GEOTHERMAL DIRECT-HEAT UTILIZATION ASSISTANCE

Paul J. Lienau
Geo-Heat Center
Oregon Institute of Technology (OIT)

KEY WORDS

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PROJECT BACKGROUND AND STATUS

The Geo-Heat Center, established in 1975 at Oregon Institute of Technology, conducts research, provides technical assistance and distributes general information on a wide range of applications in the area of geothermal energy. This program, the only one of its kind in the nation, provides rapid response, unbiased information to designers, developers and owners of systems ranging from geothermal heat pumps, through direct use to small power generation projects.

Research and development tasks are conceived carefully to address current industry needs in the areas of cost containment, equipment performance/application and system design. Recent work has identified installation cost savings of as much as 39% in piping for district heating and 75% in commercial geothermal heat pumps.

The technical assistance program, designed to augment, not compete, with private engineering firms and developers, offers technical support for system design, equipment selection and trouble shooting for geothermal systems. This program places the unique technical expertise of the Center's staff at the disposal of designers around the country.

A major obstacle to wider use of geothermal is lack of awareness. The Center's outreach program addresses this issue with a variety of information sources. Through the publication of an industry quarterly Bulletin (2,400 subscribers), handbooks, software, Internet webpage (http://www.oit.edu/~geoheat) and a dedicated geothermal technical library (5,500 volumes) a broad spectrum of information is available to the public. Beyond this, staff activity in and publications for industry and professional groups greatly enhances technology transfer efforts.

The U.S. geothermal resource base is currently the largest of all renewables and, in fact exceeds that of the combined capacity of solar, wind and tidal power. Though growing rapidly, the use of this immense resource remains distressingly small. Continued, aggressive and cost effective support of geothermal is the key to unlocking its potential.

PROJECT OBJECTIVES

The objectives of this project are to conduct direct-heat applied research and development, and to provide assistance to stimulate utilization of the nation's large low-to moderate-temperature (<90° to 150°C) geothermal resource base.

Technical Objectives

- To provide technical assistance to developers of geothermal direct use projects for space heating, geothermal heat pumps, greenhouses, aquaculture and industrial applications;
- To perform appropriate R&D to reduce the cost of installing and operating direct use projects;
- To publish information and educational materials, maintain a homepage and library to aid researchers and developers of geothermal direct use projects.

The success of this project will mean more rapid penetration of geothermal direct use into the energy sector.

Expected Outcomes

- Energy savings and reduced emissions of airborne pollutants and greenhouse gases due to more geothermal direct-heat projects on-line. For example, a 457 m, 82°C geothermal well producing 3 MWt (500 gpm) saves 28 TJ/yr of energy and reduces SO_2 by 0.1 kg, NOx by 0.6 kg and CO_2 by 687 kg per year compared to a natural gas boiler plant.
- Geothermal energy used for district heating in existing single-family homes, implemented in areas of propane, electric or fuel oil (or combinations of these with wood) resulting in a savings of about 30% per year.
- Reduced costs for geothermal greenhouse operators wishing to continue using tube type heating systems and where additional geothermal flow is not available (conventional fuel peaking offers the opportunity to reduce costs by 75% relative to conventional heating).
- Increased awareness of geothermal direct-heat developments and opportunities through Bulletins on geothermal projects, handbooks, geothermal homepage, technical papers, software, tours, and other educational materials.

APPROACH

The Geo-Heat Center's approach is to provide technical assistance (TA) to prospective geothermal users on resource data, preliminary engineering design, analysis of operational problems and technical information. The program is designed to introduce the potential user and engineering consultant to geothermal direct-heat applications. The presence of a proven and reliable source of technical advice to the consultant is critical in promoting their initial involvement with an unfamiliar resource. The Oregon Institute of Technology provides a cost share of 10% on the project. Further, the Geo-Heat Center publishes educational materials to aid engineers in the design of direct use projects.

RESEARCH RESULTS

Technical Assistance Program

The Geo-Heat Center provides assistance to those actively involved in geothermal development. Geothermal projects are allocated a limited number of man-hours (usually eight hours/project unless prior approval for additional hours are received from DOE) for analysis. Engineering and economic assistance has been provided to a broad range of clients, from the homeowner interested in geothermal space heating and municipalities engaged in geothermal district heating projects, to industrial concerns adapting geothermal resources to meet the process energy needs. During FY-96, the program handled 500 requests for technical and development assistance on geothermal direct use projects and for various types of technical information.

The program's R&D accomplishments included: (1) Geothermal District Heating in Single-Family Residential Areas, and (2) Fossil Fuel Peaking for Geothermal Heated Greenhouses, which are summarized below.

Geothermal District Heating in Single-Family Residential Areas

In the past, district heating (geothermal or conventionally fueled) has not been widely applied to the single-family residential sector. Low-heat load density is the commonly cited reason for this. Although it's true that load density in these areas is much lower than for downtown business districts, other frequently overlooked factors may compensate for load density. In particular, costs for distribution system installation can be substantially lower in some residential areas due to a variety of factors. This reduced development cost may partially compensate for the reduced revenue resulting from low-load density.

This report examined cost associated with the overall design of the system (direct or indirect system design), distribution piping installation, and customer branch lines. It concludes with a comparison of the costs for system development and the revenue from an example residential area.

Distribution system installation costs were reviewed based on the use of double line (supply and return), preinsulated ductile iron piping. This material is currently the most widely used product for new distribution projects. Actual construction cost data were used along with cost calculations to desegregate gross costs ($/m) into 11 individual areas for lines in the 76 mm to 305 mm range. Among the savings identified were:

- Installation in unpaved areas can reduce costs 12% (305 mm) to 22% (76 mm),
- Uninsulated return lines use can reduce costs 9% (76 mm) based on the use of fiberglass in place of the preinsulated ductile iron,
- Elimination of active (flaggers) traffic control can reduce costs approximately 4% over the range of 76 mm to 305 mm lines, and
- Installation in areas unencumbered by existing buried utilities can reduce costs approximately 4%.

Figure 1 presents cost data for 76mm, 152 mm and 305 mm line sizes in graphical form. The base case costs are those identified in this study as being reflective of installation in downtown paved areas. The low case costs are those assuming that all of the above cost savings could be employed in a residential setting. The substantial reduction in the smaller sizes is especially beneficial for single-family residential areas since a majority of the distribution system would be in the 76 and 100 mm size.

The location of heat exchangers between the geothermal fluid and the treated heating loop has an influence on system total cost. There are two general approaches: an indirect system in which central heat exchangers are used and only treated water is delivered to the customer, and the direct system in which geothermal fluid is delivered to the customer and individual heat exchangers are located at each user. Use of the central heat exchanger approach (indirect system) allows the elimination of additional equipment from the individual user residence. Due to the economy of scale, there is a point at which the cost of the central equipment is less than the sum of the costs for individual equipment at each user. Based on the assumptions used in this report, the central approach results in lower costs above system capacities of approximately 878 kWt (approximately 40 homes at 22 kW_t each).

Customer branch lines between the curb and the residence wall amount to a substantial expense to the homeowner when installed on a retrofit basis. Three types of piping for these branch lines were evaluated in this report: preinsulated copper ($92/m), field-insulated copper ($75/m) and preinsulated flexible polyethylene (PEX) at $102/m for installed supply and return of 25 mm pipe size. At an average length of 18 m per home, the cost of the branch lines would amount to approximately $1400 per home using field-insulated copper.

In order to evaluate the overall feasibility of geothermal district heating, an actual residential area of Klamath Falls, Oregon, was used for analysis. This area is representative of many small-to-moderate sized western towns where collocated resources have been found. An area of 16 blocks including 256 homes was selected. Costs were calculated for a complete system (construction costs only) including production wells, central plant, and distribution system. A range of costs for both the distribution system and the resource development was used. Resource development costs ranged from a single 152 m production well without injection to a system with a two 610 m production wells and one 610 m injection well. Distribution costs used the current base case costs (downtown/paved) and low case costs (residential/unpaved). Table 1 summarizes this data.

Table 1. Expected Cost Range for 256 Homes GDH System

	Low	High
Resource	$140,000	$540,000
Central Plant	225,000	225,000
Distribution	555,000	803,000
Total	$920,000	$1,568,000

Based on financing at 8% and a 75% customer connection rate, a revenue of between $452 and $771 per year per customer would be required to cover the system capital cost. Existing conventional space and domestic hot water heating costs in this area (6500 heating degree days, 102 m^2 average home size, primarily pre-1960 construction) ranges from a low of $440 per year (all natural gas) to $1050 per year (all electric).

This example suggests that for systems implemented with low-to-moderate cost resource and distribution costs, serving areas of propane, electric or fuel oil (or combinations of these with wood), that geothermal district heating can be possible.

Fossil Fuel Peaking for Geothermal Heated Greenhouses

In working with greenhouse operators over the years, the issue of combination geothermal/fossil fuel heating systems has been raised from time to time. Most often, it has been in conjunction with growers who use plastic tube type heating systems. In these systems, hot water is circulated through tubes (16 mm diameter) suspended beside the plants or under the benches. Tube systems are favored by many growers, particularly cut flower and bedding plant operators. The system offers many advantages including: lack of fans for air circulation, low capital cost and simple installation. Its major draw back is the requirement for relatively high water temperature, especially in colder climates. At lower water temperatures, the quantity of tubing required to meet 100% of the peak heating load can be impractical to install.

The quantity of fossil fuel consumed by the system is influenced by the type of equipment used to supply the peak heating duty. Two approaches are available: a central boiler located in series with and downstream of the geothermal heat exchanger or individual unit heaters located about the greenhouse. Although for larger applications, the boiler design offers lower capital costs, the unit heater approach has important operational advantages regardless of system size. With this design, the geothermal heating system continues to provide its full capacity during peaking operation. The unit heaters operate only when the load on the greenhouse exceeds the capacity of the geothermal system. The unit heaters are sized for the difference between the capacity of the geothermal system and the peak requirement of the greenhouse.

The boiler approach compromises the geothermal system capacity during peaking. To supply the required heat to the greenhouse, the boiler gradually raises the supply water temperature to the tubes as the outside air temperature drops. This results in a rising return water temperature to the geothermal heat exchanger which reduces its capacity. In most applications this results in zero capacity for the geothermal heat exchanger at the design condition. Consequently, the peaking boiler must be sized not for 60% but for 100% of the design load. This results in higher capital cost and fuel consumption.

Figure 2, presents the percentage of annual energy displaced by the baseload (geothermal) heating systems sized for 50% to 90% of the peak heating load. This plot is based on the use of unit heaters for peaking purposes in a 1 acre fiberglass/double plastic house. It is apparent that in all cases for base load systems sized for 60% or more of the peak load, 88% to 90% of annual heating energy can be displaced. Actual performance is determined by climate, temperature set points and structure heat loss.

Table 2 illustrates the overall economics for an example case. The results are based on a grower expanding his operation with a 1 acre house (fiberglass/double plastic). Effluent (@60°C) from an existing 1 acre is used to supply a tube heating system in the new construction identical to the one in the existing house. This results in a capacity of 60% of the peak load for the geothermal system in the addition. Additional flow from the geothermal supply is not available and it is not possible to install sufficient tubing to provide 100% of the peak load.

Table 2. Conventional Fuel Peaking Example - one acre greenhouse.

System	Capital Cost $/ft^2	Owning Cost $/ft^2-yr	Elec. & Maint. $/ft^2-yr	Fuel $/ft^2-yr	Total Cost $/ft^2-yr
60°C Tube/Propane	3.52	0.41	0.05	0.15	0.64
60°C Tube	3.31	0.39	0.02	0	0.43
All Propane	1.76	0.21	0.05	1.65	1.91
82° Tube	2.32	0.27	0.01	0	0.28

For comparison four different systems appear in the table: a combination 60°C tube (60%)/propane heater (40%) system, a 60°C tube (100% of peak) system, a 100% propane system and a 82°C tube (100%) system. Capital cost (in $/ft^2) appears in the 2nd column. Assuming financing at 15 years and 8%, the annual cost of ownership (in $/ft^2) appears in the 3rd column. Costs for equipment maintenance and electrical consumption are shown in column 4. Fuel costs (based on $1.00/ gal and 70% efficiency) appear in column 5. Total cost per square foot of greenhouse per year are shown in column 6.

The two geothermal systems (60°C tube and 82°C tube) are shown for comparison purposes since neither could be installed in the addition. Not surprisingly, the propane system is the most expensive in terms of annual operating cost. The combination system is quite competitive with the 60°C tube system, in terms of capital cost, since conventional heating costs constitute approximately 20% of the total operating costs of a greenhouse. An additional benefit not quantified in the above costs is the availability of the peaking system as emergency backup in the event of geothermal system failure. This would be a distinct advantage to growers operating on a single production well.

It is clear that the economics of conventional fuel peaking are unlikely to result in its use when other geothermal options are available. For situations where the grower wishes to continue using a tube type heating system and additional geothermal flow is not available, this option offers the opportunity to reduce costs by 75% relative to conventional heating.

PLANS

The Geo-Heat Center will continue to act as a clearinghouse to provide project technical assistance and information on geothermal direct use projects.

The Geothermal Direct Use Engineering and Design Guidebook will be revised and updated for 11 Chapters and printed.

R&D activities for FY-97 will include: (1) Comprehensive Greenhouse Developer Package and (2) Pumping Energy Evaluation for Groundwater Heat Pump Systems.

The Bulletin will be distributed quarterly, the homepage will be maintained, new software will be developed that will enhance the ability of design engineers on geothermal direct use projects, and information about geothermal projects and other related developments will be gathered and distributed.

INDUSTRY INTEREST AND TECHNOLOGY TRANSFER

The following is the number of requests for geothermal direct heat technical assistance during Fiscal Year 1996 from individuals, companies and municipalities:

Type of Interest	Number of Requests
Geothermal Heat Pumps	141
Space and District Heating	54
Greenhouses	19
Aquaculture	28
Industrial	8
Resource/well	84
Equipment	60
Other	106
Total	**500**

Technology transfer activities included: publication of the GHC Quarterly Bulletin (v.17, n.1-4), which includes technical articles and a geothermal progress section. Development of a geothermal homepage (www.oit.edu/~geoheat), its main headings include: What is Geothermal, Services Offered, Publication List, Bulletin, Where are the Geothermal Direct Use Project Sites (an interactive map), Where are Geothermal Resources, Directory of Consultants and Equipment Manufacturers, Funding/Disclaimer and Other Places of Interest. A Geothermal Library of over 5,500 volumes was maintained and can be accessed through the Internet on the GRC homepage. A total of 1,569 publications were requested during the fiscal year, 21 technical papers were prepared and presented, 10 groups were given tours of local geothermal facilities, and 12 geothermal progress monitor reports were prepared.

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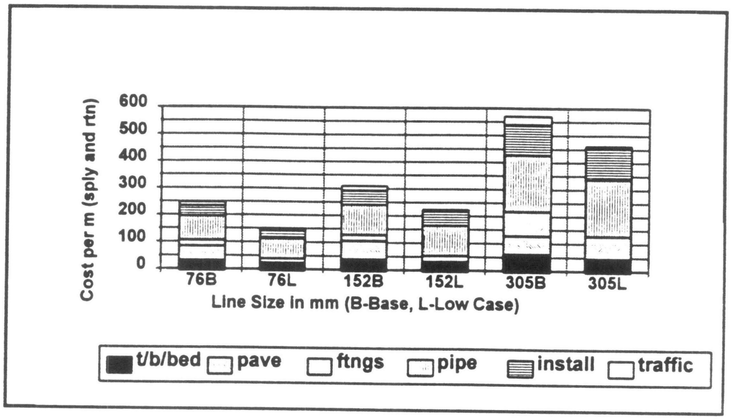

Figure 1. Installation cost of distribution piping for 76, 152 & 305 mm Base and Low Case.

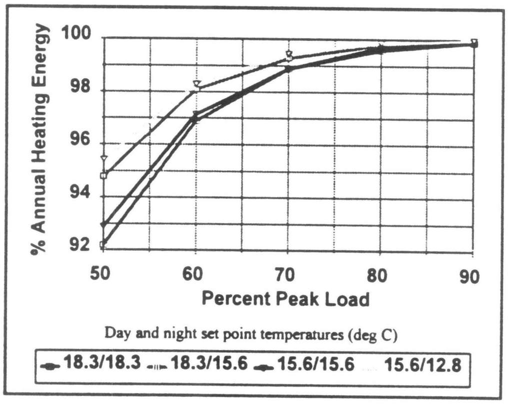

Figure 2. Annual energy displaced as a percent of peak load for a greenhouse.