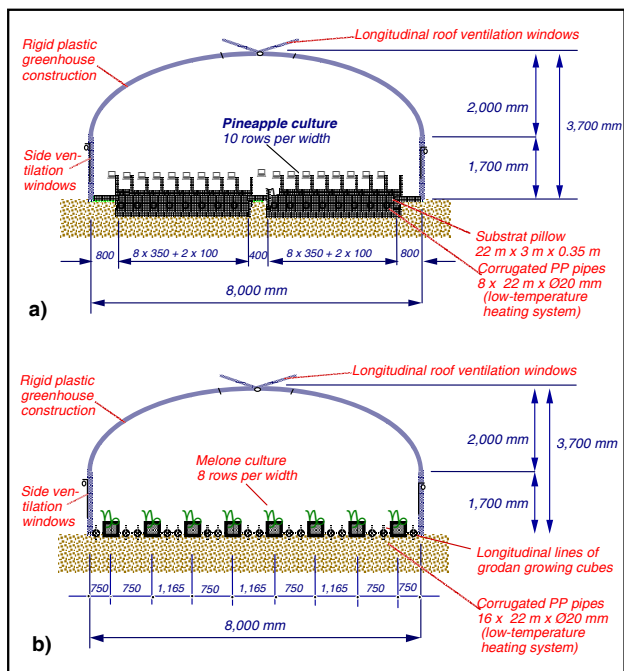


Figure 3. Greenhouses for pineapple and melon cultures.

PRODUCTION TECHNOLOGIES

As mentioned earlier, cultures are grown in local substrates or rockwool cubes (i.e., with so-called “soil-less” growing technologies [hydroponics]). That’s allows full control of the irrigation and fertilization of the plants. Distribution of the growing rows for different cultures is presented in Figures 2 (Cape-Gooseberry) and 3 (pineapples and melons). Each plant row is equipped with a drip irrigation line, which enable programmed irrigation of every piece of the plant separately. Composition of the fert-irrigation solution and irrigation of the plants is programmed and performed by means of a computerized fert-irrigation unit, placed in the central station of the project.

GEO THERMAL ENERGY RESOURCE

The effluent water of the power plant is pumped through a line made of concrete pipes which passes through the west part of the site. For peak heating (for the external design temperature conditions), about 3 L/s (48 gpm) of water is necessary for the project; however, the real flow is variable and depends on the combination of the external air temperature and intensity of solar radiation.

The regulation of the flow rate of the heating water is controlled by means of the central regulation station (Figure 4) and by local ones located in each one of the greenhouses (Figure 5). “Fan-jet” heaters are supplied directly (i.e., with water temperatures of 90°C (194°F), and the low-temperature heating systems with 35-40°C (95-104°F) by means of mixing the return (25-30°C)(77-86°F) with the fresh geothermal water (90°C)(194°F). Depending on the differences of internal temperature changes in each one of the greenhouses, an “on/off” temperature control provides for the programmed (different) internal temperatures (Figure 5). The low-temperature heating systems are set for so-called “base heating” (i.e., to work more or less continuously, with “fan-jet” heatings for “peak loadings” (i.e., below certain external air temperatures), when the first ones cannot cover the heat energy requirements of the greenhouses. In such a way, a better annual heating loading factor is reached (i.e., more or less equalized use of the available flow rate of the geothermal water). That opens the possibilities to introduce new energy users with different heat requirements and more intensive use of the available heat.

HEATING SYSTEMS

The heating systems are adjusted to the technological and temperature requirements of the cultures in greenhouses. For instance, pineapples requires stagnant air and control of the root temperature. Therefore, only the low-temperature substrate heating system is installed, made of corrugated plastic pipes 32 mm in diameter, located below the roots (Figure 3a).

The Cape-Gooseberry culture requires controlled temperatures of the air and roots, and prefers a slight vertical streaming of the warm air along the plants. Therefore, the so-called ““vegetative” heating system made of corrugated plastic pipes is installed along the plant rows. Taking into account

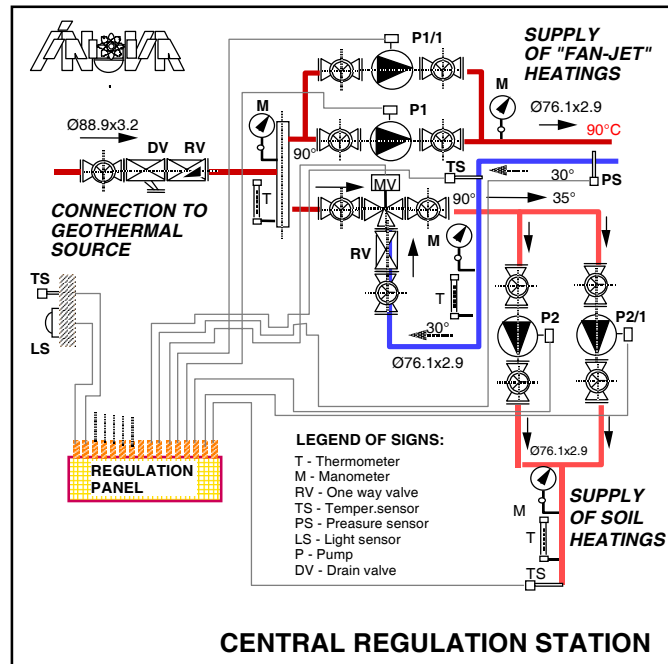


Figure 4. Central control station.

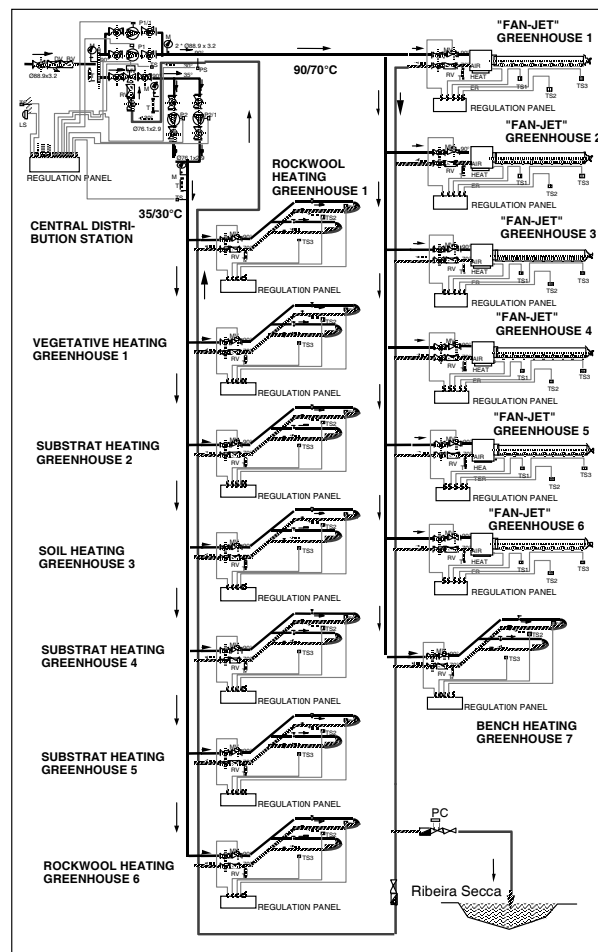


Figure 5. Geothermal water and control system.

that their heating requirements are larger than the ones which can be supplied by this system, an additional “fan-jet” air heating system is installed in order to cover the peak loadings, when external air temperature drops below minimum (Figure 2). Finally, the melon culture requires control of the soil and lower parts of the air temperature in the greenhouse. Therefore, again the “vegetative” heating system made of corrugated plastic pipes (32 mm) is installed (Figure 3b), positioned along the plant rows.

Total installed heat capacity of the systems is 52 kW (for the substrate, rockwool and bench heatings) + 120 kW (for the “fan-jet” heatings) = 172 kW.

BENEFITS OF THE USE OF GEOTHERMAL WATER

The main task of this demonstration project is to illustrate future benefits for producers of growing vegetables and fruits in the Azores. They can be summarized as follows:

- Protected crop cultivation enables control of the climate and other influencing factors for plant development. In that way, much higher productivity and quality of fruits can be obtained;
- Protect crop cultivation enables protection of the crops from external climate factors, such as the heavy rains, strong winds, etc., which are characteristic of the Azorean climate and makes it very inconvenient for growing of most of the vegetables and fruit cultures outside;
- Internal climate control also enable shortening of the normal growing period of the plants and “controlling” the time of harvest. Both provide much better economy of the production, the first one by lowering the costs of exploitation and the second one by “catching” the part of the year when the market offers the best prices for products; and
- the use of the “free” effluent water from the geothermal power plants by providing the heat requirements for protected crop cultivation allowing covering of the higher costs of production in comparison with the open-field production.

FIRST RESULTS

Taking into account that only the first set of measurements has been undertaken, it is too early to make any final conclusion about the confirmation of the initial suppositions. However, some initial indications show that a positive result can be expected, such as:

- Young plants develop much quicker than under the external climate conditions;

- Crop is much more uniform than the one grown in non-heated greenhouses and under the external climate conditions; and
- Crops look much more healthy than the ones grown in other conditions and with a better balance of the leaf mass.

The above listed results indicate that better productivity and higher yield can be expected than in the greenhouses without controlled internal climate conditions or with the open-field production. The real measure of the differences and their economic evaluation will be made during the next two growing seasons (1997/1998).

CONCLUSIONS

The agricultural geothermal project RIBEIRA Grande at Azores has been established in order to demonstrate possibilities for new family businesses in the Azores, based on the “free” geothermal energy, which up to now has not been used for direct heat application.

It is very much in accordance with the need to develop their own production of vegetables and fruits, which has up to now been totally imported from the continent because the local climate is not very convenient for open-field production (mild temperatures, but high humidity and strong winds).

The first results are very encouraging. A high production of high quality products can be expected, which can be competitive to the imported products--the latter which are rather expensive because of high transportation costs.

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PIPELINE

Progress and Development Update Geothermal Program Monitor

MEETINGS

Geothermal Resources Council 1998 Annual Meeting, San Diego, CA, September 20-23, 1998

Theme: "Geothermal: The Clean and Green Energy Choice for the World." The meeting will be held from September 20-23 at the Town & Country Hotel in San Diego, California. Distinguished keynote speakers during the meeting's opening session will highlight the role that geothermal can play in the world energy mix, with a focus on global warming, the advantages of geothermal energy over fossil fuels for power generation, and the future of geothermal development.

Special sessions will be held on Sustainability of Geothermal Resources, Pacific Rim, Mexico and Latin America, Direct Heat Utilization, Drilling, Well Completion and Logging, Geology and Geochemistry, Geothermal Exploration, Production Technology, Reservoir Engineering, Environmental Issues, and Geothermal Heat Pumps. Two short courses will be held prior to the meeting: on September 17th and 18th a course on Geothermal Drilling, A New Mindset, and on September 19th a course on Borehole Imaging. Two pre-meeting field trips will be taken to the Cerro Prieto Geothermal Field in Mexico and the Coso Geothermal Field in eastern California, and a post meeting field trip to the Imperial Valley Geothermal Field and Mineral Recovery Site. The Geothermal Energy Association will holds a trade show.

Further information and registration material can be obtained from the Geothermal Resources Council, PO Box 1350, Davis, CA 95617-1350, phone: 530-758-2360, email: grc@geothermal.org.

20th Geothermal Workshop, Auckland, New Zealand, November 11-13, 1998

The Geothermal Institute and the New Zealand Geothermal Association will host the 20th NZ Geothermal Workshop at the University of Auckland on 11, 12 and 13 November, 1998. The meeting will be a forum to exchange information on all aspects of the exploration, development and use of geothermal resources worldwide. Intending authors should submit a title to the convenors by 15 June 1998. All accepted papers will be published in the Proceedings of the Workshop which are widely distributed.

The Workshop is open to papers on all aspects of geothermal technology including, Exploration, Field Development, Utilization, Applications and Case Studies.

Intending authors can submit their title to the convenors by e-mail: geo.wshop@auckland.ac.nz. Further information can be obtained by email: <http://www.auckland.ac.nz/gei/>, or by writing

Mike Dunstall, co-convenor
Geothermal Institute
The University of Auckland
Private Bag 92019,
Auckland, New Zealand

New Zealand Geothermal Association 98 Direct Use Seminar, July 2-3, 1998

A direct utilization seminar will be held in Rotorua, New Zealand from July 2nd to 3rd. The purpose of this two-day seminar will be to identify the low grade geothermal resources of the country and present potential use opportunities for such resources and outline examples of successful economic developments, both in New Zealand and overseas. Field visits will be arranged for delegates to visit geothermal direct use applications such as greenhouses, crop drying, timber drying, and aquaculture facilities in and around Taupo and Rotorua following the seminar. If interested in attending the Seminar, or would like more information please contact the NZGA Secretariat at:

c/o IGNS
Private Bag 2000
Taupo, New Zealand
Phone: 07-374-8211

or by email to Ian Thain, the conference organizer:
i.a.thain@xtra.co.nz

International Geothermal Days, Azores 1998 - September 13-20

The International Summer School has scheduled three workshops at Ponta Delgada, Azores (Portugal). The first is an International Workshop on Heating Greenhouses with Geothermal Energy on September 14th covering: 1) Technical, Technological and Economic Feasibility of Geothermally-Heated Greenhouses in Europe and the World; 2) State of the Art in EC, Mediterranean and Central/East European Countries; 3) EC "Thermie" Project Ribeira Grande (see article in this issue of the Bulletin), and 4) Problems and Activities for Development of Geothermal Energy Application for Heating Greenhouses.

The second is an International Seminar of Electricity Production from Geothermal Energy on the 15th, and the last is an International Course on Economy of Integrated Geothermal Projects from the 16th through the 18th covering: 1) Nature and Distribution of Geothermal Energy in the World; 2) Technology of Integrated Geothermal Projects; 3) Economy of Integrated Geothermal Projects, and 4) General Problems Related to Development of Integrated Geothermal Projects.

The program is being organized locally by the Institute of Innovative Technologies of Azores (INOVA). A field trip is scheduled after the workshop on Saturday the 19th. Further information can be obtained from John Lund at the Geo-Heat Center, Professor Dr. Kiril Popovski in Skopje, Macedonia (Tel/Fax: 389-91-119-686), or Professor Dr. Jorge Rosa de Medeiros in Ponta Delgada, Azores (Fax: 351-96-65 33 24 or email: Inova@mail.telepac-pt). Registration can be made to:

International Summer School on
Direct Application of Geothermal Energy
ul. Dame Gruev br. I-III/16
91000 Skopje, Macedonia.

GENERAL

The Promise of the U.S. Geothermal Industry

The U.S. geothermal industry is composed of more than 50 mostly small companies headquartered in various states, including California, Colorado, Florida, Hawaii, Maryland, Nebraska, Nevada, New Jersey, New York, Oregon, Texas, and Utah. Direct employment is about 10,000 people in the U.S., and our indirect effect is a minimum of 20,000 additional jobs. Our operation generating capacity in the U.S. is about 2,280 megawatt, producing 14-17 billion kilowatt-hours/year in four states—California, Hawaii, Nevada, and Utah. States having excellent potential for near-term development of geothermal power include Alaska, Arizona, Idaho, Oregon, New Mexico, and Washington.

Geothermal energy is the third largest grid-connected renewable electricity source, after hydropower and biomass. We generate 17 times more electricity than solar energy and 7 times more than wind energy. The power we produce 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 per year compared with the production of the same amount of electricity from the average U.S. coal-fired plant (coal data from DOE/EIA-0348(90)). Geothermal plants in the U.S. and throughout the world continue to function normally, proving the reliability of geothermal power (Dr. P. Michael Wright, *Geothermal Energy News*, GEA, Vol. 1, No. 3, April 1998).

ARKANSAS

Geothermal Heat Pump Community Planned at Harrison

The first exclusively GeoExchange planned community and golf course in the United States will be built this year in the Ozark Mountains north of Harrison, Arkansas. The GeoExchange system will use lake water as the geothermal source for providing heating and air conditioning, and will also irrigate the golf course and serve as a supply for the fire protection system.

One of the more valuable amenities is the GeoExchange system, featuring energy efficient heating and cooling at a low cost. According to the Environmental Protection Agency, GeoExchange heating and cooling systems are the most energy efficient, environmentally clean and cost

effective space conditioning systems available. "We hope the Bear Creek Springs Community will serve as a model for other planned communities across the United States," Paul Lipe, Geothermal Heat Pump Consortium Executive Director, said.

Approximately 950 "Smart House" home-sites of varied form and dimension, in a setting featuring lakes and streams, stony ridges and lush meadows, should appeal to a broad range of residents, according to Robert Rasking, President of the Tusla, Oklahoma.-based Autumn Oaks Communities, Inc.

In addition to Autumn Oaks Communities, Inc., participants in this project include GeoExchange, based in Washington, DC; K & M Shillingford, a strategic alliance partner providing the residential geothermal units (*Business Wire* - March 31, 1998).

CALIFORNIA

The Draft Environmental Impact Statement and Environmental Impact Report (Draft EIS/EIR) prepared for the proposed Telephone Flat Geothermal Development Project (California State Clearinghouse Number 97052078) is available (being proposed by CalEnergy Company of Omaha, Nebraska). The purpose of this document is to identify potential environmental impacts that would result from the proposed construction, operation, and decommissioning of a 48 megawatt (gross) geothermal power plant with associated production and injection wells, well pads, pipelines, transmission line, and access road. The proposed power plant and well field would be located on portions of six federal geothermal leases in the Glass Mountain Known Geothermal Resource Area (KGRA) within the Modoc National Forest in Siskiyou County, California.

The Telephone Flat Project is the second of two proposed geothermal power plant projects in the Medicine Lake Highlands just south of the Oregon-California border near Klamath Falls. The first project is the proposed Fourmile Hill Geothermal Project. Pending approval of the Fourmile Hill Project (being proposed by Calpine Corporation of San Jose, California) and timely construction of its transmission line within one of six alternative utility corridors selected by the lead agencies, an interconnecting transmission line from the Telephone Flat Project power plant site to the utility corridor is proposed to be constructed.

Four open-house public meetings have been scheduled to receive comments on the Draft EIS/EIR at the following places (all from 4:00 to 8:00 PM):

Monday, July 6, 1998	Home Economics Bldg. Tulelake Fairgrounds Tulelake, CA
Tuesday, July 7	Main Lodge Mt. Shasta Park Mt. Shasta, CA
Wednesday, July 8	Miners Inn Convention Ctr 122 East Miner St. Yreka, CA

The public comment period on the Draft EIS/EIR closes on July 22, 1998. Written comments on the Drafts EIS/EIR should be addressed to:

Mr. Randall M. Sharp
USFS/BLM Project Leader
Telephone Flat Geothermal Project
800 West 12th Street
Alturas, CA 96101
Phone: 530-233-8848

HAWAII

Hawaii's River of Molten Rock Inflicts \$61 Million in Damages

Rivers of molten rock have consumed the community of Kalapana on the Big Island, destroying 181 homes, a church and a community center. The total \$61 million in damage also includes destruction of a visitor center and maintenance shop at Hawaii Volcanoes national Park.

When Kilauea erupted January 3, 1983, on the island of Hawaii, scientists at the U.S. Geological Survey's Hawaiian Volcano Observatory believed it would be short-lived, much like a pair of one-day displays the year before. Since then, however, lava of various depths has covered 39 square miles, and as if flows seven miles downhill into the sea, it has created 570 acres of new coastal land. It's estimated at 2.1 billion cubic yards of lava, enough to cover New Jersey a foot deep.

The lava has covered 16,000 acres of rare rain forest and lowland forest, and entombed thousands of ancient Hawaiian archaeological sites. One of the most significant archaeological losses was the 700-year-old Waha'ula heiau, or Hawaiian temple, which was overrun last August. Hawaiian tradition says the stone platform and walls were built by the priest Pa'ao, who came to Hawaii from islands to the south in the 1200s. There is no indication when this eruption will stop.

Don Swanson, scientist in charge of the observatory atop the volcano, points to a sign on an office wall bearing a quotation from economist John Kenneth Gallbraith: "I predict, not because I know, but because I'm asked." "There is nothing to preclude this eruption going on for another 15 years," Swanson said. "We don't see any reason to think that it's winding down." Kilauea attracts 1.5 million tourists each year, even though the spectacular fountains of lava that highlighted the early years of the eruption have subsided (AP - *Herald and News*, Klamath Falls, OR - January 22, 1998).

MICHIGAN

McDonald's Goes Underground: Fast-Food Chain Tries Geothermal (Heat Pumps)

In the metro-Detroit area, a new McDonald's store is digging in, looking for more energy-efficient, cost-saving heating and cooling. If the geothermal approach proves

successful, it could go nationwide. The utility, Detroit Edison, got S. E. Michigan "Mickey Dee" to sign a 10-year energy supplier agreement.

A McDonald's outlet being built in Westland, a suburb of Detroit, is taking on earthy airs by installing a geothermal system to provide air conditioning and heating. As the chain's first store to use geothermal comfort conditioning, as well as other energy-efficient measures, McDonald's bean counters will be taking a close look at the numbers to decide on whether to roll out or not.

Energy savings are expected to be in the range of 20 to 40% over McDonald's conventional hvac system. Payback, therefore, may be several years. But McDonald's is taking a long-term perspective.

Three WaterFurnace 11-ton rooftop geothermal units are being installed. The rooftop units in this application match the exact footprint of McDonald's standard rooftop units, to replace those models. Size of the restaurant is 1,511 sq. ft with a 1,200-sq. ft play place. Usually a McDonald's needs 37.5 to 40 tons of heating/cooling. In this case, because of the energy-efficiency improvements, 33 tons are required.

SH&G Associates of Detroit, an architect-engineering firm, is the designer of the system. Modeling and analysis was done to size the system. A thermal conductivity test was conducted on the soil, and the firm also looked at the geology. "We started hitting some really hard rock at 200 feet," remarked Kohlert. "So that's why we only planned to go to 200 feet instead of 300 feet for the geothermal "wells" (or loops). LoopMaster International, Indianapolis, drilled the "wells," 32 in all, 196 ft deep and 5 inches in diameter. Pipe used was 1-1/4 inch. A U-bend was connected to two 1-1/4-in. pipes; these U-bend coils were placed in each "well." Water is then circulated through this closed system.

The Electric Power Research Institute (EPRI) provided some funds for the project and also provided technical consulting. EPRI may also conduct the study of energy consumption data to be collected at the new McDonald's and a standard restaurant. When the study of the geothermal system is completed, McDonald's will evaluate the energy savings, environmental benefits, and marketing impact (incremental sales increase), to decide if this approach will be used in other states (Greg Mazurkiewicz - *Air Conditioning, Heating & Refrigeration News* - December 15, 1997).

NEBRASKA

Going Underground (Finally)

Although ground-coupled heat pump systems are an established hvac technology, it has been only within the last few years that schools have emerged as a viable application section in Nebraska. Safety was the initial concern—but no more. In the fall of 1995, the four schools (each 69,000 sq. ft) in the Lincoln (NE) School District, Campbell Cavett, Maxey and Roper, each opened their doors to more than 500 students in grades K through six. The school openings marked the completion of a joint project involving Lincoln Public Schools

and the municipal power utility, Lincoln Electric System (LES), to implement vertical-loop, geothermal heat pump systems in each school.

Ground-coupled heat pump (GCHP) technology, a category of ground-source heat pump technology, originally was chosen following a life-cycle cost analysis on five candidate hvac technologies performed by Alvine and Associates, an Omaha-based engineering design firm responsible for designing the hvac system to be used in each school. The analysis projected that GCHP technology would work most efficiently to meet the schools' heating/cooling needs.

In fact, the GCHP systems were expected to save the school district at least \$128,000 a year, and Lincoln School District taxpayers nearly \$3.8 million, over the next 20 years. After a year in operation, annual peak load for the new schools using the GCHP systems was determined to be roughly half of what was projected for the hvac system originally proposed before LES and the Lincoln School District decided to evaluate their options.

In addition, comparative energy analysis data compiled by LES staff after a year illustrated that the geothermal schools were achieving superior results over Lincoln elementary schools with other types of hvac systems in terms of total energy costs and total energy consumption. Data collected at several schools through the 1996-97 school year showed a significant advantage for the GCHP schools. In fact, the results actually exceed the savings projected through the initial studies and economic evaluations. The GCHP schools achieved total energy cost savings of 57% when compared to the hvac schools, along with a 40% reduction in electrical demand and a 20% reduction in electrical energy consumption.

The GCHP system designed for each school includes more than 50 water-source GCHPs, virtually one for each room in the school. The systems used either Trane Company or WaterFurnace International heat pumps, located for easier serviceability above the hallways outside the classrooms and other school rooms. The pumps are connected via a ground heat exchanger to 120 loops of thermally fused 1-in., high-density polyethylene tubing. The loops are buried in an open field, bored vertically about 240 feet into the ground, and configured in 12 rows of 10 loops and in three groups of 40 loops.

In each system, a heat transfer fluid solution consisting of 22% Dowfrost® propylene glycol-based fluid (from the Dow Chemical Co., Midland, MI) and 78% deionized water (supplied by Barton Solvents, Council Bluff, IA) is constantly circulated through the underground loops into a variable-speed pump, which then circulates the fluid through the ground heat exchanger to circulator pumps located inside each school. From there, the Dowfrost solution is circulated to the individual water-to-air heat pumps servicing each school room. Total system capacity for each school is 10,000 gallons, according to Loop Tech International, Hunstville, TX, which performed each loop field installation (Ronald S. Feuerbach, P.E. and Doug Bantom, P.E. - *Engineered Systems* - April 1998).

OREGON

"Green" Power for Sale in Oregon

For the first time, some Oregon consumers can choose to buy power in shades of green. Electric Lite, a South Carolina-based power company, is offering the Northwest's first "green" power sales, energy the company says is produced with less environmental damage. The plan guarantees that power generated on consumer's behalf comes largely from renewable sources. The power costs more, but Electric Lite officials say demand has grown for green option since customers in four Oregon cities got the chance to choose their power company. In a test program, Portland General Electric Co., has allowed 50,000 customers in Sandy, St. Helens, Hillsboro and Oregon City to choose another power company.

Electric Lite's green power option guarantees that no more than 15 percent of the power comes from coal-fired or nuclear plants. On average, as much as 40 percent of the Northwest's power can come from coal or nuclear plants. They also guarantee that at least 50 percent will come from renewables, or what the company is calling clean, sources. Electric Lite says much of its green power will initially come from geothermal plants. The geothermal power will come from plants in northern California. The plan will cost the average household \$69 a month, compared with the \$59 standard plant. The average PGE residential bill is about \$62.

Oregon lacks a formal definition of green power; but, environmental groups that have reviewed Electric Lite's proposal liked the plan. "I believe they've met the test," said Pete West, senior policy associate with Renewable Northwest Project. "We've had trouble defining what green power means; but, I think what they are offering will help create more of the right thing."

Consumers don't actually have green power diverted directly to their homes. Instead, Electric Lite is agreeing to buy more of its energy from renewable sources to supplement the energy now sold to its customers. Customers who sign up for the plan are paying a little more to support those efforts (Brent Walth - *The Oregonian* - February 12, 1998).

SOUTH DAKOTA

Natural Heating - Thousands of West River Residents Go Geothermal

Guest at Stroppel Hotel in Midland soak in it, children at Evans Plunge in Hot Springs splash in it, and tropical fish at a hatchery in Philip thrive in it. But for thousands of West River residents, the naturally hot waters from the underground Madison limestone formation heats their homes, schools and businesses. Steve Wegman of the South Dakota Public Utilities Commission estimated that there are about 10,000 deep wells in western South Dakota and about 5,000 users of geothermal heat from the Madison.

In a recent report on geothermal heating in South Dakota, John Lund of the Oregon Institute of Technology estimated that the vast Madison formation contains about 179 cubic miles of recoverable water with temperatures ranging from 86° to 216°F.

Editors note: this article and one on “Fish Thrive on Madison’s Warm Waters” along with several photographs and a map, were front-page news in the *Rapid City Journal* - January 4, 1998 - written by Dan Daly - Journal Staff Writer. These articles were based on the GHC Quarterly Bulletin, Vol. 18, No. 4 (December 1997) devoted to geothermal energy use in South Dakota. Geo-Heat Center staff assisted with background material for this article.

WASHINGTON

Callahan Hot Springs Rezone Approved by Commissioners

The Skamania County Board of Commissioners approved an application Monday for a rezone on Berge Road in Home Valley for a hot springs resort. Former county commissioner Ed Callahan applied for the rezone. He is a partner with a Japanese developer, Shikosa Management, which owns several parcels in the Home Valley area. The hot springs project is in the Home Valley urban area and includes a hot springs bathhouse, thermal pools, offices and a parking lot. Among the conditions placed on the development are a 50-ft undisturbed buffer to be maintained between the development and all springs and streams, as well as storm water retention measures (*Skamania County Pioneer* - February 11, 1998).

WYOMING

Suit Accuses Park Service of Illegally Selling Resources

The National Park Service on Thursday was accused in a lawsuit of illegally selling federal resources in secret contracts with biotech researchers who want to patent microbes from Yellowstone’s hot springs. “The Park Service cut a back-room deal and bent laws to allow the commercial

exploitation of Yellowstone,” said Joseph Mendelson, a lawyer for one of the plaintiffs, the International Center for Technology Assessment, a public interest group. The plaintiffs argue that U.S. law prohibits any natural resources—from mineral to pine cones—from being removed from national parks. The contract could be worth millions of dollars to Diversa Corp. of San Diego. The Park Service has refused to disclose what kind of royalties the federal government would receive as a result of the so-called bioprospecting for patents on the tiny organisms in the rare thermal pools (*The Oregonian* - March 6, 1998).

JAPAN

Creative Ideas on Melting Snow on Road Surfaces

A round-table discussion between Teruyuki Fukuhara, Professor at Fukui University, Jiro Sugawara, Deputy Manager, Koriyama Road Work Office, Tohoku regional Construction Bureau, Ministry of Construction, and Shigenobu Miyamoto, Senior Researcher, Fukui Prefecture Technology Research Institute on Snowfall and Construction, is reported in “New Energy Plaza,” Vol. 13, No. 2, 1997, *New Energy Foundation*. A “Sprinkler-Free Sidewalks and Roadway Sprinkler” system is used where groundwater at 15°C flows through heat exchanger ducts buried in the sidewalk and water that dropped to 7°C after melting snow on the sidewalk is sprinkled on the roadway. Heat piles (pipes?) are also used for melting snow on bridges. Water is sent through polyethylene ducts through foundation piles. Water warmed by the surrounding soil at 12°C flows slowly in the piles and is sent to the heat exchanger duct buried under the pavement for snow-melting. The cost for bridge decks is 400,000 yen per square meter (about \$300 per square foot).