REFERENCE BOOK

ON

GEOTHERMAL DIRECT USE

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Prepared for

U.S. Department of Energy
Geothermal Division

Prepared by

P. J. Lienau, J. W. Lund,
K. Rafferty and G. Culver
Geo-Heat Center
Oregon Institute of Technology
3201 Campus Drive
Klamath Falls, OR 97601
Ph: 503-885-1750
Fax: 503-885-1754

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DISCLAIMER STATEMENT

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1.0 INTRODUCTION

Enormous potential exists in the United States for geothermal direct use and geothermal heat pumps to make a significant contribution to our national energy needs while offsetting the use of fossil fuels. Geothermal projects reduce gaseous emissions and acid rain from the combustion of fossil fuels that impact our environment. Geothermal direct use has practically zero emission of greenhouse-type gases and essentially no thermal pollution.

The low-to-moderate temperature (<150°C) geothermal resource base (38,900 Quads) is much more plentiful and widespread than the high-temperature (>150°C) resource base (4,800 Quads). A recent report prepared for DOE by Meridian Corporation (Meridian, 1989) compares the magnitudes of the energy resource base in the U.S., as shown in Table 1. There is nearly 20 times more geothermal energy than the energy we could derive from burning all of the coal in the U.S., and 300 times the energy available in oil and gas. Geothermal energy is a domestic resource that contributes to our national energy security and decreases our trade deficit while saving petroleum for higher priority uses.

It is important to note the last column--Energy Reserves in Table 1 (also called the Resource in United States Geological Survey [USGS] publications). In general, Energy Reserves is the energy that can be economically and legally extracted under current or near-term economic and technological conditions. That definition, however, is subject to different interpretations by individuals and/or agencies, and as economics and technology change one must carefully consider the assumptions.

In the case of geothermal energy, the USGS Energy Reserves estimates are taken from Circular 790 (1978) and Circular 892 (1982). Circular 790 considers those resources above 90°C; while, Circular 892 addresses those resources between 90°C and 10°C above mean-annual air temperature (about 25°C for much of the US) and having a temperature gradient of 25°C/km with depth. Although Circular 790 considered depths of from 3 km to 10 km, only the 3 km depth is reported in Table 1. The USGS estimates consider both identified and what they considered at the time a reasonable amount of undiscovered resources.

The Meridian report is based on USGS estimates, modified by a study by the National Academy of Sciences--that gave a much more conservative estimate (about 100 times lower). The lowest temperature Meridian considered was 40°C and according to their definition of reserves, they considered only identified resources. Meridian's economics considers $18/bbl oil prices; whereas, when Circular 790 was written in 1978, prices were about 1-1/2 times higher, and predicted to climb even higher. Neither of these studies considered the vast amount of geothermal energy available for use by heat pumps which can utilize 4°C ground temperatures with no groundwater being required.

The 40°C lower limit is not a bad estimate for direct use. There are greenhouses and space heating applications utilizing 33°C geothermal fluids and aquaculture projects (one of the fastest growing US industries) utilizing 24°C fluids. Their contribution to the overall energy consumption is small; but, it does demonstrate that the technology is available, and the economics are good.

Table 1. U.S. Energy Resources (BBOE)*

Energy Source	Resource Base	Accessible Resources	Energy Reserves
Coal	15,079	6,577	908.0
Biomass and Solar	178,438	101,153	---
Biomass	---	---	57.7
Geothermal (USGS)	---	---	4882.0
Geothermal	256,992	3,897	42.5
Natural Gas	294	153	39.9
Petroleum	477	190	26.9
Hydro	170	27	8.0
Uranium	203	126	7.3
Solar	---	---	3.0
Wind	176,370	960	<1
Shale Oil	27,518	2,018	<1
Peat	244	61	<1

* Billion Barrels of Oil Equivalent.

USGS reported gigawatts electric and gigawatts thermal available for 30 years. This was probably based on the expected life of a fossil fueled power plant and on some temperature drop across the system based on entering fluid temperature. Unfortunately, this gives the impression that heat would be "mined" down to some minimum useable temperature and the resource abandoned. While this has apparently been true in some electrical production facilities, it has not been true in direct use installations. Geothermal district heating systems and heating of homes, schools, businesses, etc., have been ongoing for 100 years or more with no diminishing of temperature or flow rates. Profiteers may consider this under-utilization of a resource--others consider it good management. The earth has been giving off heat since its formation. It seems unlikely that it will cease in 30 years.

Lack of an adequate resource data base, risk of failure in exploration and drilling and lack of a dedicated industry have prevented geothermal direct use from achieving its full potential. Development of these resources can lead to space conditioning of buildings, greenhouse heating, aquaculture and other industrial applications. The current status is that an estimated annual energy contribution of over 4,181 GWh/yr (14.3 x 10^{12} Btu/yr) can be attributed to the direct use industry. This represents only a small fraction of the potential (Lund, et al., 1990). Table 2 gives the relative annual energy use for each direct heat application, and Figure 1 the growth rate of the direct use industry since 1975. Appendix A contains factsheets on 14 example direct use applications and Appendix B gives a tabulation of the direct use database of known U.S. projects.

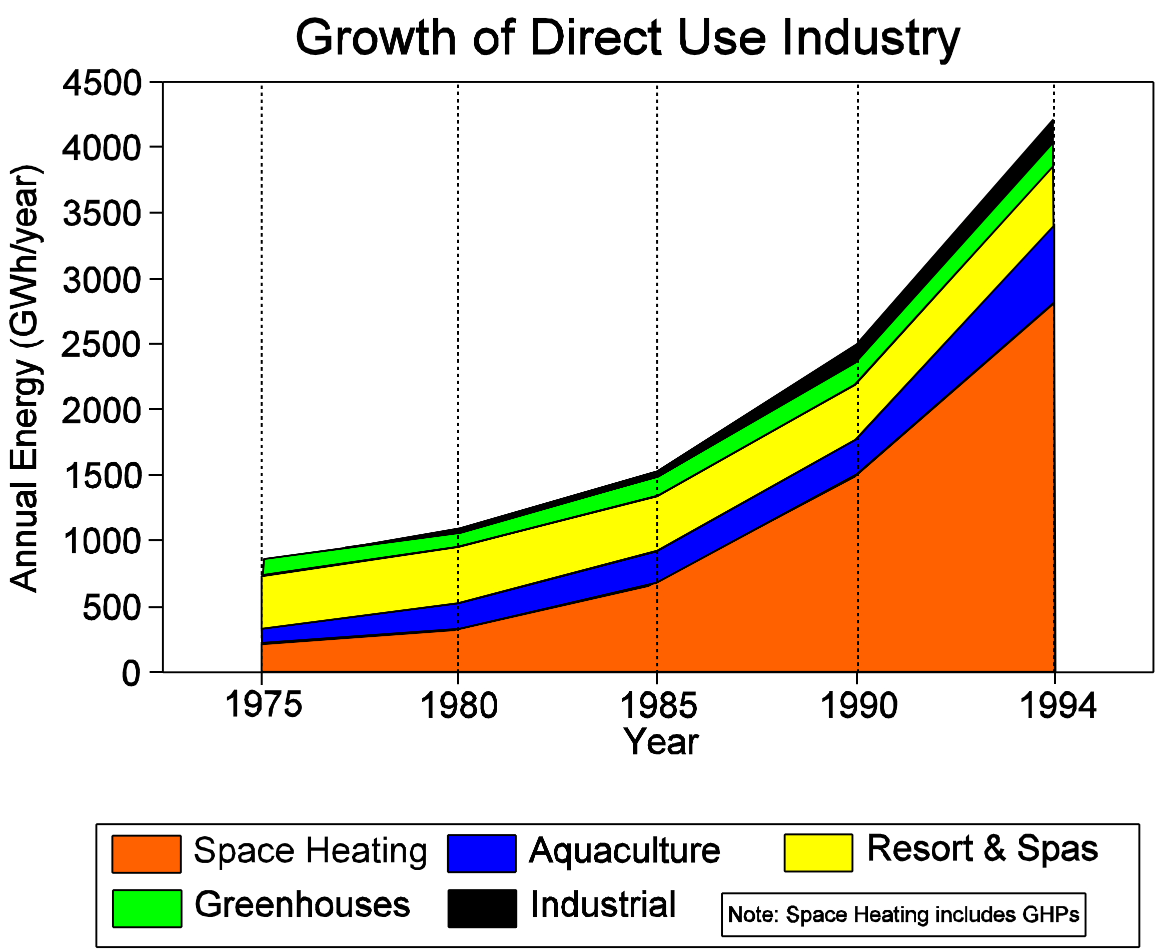

Figure 1. Growth of direct use industry.

Table 2. Annual Energy Supplied for Major Direct Use Applications

Application	Number Projects	States[a]	Temperature Range (C)	Capacity (MW_t)	Annual Energy (GWh/yr)
Space & District Heating[b]	123	6	26 to 166	169	386
Geothermal Heat Pumps	168,000[c]	50	6 to 39	1,773	2,403
Greenhouses	38	8	37 to 110	81	197
Aquaculture	27	9	16 to 93	104	574
Resorts & Spas	190	14	24 to 93	71	446
Industrial	12	6	86 to 154	43	176
Total				2,242	4,181

a. Number of states where projects are located.

b. Differs from 1990 inventory (Lund, 1990) because Mammoth Lakes and Bridgeport geothermal district heating systems were not built; therefore, they are not included in this inventory.

c. Number of equivalent 3-ton geothermal heat pump units.

Low-to-moderate temperature resources in the United States are widespread (Figure 2) and can provide a source for many direct heat applications. In contrast to other renewable resources, geothermal energy is not hindered by a cyclical output as in the case of wind and solar. It is a base load (constant output) resource which does not require sophisticated storage strategies for application. Geothermal energy in the low temperature range can have a significant impact on U.S. energy consumption, especially for space heating.

For example, one way to illustrate the economic impact of a geothermal system compared to a gas-fired boiler is to calculate the total energy delivery cost for both systems. The analysis (Appendix C) includes amortization of the capital costs, operation, and maintenance of both systems. The results of the energy cost for the geothermal systems is \$0.0042/kWh (\$1.24/10^6 Btu) compared to \$0.017/kWh (\$4.99/10^6 Btu) for the gas-fired boiler, both supplying 5.9 MW_t (20 x 10^6 Btu/hr) peak load to an application. The cost of energy from the geothermal system is only one-fourth (25%) that of the gas-fired boiler system.

Space heating in the 48° to 77°C range is by far the largest single U.S. energy use, representing 45 percent of all energy use below 260°C. Matching geothermal resources to meet these space heating requirements would result in much better use of U.S. energy reserves and reduced emissions from fossil fuels.

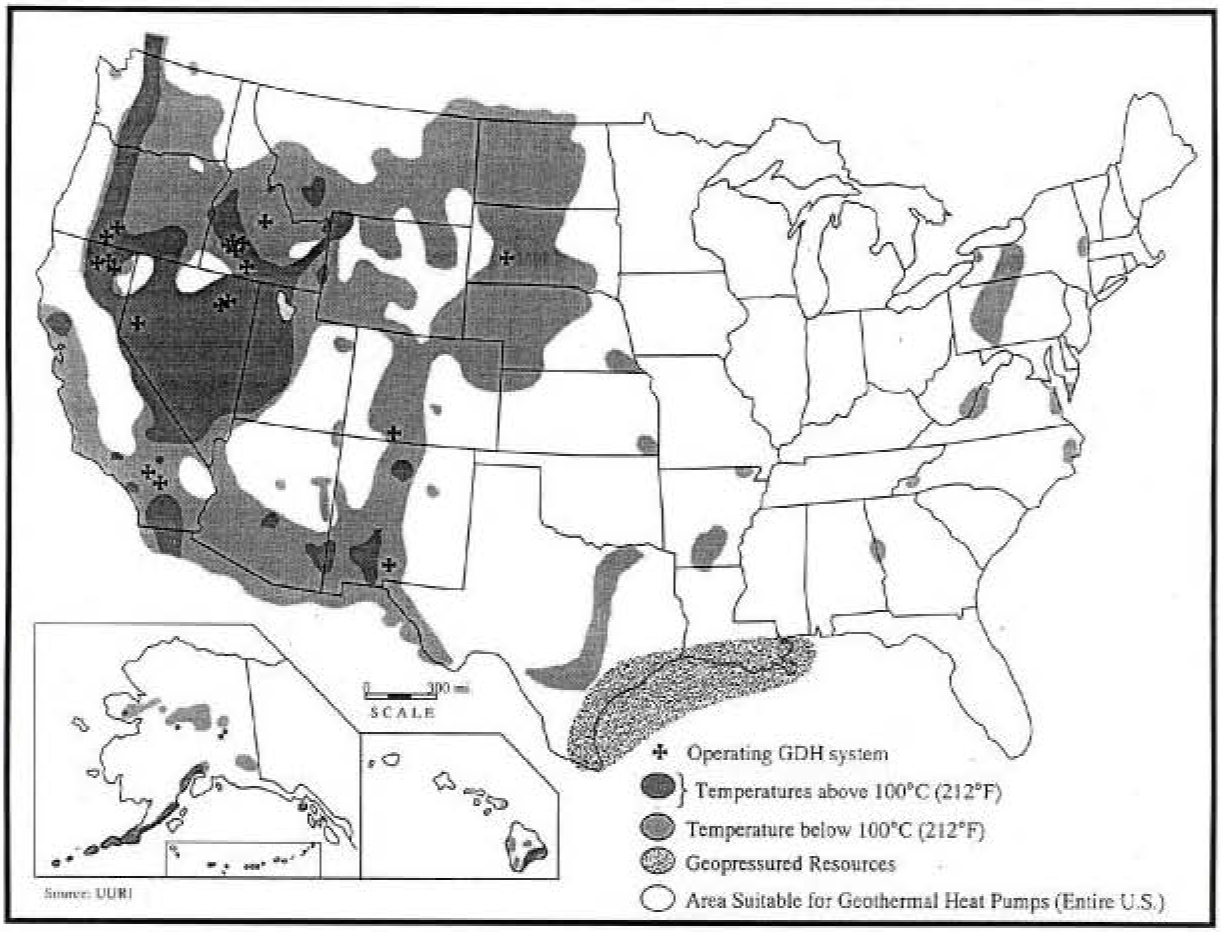

Figure 2. Generalized map of geothermal resources showing locations of geothermal district heating systems.

2.0 GEOTHERMAL HEAT PUMPS

Geothermal heat pumps (GHP) represent the largest potential use of geothermal energy. Geothermal heat pumps have national appeal because stable temperatures in the range of 4° to 21°C occur nationwide at depths below 9 m (Braud, 1992). GHPs do not necessarily require that water be pumped from the ground. Closed-loop systems utilize only the heat that is being transferred to and from the earth. The GHP is the highest efficiency heating and cooling system available, provides much lower energy costs for the consumer and greatly reduces electric peak demand for the utility. GHPs represent a demand-side management option for utilities to avoid building new power plants. A typical home equipped with a GHP will shave about 5 kW off winter peak heating demand and about 1.0 kW from summer demand. Thus, 200,000 homes using GHPs would offset a new 1,000 MW power plant with its associated emissions of CO_2, NO_x, and SO_4. Although the incremental cost of the ground coupled closed loop adds an average of about $2000 to the cost of a residential heating system, paybacks occur in 3 to 5 years from money saved on utility bills. Specific costs and savings depend on conditions at the site of interest.

Currently, the main GHP use is in midwestern and southeastern states; however, the geothermal heat pump industry is poised for tremendous growth in the entire nation during the 1990s, with the opportunity to displace 2.7 Quads of energy by the year 2030 (EIA, 1990). Unfortunately, there is a lack of data and understanding by utilities and the public as to the long-term benefits of geothermal heat pumps.

3.0 GEOTHERMAL ENERGY FOR BUILDINGS (Other than by heat pumps)

Geothermal energy for space heating of residential, commercial and institutional buildings is primarily applicable in the western half of the United States (see Figure 2). The potential for geothermal space heating is large. Geothermal resources (>50°C) are collocated within 7 km of 254 western cities that have a combined heat load estimated at 386 GWh/yr (1,317 x 10^9 Btu/yr). Geothermal district heating systems, currently operating in 20 cities, save customers 30 to 50% in heating bills compared to conventional fuels.

A showcase of a successful geothermal district heating system is that of the city of San Bernardino, California. The system consists of two production wells with an average combined flow of 5,211 L/min of 54°C water in 19 km of insulated pipelines. The system currently serves 33 buildings including government offices, the county jail, the new blood bank facility and other private buildings. Other uses include heating for the anaerobic digester at the sewage treatment plant and disinfections for the city animal shelter. In all, the buildings used 11 GWh/yr (37.5 x 10^9 Btu/yr) in FY92. By the end of 1993, there were three more facilities connected to the heating district, including two large laundries, that will triple the total heat load of the district.

The Department of Defense is looking for a place to locate a new accounting facility. San Bernardino made a proposal that included three locations in which geothermal energy could service the facility. Using geothermal energy would save approximately 18.8 x 10^{12} J per year (5.2 thousand BOE), or about $90,000 in first-year operating costs.

San Bernardino's successful implementation of a geothermal space heating system in its mild climate is noteworthy. This development demonstrates the very favorable prospects in the hundreds of other geothermal sites located in much colder climates. This technology represents considerable savings to customers while helping to meet clean air standards, especially in the Los Angeles Basin and scenic recreational areas.

To date, most geothermal direct use projects have been developed at or near previously proven resources (hot springs or areas of historic use). If geothermal direct use is to achieve even a small percentage of its great potential, two issues must be addressed:

- Energy engineers must be comfortable with direct use designs.

- The vast reserve of "masked" or hidden resources must be successfully accessed.

4.0 GEOTHERMAL ENERGY FOR INDUSTRY

Geothermal direct uses for industrial processes in the U.S., thus far, includes: gold mining, food processing, milk pasteurizing, grain drying, mushroom culture, sludge digester heating, greenhouse heating, and aquaculture. The estimated geothermal energy use for industry in the U.S. to date is 947 GWh/yr (3,232 x 10^9 Btu/yr). Direct use for industrial processes grew over four-fold during the 23-year period from 1970 to 1993 and continues to grow.

Figure 3 identifies other industrial and agricultural applications that can use geothermal energy.

Geothermal food processors, such as the vegetable dehydration plant at Brady, Nevada, can utilize sites with resource temperatures greater than 104°C for dehydration of fruits and vegetables. There are many sites in this temperature range near agriculture production areas in western states. A new dehydration plant near Gerlach, NV, began production in January 1994.

Greenhouses can utilize geothermal temperatures as low as 40°C. There are many such resources, but little is known about many of them. Most growers agree that despite the cost of wells, pumping, and the higher cost of heating equipment, geothermal saves about 5 - 8% of heating costs. While this adds to the profit margin, the main reasons for moving all or part of their operation from an urban location to a rural geothermal area include clean air with more sunlight, fewer disease problems, clean fresh water, more stable work force, and in some cases, lower taxes.

Aquaculture is one of the fastest growing industries. Catfish processing increased 21% last year. Although, only a small part of that increase involves geothermal facilities, it is well known that growth rates and food conversion are greatly enhanced with geothermal aquaculture. Geothermal aquaculture projects have obtained 50 to 300 percent growth rate increases in aquatic species as compared to solar heated ponds. Aquaculture can utilize geothermal resource temperatures as low as 21° to 27°C and can be cascaded from other uses. Current geothermal aquaculture use is 574 GWh/yr (1,960 x 10^9 Btu/yr) at 27 sites, and their number continues to increase.

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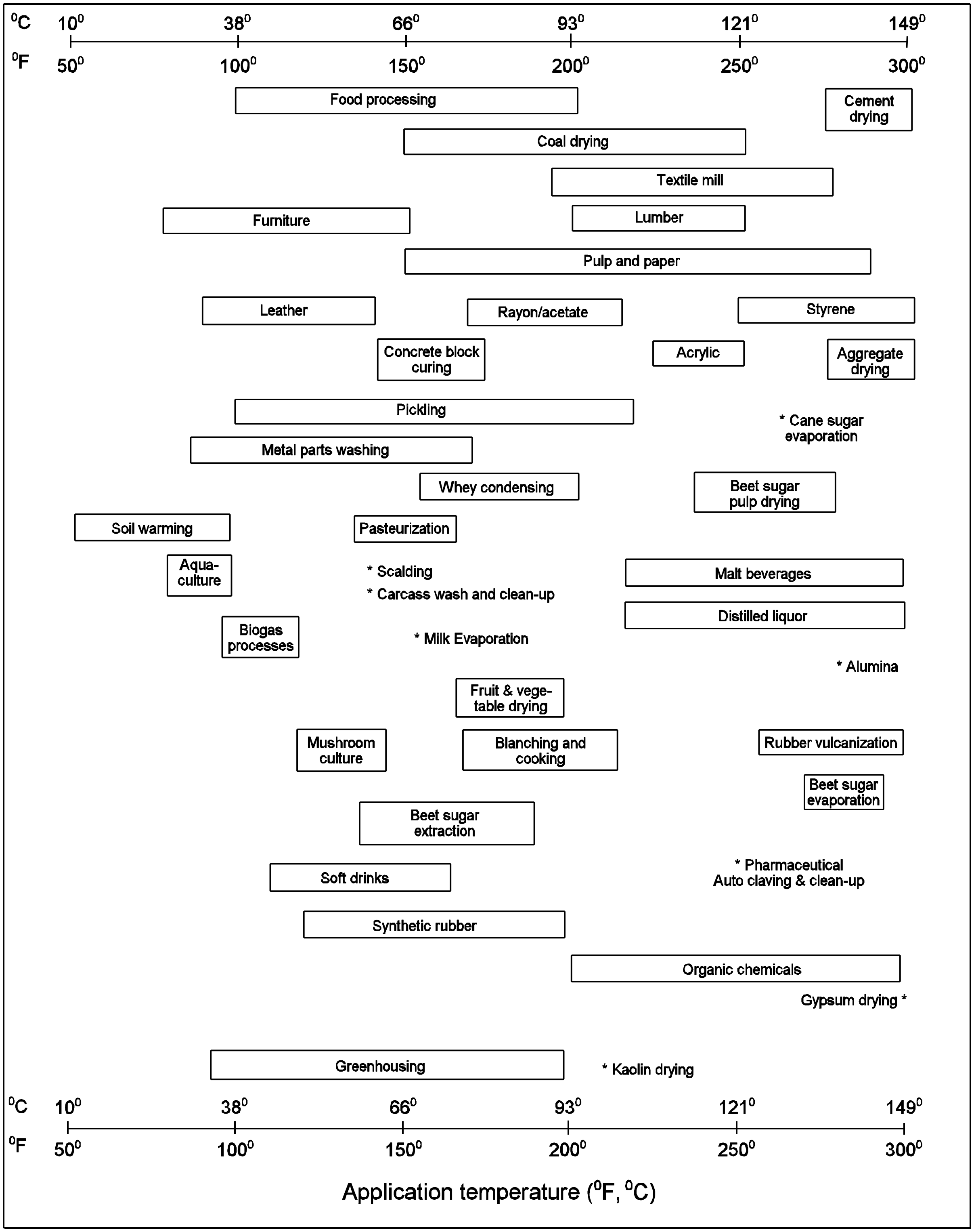

Figure 3. Application temperature range from some industrial processes and agricultural applications.

The most recent new industrial use is to increase the efficiency of heap leaching for gold and other metals in Nevada. Geothermal energy provides more efficient leaching because of higher temperature and lengthening the period during which outdoor leaching may be done. The gold and other metals were originally deposited by geothermal water--epithermal deposits--and in some cases, geothermal heat is still available to extract them. At least 10 applicable sites have been located in Nevada and similar geologic conditions occur in other states.

5.0 CONCLUSIONS

The potential for geothermal direct use in the U.S. is very large. As noted earlier, there is a difference in the estimates of reserves by the NAS and USGS of approximately two orders of magnitude. The actual number probably is about midway between the two. A current project (funded by USDOE and being carried out by the Geo-Heat Center at OIT, University of Utah Research Institute and the Idaho Water Resources Research Institute) to update information on geothermal resources has identified more than twice as many wells and springs as reported in USGS Circulars 790 (1978) and 892 (1982). These findings support the USGS theory of undiscovered hidden resources (i.e., no surface manifestations), and were discovered by geologic inference and subsurface investigations. Undoubtedly, a large number of resources remain yet to be discovered.

There has been a steady increase in geothermal direct heat utilization. Impediments to faster expansion are:

1. Lack of information about the resources, particularly low-temperature resources, which have been ignored by the larger developers who are interested in high temperature electric power production.

2. Lack of infrastructure (i.e., architects, engineers, drillers and construction companies) to capitalize on the availability and application of low-temperature direct uses.

3. The relatively high risk and high initial costs of starting geothermal direct uses compared to conventional fuels.

Continued work on resource assessment and success of installed projects will reduce both the real and perceived risks of direct use projects. Assuming this takes place, the infrastructure will expand. Conventional fuel prices will rise as reserves (both domestic and foreign) are depleted in the future. This will drive expanded use of geothermal resources.

Heat Pumps

As shown in Figure 1, heat pumps have been the fastest growing sector of low-temperature geothermal. There is good reason for this. The resource is almost universally available, and in most areas of the U.S. (depending on weather and power costs), they are more cost effective over the life span than any other heating and cooling system. The main impediments to faster growth are:

1. Lack of infrastructure (i.e., lack of experienced installation contractors, some lack of experience and knowledge by architects.

2. The current higher initial installation costs; despite lower life-cycle cost.

3. Consumer acceptance due to lack of knowledge.

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APPENDIX A

Factsheets on Direct Use Projects

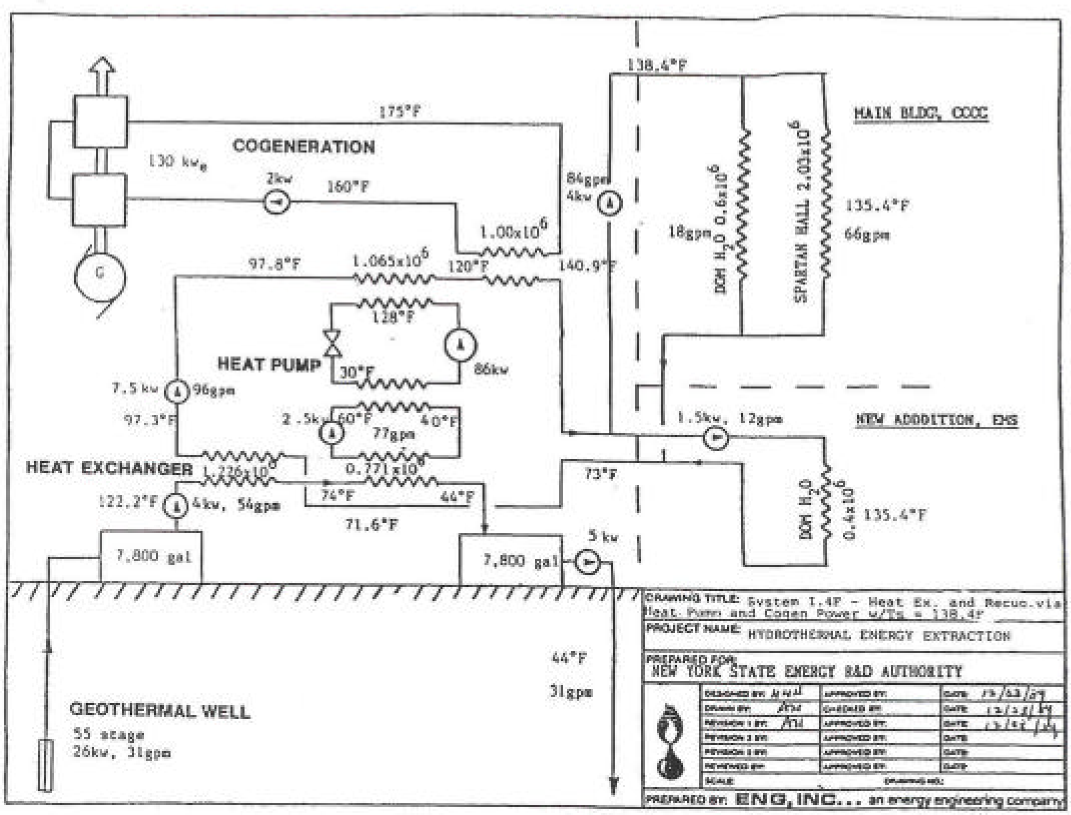
AUBURN, NY SCHOOLS HEATING SYSTEM

System Type:	Direct-use/Cogeneration - Space Heating
Location:	Auburn, NY
Construction Date:	1983
Building or Process Size:	24,900 m^2 (268,108 ft^2), 2 buildings
Resource Temperature:	52ºC (125ºF)
Well(s) Depth:	1600 m (5250 ft) production, 1560 m (5122 ft) injection
Disposal Method:	Injection
Capacity:	572 kW
Annual Energy:	0.9 GWh/yr (3.1 x 10^9 Btu/yr)

Project Summary

The Auburn project is unique in a number of respects: it is one of the few direct-use project in the eastern U.S., it employs the deepest direct-use wells of any project in the U.S., and it extracts both heat and natural gas from the well.

The system, which provides space heating for a community college and a junior high school, uses a 3-stage approach to providing heat energy from the well. In the first stage, heat is transferred from the geothermal fluid through a heat exchanger similar to most other direct-use systems. The second stage consists of extracting heat from the geothermal fluid using a heat pump. The third stage delivers heat by burning methane, produced from the well, in an engine/generator. Waste heat from the engine is delivered to the hydronic loop and electricity is used to operate the various pumps necessary to operate the loop. Under normal operating conditions, the first stage provides 335 kW, the heat pump stage 69 kW and the natural gas stage 163 kW.

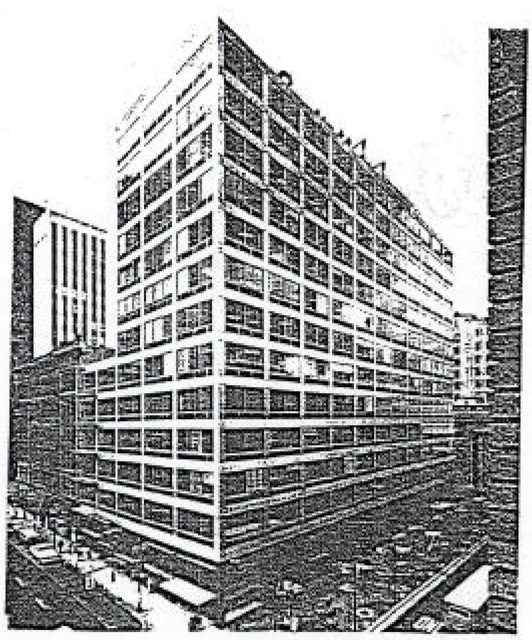


COMMONWEALTH BUILDING

System Type:	Groundwater heat pump
Location:	Portland, Oregon
Construction Date:	1948
Building or Process Size:	22,850 m^2 (246,000 ft^2)
Resource Temp.:	17º to 18ºC (62ºF to 64ºF)
Well Depth(s):	46 m to 152 m (150 ft to 500 ft)
Disposal Method:	Injection
Capacity:	Orig. 1900 kW (540 tons), current 2460 kW (700 tons)
Annual Energy:	4.8 GWh/yr (16.5 x 10^9 Btu/yr)

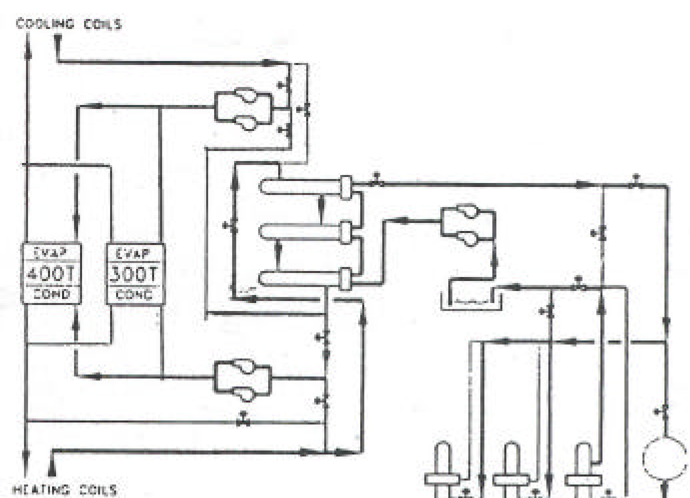
Project Summary

The Commonwealth Building (originally known as the Equitable Building) was a project characterized by a great many innovative design features for its day. Among these were the first all fluorescent lighting; the first tinted, fixed double glazing and the first use of natural color aluminum exterior skin. In addition, the HVAC system featured the first use of a groundwater heat pump system in the northwest. Designed by Portland engineer J. Donald Krosker, the original system operated without heat exchangers to isolate groundwater from the building system. Exchangers were added in 1958. A large chiller was added in 1964 and a second chiller was replaced in 1975. The design includes a novel "pre-conditioning coil to temper ventilation air. Total building energy use varies between 199 and 227 kWh/m^2 yr (63,000 and 72,000 Btu/ft^2 yr).



A National Historic Mechanical Engineering Landmark

Dedicated May 8, 1980 in Portland, Oregon



Source: Miller 1991

Current system—cooling dominant.

ELKO HEAT COMPANY GEOTHERMAL DISTRICT HEATING SYSTEM

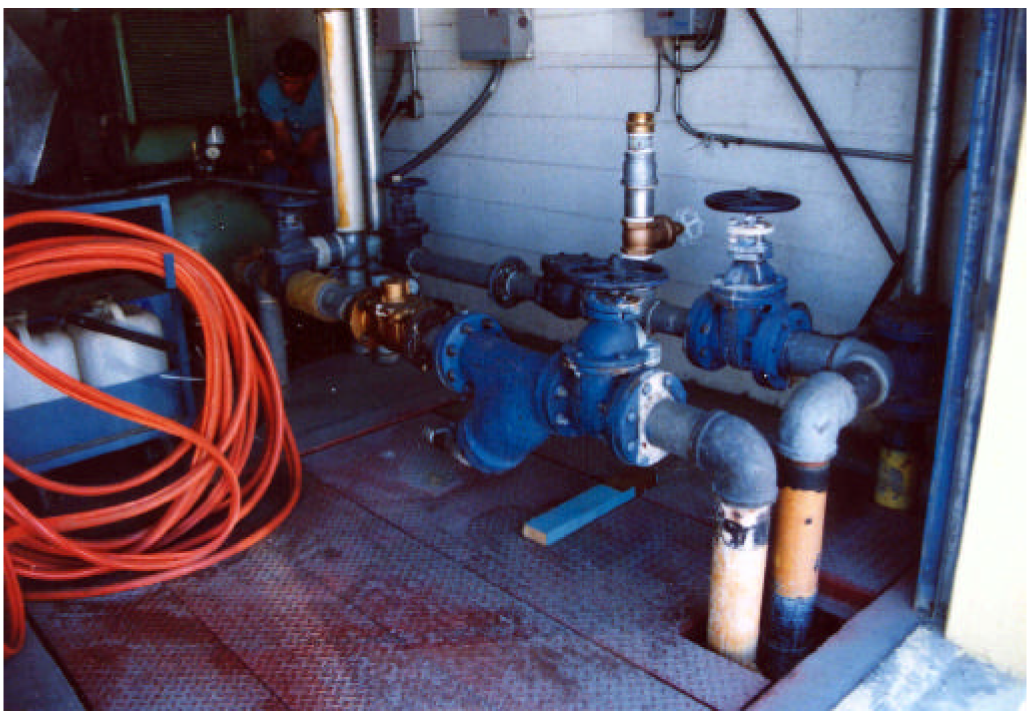
System Type:	Direct-use geothermal, district heating
Location:	Elko, NV
Construction Date:	1981
Building or Process Size:	17 buildings (1989)
Resource Temperature:	79ºC (175ºF)
Well(s) Depth:	250 m (820 ft)
Disposal Method:	Surface
Capacity:	2450 L/min (650 gpm), 3.8 MW_t
Annual Energy:	6.5 GWh/yr (22.2 x 10^9 Btu/yr), 50% cost savings to customers
Ownership:	Private - Elko Heat Company

Project Summary

This system is noteworthy in several respects. It is one of the few geothermal district systems operated by a private entity and serving a primarily private customer base. Growth of the customer base between initial construction in 1981 and 1988 had resulted in the available capacity being fully subscribed.

A single well provides 79ºC (175ºF) water to the distribution system which serves the downtown Elko area. Disposal during the warmer part of the year provides irrigation to a local golf course.

The production well for the system was completed under the USDOE Program Opportunities Notice (PON). Under this program, the government participated in the cost of exploratory well drilling. The percentage of the government participation in this project was $827,404 or 43.6% of the total of the original project. The Elko Heat Company financed the remaining $1,070,765.



Supply and return lines and control valves for laundry in Elko.

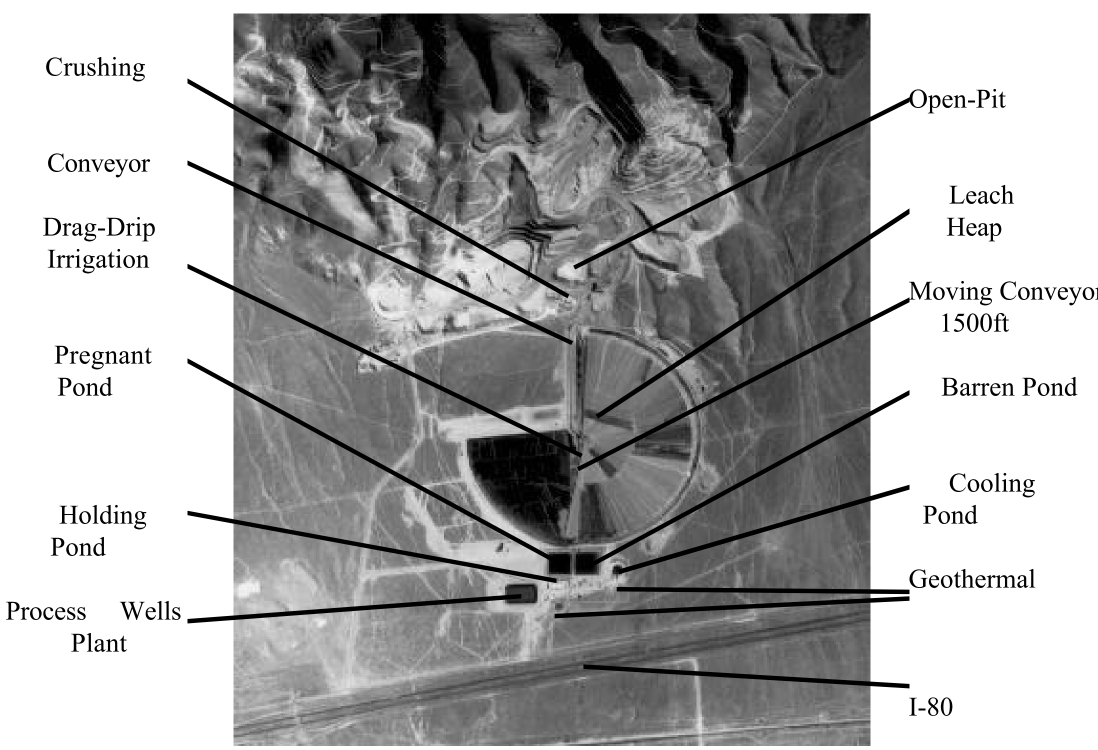
ENHANCED GOLD PROCESSING

System Type:	Direct use geothermal, industrial process, heap leaching
Location:	Round Mountain Gold Corp. is 50 miles north of Tonnopah, NV and Pegasus Gold Corp. is 50 miles north of Lovelock, NV.
Construction Date:	1990
Building/Process Size:	40,000 tons/day (ore), 286,000 oz/yr (gold)
Resource Temperature:	86°C and 114°C (186°F and 238°F)
Well(s) Depth:	305 m (1000 ft), two wells
Disposal Method:	Injection
Capacity:	4164 L/min (1100 gpm), 16.1 MWt
Annual Energy:	70 GWh/yr (240 x 10^9 Btu/yr)
Ownership:	Private

Project Summary

Gold mining is a major industry in Nevada with a total of 32 mines in operation as of 1987. Many of these mines employ a process known as heap leaching to remove gold from the low-grade ore. This process involves sprinkling the leaching solution over a large outdoor ore pile. Prior to the development of geothermal enhanced processing, the cold climate prevented operation during the coldest portions of the year (mid-October to mid-March). Using geothermal to provide low-cost process heating allows year-round operation of the mines.

Due to the low temperature of the process, vast quantities of heat can be removed from the geothermal fluids (82° supply, 27°C exit). Geothermally enhanced processing is taking place currently at two sites; but, at least 1/3 of the mines in Nevada have the potential to employ geothermal resources.



FLINT GREENHOUSES

System Type:	Direct use - space heating/greenhouses
Location:	Near Buhl, Idaho
Construction Date:	Continuing over several years, beginning in 1980. Six-tenth acre added last summer (1993).
Current Size:	3 1/4 acres of greenhouses, 3 homes, office and swimming pool
Resource:	Three wells - total peak flow 2650 L/min (700 gpm). Wells are 44°, 47° and 48°C (112°, 116° and 118°F). Depths are 183 m, 213 m and 274 m (600 ft, 700 ft and 900 ft). All wells are artesian
Disposal:	Surface to Snake River

Project Summary

The Flints family operated several greenhouses in Utah for a number of years. When looking for expansion sites, they located near Buhl, Idaho. Three artesian wells had been drilled when they acquired the property. The greenhouses are gutter connected with double polyethylene-film roof and fiberglass sides. They utilize three types of heating systems--overhead air, under bench air, and water tubes on bench. They grow indoor potted plants--varieties depend on the season. About 460,000 plants are grown annually.

Plants are trucked to their Utah operations where loads are made up for markets in Utah, Colorado, Washington, Oregon, Nevada, Montana and Wyoming. Their main markets are grocery stores, malls and wholesale florists.

Flints do the preliminary design work in-house since they know their intentions. Final design and construction is done by greenhouse A&E firms. Despite the use of automatic soil mixers, pot fillers and conveyors, the operation requires 13 full-time employees.

Being experienced growers, the start-up time was short--about 3 months from acquisition to production. Further expansion is questionable due to a moratorium on increased water usage in the area.

Geothermal heating savings ranges from 5% to 8% of total cost of a potted plant. That is enough to make a difference in the economics, reports David Flint - operator.

GALT HOUSE HOTEL, APARTMENT & OFFICE COMPLEX

System Type:	Geothermal Heat Pump
Location:	Louisville, KY
Construction Date:	1972 initial - Geothermal systems 1984
Building Size:	154,000 m^2 (1,658,000 ft^2) - 5 Buildings
Resource Temperature:	14ºC (58ºF)
Well(s):	Three, each producing 2,650 L/min (700 gpm)
	40 m (130 ft) deep - 24 m (80 ft) pumping level
Disposal Method:	River
Capacity:	15.8 MW_t (4,500-tons)

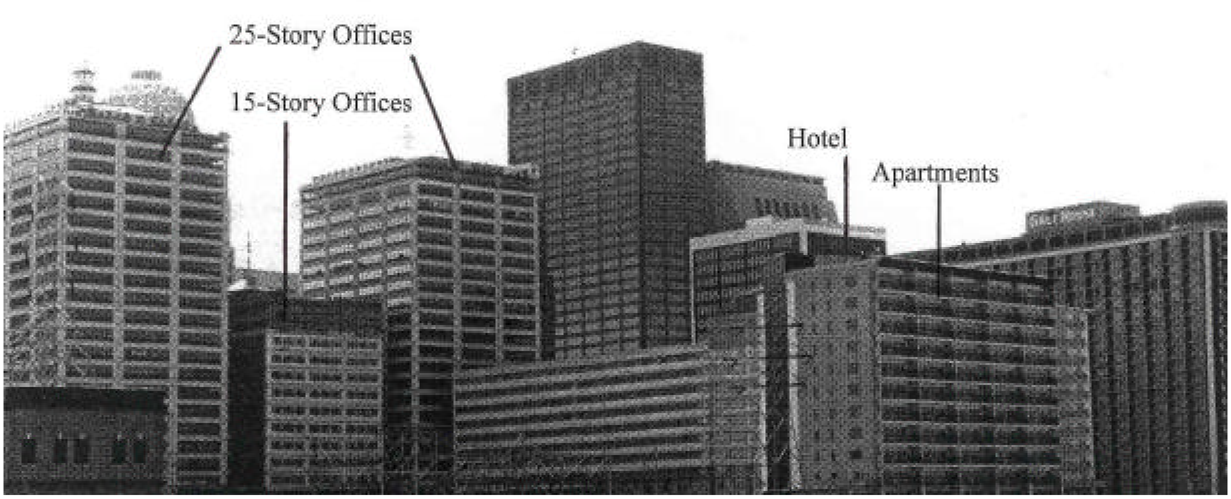
Project Summary

The original Galt House was built in 1992. The heating system consisted of gas-fired boilers and cooling towers supplying warm and cool water to 5-ton to 20-ton heat pumps conditioning the lower three floors--which are primarily meeting and public space. Hotel rooms above the 3rd floor were electrically heated with through-the-wall air conditioners for cooling. The lower three floors heat pumps were trouble-free.

When new expansion was planned (construction started 1984), the experience with the water loop heat pumps was an important influencing factor. The systems for the expansion including the Galt House East Hotel, the Galt Apartments, two 25-story office and 15-story office complex were designed as geothermal heat pump systems. An aquifer at 42 m (130 ft) was utilized to provide both heating and cooling eliminating the need for boilers and cooling towers. This resulted in both lower initial installation cost and lower operating cost.

The original Galt House Hotel and Galt House East Hotel are essentially identical. Typical summer operating costs for the Galt House is $75,000; while, the all geothermal Galt House East is $27,000 with the same occupancy rate.

The wells are pumped to a 140,000-gallon tank which in turn supplies plate-and-frame heat exchangers in each building. The building loops of fresh-treated water supply the individual heat pumps by means of two pumps serving half of each building. One extra pump serves as a spare for either of the two main pumps.



Buildings using geothermal heat pumps.

KLAMATH FALLS, OREGON GEOTHERMAL DISTRICT HEATING SYSTEM

System Type:	Direct-use geothermal, district heating
Location:	Klamath Falls, OR
Construction Date:	1981
Building or Process Size:	18 buildings (Dec. 93)
Resource Temperature:	103ºC and 106ºC (218ºF and 222ºF)
Well(s) Depth:	112 m and 274 m (367 ft and 900 ft)
Disposal Method:	Injection
Capacity:	3,790 L/min (1000 gpm), (5.9 MW_t)
Annual Energy:	5.9 GWh/yr (20 x 10^9 Btu/yr)
Ownership:	Public

Project Summary

The Klamath Falls system which was installed in a city characterized by heavy previous geothermal development (500 existing geothermal wells) had a rocky start. Existing well owners concerned about the affect of the new city system on their wells successfully prevented operation of the district system for many years. Eventually, extensive testing along with the establishment of a local geothermal advisory board overcame the difficulties in 1983 and the system has operated successfully ever since. The advisory board approach has become a model for effective communication during development.

The system was originally designed to serve a major portion of the city; but, the customer acceptance was slow.

Recently, an aggressive marketing program has boosted the customer base for the system by 40% in one year. Additional capacity is still available and will likely be subscribed in the next few years.

Plate heat exchangers on circulation pumps.

MASSON GREENHOUSES

System Type:	Direct use - greenhousing
Location:	Near Las Cruces, NM
Construction:	On-going
Size:	Currently 8 acres - available for 40 acres or more.
Resource:	Three production wells - 68º, 72º and 77ºC (155º, 162º and 171ºF), 34 m to 55 m (110 ft to 180 ft) deep with pumped production of 568 - 1325 L/min (150 - 350 gpm).
Disposal:	Injection - 2 wells

Project Summary

Masson moved a part of their operations to New Mexico to take advantage of: 1) sunlight, 2) dry atmospheric conditions, 3) availability of dependable labor, and 4) economical geothermal heating energy--in that order. The high amount of sunlight provides better growing. Dry atmospheric conditions provide less costly cooling. The rural setting provides more dependable labor. It is interesting that cheap energy was the last on the list; however, it was a consideration in site selection. Wells are shallow with low drilling costs and pumping levels are relatively shallow providing low pumping costs.

Masson grows various potted plants planned to satisfy markets at several times of the year, i.e., Christmas, Valentines Day, Memorial Day, etc. Plants are marketed directly to supermarkets and florists throughout a nine-state area. The current 8 acres provide for 8 full-time employees at the site plus truckers, etc.

Greenhouses have double polyethylene-film roofs with polycarbonate sides and ends. Engineering for the houses is pretty much in-house with construction done by greenhouse suppliers. Several heating system types are employed--radiant floor, fin-tube radiation and under-bench heating depending on plant preference. Heating costs using geothermal are about 50% of heating costs at their other operations.

Operator Alex Masson reports it took about 1-1/2 years from inception to production--much of the time waiting for permits. Assistance was provided by Jim Witcher geologist at New Mexico Energy Institute and geothermal-system design ideas from Kevin Rafferty at the Geo-Heat Center at Oregon Institute of Technology.

MILGRO

System Type:	Direct use - greenhousing
Location:	Near Newcastle, Utah
Construction Date:	Started June 1993 - production September 1993
Resource Temp.:	88ºC (190ºF)
Well Depth:	183 m (600 ft)
Disposal:	Injection well - 183 m (600 ft) deep
Capacity:	1136 L/min (300 gpm), more possible (5.7 MW_t)
Annual Energy:	12.6 GWh/yr (42.9 x 10^9 Btu/yr)

Project Summary

Milgro, a wholesale grower, moved to this site from Oxnard, California, primarily to take advantage of good light and good fresh water. Geothermal heating, a stable work force, and lower taxes are added advantages. They currently grow potted blooming plants in twenty 8 m by 91 m (27 ft by 300 ft) connected houses. Houses have double polyethylene-film roofs with fiberglass sides. The heating system consists of a plate-and-frame heat exchanger supplying 82ºC (180ºF) closed loop water to 12.7 mm (1/2 inch) diameter tubes under expanded metal benches. The low humidity permits misting cooling with vents at the ends of the houses eliminating the need for the normal evaporative cooling pad house. They also have a 280 m^2 (3,000 ft^2) refrigerated cooler for storage.

Milgro currently utilizes 16 full-time employees. They market directly to supermarkets all over the U.S.

Milgro likes the rural desert area and are thinking of expanding by adding 16,700 - 33,450 m^2 (180,000 -360,000 ft^2). They are an experienced greenhouse operator and all A&E work is done in-house.

PACIFIC AQUAFARMS

System Type:	Direct Use - Aquaculture
Location:	Niland, California
Construction Date:	1982
Process Size	12 acres
Resource Temperature:	61ºC (142ºF)
Well(s):	146 m (480 ft), produces 4164 L/min (1100 gpm) artesian
Capacity:	14.2 MW_t
Annual Energy:	49.8 GWh/yr (170 x 10^9 Btu/yr)
Product:	Primarily tilapia, a few shrimp, 340,200 kg/yr (750,000 lb/yr)
Employees:	8

Project Summary

The business was started in 1982 on a very small scale. The site was selected because it had geothermal water. Currently, there are 48 one-quarter acre ponds for a total of 12 acres with room and enough water for expansion. Fish are fed commercial tilapia pellets and the ponds are aerated with paddle wheel aerators.

Once a week, fish are harvested using a fish pump and size sorter. Small fish are returned to the pond and those large enough for sale go to a holding tank. From the holding tank, fish are pumped into trucks every morning and shipped live to markets in Los Angeles, San Diego and San Francisco, where they are sold live primarily to Asian customers. Live tilapia draw premium prices--approximately twice the average farm-gate price of catfish.

ROCKY MOUNTAIN WHITE TILAPIA

System Type:	Direct use - Aquaculture
Location:	Near Alamosa, CO
Building/Process Size:	Two greenhouse-type structures with four 9-m diameter and six 6-m diameter tanks, plus outdoor tanks 12 to 30 m diameter.
Resources:	Three wells - Well-1 at 39ºC 540 m (87ºF 2100 ft) deep, Well-2 at 31ºC 549 m (87ºF 1800 ft) deep, and Well-3 at 41ºC (105ºF 2800 ft) deep. Total available flow about 6057 L/min (1600 gpm), 5-hp pump in one well, the others artesian.
Disposal Method:	To surface with percolation.

Project Summary

As the project's name implies, the major product is white tilapia, a food fish rapidly gaining popularity in the U.S. About 90,718 kg per year (200,000 lb per year) are shipped to Toronto, Canada and New York City. Also because of the availability of economical heat, about 1 million tilapia fingerlings are over wintered and sold in the spring. Tilapia thrive in 29º - 32ºC water, survive at 18ºC, but die at about 13ºC. Fingerlings are shipped by tank truck to grow-out facilities located primarily in the south and southwest U.S.

In addition to the tilapia, alligators are grown in outdoor ponds in the tail race water. Currently (Dec. 1993), there are about 80 gators, 6 - 9 ft in length. The plan is to sell small gators and/or eggs. The current gators are not sexually mature and although they produce eggs, they are not fertile. That will take several more years.

The sight of alligators basking in the sun in a snow bank is unusual and attracts so many visitors, that the owners hired two additional employees to give guided tours of the facility. They report they had 20,000 visitors last year at $2.00 each--a nice addition to the tilapia sales.

SAN BERNARDINO GEOTHERMAL DISTRICT HEATING SYSTEM

System Type:	Direct-use geothermal, district heating
Location:	San Bernardino, CA
Construction Date:	1983
Building or Process Size:	202,000 m^2 (2,174,000 ft^2), 37 buildings
Resource Temperature:	56ºC (133ºF)
Well(s) Depth:	335 m and 284 m (1100 ft and 931 ft)
Disposal Method:	Surface
Capacity:	14,000 L/min (3700 gpm), 12.8 MW_t
Annual Energy:	22.0 GWh/yr (75 x 10^9 Btu/yr)

Project Summary

This system, operated by the San Bernardino Water System, is one of the most successful geothermal district heating systems in the nation. Despite its location in a region generally considered to have minimum heating requirements and in spite of the use of very low-temperature geothermal water, the system has experienced substantial growth over the years.

The project began as a small system to provide the digestors at the local water treatment plant with heat. The success of this initial design was expanded with funding from the California Energy Commission to the first phase of the district heating system. Several extensions have been added in recent years and the system currently serves 37 buildings comprising a total area of 202,000 m^2 (2,174,000 ft^2).

Much of the funding for development of this system came in the form of loans from the California Energy Commission. Funding for the program accrues from royalties paid by developers of geothermal electric power projects in other parts of the state. User fees pay back the loan from CEC.

SAN EMIDIO RESOURCES INC.

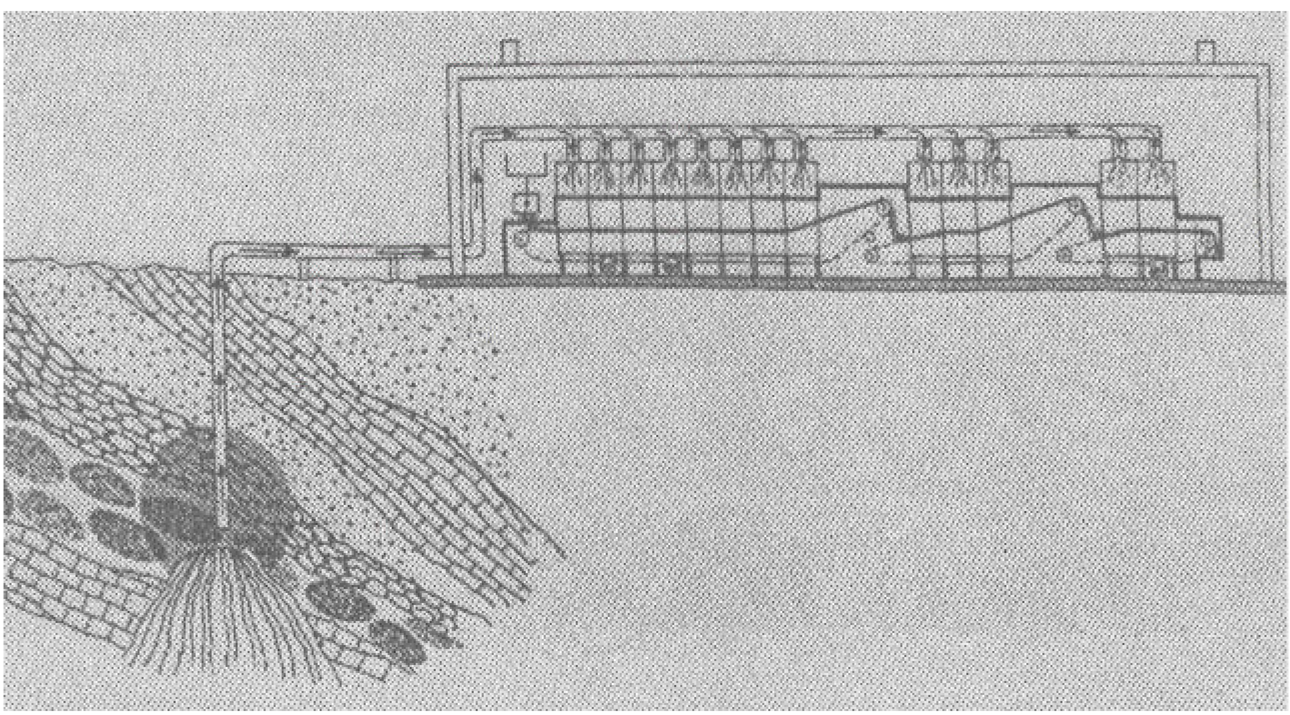
System Type:	Direct use - Food dehydration, greenhousing, soil warming, wetlands enhancement
Location:	Near Empire, Nevada
Construction Date:	Dehydration in process (Dec. 1993) - others to follow
Resource Temp:	150ºC (300ºF)
Well Depth:	150 m (492 ft)
Disposal:	Surface
Flow Rate:	11,400 L/min (3,000 gpm) from existing single well

Project Summary

San Emidio Resources Inc. will sell hot water to Integrated Ingredients (a spice and condiments production and distribution company) who are in the process of constructing a food dehydration facility. The dehydration process involves a 3-stage continuous belt dryer built by National Dryers of Philadelphia, PA. Operation is expected to start in January 1994. Primary products will be various flaked, ground, and powdered onions, and garlic. Capacity will be 6.8 million kg (15 million pounds) of dried product per year.

Empire Farms, a corporation related to--but separate from San Emidio, will pick up the effluent at 71ºC to heat greenhouses and for soil sterilization. Effluent from the greenhouses and sterilization facility in turn will be used for outdoor soil warming. A special hybrid strawberry is being considered as the crop. With soil warming, this variety will produce berries most of the year.

Effluent from the soil warming will be used to enhance and keep ice-free a wetland area for migratory and resident water fowl, fishes, etc.



RESIDENTIAL GEOTHERMAL HEAT PUMPS

System Type:	Vertical		Horizontal	
Location:	Stanchfield, MN		Zimmerman, MN	
Construction Date:	1989		1989	
Building Size:	260 m^2 (2800 ft^2)		260 m^2 (2800 ft^2)	
Loop Temperature:	1º to 21ºC (34º to 69ºF)		-3º to 32ºC (27º to 90ºF)	
Well(s)/Resource:	Five 46 m (150 ft) boreholes		549 m (1800 ft) of pipe in horizontal trench	
Capacity:	14 kW (4-ton)		18 kW (5-ton)	
Annual Energy (kWh):	GHP*	ASHP**	GHP*	ASHP**
	12,182	17,476	12,235	16,036
Savings:	30%		24%	
Installed Cost:	$6700		$6500	

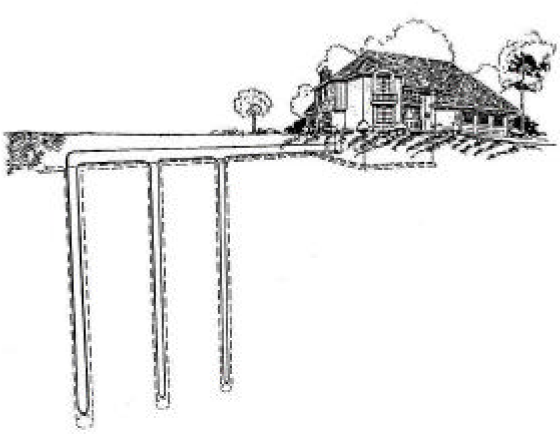
* Geothermal heat pump
** Air-Source heat pump

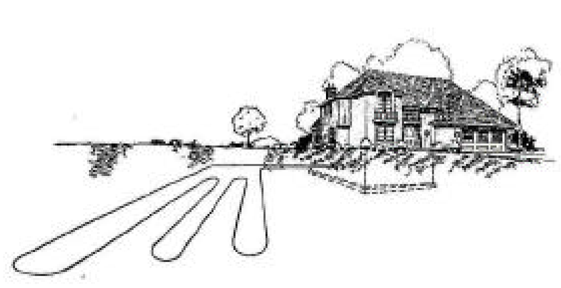
Project Summary

The thermal energy of the earth and groundwater can be used to heat and/or cool homes. One effective way to tap the energy in the ground is by using ground coupled coils. Coils are polyethylene or polybutylene pipes filled with water and antifreeze solution, which is pumped through pipes and into the house.

There are basically two configurations for ground-coupled systems: horizontal or vertical. Vertical boreholes are drilled 150 to 200 ft/ton, connected in parallel with the closed-loops to the heat pump. In the horizontal configuration, closed-loop pipes are buried in a trench, about 43 m/kW (500 ft/ton), from 1 to 2 m (4 to 6 ft) deep. Horizontal loops are affected by seasonal temperature changes and solar radiation; whereas, vertical loops have a more stable temperature environment controlled by the mean-annual temperature of the ground and the geothermal gradient.

Both homeowners and electric utility company benefit from geothermal heat pumps, which are the most efficient electric heating, cooling and domestic hot water system available today. In the case of the two Minnesota homes, the vertical GHP had an annual energy cost savings of 30% and the horizontal 24% over the air-source heat pumps. The GHP had energy cost savings of 4% compared to natural gas. The peak winter day demand reduction was 7.4 kW for the vertical and 5.7 kW for the horizontal system.





APPENDIX B

Direct Use Database

	SITE	LOCATION	Temp (C)	Flow (L/min)	Capacity (MWt)	Annual Energy (GWh/yr)
DISTRICT HEATING						
CA	Calistoga DH (planning)	Calistoga	106	NA	NA	NA
CA	Lake Elsinore DH (unused)	Lake Elsinore, CA	57	NA	NA	NA
CA	Litchfield Correctional Center	Near Susanville	77	4548	6.15	13.48
CA	Mammoth Lakes (wells drilled/planning)	Momo Co.	166	6519	NA	NA
CA	San Bernardino District Htg	San Bernardino	59	14023	12.83	21.97
CA	Susanville District Heating	Susanville, CA	77	1137	5.57	3.37
CO	Ouray DH (planning)	Ouray	69	2956	NA	NA
CO	Pagosa Springs District Htg.	Pagosa Springs	60	3032	5.13	4.81
ID	Boise City Geo. Dist. Heating	Boise	79	15160	31.15	19.40
ID	Fort Boise Veteran's Hosp.	Boise	72	NA	1.76	3.55
ID	Idaho Capitol Mall	Boise	76	2842	3.31	18.69
ID	Ketchum District Heating	Ketchum	70	3892	0.88	1.93
ID	Warm Spgs. Water District	Boise	80	6064	3.60	8.79
NM	New Mexico State University	Las Cruces	61	1580	2.18	13.45
NV	Elko County School District	Elko	88	1137	4.25	4.60
NV	Elko Disrict Heat	Elko	79	2464	3.81	6.27
NV	Warren Estates	Reno	98	3790	1.05	2.31
NV	Warren Properties	Reno	100	2691	3.63	21.18
OR	City of Klamath Falls DH	Klamath Falls	99	2729	4.39	8.32
OR	Oregon Institute of Tech.	Klamath Falls	89	2824	5.13	11.22
SD	Philip District Heating	Philip	68	1137	2.46	5.22
	Subtotal				97.29	168.56
SPACE HEATING						
AK	Baranof	20 mi E of Sitka	66	379	0.03	0.21
AK	Bell Island	40 mi N. of Ketchikan	72	114	0.15	0.73
AK	Chena Hot Springs	70 mi NE Fairbanks	57	841	0.97	4.54
AK	Circle Hot Spring	137 mi NE of Fairbanks	60	493	0.67	3.22
AK	Manley Hot Springs	Manley	59	663	0.76	3.69
AK	Melozi	Yukon Region	55	493	0.38	2.11
AK	Ophir Creek	SW Region	63	853	0.03	0.06
AR	Hot Springs National Park	Hot Springs	59	948	0.35	2.02
AZ	Buckhorn Mineral Wells	Mesa	60	NA	NA	NA
CA	Arrowhead Hot Springs	8 mi. N.E. of San Bernardino	88	1895	NA	NA
CA	Avila Hot Springs	Near San Luis Obispo	55	190	0.15	1.44
CA	Calistoga High Sch (unused)	Calistoga	93	NA	NA	NA
CA	Cedarville Elem. & High School	Cedarville, CA	57	436	0.41	1.41
CA	Desert Hot Springs	Desert Hot Springs	93	1326	0.67	5.86
CA	Fales Hot Springs		61	1137	NA	NA
CA	Ft. Bidwell (Indian Res)	Ft. Bidwell	96	5685	1.88	6.86
CA	Indian Springs School	Big Bend (Plumas Co)	53	1137	0.59	1.32
CA	Indian Valley Hospital	Greenville	43	364	0.18	0.38
CA	LDS Church	Susanville	53	341	0.26	0.59
CA	Miracle Hot Spring	N.E. of Bakersfield	50	57	NA	NA
CA	Modesto Memorial Hospital	Modesto	26	3430	NA	NA

	SITE	LOCATION	Temp (C)	Flow (L/min)	Capacity (MWt)	Annual Energy (GWh/yr)
CA	Modoc High Sch.	Alturas	73	2464	0.59	1.29
CA	Shoshone Motel & Trailer Park	Near So. entrance of Death Va.	34	758	0.09	0.56
CA	Surprise Valley Hospial	Cedarville	42	163	0.21	0.64
CA	Tecopia Hot Springs	Inyo Co.	42	758	NA	NA
CA	Twenty-Nine Palms (City of)	San Bernardino Co	60	NA	NA	NA
CA	Vichy Hot Springs	Near Ukiah	32	246	0.03	0.06
CA	Warner Springs Ranch (Resort)	45 mi. NE of San Diego	58	493	1.76	10.84
CA	White Suphur Springs	Plumas Co.	29	148	0.12	0.79
CO	Box Canyon Motel	Ouray	43	57	0.06	0.32
CO	Canon City Area	Canon City	NA	NA	NA	NA
CO	Cottonwood Hot Springs	West of Buena Vista	48	38	0.06	1.85
CO	Glenwood Hot Springs Lodge	Glenwood Springs	51	NA	0.76	1.70
CO	Health Spa	Glenwood Springs	46	23	0.03	0.12
CO	Hot Sulphur Springs	Hot Sulphur Springs	44	227	0.21	1.44
CO	Jump Steady Resort	Buena Vista	48	341	0.29	2.05
CO	Mount Princeton Area	Mount Princeton	56	NA	0.09	0.18
CO	Ouray Municipal Pool	Ouray	69	682	0.41	2.81
CO	Pagosa Springs Private Wells	Pagosa Springs	49	2558	1.46	3.81
CO	Pinkerton Hot Springs	La Plata Co. in SW CO	34	292	0.09	0.62
CO	Salida Hot Springs(Poncha Spr)	Salida	71	758	0.23	1.44
CO	Twin Peaks Motel	Ouray	43	57	0.06	0.32
CO	Waunita Hot Springs Ranch	Near Gunnison	79	379	0.73	3.81
CO	Wiesbaden Motel & Health Res.	Ouray	47	227	0.21	1.11
GA	Roosevelt Warm Springs Inst.	Warm Springs	31	3032	0.32	1.00
ID	Banbury Hot Springs	Buhl	55	303	0.23	0.67
ID	Bergdorf Hot Spring	Idaho County	45	614	0.12	0.35
ID	Corral	Camas County	75	117	0.18	0.35
ID	Del Rio Hot Springs	Preston	93	76	0.12	0.26
ID	Hooper Elementary School		27	NA	NA	NA
ID	Lava Hot Springs	Bannock County	44	6822	0.88	1.93
ID	LDS Church	Almo	34	303	0.12	0.26
ID	Miracle Hot Springs	Buhl	59	190	0.21	0.85
ID	Schutz's Hot Spring	Crouch	80	2274	0.94	3.16
ID	Twin Springs Resort	Boise	82	NA	NA	NA
MT	Boulder Hot Springs	Boulder	76	1895	0.29	1.29
MT	Bozeman Hot Springs	Bozeman	55	3703	0.59	1.70
MT	Broadwater Athletic Club & HS	Helena	67	379	0.41	1.64
MT	Fairmont Hot Springs Resort	Anaconda	71	758	0.88	4.25
MT	Hillbrook Nursing Home	Clancy	56	379	0.06	0.18
MT	Jackson Hot Springs Lodge	Jackson	58	982	0.15	0.85
MT	Lolo Hot Springs	Missoula County	44	682	0.53	3.69
MT	Warm Springs State Hospital	Warm Springs	68	341	0.56	4.28
MT	White Sulfur Springs	White Sulfur Springs	58	1743	0.15	0.38
NM	Jemez Springs		74	NA	0.18	0.38
NV	Aqua Caliente Trailer Park	Caliente	67	758	NA	NA
NV	Medical Center	Caliente	75	174	0.21	0.44
NV	Peppermill Inn & Casino	Reno	56	4548	7.03	18.46
NV	Reno-Moana Area (300)	Reno	49	NA	5.27	11.54
NV	Salem Plaza (proposed)	Reno	71	NA	NA	NA

	SITE	LOCATION	Temp (C)	Flow (L/min)	Capacity (MWt)	Annual Energy (GWh/yr)
NV	Steamboat Springs (Spa)	S. of Reno	93	2236	NA	NA
NV	Walley Hot Spring Resort	E. of Minden	71	493	1.35	8.17
NY	E. Middle School & Cayuga C.C.	Auburn	52	227	0.59	1.32
OR	Breitenbush Hot Springs	Marion County	100	3411	0.35	1.14
OR	Henley High School	Klamath Falls	53	1516	0.88	1.93
OR	Hot Lake RV Park	Union County	88	3146	0.26	0.53
OR	Hunters Hot Spring	Lakeview	94	296	0.23	0.50
OR	Jackson Hot Springs	Ashland	44	1001	0.21	1.29
OR	Klamath Apartment Bldgs. (13)	Klamath Falls	82	NA	1.90	4.16
OR	Klamath Churches (5)	Klamath Falls	88	NA	0.50	1.14
OR	Klamath County Jail	Klamath Falls	82	2653	3.08	6.74
OR	Klamath Co. Shops	Klamath County	48	428	0.47	1.05
OR	Klamath Residence (550)	Klamath Falls	82	NA	12.77	27.98
OR	Klamath Schools (7)	Klamath Falls	82	NA	2.55	5.80
OR	Lakeview Residences	Lakeview	88	190	0.12	0.26
OR	Langel Valley	Bonanza	64	76	0.03	0.03
OR	Maywood Industries of Oregon	Klamath County	48	1706	0.88	1.99
OR	Medical Hot Springs	Union County	60	379	0.15	0.32
OR	Merle West Medical Center	Klamath Falls	88	1232	3.08	7.00
OR	Olene Gap	Klamath County	87	1137	0.03	0.03
OR	Radium Hot Springs	Union	58	1137	0.18	1.05
OR	Summer Lake Hot Springs	Lake County	43	76	NA	NA
OR	Vale Residences	Vale	85	91	0.09	0.21
OR	Vale Slaughter House	Vale	66	76	0.09	0.21
OR	YMCA	Klamath Falls	64	455	0.41	0.91
SD	St. Mary's Hospital	Pierre	42	1459	1.64	3.34
TX	Cotulla High School	Cotulla	43	2274	2.90	3.81
TX	Marlin Hospital	Marlin	NA	NA	NA	NA
UT	Saratoga Springs Resort	Lehi	49	568	0.59	2.55
UT	Utah State Prison	Near Salt Lake City	81	1895	2.05	4.48
VA	Homestead Resort	Hot Springs	40	845	0.32	0.85
WY	Van Norman residence	Thermopolis	51	NA	NA	0.18
	Subtotal				72.02	217.08
GREENHOUSES						
CA	Big Bend Preventorium	Big Bend	82	341	0.03	0.12
CA	Lake County Ag Park	Lake Co.	67	1516	0.09	0.18
CA	Nakashima Nurseries	Coachella	49	7580	4.39	3.84
CA	Ramco Farms (unused)	Near Litchfield (Lassen Co.)	79	2274	NA	NA
CA	Tsuji Nurseries	Susanville, CA	60	1326	1.41	2.70
CO	Old Wright Well	Mount Princeton	71	455	0.47	2.11
CO	Trip Hot Springs	LaPlata in SW Colorado	44	NA	NA	NA
ID	Bliss Greenhouse	Bliss	66	227	0.35	1.08
ID	Cal Flint Floral	Buhl	71	1857	2.20	4.81
ID	Crook's Greenhouse	Caksia County	90	531	1.17	2.64
ID	Donlay Ranch Hot Spring	Boise County	54	273	0.35	0.94
ID	Edward's Greenhouses	Boise	47	1004	1.44	3.14

	SITE	LOCATION	Temp (C)	Flow (L/min)	Capacity (MWt)	Annual Energy (GWh/yr)
ID	Express Farms	Marsing	37	178	0.12	0.23
ID	Flint Greenhouses	Buhl	44	2160	2.67	5.83
ID	Green Canyon Hot Springs	Newdale	48	303	0.18	0.59
ID	Hunt Brothers Floral	Boise	47	758	0.88	1.93
ID	Jack Ward Greenhouses	Garden Valley	59	1478	2.02	4.42
ID	M&L Greenhouses	Buhl	44	1743	2.17	4.75
ID	Riggins Hot Springs	Idaho County	45	190	0.12	0.23
ID	Warm Springs Greenhouses	Banks	82	910	1.76	3.84
ID	Weiser Hot Springs	Weiser	70	57	0.09	0.21
MT	High Country Rose Greenhouses	Helena	66	785	2.46	9.70
MT	Montana Rose and Foral	Ennis	92	1743	1.44	4.13
NM	Beall & McCant	Cotton City	85	NA	0.06	0.21
NM	Burgett Floral Greenhouses	Cotton City	118	948	17.87	61.24
NM	J & K Growers	Las Cruces	64	NA	NA	NA
NM	Masson Radium Spgs. Farm	Radium Springs	71	3411	9.23	13.39
NM	SWTDI (NMSU)	Las Cruces	64	190	0.15	0.53
OR	Cove Hot Spring	Union County	42	857	0.21	0.41
OR	Jackson Greenhouses	Ashland	44	379	0.09	0.15
OR	Liskey Greenhouses	Klamath County	93	1895	0.79	1.73
OR	The Greenhouse	Lakeview	104	2653	1.38	2.58
UT	Milgro Nursery, Inc.	Newcastle	85	NA	5.74	12.57
UT	Troy Hygro	Newcastle	110	1819	3.52	8.79
UT	Utah Natural Growers	Newcastle	95	NA	6.89	15.09
UT	Utah Roses	Sandy	51	4548	5.98	13.07
UT	Utah Roses	Bluffdale	88	1516	3.05	9.38
WY	Countryman Well	Near Lander	37	1895	0.12	0.47
	Subtotal				80.84	196.98
AQUACULTURE						
AZ	Hyder Ranch	Between Gila Bend and Yuma	41	3222	2.05	7.18
AZ	Hyder Valley	Gila Bend	41	15160	11.72	41.08
AZ	Marana	Near Tuscon	27	3032	2.34	8.20
AZ	Safford	Safford	41	3790	2.93	10.25
CA	Aqua Farms International	Near Meca	33	5685	2.64	13.86
CA	Arrowhead Fisheries	N.E. of Susanville	23	5950	1.61	11.28
CA	Hot Creek Hatchery	Near Mammoth	16	71442	7.50	59.10
CA	Kelly Hot Springs	Alturas	93	2464	0.23	1.93
CA	Pacific Aqua Farms	Near Niland	61	6443	14.21	49.81
CA	Paso Robles Fish Farm	SanLuis Obispo Co	40	3790	2.93	20.51
CO	Kerr Aqua Farms	Alamosa	36	NA	8.26	50.69
CO	Roaring Judy Fish Hatchery	20 mi NE of Gunnison	18	4169	2.08	18.34
CO	Rocky Mtn. White Tilapia	Alamosa	NA	6064	2.34	16.41
CO	Sand Dunes Hot Spring	Hooper	48	1895	3.90	23.79
ID	Fish Breeders of Idaho	Buhl	32	23498	7.27	50.98
ID	Lunty Tropical Fish	Buhl	32	1516	0.59	4.10
ID	Star Valley Trout Ranch	SE Idaho	NA	NA	NA	NA
MT	Brooks Warm Springs	Fergus County	21	272880	NA	NA

	SITE	LOCATION	Temp (C)	Flow (L/min)	Capacity (MWt)	Annual Energy (GWh/yr)
NV	Bators-Gators	Pyramid Lake	92	NA	NA	NA
NV	Duckwater	Duckwater Reservation	33	NA	19.78	104.01
NV	Hobo Hot Springs	9 mi. So. of Carson City	41	379	0.59	4.22
NV	Jackpot		36	NA	9.38	65.63
NV	Wabuska	N. of Yerrington	132	4927	NA	NA
OR	Liskey Tropicals	15 mi. So. of Klamath Falls	82	NA	NA	NA
OR	Summer Lake Aquaculture	Summer Lake	NA	NA	NA	NA
SD	Keeton Fisheries	Phillip, SD	68	NA	1.17	8.20
WY	Jackson National Fish Hatchery	Jackson	26	379	0.56	4.86
	Subtotal				104.07	574.45
INDUSTRIAL						
CA	Calistoga Private and Commer	Calistoga	135	398	0.67	4.39
HI	Community Geothermal Tech Prog	HGPA Well	175	417	NA	NA
MT	Ennis Laundry	Ennis	83	379	0.23	0.50
NV	Geothermal Food Processors	Brady H. S. E. of Fernly	154	2842	5.57	25.20
NV	Integrated Ingredients Dehyd.	Empire	149	11370	14.06	57.72
NV	Pegusus Gold Corp Florida Cany	Humbolt House Rye Patch KGRA	114	1516	1.35	11.72
NV	Round Mountain Gold Corp	Smoky Valley, NV	86	11370	14.06	57.72
OR	Aq Dryers	Vale	93	227	0.88	1.90
OR	Highway De-icing	Klamath Falls	88	NA	0.12	0.73
OR	Oregon Trail Mushrooms	Vale	113	1042	6.04	15.85
WY	East Grand St. Bridge	Laramie	8	NA	0.06	NA
WY	I-80 16th St. off ramp	Cheyenne	8	NA	0.26	NA
	Subtotal				43.31	175.74
RESORTS & POOLS						
AK	Goddard	15 mi S of Sitka	67	49	0.03	0.21
AK	Tenakee	Chichigaf Island	43	83	0.03	0.21
AZ	Buckhorn Mineral Wells	Mesa	NA	NA	NA	NA
AZ	Castle Hot Springs	Near Wickenberg	55	1289	0.15	0.73
AZ	Safford		42	NA	NA	NA
AZ	Verde Hot Springs	Cakmp Verde	NA	NA	NA	NA
CA	Alive Polarity's Murrieta H.S.	Murrieta	NA	NA	NA	NA
CA	Aqua Caliente County Park	Santa Rosa Mtn. Wilderness	32	NA	0.09	0.53
CA	Aqua Caliente Springs Resort	Sonoma Co.	36	265	0.41	3.52
CA	Avila Hot Springs Spa & RV Resort	San Luis Obispo	NA	NA	NA	NA
CA	Bashfords Hot Mineral Spa	Niland	63	NA	0.12	0.82
CA	Big Caliente	Santa Barbara	48	NA	NA	NA
CA	Brockway Springs Resort	King's Beach	NA	NA	NA	NA
CA	California Hot Springs	Northeast of Bakersfield	52	190	0.21	1.26
CA	Campbell Hot Springs	Near Sierraville	46	303	0.18	1.38
CA	Democrat Hot Springs Resort	Kern Co	39	57	0.23	0.21
CA	Drakesbad Guest Ranch	Mineral	82	76	0.15	0.41
CA	Dr. Wilkinson's Hot Springs	Calistoga	NA	NA	NA	NA

	SITE	LOCATION	Temp (C)	Flow (L/min)	Capacity (MWt)	Annual Energy (GWh/yr)
CA	Esalen Institute	Near Big Sur	49	284	0.18	1.29
CA	Fountain of Youth Spa	Niland	58	265	0.35	2.46
CA	Furnace Creek Inn	Death Valley	32	1326	0.23	1.44
CA	Furnace Creek Ranch	Death Valley	32	1326	0.23	1.44
CA	Glen Ivy Hot Springs (Resort)	Riverside Co	41	625	0.35	2.34
CA	Grover Hot Springs State Park	Alpine Co. (S of Lake Tahoe)	64	398	0.18	1.38
CA	Harbin Hot Springs	Near Middletown	49	201	0.18	1.38
CA	Hot Creek	Near Mammoth Lakes	93	15160	NA	NA
CA	Imperial Sea View Hot Springs	Near Niland	74	NA	0.06	0.35
CA	Indian Valley Hot Springs	Greenville	NA	NA	NA	NA
CA	International Spa	Calistoga	NA	NA	NA	NA
CA	Jacumba Hot Springs Health Spa	80 mi E. of San Diego	36	57	NA	NA
CA	Keough Hot Springs	10 mi. S. of Bishop, Inyo Co.	53	2001	0.15	1.14
CA	Konocti Harbor Inn	Near Kelseyville, Lake Co.	42	493	0.47	3.22
CA	La Vide Mineral Springs	Brea	49	190	0.15	0.88
CA	Lake Elsinore	Lake Elsinore	49	303	0.35	2.46
CA	Lincoln Avenue Spa	Calistoga	NA	NA	NA	NA
CA	Matilija Hot Springs	Ventura Co	43	284	0.03	0.21
CA	Mercey Hot Springs	Los Banos	NA	NA	NA	NA
CA	Mono Hot Springs	80 mi NE of Fresno	42	201	0.06	0.29
CA	Murrieta Hot Springs Resort	12 mi. SE of Lake Elsinore	60	1137	2.43	12.77
CA	Nance's Hot Springs	Calistoga	NA	NA	NA	NA
CA	Orr Hot Springs	Near Ukiah	39	114	0.12	0.82
CA	Palm Springs Spa	Palm Springs	41	133	0.15	1.03
CA	Pan Hot Springs	San Bernardino Co (Big Bear)	32	NA	2.14	7.47
CA	Paraiso Hot Springs (Resort)	Monterey Co	46	2653	3.05	1.76
CA	Reds Meadow Hot Springs	Devils Postpile Natl Monument	46	57	NA	NA
CA	Roman Spa Hot Springs Resort	Calistoga	NA	NA	NA	NA
CA	Saline Valley Hot Springs	Near Olancha in Inyo, Co.	42	NA	NA	NA
CA	Sam's Family Spa	Desert Hot Springs	NA	NA	NA	NA
CA	San Juan Hot Springs	near San Juan Capistrano	52	76	0.03	0.18
CA	San Luis Bay Estates	San Luis Obispo Co	41	227	0.15	0.76
CA	Sierra Hot Springs	Sierraville	NA	NA	NA	NA
CA	Stewart Mineral Springs	Weed	NA	NA	NA	NA
CA	Sycamore Hot Spring (Resort)	San Luis Obispo Co.	43	568	0.64	3.81
CA	Tassajara Buddhist Meditation	Carmel Valley	43	576	0.21	1.61
CA	Tecopa Hot Springs Resort	Tecopa	NA	NA	NA	NA
CA	Town of Tecopia	Near S. entr. to Death Valley	48	NA	0.29	2.05
CA	Vichy Springs	Ukiah	NA	NA	NA	NA
CA	Warner Springs	Sarner Springs	NA	NA	NA	NA
CA	Wheeler Hot Springs	Ojai	NA	NA	NA	NA
CA	Whitmore Hot Springs	Near Bishop	35	1516	0.18	1.38
CA	Wilbur Hot Springs	Near Clear Lake	67	114	0.18	1.38
CO	4 UR Guest Ranch	Creede in Mineral Co.	57	190	0.23	1.55
CO	Cement Creek Ranch	Crested Butte N. of Gunnison	26	265	0.03	0.12
CO	Dunton Hot Springs	Near Dolores	42	95	0.03	0.09
CO	Glenwood Hot Springs Hotel	Glenwood	54	8577	2.64	18.58
CO	Glenwood Springs Vapor Caves	Glenwood	NA	NA	NA	NA
CO	Hot Sulphur Springs	Hot Sulphur springs	NA	18950	NA	NA

	SITE	LOCATION	Temp (C)	Flow (L/min)	Capacity (MWt)	Annual Energy (GWh/yr)
CO	Indian Springs Resort	Idaho Springs	46	227	0.23	1.26
CO	Jones Splashland	Alamosa	41	1175	0.82	5.57
CO	Lope Hot Springs	Ridgeway	56	76	0.03	0.12
CO	Mount Princeton Hot Springs	Mount Princeton	56	663	0.12	0.53
CO	Rendezvous in the Rockies	Buena Vista	NA	NA	NA	NA
CO	Salida Hot Springs	Salida	NA	NA	NA	NA
CO	Steamboat Springs Health & Rec	Steamboat Springs	40	531	0.50	3.46
CO	The Spa	Pagosa Springs	NA	NA	NA	NA
CO	Trimble Hot Springs	Durango	NA	NA	NA	NA
CO	Valley View Hot Springs	Near Villa Grove	37	682	0.23	1.67
CO	Waunita Hot Springs Ranch	Gunnison	79	76	NA	NA
CO	Wiesbaden Hot Springs	Ouray	NA	NA	NA	NA
ID	Bald Mountain Hot Springs	Ketchum	76	8	0.82	2.93
ID	Baumgartner Hot Springs	Featherville	40	NA	NA	NA
ID	Bear Lake Hot Springs	St. Charles	46	152	0.09	0.38
ID	Burgdorf Hot Springs	Burgdorf	NA	NA	NA	NA
ID	Challis Hot Springs	Challis	53	152	0.15	0.64
ID	Downatta Hot Springs	Downey	44	303	0.18	0.73
ID	Givens Hot Springs	Owyhee County	49	2464	0.06	0.15
ID	Gold Fork Hot Spring	Adams County	43	NA	NA	NA
ID	Green Canyon Hot Springs	Newdale	NA	NA	NA	NA
ID	Haven Lodge	Lowman	64	190	0.15	1.03
ID	Heise Hot Springs	Ririe	49	303	0.29	1.29
ID	Idaho Rocky Mountain Ranch	Stanley	41	NA	NA	NA
ID	Indian Springs Natatorium	American Falls	32	455	0.18	0.62
ID	Jim's Hot Springs	New Meadows	66	227	0.23	1.55
ID	Lava Hot Springs	Lava Hot Springs	44	NA	1.11	5.92
ID	Murphy Hot Springs	Rogerson	32	NA	NA	NA
ID	Red River Hot Springs	Elk City	NA	NA	NA	NA
ID	Riverdale Resort	Preston	NA	NA	NA	NA
ID	Robinson Bar	Clayton	57	152	0.18	0.67
ID	Russian John Hot Springs	Blaine County	39	190	NA	NA
ID	Silver Creek Plunge	Garden Valley	38	417	0.26	1.05
ID	Sligar's Thousand Springs Res.	Hagerman	93	531	0.38	2.26
ID	Terrace Lakes Recreational Ranch	Garden Valley	69	NA	NA	NA
ID	Twin Springs Resort	Boise	82	NA	NA	NA
ID	Warm Springs Resort	Idaho City	43	379	0.26	0.94
ID	Worswick Hot Springs	Camas County	66	948	NA	NA
ID	Zim's Hot Springs	New Meadows	NA	NA	NA	NA
MT	Barkell's Hot Springs	Silver Star	72	568	0.21	0.64
MT	Bear Trap Hot Spring	Norris	54	1315	1.03	7.12
MT	Bozeman Hot Spings	Bozeman	NA	NA	NA	NA
MT	Broadwater Hot Spring	Helena	NA	NA	NA	NA
MT	Camas Hot Springs	Hot Springs	40	91	0.06	0.21
MT	Camp Aqua	Hot Springs	NA	NA	NA	NA
MT	Chico Hot Springs	Park County	45	1213	0.23	1.35
MT	Elkhorn Hot Springs	Polaris	NA	NA	NA	NA
MT	Fairmont Hot Springs Resort	Anaconda	62	948	1.11	8.17
MT	Lolo Hot Springs Resort	Lolo	NA	NA	NA	NA

	SITE	LOCATION	Temp (C)	Flow (L/min)	Capacity (MWt)	Annual Energy (GWh/yr)
MT	Lost Trail Hot Springs Resort	Sula	NA	NA	NA	NA
MT	Medicine Hot Springs	Conner	45	379	0.18	0.76
MT	New Biltmore Hot Springs	Madison County	53	99	0.09	0.53
MT	Quinn's Hot Springs	Paradise	NA	NA	NA	NA
MT	Sleeping Child Hot Springs	Ravalli County	52	2009	0.21	0.73
NM	Bubbles Hot Spring	Catron County	NA	NA	NA	NA
NM	Charles Motel & Bathhouse	Truth or Consequences	NA	NA	NA	NA
NM	Jemez Springs Bathhouse	Jemez Springs	NA	NA	NA	NA
NM	McCauley Hot Spring	Near Jemez Springs	NA	NA	NA	NA
NM	Ojo Caliente Resort	50 mi N of Santa Fe	46	227	0.15	0.59
NM	Truth or Consequences		45	NA	NA	NA
NV	Ash Springs	Hieko	36	34110	NA	NA
NV	Baileys Hot Springs	E. of Death Valley Nat'l Monu.	71	NA	NA	NA
NV	Bowers Mansion	Carson City	47	284	0.41	1.38
NV	Brockway Springs Resort	N. Shore of Lake Tahoe	82	568	0.15	1.14
NV	Caliente City Pool	Caliente	79	568	1.00	2.17
NV	Caliente Hot Springs Motel	Caliente	46	152	0.12	0.70
NV	Carson Hot Springs	Carson City	49	284	0.23	1.67
NV	Darrough Hot Springs	Austin	NA	NA	NA	NA
NV	Gerlach Hot Springs	Gerlach	93	NA	NA	NA
NV	Hunt's Ash Springs	Lincoln Co. S. of Hieiko	36	34110	6.59	46.21
NV	Moana Municipal Pool	Reno	53	413	0.76	2.26
NV	River Inn Natural Hot Spring	Reno	NA	NA	NA	NA
NV	Steamboat Springs	Reno	NA	NA	NA	NA
NV	Walley's Hot Springs Resort	Genoa	NA	NA	NA	NA
NV	Warm Spring Resort	50 mi. N. of Las Vegas	32	12280	2.34	18.46
OR	Austin Hot Springs	Clackamas	86	948	0.06	0.29
OR	Bagby Hot Springs	Clackamas County	NA	NA	NA	NA
OR	Baker Swimming Pool	Baker	24	758	0.18	0.53
OR	Belknap Hot Springs	Lane	71	190	0.26	1.61
OR	Blue Mountain H.S. Guest Ranch	Prairie City	NA	NA	NA	NA
OR	Breitenbush Community	Detroit	NA	NA	NA	NA
OR	Cove Swimming Pool	Cove	NA	NA	NA	NA
OR	Crystal Crane Hot Springs	Burns	85	568	NA	NA
OR	Hunter's Lodge	Lakeview	NA	NA	NA	NA
OR	J Bar L Guest Ranch	Canyon City	NA	NA	NA	NA
OR	Jackson Hot Springs	Ashland	NA	NA	NA	NA
OR	Kah-nee-ta	Warm Springs	52	1706	1.32	8.09
OR	Klamath Swimming Pools (5)	Klamath Falls	82	NA	0.32	1.26
OR	Lehman Hot Springs	Ukiah	NA	NA	NA	NA
OR	Public Swimming Pool	Lakeview	82	76	0.23	0.53
OR	Ritter Hot Springs	Ritter	NA	NA	NA	NA
OR	Summer Lake Hot Springs	Summer Lake	NA	NA	NA	NA
SD	Evan's Plunge	Hot Springs	31	39189	1.52	10.61
TX	Stacy Park Pool	Austin	36	948	0.26	1.61
UT	Belmont Springs	Plymouth	55	13644	0.44	2.29
UT	Como Springs Resort	Morgan	28	2047	0.32	11.08
UT	Crystal Hot Springs	Honeyville	60	6822	1.03	6.27
UT	Monroe Hot Springs	Monroe	73	2274	0.29	2.29

	SITE	LOCATION	Temp (C)	Flow (L/min)	Capacity (MWt)	Annual Energy (GWh/yr)
UT	Mountain Spa Resort	Midway	46	4806	0.15	0.50
UT	Pah Tempe	2 mi N of Hurricane	42	37900	0.12	0.70
UT	Saratoga Springs Resort	Lehi	44	NA	NA	NA
UT	The Homestead	Midway	35	227	0.03	0.59
UT	Veyo Resort	18 mi N. of St. George	37	455	0.29	1.23
WA	Carson Hot Mineral Springs Resort	CArson	NA	NA	NA	NA
WA	Doe Bay Village Resort	Olga	NA	NA	NA	NA
WA	Goldmeyer Hot Springs	North Bend	NA	NA	NA	NA
WA	Soap Lake	Soap Lake	NA	NA	NA	NA
WA	Sol Duc Hot Springs	Clallam County	53	190	0.15	0.35
WY	Astoria Mineral Hot Springs	17 mi. So. of Jackson	40	379	0.29	1.93
WY	Auburn Hot Spring	Near Auburn	62	140	0.23	1.67
WY	Bronze Boot Spa	Near Cody	39	788	0.35	2.58
WY	Chief Washakie Plunge	Fort Washakie	44	568	0.59	3.98
WY	Cody Athletic Club	Cody	39	948	0.44	3.08
WY	DeMaris Hot Springs	Near Cody	36	1516	0.29	2.05
WY	Frank Nixon Residence	Saratoga	48	133	0.09	0.62
WY	Granite Creek Hot Spring	Teton County	NA	NA	NA	NA
WY	Hobo Pool	Saratoga	48	455	0.88	6.15
WY	Hot Springs State Park	Termopolis	57	11825	16.00	112.10
WY	Huckelberry Hot Springs	Grand Teton Nat'l Park	60	1137	1.23	8.61
WY	Jackalope Plunge	1 mi. So. of Douglas	30	3032	0.12	0.79
WY	Paynes Fountain of Youth RV Pk	Thermopolis	52	4624	4.45	31.20
WY	Steele Hot Springs	8 mi. E of Bouder-Sublette Co	39	95	0.06	0.53
WY	The Saratoga Inn	Saratoga	46	1706	1.32	9.23
	Subtotal				71.46	446.06
	Total				468.99	1778.87

	SITE	LOCATION	Temp (C)	Flow (L/min)	Capacity (MWt)	Annual Energy (GWh/yr)
GEOTHERMAL HEAT PUMP DATABASE						
AL	All of State		19	9475	3.81	3.46
AR	All of State	Mainly Eastern Portion	17	28425	34.90	31.17
AZ	All of State		17	NA	1.70	1.49
CO	All of State		11	NA	3.31	5.95
DE	All of State		14	23877	9.49	16.91
FL	All of State	Mainly Southern	24	985400	381.19	370.61
FL	Patrick Air Force Base	Melbourne	22	30320	11.60	40.67
GA	All of State	Southern Part Mainly	19	28425	11.31	10.08
IA	All of State		11	14402	10.81	19.31
ID	All of State		11	4624	2.40	5.27
ID	College of Southern Idaho	Twin Falls	39	4624	2.40	5.27
IL	All of State		12	50407	46.59	83.18
IN	All of State		12	191395	87.72	156.69
IN	Corporate Square	Terre Haute	13	NA	1.23	2.17
KS	All of State		14	9475	5.07	7.56
KS	Elementary Schools (3)	Garden City	15	1668	1.38	0.97
KY	All of State		15	25014	40.70	72.75
KY	Galt House		14	NA	15.82	28.27
LA	All of State		21	NA	41.61	37.09
MA	All of State		13	303	0.12	0.26
MA	English High School	Boston	13	303	0.12	0.26
MD	All of State		14	38279	21.59	38.62
MI	All of State		8	167518	62.41	167.10
MN	All of State		7	40553	16.61	44.54
MO	All of State		14	47754	24.90	22.27
MS	All of State		19	4548	1.79	1.64
MS	Commercial Buildings	Southern coastal area	21	NA	0.29	0.26
MS	Mississippi Power Co.	mainly southern part	21	NA	0.32	0.26
NE	Homestead National Monument	Beatice	14	121	0.06	0.09
NE	Northern Part of State	mainly Boyd & Keya Paho Co's	11	14402	10.81	19.31
NC	All of State		17	100435	42.40	37.88
ND	All of State	mainly the Fargo area	6	14402	8.70	23.21
ND	Buxton School	Fargo	6	NA	0.35	0.94
NJ	All of State		13	14402	10.81	19.31
NV	All of State		31	417	0.50	1.05
NV	Carlin High School	Carlin	31	227	0.26	0.59
NV	Wells High School	Wells	31	190	0.23	0.47
NV	Wells Rural Electric	Wells	NA	NA	0.00	0.00
NY	All of State	mainly north central	8	12128	6.39	17.02
NY	Sagamore Resort	Lake George (N. of Albany)	8	NA	1.23	3.22
OH	All of State		12	153116	59.89	106.91
OK	Central Part of State		17	1061	0.41	0.29
OR	All of State		20	26909	8.79	15.35
OR	Commercial Bldgs. (9)	Portland	NA	NA	0.00	0.00
OR	Thunderhead Lodge	Government Camp	20	493	0.35	0.67
PA	All of State		10	71631	31.94	56.93
PA	Factory at Masontown	S. of Pittsburgh	11	NA	0.29	0.50

	SITE	LOCATION	Temp (C)	Flow (L/min)	Capacity (MWt)	Annual Energy (GWh/yr)
SC	All of State	mainly along coast	19	67083	28.30	25.26
SD	All of State		8	11749	8.41	22.77
SD	St. Joseph Indian School	Chamberlain	23	3544	2.26	6.04
TN	All of State		16	4927	8.09	7.24
TX	All of State	Austin - 54 elem. schools & 1 new Jr. High	19	21603	91.50	81.78
UT	All of State	Salt Lake City	16	20087	7.91	13.86
VA	All of State	mainly along coast	15	23877	16.61	29.71
WA	Adams Co. Fire Station	Othello	27	38	0.06	0.06
WA	All of State		13	16676	6.62	14.62
WA	Casey House	Yakima	21	38	0.03	0.06
WA	Chinook Tower	Yakima	16	1895	0.91	1.93
WA	Clark College	Vancouver	13	NA	1.99	9.29
WA	Cowlite Co. Courthouse	Kelso	13	1516	0.88	1.76
WA	Dept. of Health & Social Serv.	Yakima	13	NA	NA	NA
WA	Elephant House at Zoo	Tacoma	NA	NA	NA	NA
WA	Farm Credit Services Bldg.	Yakima	NA	NA	NA	NA
WA	Grant County Courthouse	Ephrata	29	2274	1.08	2.46
WA	Grant Co. PUD	Ephrata	27	NA	NA	NA
WA	Nazarene Church	Yakima	NA	NA	NA	NA
WA	Red Cross Bldg.	Yakima	NA	NA	NA	NA
WA	Skove Bldg.	Yakima	NA	NA	NA	NA
WA	Sundown M Ranch	Yakima	NA	682	0.53	1.08
WA	Uelikamje, Moore & Shone, Inc.	Yakima	NA	NA	NA	NA
WA	Yakima County Jail	Yakima	24	2653	1.05	2.14
WI	All of State		8	81106	33.90	89.13
Z	Other States				538.53	615.56
					1773.28	2402.58
		Grand Total			2242.26	4181.45

NA - Not Available

APPENDIX C

Comparative Cost Analysis Between Geothermal System and Gas-Fired Boiler System

GEOTHERMAL SYSTEMS

1. Well cost - 1,000 ft

Assume: 1,000 ft well, q = 20 x 10^6 Btu/hr
60% hard drilling @ $6.25/in./ft
40% soft drilling @ $3.00/in./ft
Pump - 500 gpm @ 250 ft (lift) + 40 psi wellhead
500 gpm @ 342 ft set @ 300 ft oil
lube lineshaft @ 70% efficiency
bhp = (500 * 8.3 * 342)/(33,000 * 0.70)
= 61.4 or 75-hp driver

Drilling cost

Cost = 0.60 * 14 * 300 * $6.25	= $ 15,750
+ 0.40 * 14 * 300 * $3.00	= 5,040
+ 0.60 * 12 * 700 * $6.25	= 31,500
+ 0.40 * 12 * 700 * $3.00	= 10,080
	$ 62,370

Casing cost = 12 * 300 * $0.75	= $ 2,700
10 * 700 * $0.75	= 5,250
	$ 7,950

Pump cost - 300 ft/20 ft/stage = 15 stages

= [1570 + (510 * 15)] * 1.1	= $ 10,142
+ 10,142 * 0.60 (extra lateral)	= 6,085
+ wellhead assembly	= 2,500
+ enclosed lineshaft oil lube	= 12,570
+ 75-hp motor	= 6,500
	$ 37,797
Installation 2 days @ $75/hr	= 1,200
	$ 38,997

Well plus pump	$110,000
Plate heat exchanger @ 10^{o} approach	= $ 35,000
Piping - 1,000 ft buried	= $ 35,000
Injection well - 1,000 ft depth	= $ 70,000
	$250,000
20% Contingency	= $ 50,000
Cost Total System	= $300,000

O & M

Maintenance - overhaul pump @ 7-year interval
@ 60% of new cost
40,000 * 0.60 = $24,000
24,000 ÷ 7 = $ 3,430/yr

Electrical cost
Assume 40° ?T
1,000,000 Btu ÷ (40 * 8.33 * 1.0)
= 3,000 gal/10^6 Btu
3,000 gal ÷ 500 gpm = 6.0 min.
@ 93% motor efficiency
(61.5 hp * 745 kW/hp) ÷ 0.93 = 49.3 kW
49.3 kW (6.0/60) = 4.93 kWh/10^6 Btu
4.93 * $0.07/kWh = $0.34/$10^6$ Btu

Total geothermal heat cost calculation

@ 43% load factor - based on average of all direct use projects
Electricity = $0.34/$10^6$ Btu
Maintenance = $3430 ÷ (0.43 * 500 * 40 * 500 * 8760)/10^6)
= $0.091/$10^6$ Btu

Amortize geothermal system over 20 years @ 8%
= $30,555/yr
30,555 ÷ ((0.43 * 500 * 40 * 500 * 8760)/10^6)
= $0.81/$10^6$ Btu

Total cost/10^6 Btu
= 0.34 + 0.09 + 0.81
= $1.24/$10^6$ Btu

2. Boiler gas/oil combination system

Boiler - gas/oil combination 2 @ 10 x 10^6 Btu/hr, 620 BHP (includes material, labor, O & P)	$114,000

Boiler Accessories

Pump & motor set	2 @ 90 gal per hr	1,200
Fuel tank (2 days)		12,500
Stack 30 ft, 2 @ 30" 195/ft		11,700
Misc. controls/electrical/@ 15% boiler		17,100
Leak detection 3575 + 945 + 705 + 705 + 655 + 705		7,290
Fuel piping tank to boiler - oil		5,000
		$168,790
	20% Contingency	33,758
		$202,548

O & M

Maintenance @ 3%/yr installed cost
0.03 * 200,000 = $6000/yr

Fuel @ $3.43/$10^6$ Btu (Energy User News 3/94 - Avg. U.S. ind.)
@ 80% overall efficiency
Fuel cost = 3.43/.80
= $4.29/$10^6$ Btu

Total gas/oil boiler heat cost calculation

@ 43% load factor - based on average of all direct use projects

Maintenance = $6000/37,668 = $0.16/$10^6$ Btu
Fuel cost = $4.29/$10^6$ Btu

Amortize boiler system over 20 years @ 8%
= $20,370/yr
$20,370/37,668 = $0.54/$10^6$ Btu

Total cost/10^6 Btu = 0.16 + 4.29 + 0.54
= $4.99/$10^6$ Btu

APPENDIX D

Geo-Heat Center Publications

GEO-HEAT CENTER

The Geo-Heat Center, established in 1974, is unique in its expertise and information services. The staff consists of innovative experts in the field of geothermal direct-use and small-scale power production. 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.

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 outset 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 processes, and low-temperature wellhead electric power generation, will be allocated a limited number of man-hours for analysis (based on merit) per project. A site analysis may involve: site visit to gather information, resource evaluation based on published information and/or well profiling and water testing, application of engineering principals to determine development options and costs, economic analysis, flow diagrams, and explanation of proposed systems.

LIBRARY - The Center maintains a geothermal library of over 5,000 volumes for lay and technical readers. Volumes are available for loan by writing the GHC librarian, and you may request a GHC library subject matter listing.

PUBLICATIONS -A quarterly bulletin featuring domestic and foreign research and development is available. Technical material on resources, direct-use equipment and design schemes, and feasibility studies may be obtained by writing the GHC. The following "Publications Request Form" lists information available from the:

Geo-Heat Center
Oregon Institute of Technology
3201 Campus Drive
Klamath Falls, OR 97601
Tel: (503) 885-1750
Fax: (503) 885-1754

PUBLICATIONS REQUEST FORM

Geo-Heat Center
Oregon Institute of Technology
3201 Campus Drive
Klamath Falls, OR 97601

Due to budget restrictions, please limit your request to a maximum of five summary papers, reports and studies.

Quarterly Bulletin
1975 - Present

A quarterly Bulletin informs the geothermal technical community and the public on progress in research and development activities of direct heat utilization of low-temperature resources. This periodical provides valuable "how to" articles on various geothermal applications and equipment. It has been published since 1975 and currently has over 2,000 subscribers. Back issues of this periodical are available upon request.

☐ Please include my name on the mailing list for the Bulletin.

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GEOTHERMAL DIRECT-USE ENGINEERING AND DESIGN GUIDEBOOK

The 3rd Edition of the "Geothermal Direct-Use Engineering and Design Guidebook" is available. Engineers and developers will find technical information on low- and moderate-temperature (100º - 300ºF) geothermal applications and equipment. Chapters cover exploration, well drilling, space heating and cooling, greenhouse heating, aquaculture, industrial processes, economics, regulations and environmental aspects; 470+ pages.

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