GEOTHERMAL ENERGY UTILIZATION FOR THE HOMEOWNER

by

John W. Lund
Geo-Heat Utilization Center
Oregon Institute of Technology
Klamath Falls, Oregon 97601

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Oregon Department of Energy
111 Labor & Industries Building
Salem, Oregon 97310

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The purpose of this article is to describe how geothermal energy can be utilized for residential space heating. Background information on the resource introduce this natural source of energy, followed by an explanation of the development of the resource (mainly by drilling wells) and the extraction of the energy. Various types of heat convectors and heat exchangers are described, along with how to estimate energy requirements and the associated costs. Finally, regulations and tax advantages are covered together with additional sources of information and a list of agencies who can provide assistance.

2. RESOURCE

What is geothermal energy? It is the natural heat from the earth due to volcanic activity or radioactive decay from molten rock, heating the surrounding rock and/or ground water.

Where does geothermal energy occur? It is generally found in volcanic regions of recent geologic origin, and associated with faulting and buried permeable rock layer (aquifers).

What are the types of geothermal resources? The most common occurrence is in the form of low temperature hot water (below boiling). Other less common forms are high temperature hot water (above boiling), some of which will flash to steam when exposed to atmospheric pressure and dry steam, the latter being very rare. It may also occur as heated ground without water (hot dry rocks).

The higher temperature resources (above 350°F) are considered economical for power generation and industrial process heat, whereas the lower temperatures are used mainly for space heating, agriculture (greenhouses), and aquaculture (fish and shrimp raising). Water temperatures as low as 60°F can be used for space heating in conjunction with a water-to-air heat pump.

What are the characteristics of geothermal waters? Fortunately for Oregon, use of its geothermal resources can have a negligible impact on the environment due to the normally high water quality and the minimal construction disturbance caused by the more common direct heat applications.

In general, the chemistry of the water depends upon the type of rock through which it flows, the temperature of the rock and/or water, the retention time of the water in the aquifer, and the amount of mixing with colder ground water. Oregon geothermal water tends to be generally potable and low in total dissolved solids (TDS), typically below 1,000 parts per million (ppm) or milligrams per liter (mg/1), with a pH around 8 (basic). The major dissolved solids are sulfates, carbonates, bicarbonates, sodium, silica, and minor amounts of iron, potassium and chloride. A total dissolved solids of 3,000 to 5,000 ppm are not unusual, which will present more of a problem if used in heating systems due to scaling.

Some dissolved gases are associated with the water, mainly oxygen, ammonia, carbon dioxide and hydrogen sulfide (rotten egg smell), however, these are generally low. Much of the geothermal water in the state is artesian, resulting in a rise of the water level in a well when the producing aquifer is encountered in drilling.

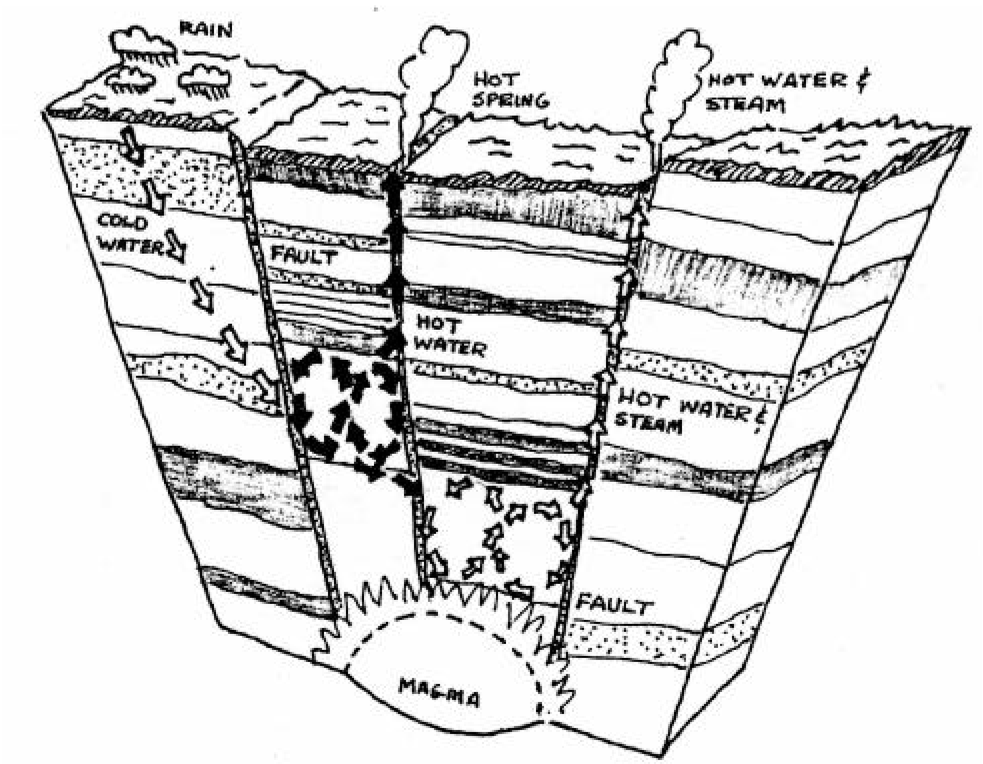


Figure 1. Model of a hot water geothermal system.

<u>How can a geothermal resource be identified?</u> Two of the best indicators of potential geothermal areas are:

- a: hot springs and
- b: hot or warm water wells in the area.

Delineation of possible reservoirs can be accomplished with detailed investigations by professionals using geology and surface alterations from past geothermal activities, geophysical methods (seismic, resistivity, gravity, magnetics, etc.), and temperature gradient holes. However, due to the high costs of these methods, they are generally used for larger installations such as for the location of industrial processing plants, electrical power plants, etc. Agencies that can provide information on resources throughout the state are listed in the Appendix.

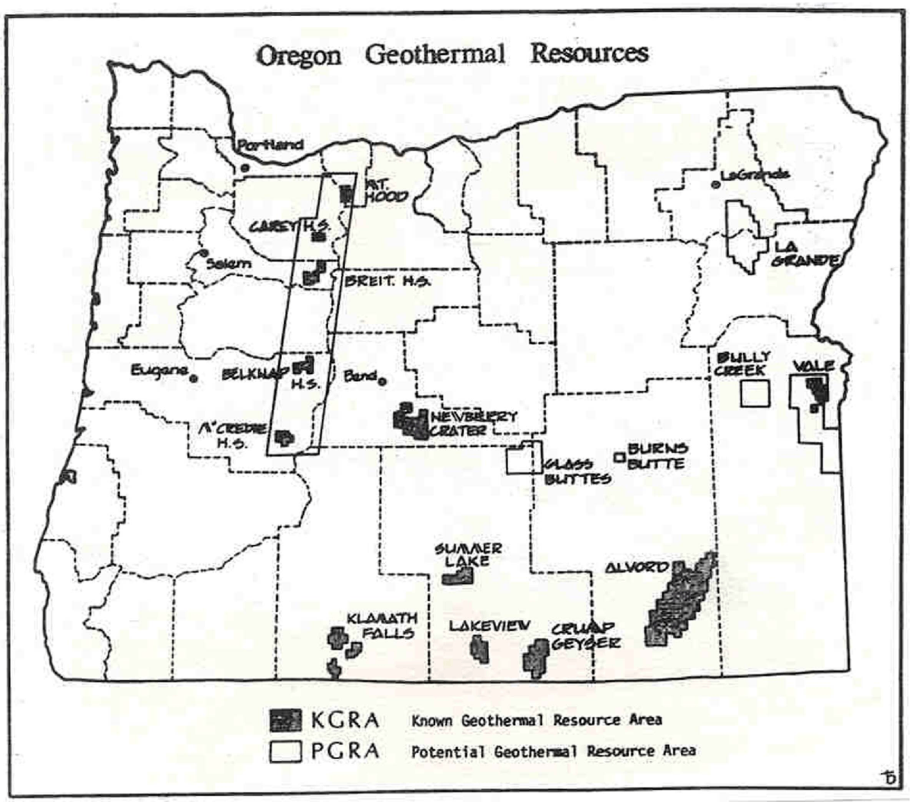


Figure 2. Map of Oregon's geothermal resources.

3. DEVELOPMENT

<u>Hot water springs.</u> When these are available they are the easiest and least expensive to use for heating applications. Little development is necessary as they can be used directly, especially in rural areas. However, fluctuations in water flow and temperature due to the seasons and adjacent use may limit the reliability of this source. Higher temperatures may exist at depth, and thus not be available with surface use.

<u>Hot water wells.</u> The more common development is to drill a well. This will minimize the impact of water level fluctuations and cooling near the surface, and increase the number of locations in which geothermal resources can be found.

For the more common low temperature resources, only the normal well drilling equipment will be necessary. The drilling equipment consists of two major types:

a. cable or percussion drilling using water and
b. rotary bit drilling using air pressure, water or drilling mud.

Drilling and casing standards are set by the Oregon Water Resources Division (WRD) and the State Department of Geology and Mineral Industries (DOGAMI). Wells with temperatures below 250°F and less than 2,000 feet in depth are considered a ground water resource and come under the jurisdiction of WRD. Wells expected to exceed either of the above depth and temperature values come under the jurisdiction of DOGAMI, as they are considered a geothermal resource. The former can be drilled with conventional cold water drilling equipment, whereas the latter require special drilling rigs and equipment (such as blow-out preventers). In all cases the driller must be licensed by the State, and local permits may be required for ground water resources and State permits required for geothermal resources. The well driller will normally apply for these permits and also must file a drilling log with WRD upon completion of the well. Copies of the applicable regulations and well completion standards can be obtained from the offices of WRD and DOGAMI (addresses listed in the Appendix I).

Drilling. Shallow geothermal wells vary from 6 to 24 inches in diameter, with 8 to 10 inches being most common. The size depends on the requirements for casing, heat exchangers and pumps. Drilling rates vary from a few feet per day to over a hundred, depending upon the rock type. Rotary drilling is usually much faster than cable drilling, but both methods will cost about the same.

Drilling fluids are necessary to lubricate the drilling tool, reduce the heat from drilling and provide a means of removing the cuttings from the hole. Water is the most common fluid used, and along with air the easiest and least costly to use. Drilling muds, generally a bentonite clay and water mixture, are necessary to prevent collapse of soft formations, sealing fractures in formations and other requirements. When using drilling muds, the well should be cleaned by pumping or other means immediately after drilling, otherwise the water bearing formation may be sealed. If possible, the use of drilling mud should be avoided, especially near the water-bearing formations.

Costs are generally charged per foot of drilling with one value for soft rock and one for hard rock. Typical costs in Klamath Falls are $1 per inch of diameter per foot of depth for soft rock and $2.50 per inch for hard rock. Costs will vary slightly elsewhere in the State. Using the Klamath Falls prices, a 200-foot well with 150 feet of soft rock and 50 feet of hard rock, 10 inches in diameter would cost:

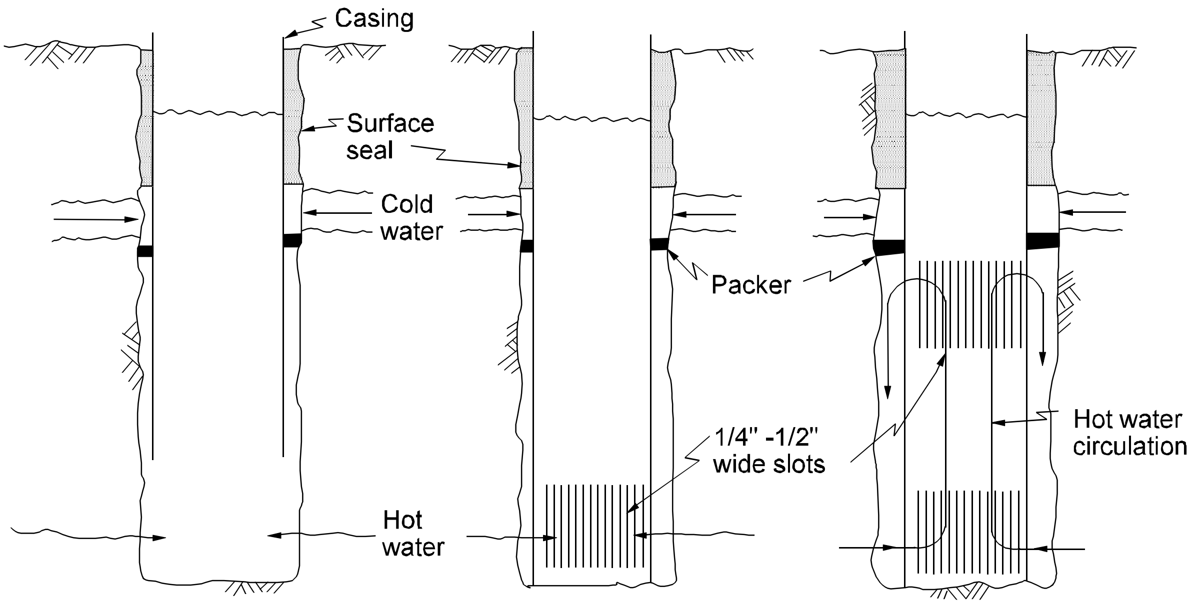
	150 x 10 x $1.00 =	$1,500.00
+	50 x 10 x $2.50 =	1,250.00
	Total =	$2,750.00

Depths below 500 feet will usually require additional costs. Move-in and move-out costs and standby time may add to the price.

Casing. Minimal surface casing or full-depth casing may be set, depending upon regulations and intended use. Steel casing of 1/4- to 5/16-inch thickness is typical, however, under certain conditions, concrete and high temperature fiberglass may be used.

The diameter of casing selected is the largest the hole can accept, except in the case where downhole heat exchangers are used, then a 2-inch clearance is desirable.

In all cases, provisions are made to seal off (with a packer) all cold water flows and other hot water flows of differing pressure than the flow to be used (Oregon WRD requirements). The casing is either stopped short of the usable aquifer or slotted to allow flow through the casing. With downhole heat exchangers the casing should also be slotted near the water surface (or below the packer) to allow proper heat circulation.



a. Short casing. b. Full depth casing. c. Downhole heat exchanger casing.

FIGURE 3. Typical examples of well casing programs.

Casing costs usually run slightly over \$1 per inch of diameter per foot of depth. Thus, an 8-inch diameter casing for our 200-foot example well would cost:

$$200 \times 8 \times \$1.00 = \$1,600.00$$

for a total drilling and casing cost of \$4,350. Grouting, the packer, driving shoe and other items may add to this cost and will vary from area to area with the state; thus, local licensed drilling contractors should be contacted for specific cost information. Consulting engineers and consulting geologists can also provide drilling information.

<u>Pumps</u>. For some heating installations, pumps will be required to extract water from the well. For shallow depths, suction pumps and jet pumps can be used. For depths below about 100 feet, deep well turbine pumps are necessary. Oil lubrication of the shaft bearings for turbine pumps is usually necessary for the high-temperature geothermal water. Pump costs will vary from several hundred to several thousand dollars, depending upon pumping depth and quantity of flow. In most cases, standard off-the-shelf products are adequate. Local pump contractors and distributors can provide advice, information, and service.

Installed pump costs can be approximated by assuming $400/hp for deep well pumps. For most residential demands, deep well pumps of less than one horsepower are adequate. This type of pump will handle flows up to 25 gallons per minute (gpm) and lifts up to 100 feet.

The horsepower requirement can be calculated from the following equation (assuming 85% pump efficiency):

$$HP = \frac{8.33 \text{ x GPM x Lift (ft)}}{550 \text{ x } 60 \text{ x } .85} = \frac{\text{GPM x Life (ft)}}{3370}$$

As an example, a well pump to handle 25 gpm and a 100-foot lift would require:

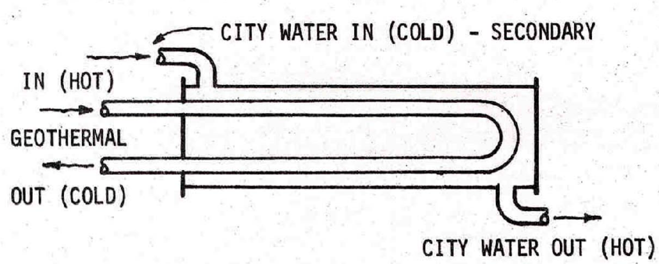
$$HP = \frac{8.33 \text{ x } 25 \text{ x } 100}{550 \text{ x } 60 \text{ x } .85} = \frac{25 \text{ x } 100}{3370} = 0.74 = 3/4 \text{ hp}$$

This pump would then cost approxiamtely:

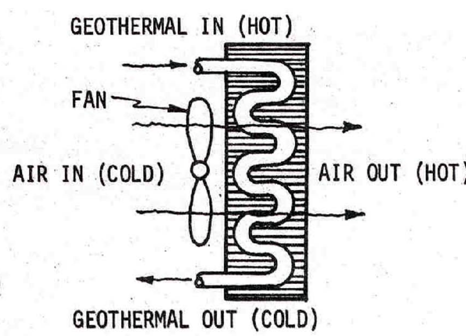
$$3/4 \text{ x } \$400 = \$300$$

4. HEAT EXCHANGERS AND HEAT CONVECTORS

General information. Heat exchangers and heat convectors (emitters) are devices that transfer heat (energy) from one media to another, such as from a geothermal fluid (primary) to city water (secondary) or to air. Examples of typical devices are shell-and-tube heat exchangers (water-to-water) and fan coil heat convectors (water-to-air). Details of specific types will be discussed later.



a. Shell-and-tube heat exchanger. (water-to-water)



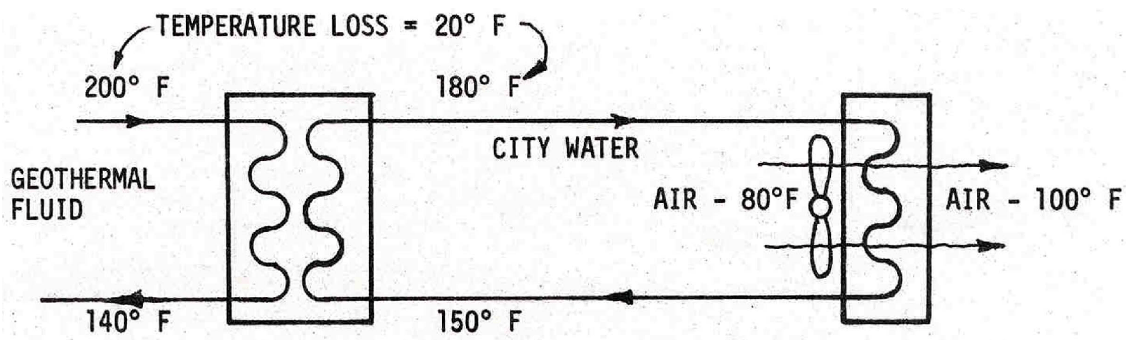
b. Forced air heat convector. (water-to-air)

FIGURE 4. Typical Examples of Heat Exchangers and Heat Convectors.

The term heat exchanger is used for devices that transfer heat at the well head or in centralized locations before the geothermal fluid enters the main heating system. These heat exchangers are used to minimize possible corrosion, scaling, or fouling of pipes, valves and other fittings in the heating system. This is especially important in highly corrosive or high mineral content fluids, and where large temperature drops may occur across heat convectors. Large temperature drops will cause minerals to precipitate out more readily and thus foul heating convectors.

The term heat convectors (or emitter) is used for devices that actually provide or transfer heat to the room or space in the residence. In some cases, the geothermal water may be used directly in the heating system and heat convectors. This will be possible for fairly benign fluids (low total dissolved solids). It is the only practical solution for low-temperature primary geothermal water (below about 120°F), however, this will in turn require larger and thus more expensive heat convectors.

The main disadvantages with heat exchangers are cost and the loss in temperature across the heat exchanger when transferring the heat from the primary to the secondary fluid. For example, a 200°F geothermal fluid may only be able to heat the secondary fluid to 180°F (resulting in a 20°F temperture loss). The smaller the temperature loss required, the more expensive the heat exchanger. For residential use, a typical temperature loss across the heat exchanger would be 20° to 30°F. The minimum practical loss would be around 10°F.



Heat Exchanger Heat Convector

FIGURE 5. Example of heat exchanger and heat convector showing temperature losses.

Two types of heat exchanger and/or heat convector design and installations are of interest:

a. new construction where only a geothermal heating system is considered and
b. retrofitting an existing fossil fuel system to handle geothermal.

In both types of installations energy requirements for space heating, domestic hot water and other services (swimming pools, greenhouses, pavement snow melting, etc.) can be provided. In almost all cases, except for extremely low temperature fluid (below 140°F for domestic hot water and 100°F for space heating), the geothermal system can provide all of the heating needs. For this reason, a back-up system is normally not required (unlike solar heating). In the case of retrofitting, the existing system may be used as a back-up for breakdowns or for peaking of low temperature geothermal fluids in colder weather.

Geothermal fluids between 60° and 90°F can be used in heat pumps to provide both space heating and cooling. Temperatures above 180°F can be used for cooling in normal absorption refrigeration units. The following diagram illustrates the ranges of temperatures for various types of heating and cooling methods.

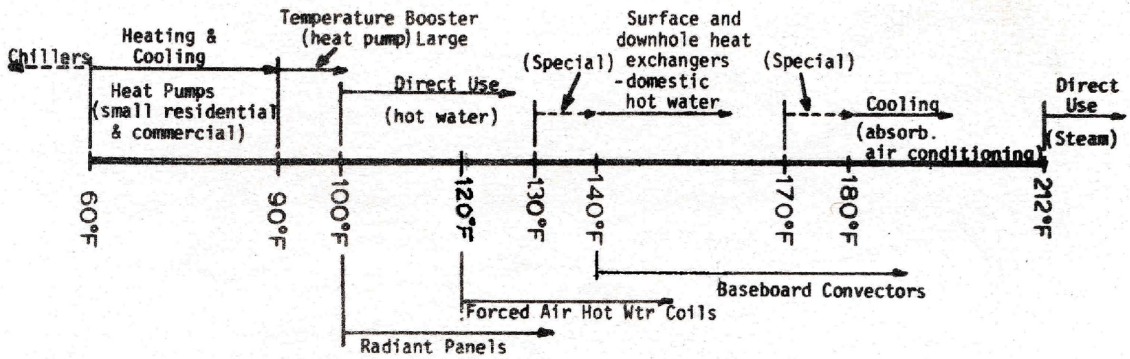


FIGURE 6. Temperature ranges for heating and cooling methods.

Heat exchangers. Three main types of heat exchangers are of interest for residential space heating:

a. shell-and-tube heat exchanger,
b. plate heat exchanger, and
c. downhole heat exchanger.

The first two listed above would be place above ground either at the well head or at a central location inside the residence. These are both commercially available units, however, the shell-and-tube heat exchanger could be constructed by a local machine shop or welding shop. The shell-and-tube type consists of U-shaped tubes inside a cylindrical shell, with the primary fluid flowing inside the tubes (see FIGURE 4a.). The plate heat exchanger consists of a series of stainless steel plates held in a rack by rods, allowing the primary and secondary fluid to counterflow across the plates. The plate heat exchanger has an advantage in that it is more efficient, requires smaller space, and is more accessible and easier to expand to meet additional heating load. Both of these two types of heat exchangers would require disposal of the geothermal fluid after it has passed through the primary side. The most environmentally acceptable method is to dispose of the fluid in an injection well.

The downhole heat exchanger avoids the problem of disposal of the geothermal fluid since only heat is "pumped" from the well. It has the disadvantage of extracting less heat than the other types, however, initial costs are less. From 100 to 300 feet of 2-inch diameter pipe below the water surface are needed to heat an average residence. A rough rule-of-thumb is to use 1 foot of double pipe below the water surface for every 2,000 BTU/hr (peak heating load) needed for well temperatures above 170°F, and 1,500 BTU/hr (peak heating load) for well temperatures below 170°F. In either case, a minimum of 50 feet should be used, unless a specialized design is considered (Reference 2).

It should be noted that the use of downhole heat exchangers require special well completion techniques that were described in the Well Drilling and Casing section of this paper. In addition, it may be necessary to provide electrical isolation junctions at the surface to reduce downhole electrolysis problems. Additional details may be found in References 2, 6 and 7. The following figures indicate some of the possible combinations of downhole heat exchangers and domestic hot water connections.

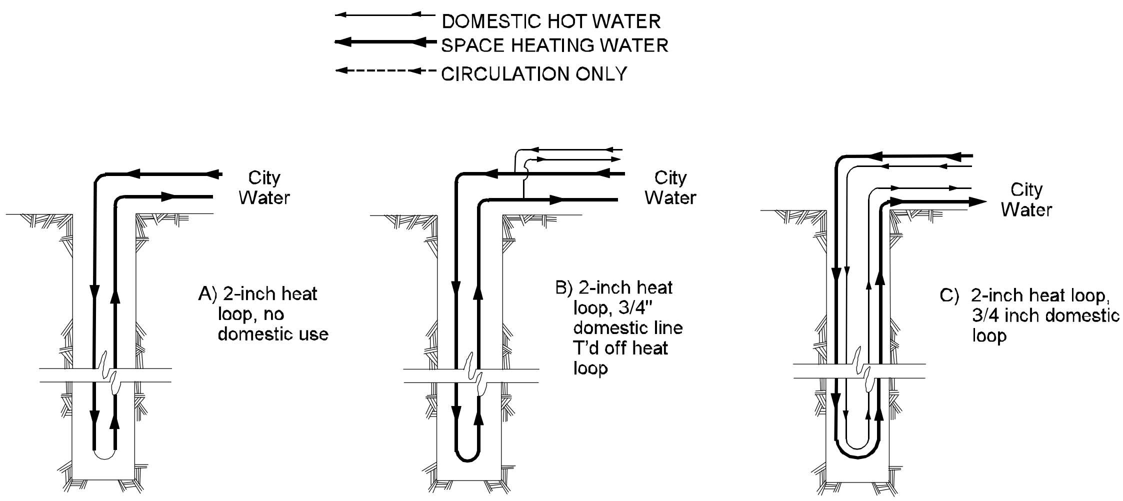


FIGURE 7. Downhole heat exchanger systems.

Heat convectors. Three major types of heat convectors (emitters) are used for space heating:

a. forced air,
b. baseboard convection, and
c. radiant panels.

All can be adapted directly to geothermal or converted by retrofitting existing systems. Retrofitting existing systems may require larger fan coil units or additional baseboard convectors if the fossil fuel system required a high design temperature (above 200°F) or the geothermal fluid has a low temperature (generally below 150°F). The details of each type of system are as follows:

Forced air. This system heats the incoming cold air by finned tube hot water coils and then distributes the heated air to the residence by ductwork to vents, usually located on outside walls. These units can economically use fluids of 120°F and higher with temperatures above 160°F being most efficient. One major advantage of forced air systems is the ability to incorporate air conditioning at a small additional cost. Retrofit would normally only require the replacement of the finned tube hot water coil with a larger unit, adding a second unit in the duct system or increasing the speed or size of the fan. The distribution system (ductwork) would not have to be modified. A new fan coil unit would cost from $200 to $300 for a typical residence.

Baseboard convection. This system uses hot water as the heat transfer medium where the hot water is distributed to convector units located at the base of outside walls. Fins attached to the piping transfer the heat to the room by means of natural convection. These units are economical above 140°F with above 160°F being the best range. The efficiency of the unit can be increased to use lower temperature water by placing a fan behind the unit to help circulate the air. Depending upon the temperature, retrofitting the system would require additional units or lengthening existing units. The retrofit costs would vary from $200 to $500 for a typical residence.

Radiant panels. This system is located in floors, walls or ceilings and radiate heat to the room. Hot water is circulated in coils of pipe (usually plastic or copper) imbedded in concrete or plaster. Their main advantage is the uniform heat provided without a draft and the lower temperature fluid that can be used. Use of fluid temperatures as low as 100°F are possible. The main disadvantage of this system is that it is difficult and expensive to repair if problems develop (especially leaks). This method is popular in garage and basement floors and for melting snow on driveways and sidewalks.

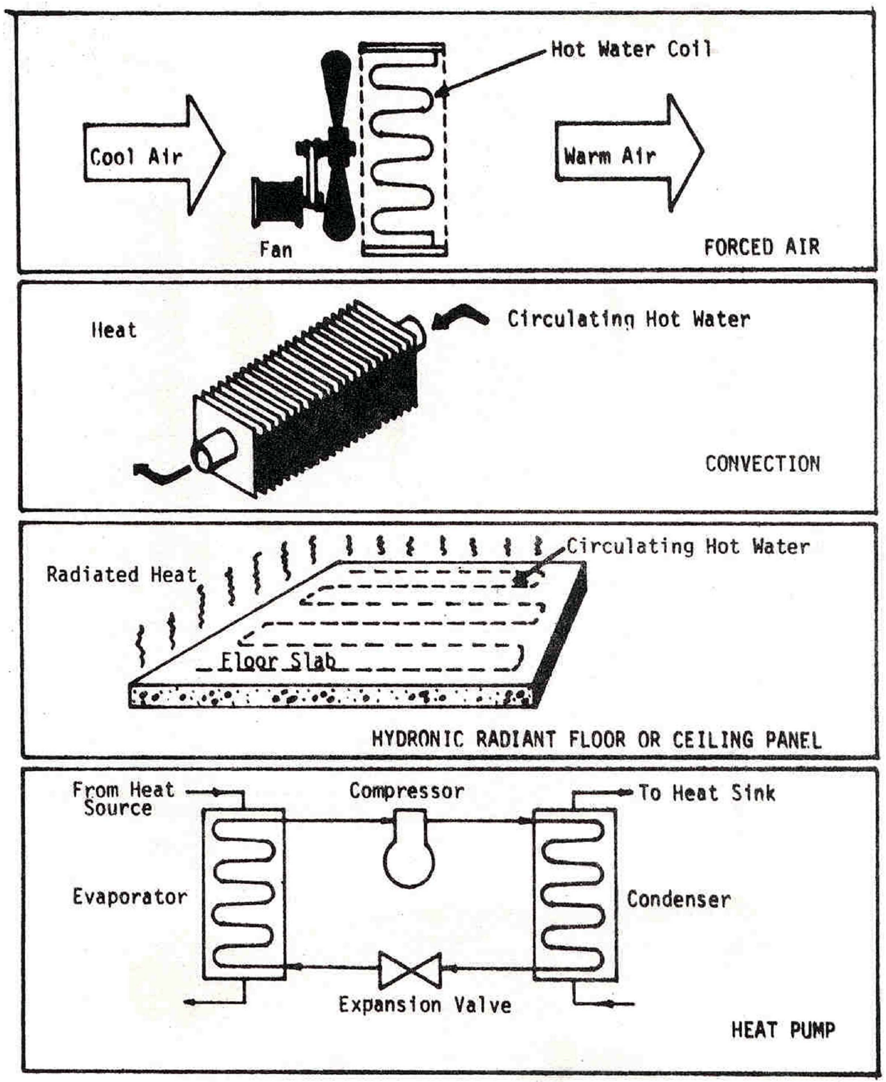


FIGURE 8. Typical heat convectors and heat pump.

Heat pumps. This system is essentially a reversible refrigeration unit for both heating and cooling, using a fluid with a low boiling point. When used for heating, heat is extracted for the geothermal fluid (well) and discharged into the room through a standard forced air system. The process is reversed for cooling. Geothermal water-to-air units have an advantage over the typical air-to-air units relying on outside air, as the latter lose efficiency when the outside temperature drops to near freezing (heating) or when the temperature rises near 100°F (cooling). With geothermal, the source (well) temperature remains nearly constant. The efficient operating range for geothermal fluids is 60° to 90°F, with 70° to 80°F optimum.

5. HEATING SYSTEM DESIGN AND COST

A typical heating system using a downhole heat exchanger is shown in FIGURE 9. The heat emitters can be one of the three described earlier– forced air, baseboard convection, or radiant panels. The downhole heat exchangers could be replaced by a well-head pump and a shell-and-tube or plate heat exchanger. An injection well or other means of disposal would be required for the latter two heat exchangers. In addition to the items already discussed, the following must be considered in the total system design.

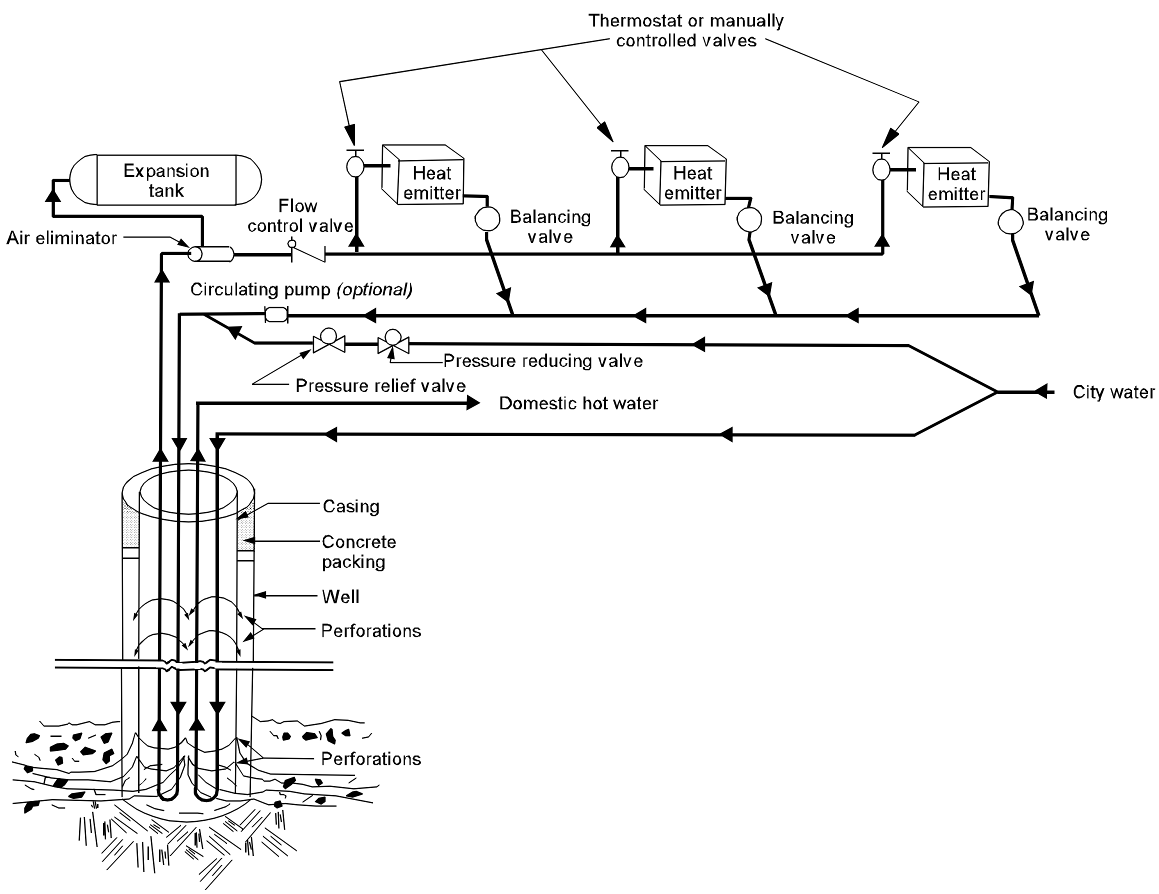


FIGURE 9. Typical hot water distribution system using a downhole heat exchanger.

Piping from well to residence. In general, the well will be located some distance from the residence. A buried pipeline from the well to the residence is the most typical means of transporting the heated water. Steel pipe is the best to use, however, possible corrosion by ground water and soil must be considered. Plastic pipe can be used to overcome the corrosion problem, however, many types have temperature limitations. Polyvinyl chloride pipe (PVC) is limited to 150°F, chlorinated polyvinyl chloride pipe (CPVC) can extend this range to 250°F. Fiberglass-reinforced plastic pipe (FRP) has a maximum operating temperature of 210°F , and asbestos cement a maximum of 200°F. The manufacturers' recommendations should be checked before using any of these pipe materials.

For pipeline distances of less than about 200 feet, insulation will probably not be necessary as the temperature loss will be minimal. Depending upon the temperature of the fluid in the pipe and the tolerable loss in temperature, longer transmission distances may require insulation. In addition to minimizing the heat loss of the fluid, the insulation must be waterproof and water tight. Ground water can destroy the value of any insulation. Above-ground and overhead pipeline installations can be considered in special cases. Insulation will probably be necessary in both of the latter two cases as they will be exposed to wind which can remove considerable heat.

Circulation pumps. Natural thermal convection is often adequate to provide water circulation in heating systems, especially those with downhole heat exchangers. A circulation pump may be required in the heating system to increase the flow of the fluid through the heat convector (to increase the heat transfer rate). This may be necessary for low-temperature geothermal fluids or in extremely cold weather. It will be mandatory when two or more residences share the same well to balance the heat load. Generally, a pump from 1/6 to 1/2 horsepower will be adequate, costing around $100.

Controls. Thermostatically controlled valves are desirable to control the heat within a residence. This is especially important with zoned heating systems, where each zone will have a thermostat. Local heating and ventilating contractors can provide detailed information and costs.

Heat load. The heat load for a residence is best determined by a heating contractor or an architect. If the home is of recent construction, this information may already have been determined when the heating system was designed. If none of this information is available, the Appendix includes a simplified method for determining the heat load. Heating loads calculated by this procedure are included only for estimating purposes and should not be used for actual sizing of a heating system.

Heating system costs. A number of items need to be considered in determining the cost of a geothermal heating system. Certain components are unique to geothermal and others are standard regardless of the fuel source (geothermal or fossil fuel). In addition, the use of geothermal energy accrues some savings that must be taken into consideration, such as no furnace required, protection against future escalation of fossil fuel prices, and state and federal tax incentives.

Geothermal component capital costs. These requirements have been discussed in detail in previous sections and are summarized here.

a. Well drilling: ($10 to $25/ft).
b. Well casing: ($8 to $12/ft).
c. Well-head pump: ($400/hp).
d. Heat exchanger:

(1) shell-and-tube or plate: ($10/1,000 BTU/hr– peak heating load).
(2) downhole: ($4/1,000 BTU/hr–peak heating load).

e. Heat pump: ($65/1,000 BTU/hr–peak heating load).
f. Circulation pump: ($100–under 1 hp).

Non-geothermal component capital costs. These are components common to any heating system, except for retrofit and oversizing costs.

a. Heat convectors (emitters):

(1) forced air: ($45/1,000 BTU/hr–peak heating load).
retrofit cost: $200 to $300.
(2) baseboard convection: ($30/1,000 BTU/hr–peak heating load).
retrofit cost: $200 to $500.
(3) radiant panels:
floor: ($40/1,000 BTU/hr–peak heating load).
ceiling: ($75/1,000 BTU/hr–peak heating load).

b. Oversized heat convectors–additional cost due to geothermal use–add 15% to the above costs for supply water temperatures below 150°F.
c. All of the heat convector costs include ductwork, wiring, controls, heating coils, fans and installation.

Annual operating cost. Depending upon the design, these may be common to both geothermal and fossil fuel systems.

a. Electricity costs to run fans, etc., for heat convectors ($25 to $50/year).
b. Electricity costs to run heat pump ($150 to $250/year).
c. Maintenance and replacement costs will vary considerably depending upon the initial workmanship, quality of components, level of preventive maintenance, etc., ($25 to $200/year, half of which is due to the geothermal component).

Comparison with fossil fuel costs. The best method to compare geothermal costs with standard fossil fuel costs (fuel oil, natural gas, electricity, coal, wood, etc.) is on an annual cost basis allowing for 10 to 15% interest on the investment. Service life is generally around 20 years for most of the heat exchangers, heat convectors and other heating components, and 50 years for the well and casing. Only the geothermal component capital costs and annual operating costs need be compared with fossil fuel costs and their associated operating and maintenance costs. Costs common to both need not be considered for the comparison. An example of annual cost calculations is presented in Appendix V.

Simplified cost estimating method. A simplified method of making a rough estimate for the annual cost of owning and operating a geothermal heating system is shown in FIGURE 10. This figure is based on using a downhole heat exchanger and includes the cost of the well, casing, downhole heat exchanger, pipeline to the house, and the annual maintenance cost. The ductwork, in-house piping, circulation pump and heat convectors are not included as most of these costs are common to all types of heating systems. The cost of capital was figured at 12%. Since the well costs are the majority of the total expenses, the figure is based on well depth and thus can be used for estimating the costs of most types of geothermal systems. The annual fossil fuel costs for a 2,000-ft^2 home is shown for comparison. The effect of the State and Federal tax credits and future fossil fuel price escalation are also shown.

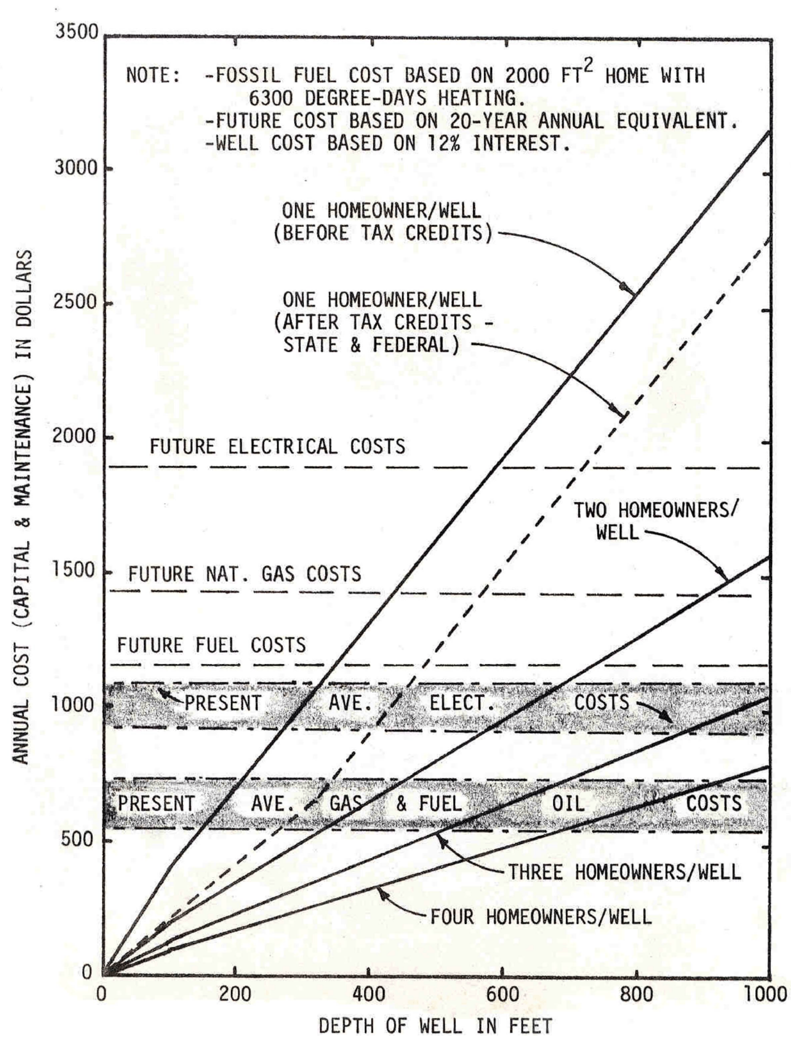


FIGURE 10. Annual geothermal well cost.

Use of a geothermal well by more than one homeowner. FIGURE 10 indicates that for well depths greater than about 300 feet, the annual costs will exceed most conventional fuel costs ($1,000/year). To justify the expense of geothermal wells over 300 feet deep , the heat load must be increased by either providing heat to a larger structure (over 2,000 ft^2), or to more than one structure. FIGURE 10 indicates the reduction in cost if two, three, or four homeowners shared one well ($500, $330, and $180 per year respectively). In most cases, a 10- to 12-inch diameter well with 8-inch diameter casing can handle at least four average homes with downhole heat exchangers. This multiple use should be considered to make more efficient use of the geothermal resource in the State. Considering future escalation of fossil fuel prices and geothermal tax credits would make geothermal more attractive.

6. GEOTHERMAL TAX CREDITS

State of Oregon tax credits. Senate Bill 339, passed in 1977, established a tax credit for alternative energy devices in Oregon, which includes geothermal. This law provides for a state income tax credit amounting to 25% of the costs (well, heat exchangers, heat emitters, etc.), up to $1,000, of an alternative energy system (solar, wind, or geothermal) which provides at least 10% of the home's total energy requirements.

To qualify for the tax credit, the residence's system must be approved (certified) by the Oregon Department of Energy before it is installed. The Oregon Department of Energy will supply the necessary forms and certify the system based on the information provided on the form. When the approved form is returned to the homeowner, the system can then be installed. This law is in effect until January 1, 1985.

For more information, call the Department of Energy at the Access 800 toll free number: 1-800-452-7813 (in Salem, call: 378-4040), or write:

Department of Energy
Labor & Industries Building
Salem, OR 97310

The State of Oregon also has a Weatherization Tax Credit program. This allows an Oregon income tax credit of 25% of the cost of weatherizing your home, up to $125. A weatherization certification lists the items which qualify for the tax credit. For additional information, call the Oregon Department of Revenue at this toll-free number: 1-800-452-2838 (in Salem, call: 378-3366).

Federal tax credits. The 1978 National Energy Tax Act provided for tax credits from geothermal energy property and for energy conservation property. The geothermal energy property includes items installed to heat or cool a person's principal residence (including providing hot water). The installed property must be expected to remain in use for at least 5 years and the owner must be the first person to use the item. Items that do not qualify for the credit are heat pumps and greenhouses. The credit allowed is 30% on the first $2,000 and 20% on the next $8,000 for a maximum of $2,200. Any unused credit can be carried over to succeeding years.

The energy conservation property includes the cost of items such as insulation, storm windows and doors, weatherstriping, etc., installed in the owner's principal residence. The credit is 15% of the costs for a maximum of $300.

For additional information, see IRS Form 5695 and Publication 903, "Energy Credits for Individuals." These may be obtained from: Form Distribution Center, Post Office Box 12626, Fresno, California 93778, for Oregon residents. The law is in effect until January 1, 1986.

7. SUMMARY

The items to be considered in a geothermal heating system may be summarized as follows:

a. Residence

  (1) Heat load determination.
  (2) Cost calculations and comparisons.

b. Well

  (1) Drilling (depth, diameter, hard vs. soft rock).
  (2) Casing (thickness, length, diameter, perforations).
  (3) Pump–if required (type, lift, horsepower).
  (4) Piping from well to residence (size, length, insulation).

c. Heating System

  (1) New or retrofit.
  (2) Heat exchangers–if required.
    (a) shell-and-tube
    (b) plate
    (c) downhole

  (3) Circulation pumps–if required (horsepower).
  (4) Heat emitters.
    (a) forced air
    (b) baseboard convection
    (c) radient panels

  (5) Heat pump (well water temperature range).
  (6) Additional heat load.
    (a) domestic hot water
    (b) pavements
    (c) greenhouse

(d) swimming pool
(e) others

d. Paper Work

(1) Oregon Tax Credit Certification (before installing system)– homeowner.
(2) Federal Tax Credit–homeowner.
(3) Well drilling permit (City or County)–well driller.
(if > 250°F or 2,000 feet deep, State DOGAMI permit required)
(4) Well log–after completion–well driller
(5) Building permit (City or County)–contractor or homeowner.
(6) Disposal permit (City or State)–homeowner.

APPENDIX I

AGENCIES TO CONTACT FOR ASSISTANCE

Oregon Department of Energy
111 Labor & Industries Building
Salem, OR 97310
1-800-452-7813
(In Salem, call: (503) 378-4040)

Geo-Heat Utilization Center
Oregon Institute of Technology
Klamath Falls, OR 97601
(541) 885-1750

Oregon Water Resources Division
Mill Creek Office Park
555 13th Street, N.E.
Salem, OR 97310
(503) 378-8455
(County Water Master can provide assistance.)

Oregon Department of Geology and Mineral Industries
1069 State Office Building
Portland, OR 97201
(503) 229-5580
(Field offices in Grants Pass and Burns)

Geothermal Direct Applications
Idaho National Engineering Laboratory
U.S. Department of Energy
550 Second Street
Idaho Falls, ID 83401
(208) 526-0111

U.S. Department of Energy
San Francisco Operations Office
1333 Broadway
Oakland, CA 94612
(415) 273-7943

APPENDIX II

REFERENCES ON GEOTHERMAL

General

[1] Armstead, H. Christopher, Editor, Geothermal Energy - Review of Research and Development, UNESCO, Paris, 1973 (can be ordered from UNIPUB, UN, New York).

[2] Kruger, Paul and Carel Otte, Editors, Geothermal Energy - Resources, Production, Stimulation, Stanford University Press, Stanford, California, 1973.

Space Heating

[1] Culver, G. Gene, Optimization of Geothermal Home Heating Systems, Contract No. E-(10-1)-1548, ERDA, Geo-Heat Utilization Center, Klamath Falls, Oregon, October, 1976.

[2] Culver, Gene & Gordon M. Reistad, Final Report: Evaluation and Design of Downhole Heat Exchangers for Direct Application, Geo-Heat Utilization Center, Klamath Falls, Oregon, December, 1978.

[3] Engen, I. A., Residential Space Heating Cost: Geothermal vs. Convectional Systems, TREE-1182, EG&G, Idaho National Engineering Laboratory, Idaho Falls, Idaho, February, 1978.

[4] -----, Geothermal Space Heating, EG&G, Idaho National Engineering Laboratory, Idaho Falls, Idaho, September, 1978. (Single-page monograph with charts.)

[5] Lienau, Paul J., Space Conditioning with Geothermal Energy, Geo-Heat Utilization Center, Klamath Falls, Oregon, November, 1978.

[6] Lienau, Paul J., and John W. Lund, Editors, Proceedings of the International Conference on Geothermal Energy, Oregon Institute of Technology, Klamath Falls, Oregon, October, 1974.

[7] Lund, John W., Geology and Energy Utilization of the Klamath Falls Known Geothermal Resource Area, Geo-Heat Utilization Center, Klamath Falls, Oregon, April, 1975.

[8] Higbee, Charles V., The Economics of Direct Use Geothermal Energy For Process and Space Heating, Geo-Heat Utilization Center, November, 1978.

APPENDIX III

COMMON UNITS AND CONVERSIONS

British Thermal Unit (BTU). The quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit (°F) at or near its point of maximum density.

The Calorie (cal). Quantity of heat needed to raise one gram of water one degree Celsius (°C) at, or close to, 16°C.

1 BTU = 252 calories
1 therm = 100,000 BTU = 10^5 BTU
1 quad = 10^{15} BTU

1°F = 9/5°C	°F = 9/5(°C) + 32
1°C = 5/9°F	°C = 5/9 (°F - 32)

1 hp = 746 watts = 2545 BTU/hr
1 kWh = 3413 BTU = 1.341 hp hr

1 meter (m) = 3.281 ft
1 centimeter (cm) = 0.3937 inch
1 kilogram (kg) = 2.205 lbs
1 gram (g) = 0.03528 oz
1 liter (l) = 0.2642 gal

1 gal of home heating oil = 140,000 BTU
1 ton of coal (bituminous) = 2.6 x 10^7 BTU
1 ft^3 of natural gas = 1035 BTU
1 lb of oak firewood = 7.9 x 10^3 BTU
1 lb of pine firewood = 8.7 x 10^3 BTU
1 ft^3 of propane = 2320 BTU
1 bbl of crude oil (42 gal) = 5.75 x 10^6 BTU
1 ton of refrigeration (U.S. standard) = 2.88 x 10^5 BTU

Note: When using these heating fuel energy values, be sure to account for the efficiency of the heating system.

Approximate cost of fossil fuel in Oregon (January 1, 1979):

Electricity: $0.026/kwh (100% efficiency)
Natural Gas: $0.3473/therm + service charge of around $3.00/month
Approx. $0.37/therm (80% efficiency)
Home Heating Oil: $0.485/gal (70% efficiency)

APPENDIX IV

HEAT LOAD CALCULATIONS

Heat Load: The heat load is best determined by a heating contractor or an architect. If the home is of a recent design, this may already have been determined when the heating system was designed. The heating load for a residence can be estimated as follows:

1. Determine the volume of the heated space (floor area times ceiling height) in ft^3 (V).

2. Determine heating load factor (HLF):

   No insulation: 6.5 $BTU/ft^3/hr$
   With roof insulation only: 5.2 $BTU/ft^3/hr$
   With roof and wall istulation: 4.0 $BTU/ft^3/hr$

   This heating load factor is based on a difference between inside and outside design temperature of 70°F. Correct this factor by a ratio of the correct temperature difference (ΔT) divided by 70.

$$HLF_c = (\Delta T/70)HLF$$

3. Multiply the corrected heating load factor by the volume of the building to obtain the peak heating load (PHL) (Peak BTU/hr).

$$PHL = HLF_c \times V$$

4. Determine the degree days (DD) of heating for your area (see map).

5. Determine the annual heating load (AHL) by multiplying the degree days by the peak heating load (PHL) and by 24 and dividing by the correct temperature difference (ΔT).

$$AHL= (DD \times PHL \times 24) / \Delta T$$

Example

Residence with 2,000 ft^2 of floor space and 8-foot ceilings and only ceiling insulation.

Inside design temperature = 65°F
Outside design temperature = 5°F
Location–near center of Jackson County (Medford)

1. Volume

$$V = 2{,}000\ ft^2 \times 8\ ft = 16{,}000\ ft^3$$

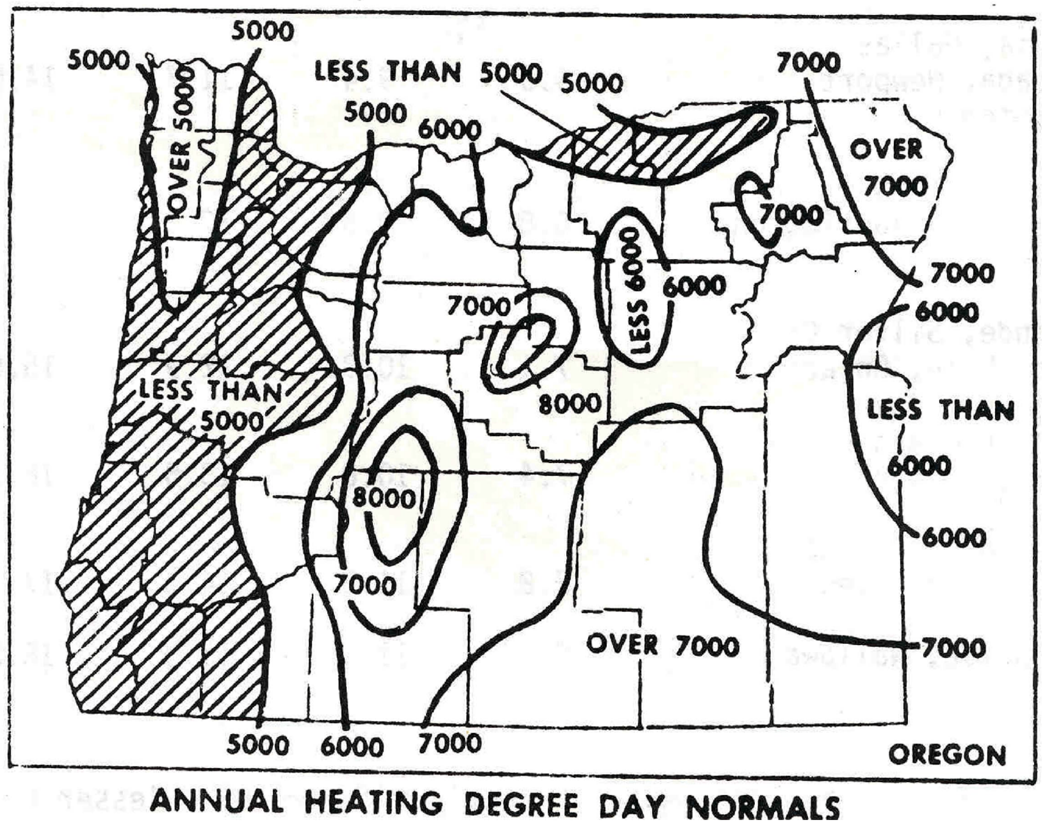


FIGURE 11. Annual Degree Days Map for the State of Oregon

* Degree Day is a unit, based upon temperature difference and time, used in estimating fuel consumption and specifying nominal heating load of a building in winter. For any one day, when the mean temperature is less than 65 degrees F., there exists as many degree days as there are Fahrenheit degrees difference in temperature between the mean temperature for the day and 65 degrees F.

2. Heating load factor

   HLF = 5.2 (ceiling insulation only)

   HLF_c = [(65-5)/70] 5.2 BTU/ft^3/hr

   = (60/70) 5.2 = 4.5 BTU/ft^3/hr

3. Peak heating load
   PHL = 4.5 x 16,000 = 72,000 BTU/hr

4. Degree days of heating (from map)
   DD approx. 5,000 degree days

5. Annual heating load

$$AHL = (5{,}000 \times 72{,}000 \times 24)/60$$

$$= 144{,}000{,}000$$

$$= 144 \times 10_6$$

$$= 144 \text{ million BTU/year}$$

Note: Heating loads calculated by this procedure are included only for estimating purposes and should not be used for actual sizing of a heating system. The wind exposure, amount of window area, types of windows, exposed walls, etc, will affect the design values.

<u>Geothermal Flow Rates</u>

An estimate of the required flow rates for geothermal fluids to provide the necessary energy can be made. The temperature of the geothermal fluid must be known and the temperature drop across the heat exchanger must be estimated. This can be approximated by:

temperature drop (TD) = (0.6 x geothermal temp.) - 70°F.

Using a 180°F geothermal temperature:

$$TD = (0.6 \times 180) - 70$$

$$= 108 - 70 = 38°F.$$

The required geothermal flow rate to deliver the required energy under peak condition is:

$$\text{peak flow rate (gal/min)} = \frac{\text{Peak Heating Load (BTU/hr)}}{500 \times \text{temp drop (°F)}}$$

$$PFR = PHL/ (500xTD)$$

using the previous example:

$$PFR = 72{,}\ 000/(500 \times 38) = 3.8 \text{ gal/min}$$

$$= 227 \text{ gal/min}$$

APPENDIX V

HEATING SYSTEM COST (1978)

Using the example figures in the text for the well and casing, and the heating load for the 2,000 ft^2 home in Appendix IV, the following total costs for a geothermal heating system can be estimated (using a downhole heat exchanger and forced air convectors).

Downhole heat exchanger size: (since temp > 170°F, use 2,000 BTU/hr/ft– See Page 10)

$$\frac{72{,}000 \text{ BTU/hr}}{2{,}000 \text{ BTU /hr/ft}} = 36 \text{ ft below the water line (50-foot minimum)}$$

Assume the water line is 25 feet below the surface: use 25 + 50 = 75' total length.

Costs:

200' deep well:	$ 2,750.00
Casing:	1,600.00
Downhole pump:	None
Downhole heat exchanger	
$4/ft x 75 ft =	300.00
Supply line to home	
(assume 100 feet at $4/ft) =	400.00
Total geothermal capital cost:	$ 5,050.00
Annual operating cost for electricity approx.:	None
Annual maintenance cost approx.:	$30/year

Total annual cost using 12% interest and 50-year life for the well and 20-year life for the heat exchanger, piping, etc. (capital recovery factor = crf):

Geothermal components:

a. Well and Casing: $4,350 x crf_{50}
= 4,350 x 0.1204 = $524/year.

b. Heat Exchanger, Piping, etc.:
$700 x crf_{20}
= 700 x 0.1339 = $95/year.

c. Maintenance and Operating: $30/year
Total Annual Geothermal Cost: $649/year

This compares with the approximate cost of $700/year obtained from FIGURE 10. Considering income tax credits, a $1,000 State credit (maximum allowed) and $1,210 Federal credit can be taken, for an annual savings of approximately $268. This then reduces the total annual geothermal cost to $649 - $268 = $381/year. This compares with the approximate cost of $410/year obtained from FIGURE 10. Note that the maximum total tax credit ($1,000 + $2,2000) amounts to approximately $400 per year savings.

Comparing with fossil fuel:

(144 x 10^6 BTU/year energy requirement for the home.)

1. Electricity (100% efficient):

(144 x 10^6 BTU/yr)/(3,413 BTU/kWh) x ($0.026/kWh) = $1,097/year

2. Natural gas (80% efficient):

(144 x 10^6 BTU/yr)/(0.80) x ($0.37/$10^5$ BTU) = $666/year

3. Fuel oil (70% efficient):

(144 x 10^6 BTU/yr)/(0.70)x(140,000 BTU/gal) x ($0.485 x gal) = $713/year

The fossil fuel costs are based on present rates (December, 1978) and do not reflect future escalations. Based on projections by the Oregon Department of Energy, present value of these costs over a 20-year period would be approximately 1.9 times the current annual electricity costs, 2.2 times the current annual natural gas costs, and 1.8 time the current annual fuel oil costs. For our example, this would give costs of $2,084/year, $1,465/year, and $1,283/year, respectively. FIGURE 12 illustrates the estimated trend in future fossil fuel price escalations based on the average values in FIGURE 10. Various annual well costs are shown for comparison.

The cost of the non-geothermal portion of the heating system can also be determined, however, it was not figured in the comparison as this would be common to all systems:

Costs:

Forced air convectors (includes ductwork, controls, etc., See Page 15):

$$\frac{\$30}{1{,}000\ \text{BTU/hr}} \times 72{,}000\ \text{BTU/hr} = \$2{,}160.00$$

Circulation pump:	100.00
Total non-geothermal capital cost:	$2,260.00

Annual operating cost for electricity approx.: $30/year

Annual maintenance cost approx.: $30/year

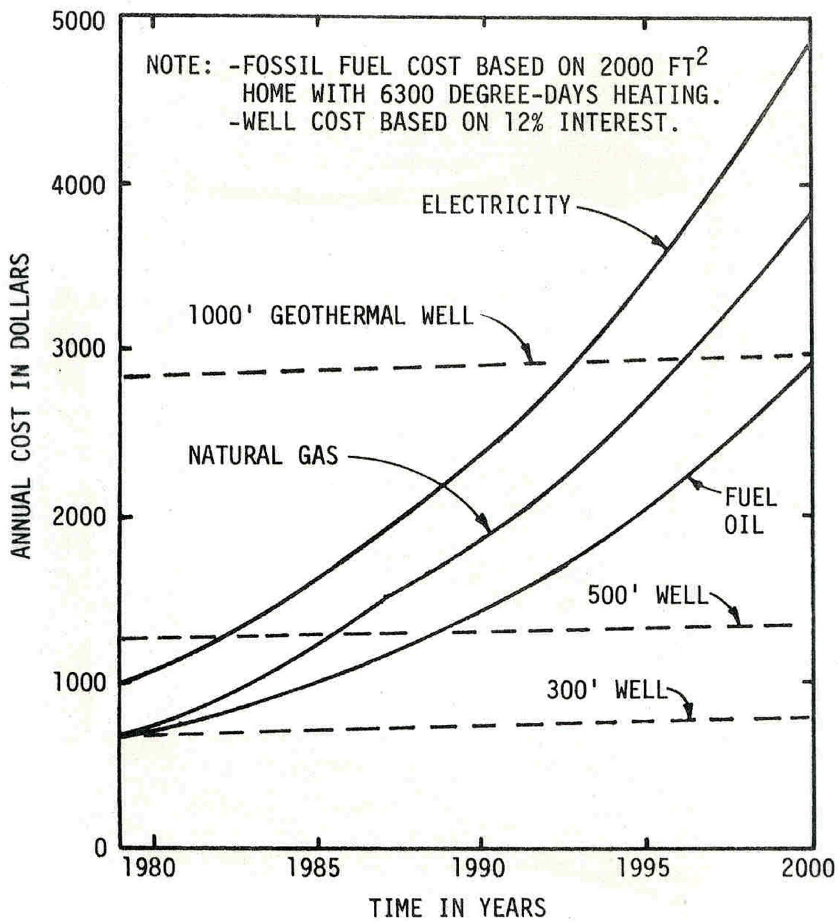


FIGURE 12. Fossil fuel annual costs escalations based on Oregon Department of Energy Projections.

The total annual cost of the non-geothermal portion would then be (assuming 20-year life):

a. Heating System: $2,260 x crf_{20}

= 2,260 x 0.1339 = $303/year

b. Annual maintenance and operating: $ 60/year

Total annual non-geothermal cost: $363/year

This assumes a new construction for the heating system; retrofit costs would be $200 to $300 (total capital cost). It appears that the tax credits will apply to either the new heating system cost or the retrofit costs.

TECHNICAL ASSISTANCE PROGRAM

GEO-HEAT UTILIZATION CENTER
Oregon Institute of Technology

Under the technical assistance program up to 100 man hours of consultation can be provided, at no cost, to private, public, or corporate entities intending the direct utilization of geothermal energy. Application areas include but are not limited to, space heating and cooling, district heating, aquaculture food production and processing, drying, chemical and pharmaceutical processes, animal husbandry, etc. Assistance will be given primarily for projects in the Pacific Region states of Alaska, Washington, Oregon, California, and Hawaii. Projects in other regions and indirect uses or electrical power generation projects should request assistance through other technical assistance programs.

Consultation may be in the form of limited resource evaluation, engineering feasibility and economic studies, materials selection and corrosion problems, conceptual design, consultation with private engineering or consulting geologists, etc.

The program is intended to provide assistance to persons with little or no experience in the geothermal field in order to promote the rapid development of geothermal resources. The program is <u>not</u> intended to compete with consulting engineers and geologists and Geo-Heat personnel will not provide detailed plans, specifications or services when qualified private consulting is available.

Requests for assistance will be prioritized based on proposed implementation dates. Existing fossil fuel users considering conversion to geothermal energy will be provided early assistance.

Additionally, technical personnel are available for informational seminars or speaking engagements to interested groups, trade and technical associations, technical seminars, etc.