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MAY 1983

BY: OREGON INSTITUTE OF TECHNOLOGY GEO-HEAT CENTER

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**ASSESSMENT OF GEOTHERMAL
POTENTIAL FOR
ASHLAND**

**Prepared for:
The City of Ashland, Oregon**

**Prepared by:
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May 1983

ACKNOWLEDGEMENT

This analysis of the Ashland geothermal resource is based on work performed during 1981 and 1982 by the Oregon Department of Geology and Mineral Industries. Unfortunately, the report for that work will not be published until after the Geo-Heat Center's work on possible utilization of the resource is completed. The Geo-Heat Center is indebted to Gerald Black of D.O.G.A.M.I. and Monty Elliott, Jud D'Allura and Bill Purdon of Southern Oregon State College for providing a draft of their report and for assisting in the interpretation of the data it includes.

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I. EXECUTIVE SUMMARY

Recent work in the Ashland area by the Oregon Department of Geology and Mineral Industries has identified a low temperature geothermal resource on the order of 65-90°F. There is some indication that a warmer resource (160-200°F) may exist at depth, however, its location and depth are unknown. As a result, this report concentrates on utilization of the accessible low temperature resource through the use of water source heat pumps. These machines absorb heat from the 65-90°F water, amplify its temperature and deliver it to some higher temperature use.

The ability of water source heat pumps to economically compete with other energy systems is a function of the temperature and heat requirements of a particular application and of local utility availability and rates. In Ashland, natural gas is widely available. This natural gas is a relatively inexpensive energy source and heat pumps, therefore, may be difficult to justify. This situation is compounded by the mild climate of Ashland and the existence of an effective energy efficient building ordinance for residential developments.

Water-to-air heat pumps were examined for residential, commercial and industrial sectors in two applications; space heating and process heating.

In the residential sector, the most attractive areas for heat pump use appear to be those not currently served by city water or natural gas service.

Simple payback periods for these applications vary from 9.5 years to well over 20 years depending upon the specific characteristics of the site.

In the commercial sector, heat pump use for space heating of government funded office type structures appears to be a viable option. This is particularly true if air conditioning is used. The payback periods for heat pump use in commercial office buildings and retail establishments, however, are beyond the values generally considered attractive by private entities.

Water source heat pumps for industries which could be located in the northeastern section of town could be a realistic option. The most ideal situation would be for users with large heat requirements, high annual load factors and low temperature process loads.

II. GENERAL GEOLOGY

Figure II-1 is taken from the geology map of Elliott, D'Allura and Purdon. The colored areas were mapped in 1981 specifically for D.O.G.A.M.I.'s project in evaluating the low temperature resource in the Ashland area.

The geology of the area near the city of Ashland is dominated by the Mount Ashland pluton. This quartz diorite intrusive, some 130 million years old, forms the hills to the west and south, extends under the sedimentary rocks to the east and north, and the recent alluvium at the northeast edge of the city. Rocks of the pluton were encountered in three drill holes; the Ashland

Greenhouses well (at 982 feet), and the temperature gradient holes at Darex (305 feet) and the SOSC gym (392 feet).

The contact between the pluton and overlying sedimentary rock of the Hornbrook formation dips to the northeast at approximately 25° in the vicinity of the city. The four warm springs in the Ashland area are located at, or very near, the surface expression of this contact and are along a generally northwest trending line.

The oldest rocks in the immediate area are the Applegate formation which are some 200 million years old. These rocks outcrop just northwest of the city and were contact metamorphosed during the emplacement of the Mount Ashland pluton. The contact between the Applegate formation and the Mount Ashland pluton is a zone of mixed rocks with stringers of diorite intruding the Applegate formation. This contact zone was encountered in the temperature gradient hole just west of the Butler Ford building at 230 feet. The contact zone should have high permeability, approaching that of fractured rock, and indeed artesian flow roughly estimated at 100 gpm was encountered in that zone.

Jackson Hot Springs is located at the contact between the Applegate formation, the Mount Ashland pluton and the Hornbrook formation. As might be expected in high permeability zones, Jackson Hot Springs is the warmest of the springs in the area. This spring issues from about 10 orifices with reported temperatures ranging from 95°F to 110.3°F and the warm water probably has mixed with cooler surface water before reaching the surface.

The location of several faults has been approximated in the pluton to the

west and south of the city outside the area shown in Figure II-1. These generally trend northwesterly although two near the southern part of the city, and several on the eastern side of the valley trend northeasterly as shown in Figure II-1. These northeasterly trending faults are not apparent on the surface east of the contact between the pluton and overlying sedimentary rock indicating they are pre-Hornbrook in age. Only one fault in the Hornbrook has been mapped and is to the south and east as shown.

No surface faults likely to act as conduits for geothermal fluids have been mapped in the area immediately east of the hot spring line. There are, however, faults to the southeast, the extensions of which would pass through this area. One of these, which extends for several miles, terminates at Pompadour Bluff. It is interesting to note that several sill and dike like intrusives of tertiary age (30-35 million years) occur along, and are generally aligned with, what might be postulated as extensions of these faults. Black postulates a subsurface northwest trending fault passing near the confluence of Bear Creek and Ashland Creek and just east of the Ashland Greenhouses warm well as shown in Figure II-2. One of the intrusives has been mapped at the surface less than a half of mile east of the greenhouses well and is aligned with Black's postulated fault. There may be additional intrusives in the area that are not apparent at the surface. In a personal communication, Black noted that these intrusives could provide a small zone of high permeability and a conduit for warm water.

Heat flow as measured in the test holes in the southeast part of the city

and in "scrounge" holes in the valley to the northeast indicate near normal values. Heat flows in the northwest part of the city are higher and indicate that the underlying aquifer is warmer in that part of the city.

A. Availability of Geothermal

It is assumed that the hydrothermal resource in the Ashland area is similar to the fault controlled, forced convection resources in the basin and range areas in the Western United States. In these resources, meteoric water from nearby highlands percolates slowly downward to considerable depth and is heated by the local natural thermal gradients. The heated water eventually migrates to conduits to the surface such as faults or other highly permeable zones and rapidly rises to the surface to emerge as hot springs. The convection is forced by both the hydrogeology and thermal pressure heads. In the Ashland area, the conduits apparently do not reach the surface and the warm water encounters the impermeable Hornbrook formation where it migrates more slowly along the contact and eventually surfaces as springs along the line which is the surface expression of the contact. Figure II-3, from Black's report, is a cross section through northwest Ashland along line A-A' of Figure II-1. The cross section passes through Helman Hot Springs and the Ashland Greenhouses well.

Geochemistry, the use of the relative abundance of certain chemical elements to predict geothermal reservoir temperatures, indicates that minimum reservoir temperatures in the Ashland area may be as high as 195°F to 215°F. This is

Figure II-1. Geologic map of the Ashland, Oregon area.

the predicted temperature, at depth, where water-rock equilibrium takes place and assumes there is sufficient abundance of the chemicals in the rocks at depth and that no mixing or chemical re-equilibrium takes place as the water moves from the reservoir to the surface. In many low temperature systems some mixing and perhaps re-equilibrium does occur, therefore, predicted temperatures may be lower than actual temperatures at depth. Even so, for very low temperature spring geochemistry, experience has shown that temperatures as high as those predicted are rarely encountered during drilling, probably because water-rock equilibrium occurs at depths well below those economic for drilling and some cooling occurs as the water travels to the surface. For low temperature systems, the Na, K, Ca geothermometer with Mg correction factor has proven to be the most accurate. In the Ashland case, the amount of potassium in the thermal waters was generally below detectable limits and this method was not included.

In the Ashland case, the temperature of the water at the time it reaches the Mount Ashland/Hornbrook contact zone is not known. If there is a fault and it is located where postulated, it can be inferred that the temperature is not much above 88°F. The water would rise to the contact approximately 500 feet northeast of the Ashland Greenhouses well, travel southwesterly up the contact to the greenhouses well, and continue another 1,600 feet to surface at Helman Hot Springs. Since the temperature of Helman Hot Springs and the greenhouses well are the same, the temperature where the water leaves the fault some 500 feet further "upstream" cannot be much higher. This means

Figure II-2. Geologic map of the Ashland, Oregon area with postulated fault.

GEOLOGIC CROSS SECTION

Figure II-3

Cross section
along line A-A' of Figure
1. Arrows show hypothetical
flow of geothermal fluids.

that, in order to obtain fluids hot enough for direct use, a well would have to intersect the fault at depth. Since neither the location nor the dip of the fault are known, it is impossible to accurately site a well to intersect it.

The fault, if in fact it exists as postulated, probably is producing warm or hot fluids only in the section northwest of Mountain Avenue extending to somewhere east to northeast of Jackson Hot Springs. Heat flows are high in the area north of Mountain Avenue. Heat flows in the area south of Mountain Avenue are lower suggesting that the warm aquifer does not underlie that part of the city.

A second possible explanation of the Ashland hydrothermal system is that instead of rising along a fault, the warm waters are rising along the contact zones. One such zone is between the Applegate formation and the Mount Ashland pluton and the water is surfacing at Jackson Hot Springs. A separate conduit may exist at the contact between the Mount Ashland pluton and the tertiary intrusive dike structure that surfaces about where Mountain Avenue crosses Bear Creek. This second conduit would explain the location and temperatures of White Sulphur Spring, the old Twin Plunges site, Helman Hot Springs and the Ashland Greenhouses well. The springs occur on the surface contact where one would expect the plume of warm water to extend, and the temperatures are approximately inversely proportional to the distance from the intrusive as might be expected. However, in that case, the Darex hole should have encountered water at a temperature slightly higher than Helman

Hot Springs or about 90°F rather than the 72°F actually recorded, and the SOSC gym hole should have had a higher heat flow and temperature gradient in its lower portion. The fault with upward flow northwest of Mountain Avenue, therefore, seems the most probable.

Further evidence supporting the existence of a fault or the contact zone conduits could be obtained by geophysical methods. These might include active seismic to assist in locating the fault and a resistivity survey which should provide information on the extent of the near surface warm water. A magnetic survey could provide information on the possible existence and extent of any subsurface tertiary intrusives that may provide contacts and conduits to the near surface. Although these geophysical studies could provide more information, they are expensive and probably not justifiable unless a large heat load would be served. In any case, drilling is the only means of confirming the existence of a resource hotter than the 110°F which has been measured in Jackson Hot Springs.

The volume and rate of upward flow of geothermal water appear to be low as compared to other fault controlled geothermal systems such as Klamath Falls, Oregon and the Moana area in Reno, Nevada where geochemistry indicates similar reservoir temperatures. If the water reaching the Mount Ashland pluton/Hornbrook formation contact is about 90°F as assumed above, then the depth where fluids of 160°F to 200°F could be obtained from the fault might be as much as 3,000 feet. Considering that a well that deep would cost in the neighborhood of \$240,000, the geophysical work noted above might be

advisable before a well is seriously contemplated. It should also be noted that the flows might be low even if the temperature was high.

B. Heat Pump Resource

If developers do not want to assume the expense of geophysical exploration and/or the risk of drilling, a low temperature resource suitable for heat pump applications exists under at least a portion of the city. For simple space heating of homes and commercial establishments, suitable temperatures are available especially in the area east of the Hornbrook/Mount Ashland pluton contact and north of Southern Oregon State College. The economics of each application will depend on the heat load and costs of drilling the well or wells to obtain and dispose of the fluids as required.

Since the contact dips fairly uniformly northeast at 20° to 30°, depth to the warm water varies with distance from the contact. For every 1,000 feet northeast from the surface contact to a well, the depth to the warmest water will increase by 470 to 570 feet. Although drilling will be fairly easy in the shales and sandstones of the Hornbrook formation, the costs will be prohibitive for individual home owners at relatively short distances from the surface contact.

In the area northwest of Mountain Avenue and generally west of Bear Creek, warmer temperatures suitable for high efficiency heat pumps for industrial

applications are probably available. Fortunately, there are also areas zoned for light industrial/commercial uses in the northwest section of the city and the adjacent county area. Temperatures much above 90°F should not be expected except near Jackson Hot Springs where they may rise to 110°F-120°F.

It should be noted that there is some danger of high producing wells (several hundreds of gallons per minute) located in very close proximity to Jackson Hot Springs interfering with the flow of the springs. Such wells should be test pumped at maximum projected rates for at least several days to insure interference will not occur.

The primary emphasis of the balance of this report will concern water source heat pumps and factors affecting their use in Ashland.

Since all of the geological information available suggests that maximum accessible geothermal resource temperatures are in the range of 85°F, there is little potential for direct use of this water. Figure II-4 shows temperature requirements for various industrial applications of geothermal energy. It is evident that requirements for the majority of applications exceed available resource temperatures. A similar situation exists in the area of space heating. Figure II-5 shows temperature requirements for the various methods of applying space heat. Again, all requirements exceed the available resource temperature.

The heat pump provides one means for extracting heat from the warm water and delivering it, at some increased temperature, to a higher temperature

Figure II-4. Application temperature range for some industrial processes and agricultural applications.

APPLICATION CONSIDERATIONS

WATER / WATER HEAT PUMPS

Figure II-5

application. As a result, heat pumps from a practical standpoint could be employed to allow heat in Ashland's low temperature resource to be used for some of the applications shown in Figures II-4 and II-5.

The advantages, limitations and economics of using these devices in the Ashland area will be discussed in the following sections.

III. HEAT PUMP BASICS

In the simplest terms, a heat pump can be thought of as a temperature amplifier. Basically, it is a machine which absorbs a quantity of heat from some temperature source and through a thermodynamic process delivers this quantity of heat to a higher temperature sink.

Before getting into a discussion of the basics of heat pump operations, an understanding of some of the characteristics of heat is necessary. The first of these is a measure of the quantity of heat and is called the British thermal unit or Btu. A Btu is the quantity of heat required to raise one pound of water 1°F. The second characteristic, temperature (units of °F or °C), is a measure of the intensity of heat. The higher the temperature of a quantity of heat, the more useful it is. A heat pump is a device which moves a fixed quantity of heat from a low temperature to a higher temperature.

Figure III-1 shows the four basic components of the heat pump; compressor, condenser, evaporator and expansion device.

SCHEMATIC DIAGRAM WATER / WATER HEAT PUMP

Figure III-1

Starting at the evaporator, some medium, usually air or water, is passed through a heat exchanger, transferring heat to the refrigerant. This addition of heat causes the liquid refrigerant to boil at a relatively low temperature and pressure. This low pressure refrigerant, now a gas, is then taken into the compressor where it is raised to a higher temperature and pressure for delivery to the condenser. At the condenser another medium (again, usually air or water) is passed through a heat exchanger absorbing the heat gained by the refrigerant in the evaporator and that added by the compressor. This rejection of heat allows the high pressure gas to condense to a liquid phase. The liquid refrigerant then flows through the expansion device into the evaporator to repeat the process.

Figure III-2 presents the cycle on a pressure-enthalpy diagram. This diagram is used by engineers to analyze refrigeration and heat pump cycles. Again, the four basic operations of the cycle are shown with evaporation occurring from point 1 to 2, compression from 2 to 3, condensation from 3 to 4 and expansion from 4 to 1.

This diagram is useful because it illustrates the performance of the cycle. A heat pump is really just a refrigeration cycle in which heat output is the desired quantity. When maintenance of a "cold" space is the desired product, the machine is referred to as a refrigerator. In either case, it is necessary to move the same quantity of heat from a low temperature to a higher temperature. Since this is opposite from the direction which heat would normally tend to flow, it is evident that some work input is necessary to

accomplish the task, hence the name heat "pump". In addition, the magnitude of this work input is related to the temperature range over which the heat is transported. The work input occurs at the compressor portion of the cycle and is usually in the form of electrical input to a compressor motor.

When the cycle is operating in the refrigeration or air conditioning mode, the useful output is the amount of heat removed from the "cold" space which is represented in Figure III-2 by A. The amount of work input is represented by B (the work of the compressor). So, the index of performance for the cycle would be A/B or output over input. For a heat pump operating between the same two temperatures, the useful output is the heat rejected in the condenser, which is indicated as C. Again, the work input is represented by B. So, the index of performance for the heat pump mode would be C/A . It is evident that operation in the heat pump mode produces more useful output per unit input than operation in the refrigerant mode.

For heat pumps, this index of performance is called the C.O.P. or coefficient of performance. It is defined as the heating output divided by the energy input. Since output is usually measured in Btu/hour and input in kilowatts, a conversion factor of 3,413 Btu/hour per kw is usually necessary for calculations as in the following example. For a 1,000,000 Btu/hour heat pump which requires 7.3 kw input:

HEAT PUMP VAPOR / LIQUID CYCLE

Figure III-2

$$\text{COP} = \frac{1,000,000 \text{ Btu/hr}}{7.3 \text{ kw} \times 3,413 \frac{\text{Btu/hr}}{\text{kwh}}} = 4.0$$

As mentioned earlier, the COP is affected by the range of temperature over which the heat is being transported. As the size of this temperature range is increased, the COP is decreased. In addition, the size, type and quality of manufacture have some bearing on the performance.

In terms of type, there are basically two; water source heat pumps and air source heat pumps. Air source heat pumps are generally small units (less than 20 ton capacity) and are available in split system or single package configurations. These machines are used in residential and light commercial construction. Water source heat pumps are available in two designs; water-to-air and water-to-water. Water-to-air units are similar to air source heat pumps in size and application. Water-to-water units are generally large machines (available up to 20,000,000 Btu/hr) and are used primarily for industrial applications and large space heating applications.

The basic problem with air source heat pumps is illustrated in Figure III-3. As outside air temperature decreases, the heat pump capacity decreases. This is the opposite of the affect of decreasing outside temperature on space heating requirements since more heat is required at the lower temperature. As a result, a means of compensating for the difference in capacity of the heat pump and requirements of the space is necessary. This is usually accomplished through the use of electric resistance heat elements.

Figure III-3. Illustration of the space heating load line, heat pump capacity and electric resistance heat staging as a function of the ambient temperature.

Source: Paper presented at Symposium on Residential and Commercial Heat Pumps, Hilton Hotel, Portland (3/31/83). Paper by Gordon Reistad, Oregon State University. "Heat Pump Basics"

Because the COP of electric resistance heat is 1.0 (one unit of heat output for each unit of electrical input), this system usually results in seasonal COP's (total heating energy supplied ÷ total energy input) of 1.5 to 2.0. These values are dependent upon the local climate in which the heat pump is installed.

The relatively poor performance of the air source heat pump is due to two principal factors. As mentioned above, the temperature of outside air (the heat source for air source heat pumps) varies over a wide range. In addition, the average temperature during the heating season may be on the order of 35°F or less (Ashland mean winter temperature is approximately 45.4°F). On the other hand, the water heat pump has the advantage of an almost constant temperature source. In many cases this source is ground water. In Ashland, ground water temperatures measured during the recent D.O.G.A.M.I. testing were on the order of 60-75°F. Comparing a water-to-air heat pump to an air-to-air heat pump for space heating (sink equal to about 70°F), it is obvious that the water-to-air unit is operating over a smaller temperature range. This results in higher COP's as discussed above.

Figure III-4 shows the performance of 7 brands of small (3 ½ ton) water-to-air heat pumps of the type which would be used in residential and light commercial applications. As indicated, for most equipment there is not as great an increase in performance with source temperature as might be expected. This is primarily due to the fact that these machines are generally designed to operate in the 45-60°F ground water temperature range. The resulting

PERFORMANCE OF SMALL WATER-TO-AIR HEAT PUMPS

component mismatch which occurs at higher source water temperatures reduces the rate of COP increase which might be expected.

Larger machines of the water-to-water design show marked improvement in COP with increased source temperature. This is illustrated in Figure III-5. This is due to the use of capacity controls on compressors and condenser and evaporator heat exchangers. As a result of these controls, the capacity of individual components can be adjusted to allow a closer match with the balance of the system.

IV. HEAT PUMP APPLICATIONS IN ASHLAND

Energy use in Ashland can be roughly divided into three categories: Residential, Commercial and Industrial. With regard to heat pump applications, space heating would constitute the major heat pump use in the residential and commercial areas, serving such structures as single and multi-family buildings, retail stores and office buildings. In the industrial sector, process heat requirements would provide the major application. In order to assess the characteristics of heat pump use in each of these areas, the following section examines specific examples of heat pump applications in the Ashland area.

A. Residential - Individual Single Family

In the residential sector, heat pump use can be divided into two cat-

COP VS. WATER TEMPERATURE

Figure III-5

egories; individual single family home use and larger development type central system use. Since most of the residential area yet to be developed in Ashland is zoned for single family dwellings, this section examines only applications dealing with these structures.

Table IV-1 outlines the basic characteristics of the home chosen for analysis of single family individual use.

Table IV-1

Floor Area	1500 sq. ft.
Wall	R-19
Ceiling	R-19
Floor	R-19
Glass	Double
Infiltration	.75 changes/hr
Outside Design Temperature	19°F
Inside Design Temperature	68°F
Peak Heat Loss	25,152 Btu/hr
Annual Requirement	36.7 X 10 ⁶ Btu/yr

The annual heating requirement for the home was based on 4,966 degree days for October through May (U.S. National Weather Service Meteorological Data).

In order to assess the attractiveness of the heat pump system, it was compared to the most common types of heating systems in the Ashland area. Because of the wide availability of natural gas, two gas fired systems were included; a standard gas fired forced air furnace (75% efficiency) and a highly efficient pulse combustion forced air furnace (90% efficiency). In

addition, an electric resistance, forced air furnace was included. Only forced air systems were considered because these provide the least incremental costs for the heat pump system, i.e. ductwork is also required for these systems reducing the additional cost for the heat pump.

For the water-to-air heat pump, it was assumed that two wells would be required; one production and one injection. These were assumed to be 150 feet deep, standard domestic water wells. The production well would have a 1 1/2 horsepower submersible pump with controls and pressure tank above ground. In addition, 130 feet of buried piping was included for transport of water to and from the wells and house. A COP of 3.0 was used for all residential heat pump analyses. This figure could be somewhat higher depending upon the depth of the production well and the proximity to the contact between the Mount Ashland pluton and the Hornbrook formation. However, in view of the relatively flat performance of these machines (see Figure IV-6) with respect to resource temperature, the value of 3.0 was considered to be representative.

The following table outlines key aspects of each system as they relate to economic analysis. All utility costs are based on current Ashland rates. Installation costs are based upon figures obtained from heating and air conditioning contractors.

Water-to-Air Heat Pump vs Natural Gas Furnace @ 75% Efficiency

Incremental Capital Cost	\$9378
Incremental Maintenance	52/yr
Annual Natural Gas Cost (furnace)	340/yr
Annual Electricity Cost (heat pump)	180/yr

Heat Pump vs Natural Gas Furnace @ 90% Efficiency

Incremental Capital Cost	\$8068
Incremental Maintenance	22/yr
Annual Natural Gas Cost (furnace)	283/yr
Annual Electricity Cost (heat pump)	180/yr

Heat Pump vs Electric Resistance Furnace

Incremental Capital Cost	\$9518
Incremental Maintenance	54/yr
Annual Electricity Cost (resistance furnace)	461/yr
Annual Electricity Cost (heat pump)	180/yr

City Water Heat Pump vs Natural Gas Furnace at 75% Efficiency

Incremental Capital Cost	\$2410
Incremental Maintenance	52/yr
Annual Natural Gas Cost (furnace)	340/yr
Annual Electricity Cost (heat pump)	154/yr
Water Costs	295/yr

Both maintenance and capital costs in the above table are shown as incremental. That is, they are the difference between the costs associated with the conventional system and those for the heat pump system. Details of the calculations associated with these figures are shown in the Appendix.

The following analyses are based upon the use of Oregon Department of Energy inflation rates. These rates are shown in the table below.

Table IV-2

<u>Years / Natural Gas</u>	<u>Years / Electricity</u>	<u>Years / Basic Inflation Rate</u>
1983-85 2.8%	1983-2002 1.7%	1983-2002 6.5%
1986-87 2.2%		
1988 .9%		
1989-2002 2.1%		

Tables IV-3 through IV-6 show the life cycle analysis for these four cases. The system analyzed in Table IV-3 is the standard natural gas furnace versus the water-to-air heat pump. Each of the following tables is similar in configuration so only Table IV-3 will be described in detail. Column 1 shows the natural gas purchases over the life of the system. Column 2 shows electrical purchases for the heat pump system over the 20 years. Column 3 shows incremental maintenance costs for the heat pump system over the natural gas system. Column 4 shows the net energy savings which consist of subtracting Columns 2 and 3 from Column 1. These values are the savings generated by the use of the heat pump system. Column 5 sums the individual yearly savings from Column 4 for a cumulative cash flow. Column 6 discounts the Column 4 values at 10%. Column 7 sums the yearly discounted cash flows from Column 6 to show a cumulative discounted cash flow.

The significance of the discounted payback lies in the fact that the incremental cost of the heat pump is considered an investment. As a result, instead of putting money into the heat pump system it could be placed in a savings account for example. Since a savings account pays interest, the original amount deposited grows in value over the years. Similarly, the investment in the heat pump system over the natural gas system generates savings. In our analysis, a discount rate of 10% was used. This means that if the discounted payback (lower right hand corner of the sheet) just equals 20 years, the rate at which the savings from the system are accumulating results in a return to the home owner the same as if he deposited his money in a savings account

Table IV-3
Heat Pump vs 75% Natural Gas Furnace

**LIFE CYCLE COST ANALYSIS
FOR
SINGLE FAMILY RESIDENTIAL**

**Incremental Capital cost
Cost of capital**

**9378
10%**

	1	2	3	4	5	6	7
	Natural Gas	Electricity	O & M	Net Energy	Cumulative	Discounted	Cumulative
	Present	Geothermal	Geothermal	Savings	Cash Flow	Cash Flow	Discounted
	System	System	System	Cash Flow			Cash Flow
Year zero cost	340	180	52				
Year							
1983	369	195	55	119	119	108	108
1984	400	211	59	131	249	108	216
1985	434	228	63	143	393	108	324
1986	472	247	67	158	551	108	432
1987	513	267	71	175	726	109	540
1988	551	289	76	186	913	105	646
1989	598	313	81	205	1118	105	751
1990	650	338	86	226	1344	105	856
1991	706	366	92	248	1592	105	962
1992	767	396	98	273	1865	105	1067
1993	832	428	104	300	2165	105	1172
1994	904	463	111	330	2495	105	1277
1995	982	501	118	362	2858	105	1382
1996	1066	543	126	398	3256	105	1487
1997	1158	587	134	437	3693	105	1592
1998	1258	635	142	480	4173	104	1696
1999	1366	687	152	527	4700	104	1800
2000	1483	744	162	578	5278	104	1904
2001	1611	805	172	634	5912	104	2008
2002	1749	871	183	695	6607	103	2111
Total	17870	9113	2150	6607		2111	

Simple Payback

NA

Discounted Payback

NA

Heat Pump vs 90% Natural Gas Furnace

LIFE CYCLE COST ANALYSIS FOR SINGLE FAMILY RESIDENTIAL.

Incremental Capital cost
Cost of capital

8068
10%

	1	2	3	4	5	6	7
	Electricity Present System	Electricity Geothermal System	O & M Geothermal System	Net Energy Savings Cash Flow	Cumulative Cash Flow	Discounted Cash Flow	Cumulative Discounted Cash Flow
Year zero cost	283	180	22				
Year							
1983	307	195	23	89	89	81	81
1984	333	211	25	97	186	81	161
1985	361	228	27	107	293	80	242
1986	393	247	28	118	411	81	322
1987	427	267	30	130	541	81	403
1988	459	289	32	138	679	78	481
1989	498	313	34	151	830	78	558
1990	541	338	36	166	997	78	636
1991	588	366	39	183	1180	78	714
1992	638	396	41	201	1381	77	791
1993	693	428	44	221	1601	77	868
1994	753	463	47	242	1844	77	946
1995	817	501	50	266	2109	77	1023
1996	888	543	53	292	2401	77	1099
1997	964	587	57	320	2721	77	1176
1998	1047	635	60	351	3073	76	1253
1999	1137	687	64	385	3458	76	1329
2000	1235	744	68	423	3881	76	1405
2001	1341	805	73	463	4344	76	1481
2002	1456	871	78	508	4852	75	1556
Total	14874	9113	910	4852		1556	

Simple Payback

NA

Discounted Payback

NA

Table IV-5
Heat Pump vs Electric Resistance Furnace

**LIFE CYCLE COST ANALYSIS
FOR
SINGLE FAMILY RESIDENTIAL**

**Incremental Capital cost
Cost of capital**

**9518
10%**

	1	2	3	4	5	6	7
	Electricity Present System	Electricity Geothermal System	O & M Geothermal System	Net Energy Savings Cash Flow	Cumulative Cash Flow	Discounted Cash Flow	Cumulative Discounted Cash Flow
Year zero cost	461	180	54				
Year							
1983	499	195	58	247	247	224	224
1984	540	211	61	268	514	221	445
1985	584	228	65	291	805	218	664
1986	632	247	69	316	1121	216	879
1987	684	267	74	343	1463	213	1092
1988	740	289	79	372	1835	210	1302
1989	800	313	84	404	2239	207	1510
1990	866	338	89	438	2678	205	1714
1991	937	366	95	476	3154	202	1916
1992	1014	396	101	517	3671	199	2115
1993	1097	428	108	561	4231	197	2312
1994	1187	463	115	609	4840	194	2506
1995	1284	501	122	660	5500	191	2697
1996	1390	543	130	717	6217	189	2886
1997	1504	587	139	778	6994	186	3072
1998	1627	635	148	844	7838	184	3255
1999	1760	687	158	915	8753	181	3436
2000	1905	744	168	993	9747	179	3615
2001	2061	805	179	1077	10824	176	3791
2002	2230	871	190	1169	11993	174	3965
Total	23338	9113	2233	11993		3965	

**Simple Payback
Discounted Payback**

**17.77
NA**

City Water Source Heat Pump vs Natural Gas Furnace (75%)

LIFE CYCLE COST ANALYSIS FOR SINGLE FAMILY RESIDENTIAL

Incremental Capital cost
Cost of capital

2410
10%

	1	2	3	4	5	6	7
	Natural Gas Present System	Electricity Geothermal System	O & M Geothermal System	Net Energy Savings Cash Flow	Cumulative Cash Flow	Discounted Cash Flow	Cumulative Discounted Cash Flow
Year zero cost	340	154	347				
Year							
1983	369	167	370	-167	-167	-152	-152
1984	400	180	394	-174	-341	-143	-296
1985	434	195	419	-180	-521	-135	-431
1986	472	211	446	-185	-706	-127	-557
1987	513	228	475	-191	-897	-118	-676
1988	551	247	506	-202	-1099	-114	-790
1989	598	267	539	-208	-1307	-107	-897
1990	650	289	574	-214	-1521	-100	-996
1991	706	313	612	-219	-1740	-93	-1089
1992	767	339	651	-223	-1963	-86	-1175
1993	832	366	694	-228	-2191	-80	-1255
1994	904	397	739	-231	-2422	-74	-1329
1995	982	429	787	-234	-2656	-68	-1397
1996	1066	464	838	-236	-2892	-62	-1459
1997	1158	502	892	-237	-3129	-57	-1515
1998	1258	543	950	-236	-3365	-51	-1567
1999	1366	588	1012	-235	-3600	-46	-1613
2000	1483	636	1078	-231	-3831	-42	-1655
2001	1611	688	1148	-226	-4056	-37	-1692
2002	1749	745	1223	-218	-4275	-32	-1724
Total	17870	7796	14348	-4275		-1724	

Simple Payback
Discounted Payback

NA
NA

which yielded 10% interest. If the discounted payback is larger than 20 years (indicated by n/a), this indicates that the return is less than 10%.

In order to determine the suitability of the heat pump system, it is necessary to compare the total savings generated by the system over its life time to the investment necessary to acquire the system. The number of years required for the values in Columns 4 to 7 to equal the capital cost is known as the payback period (simple or discounted). These payback periods are shown in the lower right hand corner of each sheet. In this case, there is no payback since the savings generated by the heat pump
→ system over the 20 years are less than the capital investment for the system.

The same situation exists for the heat pump system when compared to the 90% efficient natural gas furnace (Table IV-4). Although this case shows a lower capital cost, the better performance of the natural gas system reduces the annual savings generated by the heat pump. This results in only a \$4,856 savings over the 20 year life compared to the \$8,068 capital investment.

When the heat pump system is compared to the electric resistance furnace, the situation is somewhat improved. In this case, a simple payback of 17.8 years results. For practical purposes, however, this is still well beyond the time period which would be considered economically justifiable in most cases.

Table IV-6 shows the life cycle costs of operating a water-to-air heat pump using city water for a heat source. Column 3 in this table includes,

in addition to maintenance, the cost of purchasing the required city water to operate the heat pump. It is obvious from the negative signs in Columns 4 through 6 that this system has annual costs in excess of that for the natural gas system. As a result, the longer the system is operated the deeper the owner goes into the hole. In addition, the temperature of the city water would likely result in lower heat pump COP than those using ground water. However, this was not considered.

In view of the extended payback periods shown in Tables IV-3 through IV-5, additional cases were examined in an effort to reduce the amount of time required to recoup the capital investment. The following table indicates the effect of doubling the annual heating load. This was an effort to reflect the condition which would occur in; 1) a similarly insulated home of larger floor area (~3,000 sq. ft.), or 2) an older, less heavily insulated house of similar floor area (~1,500 sq. ft.). The somewhat higher capital costs are the result of increased heat pump capacity.

Heat Pump vs Natural Gas Furnace @ 75% Efficiency

Incremental Capital Cost	\$11,078
Incremental Maintenance Cost	52/yr
Annual Natural Gas Cost (furnace)	780/yr
Annual Electricity Cost (heat pump)	360/yr

Heat Pump vs Natural Gas Furnace @ 90% Efficiency

Incremental Capital Cost	\$9,768
Incremental Maintenance Cost	22/yr
Annual Natural Gas Cost (furnace)	566/yr
Annual Electricity Cost (heat pump)	360/yr

Table IV-7
LIFE CYCLE COST ANALYSIS
FOR
SINGLE FAMILY RESIDENTIAL

Incremental Capital cost
Cost of capital

11078
10%

Heat Pump vs 75% Natural Gas Furnace
Double Heating Load

	1 Natural Gas Present System	2 Electricity Geothermal System	3 O & H Geothermal System	4 Net Energy Savings Cash Flow	5 Cumulative Cash Flow	6 Discounted Cash Flow	7 Cumulative Discounted Cash Flow
Year zero cost	780	360	52				
Year							
1983	846	390	55	401	401	365	365
1984	918	421	59	438	839	362	727
1985	996	456	63	477	1317	359	1085
1986	1083	493	67	523	1839	357	1442
1987	1177	534	71	572	2411	355	1798
1988	1264	578	76	611	3022	345	2142
1989	1373	625	81	667	3689	342	2485
1990	1491	676	86	729	4418	340	2825
1991	1619	732	92	796	5214	338	3162
1992	1759	792	98	869	6083	335	3497
1993	1910	857	104	949	7033	333	3830
1994	2074	927	111	1036	8069	330	4160
1995	2252	1003	118	1132	9201	328	4488
1996	2446	1085	126	1235	10436	325	4814
1997	2657	1174	134	1349	11785	323	5136
1998	2885	1270	142	1472	13257	320	5457
1999	3133	1375	152	1607	14864	318	5775
2000	3403	1487	162	1754	16618	315	6090
2001	3695	1609	172	1914	18531	313	6403
2002	4013	1741	183	2089	20620	310	6713
Total	40995	18225	2150	20620		6713	

Simple Payback
Discounted Payback

14.48
NA

FOR ANALYSIS
SINGLE FAMILY RESIDENTIAL

Incremental Capital cost
Cost of capital

9768
10%

Heat Pump vs 90% Natural Gas Furnace
Double Heating Load

	1	2	3	4	5	6	7
	Natural Gas Present System	Electricity Geothermal System	O & M Geothermal System	Net Energy Savings Cash Flow	Cumulative Cash Flow	Discounted Cash Flow	Cumulative Discounted Cash Flow
Year zero cost	566	360	22				
Year							
1983	614	390	23	201	201	183	183
1984	666	421	25	220	421	182	365
1985	723	456	27	240	661	181	545
1986	786	493	28	264	926	180	726
1987	854	534	30	290	1216	180	906
1988	917	578	32	308	1523	174	1079
1989	996	625	34	337	1861	173	1252
1990	1082	676	36	369	2230	172	1425
1991	1175	732	39	405	2634	172	1596
1992	1276	792	41	443	3077	171	1767
1993	1386	857	44	485	3563	170	1937
1994	1505	927	47	531	4094	169	2106
1995	1634	1003	50	582	4676	168	2275
1996	1775	1085	53	637	5312	168	2443
1997	1928	1174	57	697	6009	167	2610
1998	2093	1270	60	763	6772	166	2776
1999	2274	1375	64	835	7607	165	2941
2000	2469	1487	68	913	8520	164	3105
2001	2681	1609	73	999	9520	163	3268
2002	2912	1741	78	1093	10613	163	3431
Total	29748	18225	910	10613		3431	

Simple Payback
Discounted Payback

19.23
NA

Table IV-9

LIFE CYCLE COST ANALYSIS
FOR
SINGLE FAMILY RESIDENTIAL

Incremental Capital cost
Cost of capital

11218
10%

Heat Pump vs Electric Resistance Furnace
Double Heating Load

	1	2	3	4	5	6	7
	Electricity Present System	Electricity Geothermal System	O & M Geothermal System	Net Energy Savings Cash Flow	Cumulative Cash Flow	Discounted Cash Flow	Cumulative Discounted Cash Flow
Year zero cost	922	360	54				
Year							
1983	998	390	58	551	551	501	501
1984	1079	421	61	597	1147	493	994
1985	1168	456	65	647	1794	486	1480
1986	1264	493	69	701	2495	479	1958
1987	1367	534	74	759	3254	472	2430
1988	1479	578	79	823	4077	465	2894
1989	1601	625	84	892	4969	458	3352
1990	1732	676	89	966	5935	451	3803
1991	1874	732	95	1047	6982	444	4247
1992	2028	792	101	1135	8117	437	4684
1993	2194	857	108	1229	9346	431	5115
1994	2374	927	115	1332	10678	424	5540
1995	2569	1003	122	1443	12122	418	5958
1996	2779	1085	130	1564	13685	412	6369
1997	3007	1174	139	1694	15379	406	6775
1998	3254	1270	148	1835	17215	399	7174
1999	3520	1375	158	1988	19203	393	7568
2000	3809	1487	168	2154	21357	387	7955
2001	4121	1609	179	2334	23691	382	8337
2002	4459	1741	190	2528	26218	376	8712
Total	46676	18225	2233	26218		8712	

Simple Payback
Discounted Payback

12.37
NA

Heat Pump vs Electric Resistance Furnace

Incremental Capital Cost	\$11,218
Incremental Maintenance Cost	54/yr
Annual Electricity Cost (resistance)	922/yr
Annual Electricity (heat pump)	360/yr

Life cycle costs for these three cases are shown in Tables IV-7, IV-8 and IV-9. As might be expected, the increased energy requirements and attendant savings result in somewhat better payback periods than those in Tables IV-3 through IV-6. Specifically, the heat pump system shows simple payback of 14.5 years compared to standard natural gas, 19.2 years compared to high efficiency natural gas, and 12.4 years compared to electric resistance. However, despite the decrease in simple payback, none of the cases shows a value for discounted payback. In addition, the payback periods remain beyond the values which would be considered by the average homeowner.

A final three cases were examined in which the injection well was removed from the system. This situation would correspond to an area in which some other means of disposal (sewer, surface, etc.) was available. Removing the injection well from the system has the effect of reducing the capital cost as indicated in the following table. Heating requirements remain at the levels used in the previous three cases.

Heat Pump vs Natural Gas Furnace @ 75% Efficiency

Incremental Capital Cost	\$8,704
Incremental Maintenance Cost	52/yr
Annual Natural Gas Cost (furnace)	780/yr
Annual Electricity Cost (heat pump)	360/yr

Table IV-10

LIFE CYCLE COST ANALYSIS
FOR
SINGLE FAMILY RESIDENTIAL

Incremental Capital cost
Cost of capital

8704
10%

Heat Pump vs 75% Natural Gas Furnace
Double Heating Load/No Injection Well

	1	2	3	4	5	6	7
	Natural Gas Present System	Electricity Geothermal System	O & M Geothermal System	Net Energy Savings Cash Flow	Cumulative Cash Flow	Discounted Cash Flow	Cumulative Discounted Cash Flow
Year zero cost	780	360	52				
Year							
1983	846	390	55	401	401	365	365
1984	918	421	59	438	839	362	727
1985	996	456	63	477	1317	359	1085
1986	1083	493	67	523	1839	357	1442
1987	1177	534	71	572	2411	355	1798
1988	1264	578	76	611	3022	345	2142
1989	1373	625	81	667	3689	342	2485
1990	1491	676	86	729	4418	340	2825
1991	1619	732	92	796	5214	338	3162
1992	1759	792	98	869	6083	335	3497
1993	1910	857	104	949	7033	333	3830
1994	2074	927	111	1036	8069	330	4160
1995	2252	1003	118	1132	9201	328	4488
1996	2446	1085	126	1235	10436	325	4814
1997	2657	1174	134	1349	11785	323	5136
1998	2885	1270	142	1472	13257	320	5457
1999	3133	1375	152	1607	14864	318	5775
2000	3403	1487	162	1754	16618	315	6090
2001	3695	1609	172	1914	18531	313	6403
2002	4013	1741	183	2089	20620	310	6713
Total	40995	18225	2150	20620		6713	

Simple Payback
Discounted Payback

12.56
NA

FOR

SINGLE FAMILY RESIDENTIAL

Incremental Capital cost
Cost of capital7394
10%Heat Pump vs 90% Natural Gas Furnace
Double Heating Load/No Injection Well

	1	2	3	4	5	6	7
	Natural Gas Present System	Electricity Geothermal System	O & M Geothermal System	Net Energy Savings Cash Flow	Cumulative Cash Flow	Discounted Cash Flow	Cumulative Discounted Cash Flow
Year zero cost	566	360	22				
Year							
1983	614	390	23	201	201	183	183
1984	666	421	25	220	421	182	365
1985	723	456	27	240	661	181	545
1986	786	493	28	264	926	180	726
1987	854	534	30	290	1216	180	906
1988	917	578	32	308	1523	174	1079
1989	996	625	34	337	1861	173	1252
1990	1082	676	36	369	2230	172	1425
1991	1175	732	39	405	2634	172	1596
1992	1276	792	41	443	3077	171	1767
1993	1386	857	44	485	3563	170	1937
1994	1505	927	47	531	4094	169	2106
1995	1634	1003	50	582	4676	168	2275
1996	1775	1085	53	637	5312	168	2443
1997	1928	1174	57	697	6009	167	2610
1998	2093	1270	60	763	6772	166	2776
1999	2274	1375	64	835	7607	165	2941
2000	2469	1487	68	913	8520	164	3105
2001	2681	1609	73	999	9520	163	3268
2002	2912	1741	78	1093	10613	163	3431
Total	29748	18225	910	10613		3431	

Simple Payback
Discounted Payback16.74
NA

Table IV-12

LIFE CYCLE COST ANALYSIS
FOR
SINGLE FAMILY RESIDENTIAL

Incremental Capital cost
Cost of capital

8944
10%

Heat Pump vs Electric Resistance Furnace
Double Heating Load/No Injection Well

	1	2	3	4	5	6	7
	Electricity Present System	Electricity Geothermal System	O & M Geothermal System	Net Energy Savings Cash Flow	Cumulative Cash Flow	Discounted Cash Flow	Cumulative Discounted Cash Flow
Year zero cost	922	360	54				
Year							
1983	998	390	58	551	551	501	501
1984	1079	421	61	597	1147	493	994
1985	1168	456	65	647	1794	486	1480
1986	1264	493	69	701	2495	479	1958
1987	1367	534	74	759	3254	472	2430
1988	1479	578	79	823	4077	465	2894
1989	1601	625	84	892	4969	458	3352
1990	1732	676	89	966	5935	451	3803
1991	1874	732	95	1047	6982	444	4247
1992	2028	792	101	1135	8117	437	4684
1993	2194	857	108	1229	9346	431	5115
1994	2374	927	115	1332	10678	424	5540
1995	2569	1003	122	1443	12122	418	5958
1996	2779	1085	130	1564	13685	412	6369
1997	3007	1174	139	1694	15379	406	6775
1998	3254	1270	148	1835	17215	399	7174
1999	3520	1375	158	1988	19203	393	7568
2000	3809	1487	168	2154	21357	387	7955
2001	4121	1609	179	2334	23691	382	8337
2002	4459	1741	190	2528	26218	376	8712
Total	46676	18225	2233	26218		8712	

Simple Payback
Discounted Payback

10.67
NA

Heat Pump vs Natural Gas Furnace at 90% Efficiency

Incremental Capital Cost	\$7,394
Incremental Maintenance Cost	22/yr
Annual Natural Gas Cost (furnace)	566/yr
Annual Electricity Cost (heat pump)	360/yr

Heat Pump vs Electrical Resistance Furnace

Incremental Capital Cost	\$8,844
Incremental Maintenance Cost	54/yr
Annual Electricity Cost (furnace)	922/yr
Annual Electricity Cost (heat pump)	36/yr

Tables IV-10, IV-11 and IV-12 show the life cycle costs for the systems described in the table above. The payback results for these three cases are approximately two years lower as a result of the decreased capital costs. However, there is still insufficient savings on the life of the system to generate a discounted payback figure.

Table IV-13 summarizes the results of the single family residential heat pump analysis.

Table IV-13

	<u>Incremental Capital Cost</u>	<u>20 yr Savings</u>	<u>Simple Payback</u>	<u>Discounted Payback</u>
<u>Base Case</u>				
Heat Pump vs 75% Nat. Gas	9,378	6,607	n/a	n/a
Heat Pump vs 90% Nat. Gas	8,068	4,852	n/a	n/a
Heat Pump vs Elect. Resist.	9,518	11,913	17.8	n/a
City Wtr. Heat Pump vs 75% Nat. Gas	2,410	-4,275	n/a	n/a
<u>Double Heating Load</u>				
Heat Pump vs 75% Nat. Gas	11,078	20,620	14.5	n/a
Heat Pump vs 90% Nat. Gas	9,678	10,613	19.2	n/a
Heat Pump vs Elect. Resist.	11,218	26,218	12.4	n/a

Table IV-13 cont'd:

	<u>Incremental Capital Cost</u>	<u>20 yr Savings</u>	<u>Simple Payback</u>	<u>Discounted Payback</u>
<u>Double Heating Load/1 Well</u>				
Heat Pump vs 75% Nat. Gas	8,704	20,620	12.6	n/a
Heat Pump vs 90% Nat. Gas	7,394	10,613	16.7	n/a
Heat Pump vs Elect. Resist.	8,944	26,218	10.7	n/a

It is obvious that the heat pump competes best against the electric resistance furnace. This is not surprising in view of the high unit cost of heating with electric resistance. The next system against which the heat pump competes best, in terms of payback, is the standard natural gas furnace and finally the high efficiency gas furnace.

Several factors could increase the economic attractiveness of the water-to-air heat pumps for single family residential use. In all the cases considered, the cost of the water well was considered as part of the capital cost for the heat pump system. This would be the case in areas which city water services are available. However, in an area in which city water is not available, a domestic water well would be required. As a result, well and production pump cost could be eliminated from the capital cost. This situation would apply to outlying areas around the city.

The insulation levels used for this analysis are below that found in the Ashland City Ordinance covering housing developments. However, they are above that found in the majority of existing housing stock. It is possible that, on a retrofit basis, in a home with minimal wall insulation

and an existing well, the cost of a heat pump may be competitive with that of insulation retrofit.

Most areas in Ashland are currently served with natural gas. These areas correspond generally with those served by city water. However, there may be some areas which are served by city electrical service but not water or natural gas. These areas would be good candidates for ground water heat pump applications. Conversations with local Ashland residents indicate that central air conditioning is not widely used. However, if a home owner was considering the installation of air conditioning in a new home in conjunction with natural gas or electric resistance furnace, a heat pump could be an economically competitive option. This would be particularly true in an area which is not served by city water.

In an effort to evaluate the impact of changes in inflation rates, a sensitivity analysis was run in which changes were made in the ODOE rates. Each of the life cycle sheets in Tables IV-3 through IV-12 were run four additional times. The first two of these runs were made at electrical inflation rates shown in Table IV-13 and a natural gas rate of 1% above the ODOE rate for 20 years and 3% above the ODOE rate for 20 years. Table IV-14 summarizes the results of this analysis.

When the figures in this table are compared to those in Table IV-13, it is apparent that there is not a dramatic change in the simple payback period for any of the systems. The only system which showed a simple pay-

back of less than 10 years was the ground water heat pump when compared to an electric resistance furnace in a home with approximately 3,000 square feet, no injection well and an electricity inflation rate of 3% above that forecast by ODOE. Even under these conditions, the discounted payback does not occur for 15 years.

The state of Oregon has recently eliminated the temperature requirement for heat pump tax credit. Instead, a minimum COP of 3.0 is required for qualification. Most areas of Ashland would qualify under the new guidelines. The maximum project cost eligibility is \$4,000. With the 25% credit, this would amount to a \$1,000 credit. When the credit is applied to the capital cost of the system, a shorter payback would result. However, in most cases examined the effect would not be sufficient to reduce payback periods by the required amount.

Based on this data, it does not appear that a ground water heat pump will be an attractive option for the majority of single family houses in Ashland. Given the right combination of utility inflation rates, heating load and well requirements, the water-to-air heat pump can be economically competitive. However, this is likely to be a rare occurrence.

B. Residential - Group

The second type of residential use would involve a central system serving a group of homes. Under this type of system, a single large

RESULTS OF INFLATION RATE SENSITIVITY ANALYSIS

Table IV-14

<u>System</u>	<u>Cap. Cost</u>	<u>Nat. Gas @ 1% Above ODOE</u>	<u>Nat. Gas @ 3% Above ODOE</u>	<u>Electricity @ 1% Above ODOE</u>	<u>Electricity @ 3% Above ODOE</u>
Heat Pump vs 75% Nat. Gas	9,378	n/a	16.09	n/a	n/a
Heat Pump vs 90% Nat. Gas	8,068	n/a	16.7	n/a	n/a
Heat Pump vs Elect. Resist.	9,518	-	-	16.9	15.4
<u>City Water</u>					
Heat Pump vs 75% Nat. Gas	2,410	n/a	n/a	-	-
<u>Double Heating Load</u>					
Heat Pump vs 75% Nat. Gas	11,078	13.3	11.6	15.2	18.2
Heat Pump vs 90% Nat. Gas	9,678	16.9	14.1	n/a	n/a
Heat Pump vs Elect. Resist.	11,218	-	-	11.8	10.8
<u>Double Heat. Load/1 Well</u>					
Heat Pump vs 75% Nat. Gas	8,704	11.6	10.2	13.2	15.2
Heat Pump vs 90% Nat. Gas	7,394	14.8	12.4	18.8	n/a
Heat Pump vs Elect. Resist.	8,944	-	-	10.2	9.5

production well would supply water for the entire development. As a result, the well costs are spread over a large number of homes reducing the resource development cost per home as compared to the single family approach. However, this advantage is reduced by the necessity for a distribution system for the water.

The system layout is shown in Figure IV-15. The development chosen for this example consists of 47 single family homes similar to the one used in the previous example for individual single family analysis. The buried PVC distribution system would deliver water to each of the heat pumps. Cooled water would then be rejected into the disposal well after use.

The water-to-air heat pump system was compared to natural gas furnaces (75% efficient) and electric resistance furnaces for life cycle cost analysis. The following table shows input data for the life cycle cost analysis.

Heat Pump vs Natural Gas Furnace

Incremental Capital Cost	\$304,000
Incremental Maintenance Cost	5,689/yr
Annual Electricity Cost (furnace)	11,681/yr
Annual Natural Gas Cost (heat pump)	19,222/yr

Heat Pump vs Electrical Resistance Furnace

Incremental Capital Cost	\$304,000
Incremental Maintenance Cost	5,689/yr
Annual Electricity Cost (furnace)	26,022/yr
Annual Electricity Cost (heat pump)	11,681/yr

Piping Layout for Residential Group Analysis

Table IV-16

LIFE CYCLE COST ANALYSIS
FOR
RESIDENTIAL GROUP

Incremental Capital cost
Cost of capital

304000
10%

Heat Pump vs 75% Natural Gas Furnace

	1	2	3	4	5	6	7	8
	Natural Gas Present System	Electricity Geothermal System	Insurance Geothermal System	O & M Geothermal System	Net Energy Savings Cash Flow	Cumulative Cash Flow	Discounted Cash Flow	Cumulative Discounted Cash Flow
Year zero cost	19222	11681	1520	5689				
Year								
1983	20856	12639	1550	6059	608	608	553	553
1984	22629	13675	1581	6453	919	1527	760	1312
1985	24552	14797	1613	6872	1270	2798	954	2267
1986	26688	16010	1645	7319	1714	4512	1171	3438
1987	29010	17323	1678	7794	2215	6726	1375	4813
1988	31157	18743	1712	8301	2401	9127	1355	6168
1989	33836	20280	1746	8841	2969	12096	1524	7692
1990	36746	21943	1781	9415	3607	15703	1683	9374
1991	39906	23742	1817	10027	4320	20023	1832	11206
1992	43338	25689	1853	10679	5117	25140	1973	13179
1993	47065	27796	1890	11373	6006	31146	2105	15284
1994	51113	30075	1928	12112	6998	38144	2230	17514
1995	55509	32541	1966	12900	8101	46245	2347	19861
1996	60282	35210	2006	13738	9329	55574	2457	22317
1997	65467	38097	2046	14631	10693	66267	2560	24877
1998	71097	41221	2087	15582	12207	78474	2657	27534
1999	77211	44601	2128	16595	13887	92361	2747	30281
2000	83851	48258	2171	17674	15748	108109	2832	33113
2001	91062	52215	2214	18823	17810	125919	2912	36025
2002	98894	56497	2259	20046	20092	146011	2987	39012
Total	1010268	591352		235234	146011		39012	

Simple Payback

NA

Discounted Payback

NA

Table IV-1/
LIFE CYCLE COST ANALYSIS

FOR
RESIDENTIAL GROUP

Incremental Capital cost
Cost of capital

30400 •
1

Heat Pump vs Electric Resistance

	1	2	3	4	5	6	7	8
	Electricity Present System	Electricity Geothermal System	Insurance Geothermal System	O & M Geothermal System	Net Energy Savings Cash Flow	Cumulative Cash Flow	Discounted Cash Flow	Cumulative Discounted Cash Flow
Year zero cost	26066	11681	1520	5689				
Year								
1983	28203	12639	1550	6059	7955	7955	7232	7232
1984	30516	13675	1581	6453	8807	16762	7278	14511
1985	33018	14797	1613	6872	9737	26499	7315	21826
1986	35726	16010	1645	7319	10752	37251	7344	29170
1987	38655	17323	1678	7794	11860	49111	7364	36534
1988	41825	18743	1712	8301	13069	62180	7377	43911
1989	45255	20280	1746	8841	14388	76568	7383	51294
1990	48966	21943	1781	9415	15826	92395	7383	58678
1991	52981	23742	1817	10027	17395	109790	7377	66055
1992	57325	25689	1853	10679	19104	128894	7365	73420
1993	62026	27796	1890	11373	20967	149861	7349	80769
1994	67112	30075	1928	12112	22997	172858	7328	88097
1995	72615	32541	1966	12900	25208	198066	7302	95398
1996	78570	35210	2006	13738	27616	225682	7272	102671
1997	85013	38097	2046	14631	30239	255921	7239	109910
1998	91984	41221	2087	15582	33094	289015	7202	117112
1999	99526	44601	2128	16595	36202	325217	7162	124274
2000	107687	48258	2171	17674	39585	364802	7120	131394
2001	116518	52215	2214	18823	43266	408067	7074	138468
2002	126072	56497	2259	20046	47271	455338	7026	145495
Total	1319595	591352		235234	455338		145495	

Simple Payback
Discounted Payback

16.41
NA

Tables IV-16 and IV-17 show the life cycle costs for the systems outlined in the table above.

When the heat pump is compared to the natural gas furnaces, a 20 year savings of \$146,011 is generated. This does not compare favorably to the capital cost of \$304,000. As a result, it does not appear that in this situation the heat pump system would be recommended over the natural gas furnace system.

In the case of the electric resistance furnace comparison, a simple payback of 16.4 years results. However, there is no discounted payback since the 20 year discounted savings amounts to only \$145,495 or about half of the capital cost of \$304,000.

The characteristics of the above project were chosen to provide the most conservative results. There are several factors which could improve the economics.

- 1) If the homes were to be air conditioned, this could substantially reduce the incremental cost for the heat pump. For example, the current incremental capital cost for the heat pump system divided among the 47 houses amounts to \$6,468 per house. If air conditioning were to be supplied, this incremental capital cost would be reduced to \$4,458 per house. Two additional runs were made at increased inflation rates to examine their effect and that of the reduced capital investment. These runs are discussed below.
- 2) If the development were to be located outside the city water service area, capital costs for the well, pump and a portion

of the distribution system would be reduced since these would be required for domestic water service.

- 3) The site arrangement shown in Figure IV-15 contains large individual properties. If the development were arranged in a more densely populated fashion, capital costs for the distribution system could be reduced.

An additional consideration, with regard to the type of system, should be mentioned. Because a development such as this is usually constructed by one entity and sold to a group of individual owners, there is a problem with capital costs and savings resulting from the use of heat pumps. Specifically, the developer must provide the additional capital cost for the system and the home owners derive their benefits through lower heating costs. Because of the lack of tax benefits associated with heat pump use, there is little incentive for the developer to install such a system. The only alternative is to raise the price of the homes which may have negative marketing effects. This situation could be addressed through a density bonus system similar to the one developed for building insulation levels.

The operation and maintenance of the distribution system would have to be carried out over a long period of time. This would require the formation of some entity to perform the task, such as a home owners association.

The system analyzed above uses a large number of individual heat pumps. This system was chosen over the central heat pump method for a variety of reasons, but primarily because:

- 1) The individual heat pumps eliminate the necessity for an insulated distribution system, and

- 2) The individual heat pumps allow each home owner to select heating or cooling mode, thus eliminating the requirement for an insulated four pipe distribution system.

As in the individual single family residential analysis, additional life cycle costs were run at various inflation rates for the residential single family group. The rates used are the same as in the previous example:

- Run 1: Natural gas at 1% above ODOE rates for 20 years
- Run 2: Natural gas at 3% above ODOE rates for 20 years
- Run 3: Electricity at 1% above ODOE rates for 20 years
- Run 4: Electricity at 3% above ODOE rates for 20 years

Table IV-18 summarizes the results of this analysis. For the water-to-air heat pump compared to standard natural gas furnaces, at a gas inflation rate of 3% above ODOE, forecast for the simple payback is shown as 16.1 years. This is based on a 20 year savings of \$595,682 compared to the original \$235,234 for the original run. Although this appears to be a substantial improvement, when these figures are brought back to present value, they are still far less than the required capital investment. Two additional runs were made to examine the situation in which the proposed homes would be air conditioned. This has the effect of reducing the required incremental capital cost for the heat pump system. For the water-to-air heat pump compared to the natural gas furnace under these conditions (and at the accelerated inflation rate of 3% above ODOE), a simple payback

of 14.2 years results. For the water-to-air heat pump compared to the electric resistance furnace (at the accelerated electric inflation rate of 3% above ODOE) an 11.1 year payback results.

As in the individual single family residential, these figures are within consideration. However, the combination of factors necessary to bring about such payback figures are unlikely to occur.

C. Commercial Applications

As in the residential sector, the primary application in the commercial area will be in space heating systems. In order to evaluate a specific case of this type of use, a planned city office/warehouse facility was chosen for analysis.

The facility planned for the southeast section of Ashland would be an approximately 17,000 square foot building of which 9,000 square feet would be office area and 8,000 square feet warehouse. Because this building is only in the preliminary planning stages, no detailed plans were available at the time of this report. As a result, the following assumptions were made with regard to the construction:

Windows	Double Glaze
Roof	R-7
Two Story	
.75 air changes/hr occupied areas	
1.5 air changes/hr unoccupied areas	
Outside Design Temp.	19°F
Inside Design Temp.	68°F
IDT (warehouse)	60°F
Peak Load	305,702 Btu/hr

SUMMARY OF LIFE CYCLE COST ANALYSIS
FOR
RESIDENTIAL GROUP AT INCREASED INFLATION RATES

Table IV-18

<u>System</u>	<u>@ ODOE Rates</u>	<u>Nat. Gas @ 1% Over ODOE Rates</u>	<u>Nat. Gas @ 3% Over ODOE Rates</u>	<u>Electricity @ 1% Over ODOE</u>	<u>Electricity @ 3% Over ODOE</u>
Heat Pump vs 75% Nat. Gas	n/a	n/a	16.1	n/a	n/a
Heat Pump vs Elect. Resist.	16.41	-	-	15.2	13.4
<u>Homes Equiped for Air Cond.</u>					
Heat Pump vs 75% Nat. Gas	-	-	14.2	-	-
Heat Pump vs Elect. Resist.	-	-	-	-	11.1

Because of the nature of the building design, shown in Figure IV-19, and the use of the areas, the building was divided into four zones; three occupied zones and one warehouse zone. Each of these areas would have it's own climate control system. The conventional system used for comparison to the water-to-air heat pump was a standard rooftop gas heating/ electric cooling unit. In the warehouse area, it was assumed that cooling would not be provided. Equipment for that area was assumed to consist of gas fired unit heaters. Input data for the life cycle analysis is shown in the following table.

Table IV-20

Water-to-Air Heat Pump vs 75% Natural Gas

Incremental Capital Cost	\$25,258
Incremental Maintenance Cost	40/yr
Annual Natural Gas Cost	4,587/yr
Annual Electrical Use Cost (heat pump)	3,092/yr

Water-to-Air Heat Pump vs 75% Natural Gas (no injection well)

Incremental Capital Cost	\$21,084
Incremental Maintenance Cost	40/yr
Annual Natural Gas Cost	4,587/yr
Annual Electrical Use Cost (heat pump)	3,092/yr

The life cycle costs for the data are shown in Tables IV-21 and IV-22. Both approaches show simple and discounted paybacks of less than 20 years. This means that for the city, the water-to-air heat pump would be a less expensive system to operate after a 20 year life than a natural gas system. A second run was made at a lower capital cost to simulate surface disposal

Figure IV-19
Ashland Service Center

LIFE CYCLE COST ANALYSIS
FOR
ASHLAND WAREHOUSE
Commercial

Incremental Capital cost
Cost of capital

25258
10%

	1	2	3	4	5	6	7
	Natural Gas	Electricity	O & M	Net Energy	Cumulative	Discounted	Cumulative
	Present	Geothermal	Geothermal	Savings	Cash Flow	Cash Flow	Discounted
	System	System	System	Cash Flow			Cash Flow
Year zero cost	4587	3092	40				
Year							
1983	4977	3346	43	1589	1589	1444	1444
1984	5400	3620	45	1735	3323	1434	2878
1985	5859	3917	48	1894	5217	1423	4301
1986	6369	4238	51	2079	7297	1420	5721
1987	6923	4585	55	2283	9579	1417	7138
1988	7435	4961	58	2415	11994	1363	8502
1989	8074	5368	62	2644	14638	1357	9858
1990	8769	5808	66	2894	17533	1350	11209
1991	9523	6285	71	3168	20700	1343	12552
1992	10342	6800	75	3467	24167	1337	13889
1993	11231	7358	80	3794	27961	1330	15218
1994	12197	7961	85	4151	32112	1323	16541
1995	13246	8614	91	4542	36654	1316	17857
1996	14385	9320	97	4969	41622	1308	19165
1997	15622	10084	103	5435	47057	1301	20466
1998	16966	10911	110	5945	53003	1294	21760
1999	18425	11806	117	6502	59505	1286	23046
2000	20010	12774	124	7111	66616	1279	24325
2001	21730	13822	132	7777	74393	1272	25597
2002	23599	14955	141	8503	82896	1264	26861
Total	241083	156533	1654	82896		26861	

Simple Payback 10.29
Discounted Payback 18.73

Figure IV-22

LIFE CYCLE COST ANALYSIS
FOR

ASHLAND WAREHOUSE

Commercial - No Injection Well

Incremental Capital cost
Cost of capital

21084
10%

	1	2	3	4	5	6	7
	Natural Gas Present System	Electricity Geothermal System	O & M Geothermal System	Net Energy Savings Cash Flow	Cumulative Cash Flow	Discounted Cash Flow	Cumulative Discounted Cash Flow
Year zero cost	4587	3092	40				
Year							
1983	4977	3346	43	1589	1589	1444	1444
1984	5400	3620	45	1735	3323	1434	2878
1985	5859	3917	48	1894	5217	1423	4301
1986	6369	4238	51	2079	7297	1420	5721
1987	6923	4585	55	2283	9579	1417	7138
1988	7435	4961	58	2415	11994	1363	8502
1989	8074	5368	62	2644	14638	1357	9858
1990	8769	5808	66	2894	17533	1350	11209
1991	9523	6285	71	3168	20700	1343	12552
1992	10342	6800	75	3467	24167	1337	13889
1993	11231	7358	80	3794	27961	1330	15218
1994	12197	7961	85	4151	32112	1323	16541
1995	13246	8614	91	4542	36654	1316	17857
1996	14385	9320	97	4969	41622	1308	19165
1997	15622	10084	103	5435	47057	1301	20466
1998	16966	10911	110	5945	53003	1294	21760
1999	18425	11806	117	6502	59505	1286	23046
2000	20010	12774	124	7111	66616	1279	24325
2001	21730	13822	132	7777	74393	1272	25597
2002	23599	14955	141	8503	82896	1264	26861
Total	241083	156533	1654	82896		26861	

Simple Payback 9.11

Discounted Payback 15.48

of the geothermal fluids. The elimination of the injection well has the effect of lowering the simple payback by one year, and discounted payback by three years resulting in paybacks of 9.1 years and 15.5 years respectively.

As in the previous examples, the warehouse/office facility was also examined under accelerated inflation rates for electricity and natural gas. Each of the two cases above was examined at natural gas inflation rates of 1% and 3% above the rates forecast by ODOE. In addition, each case was run at electricity inflation rates of 1% and 3% above ODOE's predicted rates.

Table IV-23
Simple Payback Results

<u>System</u>	<u>Nat. Gas @ 1% Over ODOE Rate</u>	<u>Nat. Gas @ 3% Over ODOE Rate</u>	<u>Elect. @ 1% Over ODOE Rate</u>	<u>Elect. @ 3% Over ODOE Rate</u>
Heat Pump vs Nat. Gas (2 well system)	9.3	7.9	11.3	n/a
Heat Pump vs Nat. Gas (1 well system)	8.3	7.2	9.9	n/a

Since the only system compared to the heat pump for this application was a natural gas system, accelerated natural gas rates have a positive effect upon the economics while accelerated electricity rates have a negative effect. In each case, electrical inflation rates of 3% above ODOE's rates produce a situation in which the natural gas system would be the least expensive system. At all other rates, the heat pump system appears to be the choice.

It should be pointed out that the insulation levels assumed for this building are quite low in comparison to most new buildings. This is par-

ticularly true in the warehouse area. As a result, heating requirements on an annual basis are unusually high. This has the effect of generating a large annual savings for the heat pump system over the natural gas system.

In many commercial buildings, particularly retail establishments and office buildings, there will be a significant contribution to the heating requirements from internal heat sources (people, lighting, office equipment, etc.). This situation will tend to reduce annual heating requirements and, thus, annual savings from a heat pump system. As a result, the heat pump may not be an economical option. However, if the building is large enough to require an appreciable amount of ventilation air, the heating requirement may be high enough to warrant an analysis. Each application would have to be analyzed on an individual basis.

The payback periods shown for the city facility are on the order of 7 to 11 years depending upon the system and inflation rates used. This is certainly within the realm of consideration for a public entity. However, it is probably beyond the time frame which a private entity would consider. This would be particularly true for buildings and shopping centers. Since a majority of buildings in the commercial section are subject to these conditions, water-to-air heat pumps will probably not play a major role in this area. However, they should be considered in all cases for new construction in the public section such as the Ashland office/warehouse.

D. Industrial Applications

As mentioned earlier, ground water heat pump applications in the residential and commercial areas would consist primarily of space heating systems. In the industrial section, however, process heating would provide the primary load.

Since process loads vary widely in temperature requirements and duty from industry to industry, they are more difficult to characterize with a specific example. In order to evaluate the impact of various characteristics of process applications, a series of graphs were developed. Each of the graphs compares various costs associated with industrial heat pumps to those of a gas boiler, the most likely source of process heat in Ashland.

The first graph (Fig. IV-24) is a plot of the performance of large industrial heat pumps as influenced by source and sink temperatures. This graph gives an indication of the performance of a heat pump in a particular application. To find the COP, enter the bottom of the graph at the source water temperature (in Ashland, under the best of conditions this would amount to about 85°F). Move vertically until the process temperature is intersected on the y axis. For example, at a source temperature of 70°F and a process temperature requirement of 130°F, a COP of 3.6 would result.

Once the COP is known, an energy cost can be developed and compared to other heating sources. This is illustrated in Figure IV-25. This graph shows energy cost in dollars per million Btu for heat pumps versus natural gas fired boilers. Curves for 2.0, 3.0 and 4.0 COP and 75% boiler efficiency

Figure IV-24

NATURAL GAS VS WATER SOURCE HEAT PUMP

Figure IV-25

are shown. In order to compare a heat pump energy cost for a particular application to a gas boiler, the COP from Figure IV-24 is used. Enter the bottom of the graph at the applicable electricity rate and move vertically until the proper COP curve is intersected. Read the cost per million Btu to the left. The same procedure is used for the gas boiler and applicable gas rate. Values based on current Ashland rates are shown. From the difference in cost for energy and the total energy requirement on an annual basis, a gross savings from the operation of the heat pump can be determined. Using the data from the previous example and Ashland electric and gas rates, the difference in cost of energy per million Btu would amount to \$3.75. Multiplying this figure by the annual heat requirement would result in a gross annual savings.

It is important to note, however, that there are a number of other costs which must be considered in the evaluation of an industrial heat pump application. These costs include:

- Capital Costs (incremental)
- Maintenance Costs
- Well Costs
- Pumping Costs

Each of these costs would be subtracted from the gross annual savings to arrive at a net savings.

Figure IV-26 shows a plot of the installed cost of water source heat pumps vs gas boiler for process applications. Heat pump cost is heavily influenced by the source and sink temperature involved. The data used in the development of the heat pump curves was collected from a number of different appli-

cations. Source temperatures ranged from 60°F-85°F and sink temperatures from 100°F-140°F. The shift which occurs in the middle of the curve is the result of a change in compressor design in the larger capacity heat pumps.

Figure IV-27 shows maintenance costs for heat pumps and gas boilers based on 3% of capital cost. The difference between costs for the two would constitute the incremental maintenance cost for the heat pump.

Figure IV-28 is a plot of well pumping costs for a heat pump system and is arranged to supply a value in dollars per million Btu. The graph is based upon an evaporator Δt of 10°F and a heat pump COP of 4.0. Cost per million Btu is plotted against total pump head. This latter value would vary from site to site.

Figure IV-29 is a plot of well costs for 6 inch and 8 inch wells, the diameter most likely to be required for an industrial application. The x axis is labeled 'distance from contact'. The contact referred to is that of the Mt. Ashland pluton and Hornbrook/Applegate formation mentioned in the geology section of this report. In order to provide a conservative estimate of costs, it was assumed that a well for an industrial application would be drilled to the depth of the contact in order to obtain the warmest water. This would probably be the case for location close to the contact and in the north section of town. However, due to water temperatures in most of the city, well depth may only be that which would provide adequate ground water supplies.

**COST OF BOILER INSTALLED
VS
COST OF HEAT PUMP INSTALLED**

Table IV-26

MAINTENANCE COST OF HEAT PUMP

VS

GAS BOILER

Table IV-27

PUMPING COST

Figure IV-28

Figure IV-29

Using the values from these graphs will allow a rough estimate of the potential for an industrial heat pump application. The following example illustrates this procedure.

Load 800,000 Btu/hr	80°F Source
Annual Load Factor 25%	120°F Process Requirement
	COP 4.0
Annual Load $8,760 \times .25 \times 800,000 = 1.752 \times 10^9$ Btu/yr	

From Figure IV-25:

Cost/10 ⁶ Btu Nat. Gas =	\$8.20
Cost/10 ⁶ Btu Heat Pump =	<u>4.00</u>
Difference =	\$4.20

Gross Savings per year:

1.752×10^9 Btu/yr $\times$ \$4.20/10⁶ Btu = \$7,258/yr

From Figure IV-26:

Cost of Boiler =	\$6,900
Cost of Heat Pump =	<u>47,000</u>
Difference	\$40,100

From Figure IV-29:

Well Costs (assume 6" well, 800' from contact) = \$8,000

From Figure IV-27, maintenance costs:

Boiler =	\$200/yr
Heat Pump =	<u>1,390/yr</u>
Difference	\$1,190/yr

From Figure IV-28:

Pumping Cost (assume 150' head) = \$.325/10⁶ Btu

Annual Cost = \$.325/10⁶ Btu X 1.752 X 10⁹ Btu/yr = \$569/yr

Simple payback equals:

(Heat pump incremental cost + well cost) ÷ [(gross savings) -
(maintenance costs + pumping costs)] =

(40,000 + 8,000) ÷ [(7358) - (1190 + 569)] =

8.59 years

This very simple calculation shows the incremental investment in the heat pump system would have a simple payback of 8.6 years.

However, most industrial loads would be associated with the private sector. As a result, the impact of taxes on each application should be taken into account. Since there is no simple method to predict the impact of taxes, a specific example is provided below for illustration purposes. Data for the example above was used as input to the life cycle analysis shown in Tables IV-30a and IV-30b. The table below provides a summary of that data.

Table IV-31

Incremental Capital Cost	\$64,000
Incremental Maintenance	1,422/yr
Insurance	329/yr
Electrical Usage (heat pump)	6,955/yr
Natural Gas (boiler)	14,366/yr

As shown, the life cycle analysis takes into account depreciation, tax credits (investment) and federal taxes (@ 46%). In this particular case

Table IV-30a

LIFE CYCLE COST ANALYSIS
FOR
HEAT PUMP VS INDUSTRIAL BOILER

	1	2	3	4	5	6	7
	Natural Gas Present System	Electricity Geothermal System	Insurance Geothermal System	O & M Geothermal System	Net Energy Savings Cash Flow	Depreciation	Net Income Before Taxes
Year zero cost	14366	6955	324	1422			
Year							
1983	15587	7525	330	1514	6217	3245	2972
1984	16912	8142	337	1613	6820	3245	3575
1985	18350	8810	344	1718	7478	3245	4233
1986	19946	9532	351	1829	8233	3245	4988
1987	21681	10314	358	1948	9061	3245	5816
1988	23286	11160	365	2075	9686	3245	6441
1989	25288	12075	372	2210	10631	3245	7386
1990	27463	13065	380	2353	11665	3245	8420
1991	29825	14137	387	2506	12795	3245	9550
1992	32390	15296	395	2669	14030	3245	10785
1993	35175	16550	403	2843	15380	3245	12135
1994	38200	17907	411	3028	16855	3245	13610
1995	41486	19375	419	3224	18467	3245	15222
1996	45053	20964	428	3434	20228	3245	16983
1997	48928	22683	436	3657	22151	3245	18906
1998	53136	24543	445	3895	24253	3245	21008
1999	57705	26556	454	4148	26548	3245	23303
2000	62668	28733	463	4418	29054	3245	25809
2001	68058	31090	472	4705	31791	3245	28546
2002	73910	33639	481	5011	34779	3245	31534
Total	755047	352098	8030	58798	336121	64900	271221

Incremental Capital cost
Cost of capital

64900
10%

8	9	10	11	12	13	14
Federal Taxes	Net Income After Taxes	Add Tax Credit & Depreciation	After Tax Cash Flow	Cumulative After Tax Cash Flow	Discounted After Tax Cash Flow	Cumulative After Tax Discounted Cash Flow
1367	1605	9735	11340	11340	10309	10309
1644	1930	3245	5175	16515	4277	14586
1947	2286	3245	5531	22046	4155	18741
2295	2694	3245	5939	27985	4056	22798
2675	3141	3245	6386	34370	3965	26763
2963	3478	3245	6723	41093	3795	30558
3398	3989	3245	7234	48327	3712	34270
3873	4547	3245	7792	56119	3635	37905
4393	5157	3245	8402	64521	3563	41468
4961	5824	3245	9069	73589	3496	44964
5582	6553	3245	9798	83387	3434	48398
6261	7349	3245	10594	93981	3376	51774
7002	8220	3245	11465	105446	3321	55095
7812	9171	3245	12416	117862	3269	58364
8697	10209	3245	13454	131316	3221	61585
9664	11344	3245	14589	145905	3175	64760
10719	12584	3245	15829	161734	3132	67892
11872	13937	3245	17182	178916	3090	70982
13131	15415	3245	18660	197576	3051	74033
14506	17029	3245	20274	217849	3014	77047
124762	146459		217849		77047	

Simple Payback
Discounted Payback

9.04
16.04

the simple payback including taxes is very close to the abbreviated method shown above. However, this may vary from case to case. The discounted payback is shown as 16 years. Since a 10% discount rate was used, this implies that the rate of return for the project is slightly greater than 10%. For the private sector, this is probably somewhat low.

The economics of this or any other application can be enhanced by an increase in the annual load factor or, stated another way, larger annual heating requirements. Contrary to space heating application where the annual requirement is primarily weather dependent, process loads are dependent upon the operating schedule of the industrial application. As a result of the above example, an annual load factor in excess of 25% would be a positive indication of heat pump potential.

Since heat pump energy cost is dependent upon COP, the temperature requirement of the application will also be a critical factor as far as heat pump suitability. Based on the resource temperature in Ashland, process temperature requirements of 140°F or below would probably be realistic for consideration. Figure II-4 gives an indication of some of the processes which take place in this temperature range. Referring to Figure II-5, it is obvious that as resource temperature decreases at a constant process temperature, the COP of the heat pump decreases. Since the highest resource temperatures are located in the north section of Ashland, the highest temperature process application would have the best potential in this area.

V. CONCLUSIONS AND RECOMMENDATIONS

The geology of the area near the city of Ashland is dominated by the Mount Ashland pluton. The contact between the pluton and the overlying rock of the Hornbrook formation dips to the northeast at approximately 25% in the vicinity of the city. Four warm springs in the city are located at or near the surface expression of this contact, along a north-west trending line. The warmest water temperature recorded in the recent DOGAMI testing conducted in the Ashland area is on the order of 95°F at the Jackson Hot Springs. Resource temperatures decrease as one moves toward the city.

Warm water flow is thought to occur either along faults or along contact zones between rock formations. In any case, accessible resource temperatures are less than 90°F. Geochemical analysis indicates that a hotter resource (160°F-200°F) may exist at depth. However, the location and depth of a well required to access this fluid is unknown. As a result, a substantial exploration effort would be required. In order to make use of the accessible resource, heat pumps would be necessary.

This report examined the economics of heat pump use in Ashland in three primary areas:

- Residential Space Heating
- Commercial Space Heating
- Industrial Process

Water source heat pump economics are most positive in situations in which

they are competing against other systems operating with expensive fuels such as electric resistance. In addition, large heating requirements are a positive characteristic.

In Ashland, the primary energy source for both space heating and process applications is natural gas. This is a relatively inexpensive source of energy causing heat pumps to be difficult to justify. In addition, the city of Ashland has developed construction guidelines for new residential developments which tend to substantially decrease space heating requirements. This, in conjunction with the relatively mild weather in the area, combine to reduce the annual heating requirements. As a result, wide application of heat pumps in Ashland does not seem to have great potential. However, there are a number of situations in which heat pumps can be a realistic option and, in fact, provide a less expensive method of heating than natural gas.

In the case of an individual single family residence, calculations indicate that, within the city of Ashland, even under conditions of accelerated natural gas inflation rates, the most attractive simple payback period is on the order of 12 years. This is for a system consisting of a production well, pump, water-to-air heat pump, for a 3,000 square foot house. This extended payback period is due to the availability of inexpensive natural gas and city water. City water service eliminates the need for a domestic water well for users served by this system. As a result, this cost must be considered part of the heat pump capital cost. The heat

pump is slightly more competitive against electric resistance under similar conditions showing a payback of 9.5 years.

The most attractive situation for individual single family use would occur in areas served by the city electric service, but outside the city water and natural gas areas. Under these conditions, the heat pump would be competing against more expensive heating methods, and would not have to shoulder the cost of a domestic water well and production pump.

For developments of single family or multi-family residences, the conclusions are similar to those for individual residential applications. In this situation a large single well would serve a number of residences with source water. Although this approach spreads the well cost over a larger number of houses, the reduction in unit well costs is compensated for by increased distribution piping costs.

As in the individual single family analysis, several scenarios were examined for a residential development heat pump system. When the water-to-air heat pumps were compared to natural gas furnaces, the most attractive situation occurred when natural gas inflation rates were accelerated to 3% per year. Under these conditions, the additional cost of the heat pump system was paid back in 16 years. If the homes in the project were to be air conditioned (resulting in less incremental cost for the heat pumps), this figure is decreased to 14 years. The figures for the heat pump compared to electric resistance are slightly better.

Again, the most attractive candidates in this category would be developments outside natural gas and city water service areas. An additional consideration in a development situation concerns capital cost. The additional capital cost for the system must be provided by the developer. However, savings from the system are collected by the home owner. This removes the incentive for the developer to install such a system. It is possible that this situation could be addressed through a system such as that used for higher insulation levels in the Ashland ordinance.

Since there is not a great deal of residential area to be developed in Ashland and most of this area is served by both city water and natural gas, the potential for the type of system described above is small.

The economics shown in this study for residential applications could be slightly improved as a result of a recent decision by the state of Oregon. Tax credits up to a maximum of \$1,000 are available for heat pump application with COP's of 3.0 or greater.

Commercial applications in Ashland would consist primarily of space heating offices and retail establishments. Again in this area, the availability of natural gas and city water reduce the potential for heat pump development. However, it appears that city and state owned structures provide some good prospects for heat pump applications. This is primarily due to the fact that the economic criteria of government agencies is gen-

erally less restrictive. An analysis was done on the proposed Ashland city warehouse/office building planned for the southeast part of town. Due to the relatively high heat load of the building and the use of air conditioning, a simple payback of the heat pump system of 10.3 years results. This drops to approximately 8 years at accelerated inflation rates. Based on the 10.3 year figure, the city should seriously consider such a system at this facility. For other new municipal construction which would be air conditioned, the heat pump system should be considered, providing well drilling sites are available.

Industrial applications for water source heat pumps would consist primarily of process heating loads. In order to assess the potential of such systems, a series of graphs were developed. Using specific information from a particular application, a rough indication of heat pump feasibility can be derived. However, in general terms, a successful application of a water source heat pump for process heating would have the following characteristics.

- high annual load factor (>25%)
- low process temperature requirement (<140°F)
- located in the northeast section of Ashland close to the geological contact

A life cycle analysis was performed for a generic industrial load consisting of a peak 800,000 Btu/hr and a 25% load factor. Including considerations for taxes and tax credits, an after tax simple payback of 9 years resulted.

In summary, the best prospects for heat pump application in the Ashland area are for residential construction outside the city limits, new government sponsored construction within the city, and possibly industrial loads in the northeast section of town.

VI. APPENDIX

A. Appendix A - Geology

Results of a geothermal resource assessment of the Ashland, Oregon, area, Jackson County

by Gerald L. Black, Oregon Department of Geology and Mineral Industries, and Monty Elliott, Jad D'Allura, and Bill Purdom, Southern Oregon State College, Ashland, Oregon

Figure 1. Geologic map of the Ashland, Oregon, area.

INTRODUCTION

As part of its low-temperature geothermal resource assessment program, the Oregon Department of Geology and Mineral Industries (DOGAMI) drilled five temperature-gradient holes in the Ashland, Oregon, area during June of 1982. A sixth hole was drilled in the Cascade Mountains east of Ashland during the same period. This last hole was drilled as part of a continuing evaluation of the geothermal potential of the Cascade Range in Oregon. It was sited to aid in defining the position and/or existence of a transition from lower (~ 40 milliwatts per square meter [mWm^{-2}]) to higher ($>100 \text{ mWm}^{-2}$) heat flow which has been identified in the northern and central Cascade Range in Oregon.

Ashland, a city of 14,975 inhabitants, is located in southwestern Oregon in Jackson County (Figure 1). There are four warm springs located in or near the city (Figure 1). Jackson Hot Springs, the warmest of the four, is located northwest of the city limits (Figure 1). A temperature of 35°C has been reported for Jackson Hot Springs (Berry and others, 1980), but DOGAMI personnel have measured temperatures as high as 43.5°C in the warmest of the approximately ten orifices which occur in the hot springs area. The three other springs lie on a north-northwest-trending line within the city limits (Figure 1). They include Helman Hot Springs (31.5°C), White Sulphur Spring (28.5°C), and the Southern Pacific Spring. A resort located at Jackson Hot Springs represents the only commercial use of geothermal fluids in Ashland.

GEOLOGY

The city of Ashland lies on the boundary between the Klamath Mountains and Western Cascades physiographic provinces. The geology in the immediate vicinity of the city was mapped in 1981 by three of the authors (Elliott, D'Allura, and Purdom) specifically for the low-temperature geothermal resource assessment project. Figure 1 is taken from their map.

Quartz diorites of the Late Jurassic Mount Ashland Pluton dominate the terrain west of the city. The rocks of the pluton were encountered in two of the five temperature-gradient holes drilled for the project (Darex at 93 m [305 ft] and SOSG Gym at 120 m [392 ft]; see Figure 2). In addition, a well drilled at the Ashland Greenhouses (Figure 1) encountered the contact between the pluton and the overlying Hornbrook Formation at a depth of 299 m (982 ft).

Cropping out northwest of the city are rocks of the Late Triassic Applegate Group. These rocks were contact metamorphosed during the emplacement of the Mount Ashland Pluton. The Butler Ford hole encountered Applegate Group rocks at 352 m (115 ft) (Figure 2). The contact between the metamorphic rocks and the pluton is a zone of mixed rocks, where stringers of quartz diorite complexly intrude the Applegate Group. Jackson Hot Springs is located near the contact between the Applegate Group, the Mount Ashland Pluton, and the Hornbrook Formation.

Greenish to gray sandstones and mudstones of the Late Cretaceous Hornbrook Formation nonconformably overlie

the Mount Ashland Pluton and the associated metamorphic rocks of the Applegate Group. The Hornbrook Formation, which represents a marine onlap sequence, dips rather uniformly northeastward at about 25° (Figure 1). The four warm springs occurring in the Ashland area are located at the contact of the Hornbrook Formation with the Mount Ashland Pluton, and all five of the temperature-gradient holes drilled in the Ashland area were collared in Hornbrook Formation sediments.

The Hornbrook Formation is in turn unconformably overlain by the Eocene to late Oligocene Payne Cliffs formation which consists of fluvial conglomerates and sandstones. Tertiary intrusions of basaltic composition occur east and southeast of the city, but neither they nor the rocks of the Payne Cliffs formation were encountered in any of the drill holes. Figure 2 shows the lithologies of the five temperature-gradient holes drilled in the Ashland area.

Figure 2. Lithologies of Ashland, Oregon, temperature-gradient holes.

HEAT FLOW

Based on data from a U.S. Geological Survey (USGS) hole drilled as part of a regional heat-flow study of southwestern Oregon and northern California (Mase and others, 1982) and on temperature gradients measured by DOGAMI in unused water wells ("free" holes) during the summer of 1981 (Blackwell and others, 1982), the background heat flow in the Ashland area is approximately 42 mWm⁻². Typical background-temperature gradients are 16°-18° C/km in the quartz diorite of the Mount Ashland Pluton and 20°-25° C/km in the sedimentary rocks of the Hornbrook Formation. The USGS hole is located near Winburn Camp, about 6.5 km (4 mi) south of Ashland. The DOGAMI "free" holes are scattered around the outskirts of the town, mostly in the valley to the east-northeast.

The heat-flow data for the six holes drilled as part of the Ashland low-temperature assessment project are summarized in Table 1. Also included in Table 1 are heat-flow data for a 344-m (1,130-ft) well drilled at the Ashland Greenhouses (39S/1E-48BD) during 1981 and 1982. The temperature-depth curves for the six holes are reproduced in Figure 3. The data for the Ashland Greenhouses hole have been published previously (Blackwell and others, 1982) but are reproduced here because information obtained from the hole was invaluable in understanding the nature of the low-temperature resource at Ashland. It should be noted that the thermal conductivities listed in Table 1 for the Ashland Greenhouses hole were determined on cuttings from the Darea hole, the nearest hole for which cutting samples were available. All thermal-conductivity measurements were performed under the direction of David D. Blackwell at Southern Methodist University, using the divided-bar technique of Sass and others (1971).

The temperature-depth curve of the Butler Ford hole (Figure 3) above 70 m (230 ft) is a good example of fluid upflow within the well bore. During drilling of the well, artesian flow was encountered at about 70 m (230 ft). Normally in temperature-gradient wells the intraborehole movement of fluids is prevented by grouting the hole from bottom to top with cement. Since the quantity of fluid encountered in the Butler Ford hole (~100 gallons per minute [gpm]) represented a potential low-temperature resource, the decision was made not to grout the hole in order to preserve it for possible later use. Instead, the well was sealed with a welded-steel plate. Beneath the artesian zone at 70 m (230 ft), the temperature-depth curve appears conductive. The heat-flow value (118 mWm⁻²) for the lower portion of the hole is high but reasonable, considering the nearness of the hole to Jackson Hot Springs (Figure 1).

The temperature-depth curve for the Darea hole results from variations in thermal conductivity. There are three linear segments with breaks in slope at 50 m (165 ft) and 100 m (330 ft) (Figure 3). The lithology in the hole consists predominantly of shale to 49 m (160 ft), sandstone from 49 m to 94 m (160 to 310 ft), and quartz diorite from 94 m to 148 m (310 to 486 ft).

Figure 3. Temperature-depth curves for the Ashland, Oregon, low-temperature assessment program.

(Figure 2). Temperature gradients are typically higher where the thermal conductivities are lower (Table 1). The disparity in heat-flow values between the lower and upper part of the hole (Table 1) most probably reflects the presence of a warm-water aquifer at or near the contact of the Hornbrook Formation with the Mount Ashland Pluton. The difference in heat flow between the upper and lower portions of the Ashland Greenhouses hole is probably due to the same aquifer and will be discussed in more detail in a later section.

The temperature-depth curves for both the Justice Center and SOSC Gym holes are typical of conductive heat flow. The highly convex nature of the curve for the upper part of the SOSC Gym hole (Figure 3) is a microclimatic effect resulting primarily from solar heating. The hole collar is located on the margin of a large parking lot, where evapotranspiration does not effectively moderate the near-surface temperatures. The hole is also adjacent to the Southern Oregon State College steam plant, which may be partly responsible for the high near-surface temperatures. A similar, but smaller, microclimatic effect can be seen in the upper portion of the Justice Center hole (Figure 3) which is located in a large, open, flat field with sparse vegetation.

The temperature-depth profile for the hole at the Rodeo Grounds is typical of intraborehole downflow. The hole was not grouted to prevent intraborehole fluid movement, and as a result it is isothermal to a depth of 80 m (264 ft). Below that depth, the temperature gradient is linear, and the heat flow is conductive.

The hole at Corral Creek, which is located east of the map area of Figure 1, also possesses a linear temperature-depth curve and conductive heat flow.

Based on the above analyses, it appears that the Rodeo Grounds, SOSC Gym, and Justice Center holes all represent "background," or average, heat-flow values for the Ashland area. The heat-flow values for these three holes (50 to 65 mWm⁻²) are somewhat higher than the background value (42 mWm⁻²) quoted at the beginning of this section. There are several possible explanations for the discrepancy: (1) The regional heat flow increases from west to east (toward the Cascade Mountains), and the background value of 42 mWm⁻² was based primarily on a hole located west of the city. It is possible that the

regional heat flow in the Ashland area is greater than 42 mWm⁻². (2) A warm aquifer located at the Hornbrook Formation-Mount Ashland Pluton contact may underlie the entire Ashland area. The aquifer would not need to be particularly large or particularly warm to produce the required increase in temperature gradient (and hence, heat flow). (3) The lithologies in the upper part of the drill holes consisted mostly of shales and fine siltstones (Figure 2). The in-situ thermal conductivities of shales are nearly always lower than values obtained from laboratory measurements with a divided bar (D.D. Blackwell, personal communication, 1981). The discrepancy is due to the impossibility of preserving the in-situ anisotropic nature of shale in measurements on randomly oriented cuttings fragments. The thermal conductivity values of Table 1 may thus be slightly inflated, resulting in increased heat-flow values. (4) The higher heat flow may be due to thermal refraction at the contact between bodies of higher thermal conductivity (Mount Ashland Pluton) and lower thermal conductivity (Hornbrook Formation), in a manner analogous to many Basin and Range situations (Blackwell and others, 1978). (5) Terrain corrections have not been completed for the holes listed in Table 1.

Since temperature gradients lower than those measured in the SOSC Gym, Rodeo Grounds, and Justice Center holes have been measured in "free" holes east of Ashland, it is doubtful that a regional eastward increase in heat flow is the cause of the anomaly. It is also unlikely that a warm aquifer underlies the entire city, as no such aquifer was identified in the three holes mentioned above. Two of the three holes were slightly artesian, but the artesian zones were located within the Hornbrook Formation rather than at the contact between the Hornbrook Formation and the Mount Ashland Pluton. It is also improbable that thermal refraction can account for much, if any, of the anomaly. The contrast in thermal conductivities between the quartz diorites of the Mount Ashland Pluton and the sedimentary rocks of the Hornbrook Formation is not nearly as great as the conductivity contrast between the unconsolidated sediments of the basins and the bedrock of the ranges in the Basin and Range province. The thermal conductivities in the latter situation often differ by a factor of two or more (Blackwell and others, 1978). It is more likely that the higher

Table 1. Heat-flow information for the Ashland, Oregon, drill holes.

Hole name	Location	Lat. (N.)	Long. (W.)	Collar elev. (m)	Depth (m)	Depth interval (m)	Thermal conductivity (Wm ⁻¹ °K ⁻¹)	Gradient (°K/km)	Heat flow (mWm ⁻²)
Butler Ford	38S/1E-310AD	42°13.10'	122°44.32'	510	107	70-107	1.90	62.0	118
Ashland Greenhouses	39S/1E-488D	42°12.72'	122°42.3'	536	344	180-300 310-330	(1.77) (2.07)	53.5 28.7	95 59
Darex	39S/1E-4CDD	42°12.05'	122°42.52'	502	148	10-50 55-90 100-148	1.77 2.64 2.07	84.8 63.1 41.5	149 167 86
Justice Center	39S/1E-108CB	42°11.70'	122°41.82'	573	154	65-115 125-154	2.06 1.85	29.8 36.5	61 68
SOSC Gym	39S/1E-10CDB	42°11.25'	122°41.45'	603	123	60-123	1.98	25.1	50
Rodeo Grounds	39S/1E-140B8	42°10.62'	122°40.07'	635	154	100-150	1.85	33.0	61
Corral Creek	40S/4E-5D8	42°07.08'	122°22.5'	1055	99	65-100	1.31	43.5	57

Table 2. Silica geothermometers for springs and wells in the Ashland, Oregon, area.

Name	Type of Source	Location	Measured Surface Temp.	S1 Conductive	S1 Adiabatic	S1 Chal	S1 Opal
Jackson Springs North	spring	38S/1E-3108B	43.5	92.8	94.7	62.2	-21.7
Jackson Springs South	spring	38S/1E-3108D	42.5	92.8	94.7	62.2	-21.7
Jackson Hot Springs Well	well	38S/1E-310AB	22.5	50.5	57.4	18.1	-56.5
Butler Ford	well	38S/1E-310AD	18.4	104.5	104.9	74.8	-11.7
Helman Hot Spring	spring	39S/1E-4CB0	31.5	83.4	86.5	52.2	-29.6
White Sulphur Well	well	39S/1E-98BA	28.5	73.6	78.0	42.0	-37.8
Darex	well	39S/1E-4C00	21.1	91.7	93.8	61.0	-22.6
Justice Center	well	39S/1E-108CB	16.8	67.1	72.2	35.1	-43.1
Lithia Spring	spring	39S/1E-12DAD	12.5	85.9	88.7	54.9	-27.5
Lithia Wells	well	39S/2E-7CCA	18.5	100.9	101.7	70.9	-14.8
Buckhorn Mineral Springs	spring	40S/2E-12A00	5.5	112.9	112.1	83.9	-4.5
Corral Creek	well	40S/4E-50B	14.5	110.5	110.0	81.25	-6.6

background heat flow measured in the above three holes results from a combination of the effects of errors in the measurement of thermal conductivities of shales and the lack of terrain corrections. The terrain corrections, when completed, can be expected to lower the temperature gradients and, hence, the heat-flow estimates by approximately 5 to 10 percent (D.D. Blackwell, personal communication, 1982). It is interesting to note that the lowest heat-flow value of 50 mWm⁻² (Table 1) was obtained from a predominantly sandstone section of the SOSG Gym hole, which should be relatively immune to large errors in the measurement of thermal conductivity. A 10-percent decrease in the heat-flow estimate (resulting from the terrain correction) would result in a heat-flow value of 45 mWm⁻², which is very close to the USGS estimate of 42 mWm⁻² at Winburn Camp.

GEOOTHERMOMETRY

By making certain basic assumptions, the chemical compositions of thermal waters can be used to estimate the subsurface temperatures of geothermal reservoirs. The assumptions are as follows: (1) Temperature-dependent reactions occur at depth. (2) All of the chemical constituents involved in the temperature-dependent reactions are sufficiently abundant. (3) Water-rock equilibrium occurs at the reservoir temperature. (4) Re-equilibration does not occur at a lower temperature as the water flows from the reservoir to the surface. (5) The thermal water does not mix with cool, shallow ground water (Fournier and Rowe, 1966). While assumptions (1) and (2) are probably valid for most hot spring systems, assumptions (3), (4), and (5) are less often fulfilled, particularly in low-temperature systems. As a result, the temperatures indicated by the chemical geothermometers tend to be minima.

Table 2 is a tabulation of minimum estimated reservoir temperatures calculated from various silica geothermometers. Included in the table are waters from warm and cold springs in the Ashland area and from the DOGAMI temperature-gradient wells. For the ranges in temperature and flow rate in-

volved, the conductive silica geothermometer probably gives the best estimate of minimum reservoir temperature. The sodium/potassium geothermometers were not included in Table 2, because the amount of potassium in the thermal waters was generally less than the minimum detectable concentration.

As can be seen in Table 2, minimum reservoir temperatures in the Ashland area are on the order of 100° C. The low value of 50.5° C for the Jackson Hot Springs well probably results from the mixing of shallow ground water with the deeper thermal water. The minimum estimated reservoir temperature for the Justice Center hole is also low, probably because the hole is located south of the main geothermal anomalies and thus did not encounter geothermal fluids. It is also possible that geothermal fluids were not encountered because the well did not penetrate the Mount Ashland Pluton-Hornbrook Formation contact, the aquifer which carries the fluids in the geothermal areas to the north. This second possibility is considered unlikely because the heat flow in the hole (Table 1) is significantly lower than that in the holes to the north (Darex, Ashland Greenhouses, and Butler Ford).

INTERPRETATION

Figure 4 is a cross section through northwest Ashland along line A-A' of Figure 1. The cross section passes through Helman Hot Springs and the Ashland Greenhouses well.

Figure 4. Cross section along line A-A' of Figure 1. Arrows show hypothetical flow of geothermal fluids.

As stated in the introduction, the warm springs in the Ashland area occur on or very close to the mapped contact between the Hornbrook Formation and the underlying Mount Ashland Pluton (Figure 1). It is believed that the positions of the hot springs in the Ashland area are stratigraphically controlled but that the high-temperature geothermal fluids are the result of a forced-convection geothermal system analogous to many known Basin and Range systems.

In a forced-convection system, ground-water recharge in a highland adjacent to a basin penetrates slowly downward to great depths. As the water penetrates downward, it is heated by the natural geothermal gradient. Eventually it reaches a zone of high vertical permeability, such as a fault zone. It then rises rapidly to the surface along the fault zone to emerge at the surface as a spring or series of springs. In effect, the heat is "mined" from beneath the recharge area and is "deposited" in the zone of convective upflow.

In the Ashland area, the geothermal water apparently does not reach the surface along a fault zone. Instead, it appears that as the water moves upward along the postulated fault it encounters the contact between the Mount Ashland Pluton and the Hornbrook Formation. The water is confined to the contact zone by the impermeable shales of the Hornbrook Formation and is driven up the structural dip by the hydrologic head until it emerges at the surface as a series of warm springs at the contact (Figure 4).

The precise position of the fault zone is unknown, as no surface fault likely to act as a conduit for fluids has been mapped in the area east of the hot-spring line (Figure 1). It must, however, lie between the Ashland Greenhouses well and a "free" well located 3 km (1.8 mi) due east of the Ashland Greenhouses well (Blackwell and others, 1982). This second well is 177 m (581 ft) deep and has a reliable temperature gradient of only 27° C/km. As no warm springs occur in the area east of the Ashland Greenhouses well, it is quite likely that the fault is pre-Hornbrook Formation in age and therefore does not reach the surface.

GEOHERMAL POTENTIAL

Most of the low-temperature geothermal potential in the Ashland area is confined to the northwestern part of the city. Data from the Rodeo Grounds, SOSC Gym, and Justice Center holes indicate that heat flow is only "background" (50 to 65 mWm⁻²) in the southeastern area and that fluid temperatures in these areas, even if sufficient fluid volumes could be found, would not much exceed 20° C.

In the northwest part of town, the potential is highest between the existing hot springs and the fault(?) which controls distribution of the fluids. The lateral flow of warm water along the Hornbrook Formation-Mount Ashland Pluton contact makes it possible to find geothermal fluid down the structural dip from the hot-spring line, but the temperature of the water will probably not much exceed the surface temperature of the nearest spring. It is interesting to note that the highest temperature in the Ashland Greenhouses hole was 31.4° C, measured at a depth of 330 m (1,083 ft). The measured surface temperature of Helman Hot Springs, the nearest spring updip from the Greenhouse hole, is 31.5° C (Table 2). In order to encounter fluids at temperatures significantly greater than the temperatures of the springs, drill holes will have to be sited to intersect at depth the faults controlling the distribution of the geothermal fluids. Since neither the precise location nor the dip of the controlling faults is known for certain, the optimum sites for such drill holes are not known. Most probably, however, they lie a short distance east of the Ashland Greenhouse well. In any case, the maximum temperature encountered will not much exceed 100° C and will almost certainly be less.

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REFERENCES CITED

- Berry, G.W., Grim, P.J., and Ikeman, J.A., 1980, Thermal springs list for the United States. National Oceanic and Atmospheric Administration key to Geophysical Records Documentation No. 12: Boulder, Colo., National Geophysical and Solar-Terrestrial Data Center, 59 p.
- Blackwell, D.D., Black, G.L., and Priest, G.R., 1982, Geothermal gradient data (1981): Oregon Department of Geology and Mineral Industries Open-File Report 0-82-4, 430 p.
- Blackwell, D.D., Hull, D.A., Bowen, R.G., and Steele, J.L., 1978, Heat flow of Oregon: Oregon Department of Geology and Mineral Industries Special Paper 4, 42 p.
- Fournier, R.O., and Rowe, J.J., 1966, Estimation of underground temperatures from the silica content of water from hot springs and wet-steam wells: *American Journal of Science*, v. 264, no. 9, p. 685-697.
- Mase, C.W., Sass, J.H., Lachenbruch, A.H., and Munroe, R.J., 1982, Preliminary heat-flow investigations of the California Cascades: U.S. Geological Survey Open-File Report 82-150, 240 p.
- Sass, J.H., Lachenbruch, A.H., and Munroe, R.J., 1971, Thermal conductivity of rocks from measurements on fragments and its application to heat-flow determinations: *Journal of Geophysical Research*, v. 76, no. 14, p. 3391-3401. □

Geothermal Resources Council calls for papers for October meeting in Portland

The Geothermal Resources Council will hold its annual meeting October 24-27, 1983, at the Red Lion-Jantzen Beach Hotel in Portland. The three-day meeting will include a technical program consisting of oral and poster presentations, commercial and educational exhibits, photo contest winner display, luncheons, special events, guests' program, and field trips. Special sessions scheduled for the meeting will focus on geothermal resource development in the Cascade Range and on industrial geothermal water heat pumps.

The Council's annual meeting is intended to provide a forum for exchange of new and significant information on all aspects of the development and use of geothermal resources. Papers are solicited in the following areas: exploration (geology, geophysics, and geochemistry), drill technology, reservoir engineering, power generation, direct use, legal/institutional aspects, economics/financing, environmental, and case histories. Papers must be submitted by Friday, June 3, 1983. Authors' packets containing detailed instructions and blue-lined sheets to be used for papers may be obtained from the Geothermal Resources Council, P.O. Box 1350, Davis, CA 95617, phone (916) 758-2360.

The Council is holding its fourth annual photograph contest in conjunction with the annual meeting to recognize artistic merit in recording geothermal development and to augment the Geothermal Resources Council's photo library. For information about the photo contest or any other aspect of the meeting, contact the Geothermal Resources Council at the above address. □

B. Appendix B - Heat Pump Basics

WT CALCULATIONS

FUELER MOD 042 11 gm EA 70°

60°	-	3.33	(45700 ÷ 4020 × 3.413)	=	3.33
65°	-	51800	÷ 4150 3.413	=	3.66
70°	-	54100	(4275 3.413)	=	3.71
75°	-	56100	(4400 3.413)	=	3.76

Command Air MOD. 500 12.5 gm EA 70°

60°	-	76900	÷ 5200 3.413	=	3.38
70°	-	85000	6400	=	3.57
80°	-	93200	7000	=	3.85

← Compression only

WHALEN MOD 1200 70° EA

55	-	(.99 51800) ÷ (.92 - 4.26.3413)	=	3.28	
60	-	.94	94	=	3.30
65	-	1.00	1.00	=	3.30
70	-	1.02	1.02	=	3.30
74	-	1.05	1.04	=	3.34
80	-	1.10	1.08	=	3.36

INTERNATIONAL MOD. 1200 ÷ C 2.5 gm/ton

57.50	-	26550	- 2500 ÷ 3.413	=	2.73
63.55	-	29595	2900	=	2.99
69.60	-	31739	3000	=	3.09
74.65	-	35500	3100	=	3.37
80.70	-	39440	3200	=	3.52
85.75	-	42515	3300	=	3.77
90	-	46600	3400	=	4.07
95	-	51445	3500	=	4.31

TEC MOD 042 1200 4° gm 1000 gm

40	-	Given	=	2.96
42	-		=	3.05
47	-		=	3.16
52	-		=	3.26
57	-		=	3.32
62	-		=	3.40

WEATHER KING WPH-44-1 12 gm

60°	-	44900	÷ 4430 3.413	=	2.69
65°	-	47000	4571 3.413	=	2.77
70°	-	49100	4693 3.413	=	2.84
75°	-	51200	4776 3.413	=	2.92

SECC MOD 500 42, 70° EA

60	-	42000	÷ 4400 3.413	=	2.76
70	-	47100	÷ 4545	=	2.94
80	-	53630	÷ 5235	=	3.00

C. Appendix C - Residential

PIPING COSTS - UNINSUL. SCH 40 P.V.C.

SIZE	MAT'L	INST	FLY'S 2 / %	1.25 O&P	T&B 7.00	TOTAL
1	.363	1.83	.55 / 25	.69	↓	10.43
1½	.504	2.24	.55 / 20	.82		11.11
2	.599	2.36	.44 / 15	.85		11.24
3	1.22	2.95	.42 / 10	1.15		12.74
4	1.75	3.49	.52 / 10	1.44		14.20
6	3.33	4.58	.79 / 10	2.18		17.88
8	5.14	5.98	1.17 / 10	3.22		23.11
10	13.43	7.91	2.13 / 10	5.87		36.34

2 LINES IN ONE TRENCH 1.4 x INST., 2.0 x MAT'L, 2.0 x FLY'S

SIZE	MAT'L	INST	FLY'S	1.25 O&P	T&B 7.0	TOTAL
1	.726	2.56	1.10	1.10	↓	12.49
1½	1.008	3.14	1.10	1.31		13.56
2	1.19	3.30	.88	1.34		13.71
3	2.44	4.13	.84	1.85		15.75
4	3.50	4.89	1.04	2.36		18.79
6	6.66	6.41	1.58	3.66		25.31
8	11.48	8.37	2.34	5.55		34.74
10	26.86	11.07	4.16	10.52		59.61

RESIDENTIAL - GROUP

SPACE HEAT ONLY - 1800 FT² HOMES @ 16.8 BTU/HR·FT²
47 HOMES

$$1800 \text{ FT}^2 \cdot 16.8 \text{ BTU/HR·FT}^2 = 30240 \text{ BTU/HR}$$

$$47 \cdot 30240 = 1,421,280 \text{ BTU/HR}$$

ANNUAL LOAD:

$$\frac{1,421,280 \cdot 4066 \text{ D.D.} \cdot 24 \text{ HR/DAY}}{49} (.60) = 2.074 \times 10^9 \text{ BTU/YR}$$

COP OF 3.0

$$2.074 \times 10^9 \text{ BTU/YR} \div (3.0 \cdot 3413 \text{ WATT/KWH}) = 202579 \text{ KWH/YR}$$

CAPITAL COSTS:

PIPING	-	74000
WELL PUMPS & DRIVE	-	53000
CIRC. PUMP & SPARE	-	5000
HEAT PUMPS 47.3100	-	145000
WELLHEAD BLOBS	-	10000
MISC. MECH & ELEC	-	10000
SUBJECT GAS FLEXIBLES 47.690	-	(33000)
		<u>264000</u>
	WELLS	<u>40000</u>
		304000

OPERATING COSTS

MAINTENANCE

$$\text{PIPING @ } 1/2\% \quad 74000 \cdot .005 \left(\frac{304}{264} \right) = 426$$

$$\text{EQUIP @ } 3\% \quad 49000 \cdot .03 \left(\frac{304}{264} \right) = 2649$$

INSURANCE @ 1/2% INST. COST

$$.005 \cdot 304000 = 1520$$

ELECTRICAL USE

$$\text{HEAT PUMPS} = 202579 \text{ KWH/YR}$$

$$\text{WELL PUMP} = 16426 \text{ " "}$$

$$\text{CIRCULATING} = 23349 \text{ " "}$$

$$272353 \text{ KWH/YR} \cdot .04239 = 11681$$

NATURAL GAS SAVINGS

$$2.074 \times 10^9 \text{ BTU/YR} \div .75 \cdot 1000000 = 27653 \text{ T/YR}$$

$$27653 \cdot .6851 \text{ \$/T} = 19222 \text{ \$/YR}$$

EXAMPLE OF RESIDENTIAL WATER TO AIR HEAT PUMP USING CITY WATER

BASIS: R-19 ROOF, R-19 FLOOR, R-19 WALL, DBL GLASS, 215% WALL
1500 FT², .75 BTU/HR INFL, 5099 BTD LN 68°, TOUT 19°

HEAT LOSS FROM ENCL FAMILY SHEET
LOAD 36,706,726 BTU/YR
4.93 BTU/DO/FT²

C COP OF 3.0

$$36,706,726 \text{ BTU/YR} \div (3413 \cdot 3.0) \cdot .04289 = 154 \text{ ¢/YR}$$

ELECTRICAL INPUT 3590 kWh/YR
12,254,651 BTU/YR

REQUIRED HEAT INPUT FROM WATER -

$$36,706,726 - 12,254,651 = 24,452,075 \text{ BTU/YR}$$

C 10' Δt, 1.0 BTU/Δt °F

$$24,452,075 \div (10 \cdot 1.0) = 2,445,207 \text{ ¢/YR}$$

C 62.4 ¢/FT³

$$2,445,207 \text{ ¢/YR} \div 62.4 \text{ ¢/FT}^3 = 39,186 \text{ FT}^3/\text{YR}$$
$$39,186 \text{ FT}^3/\text{YR} \div 100 = 391.2 \cdot 100 \text{ FT}^3$$

ASSUME REQUIREMENT FOR 1" SERVICE

$$5.00 \text{ PER MONTH} \cdot 12 \text{ MO} = 60 \text{ ¢/YR}$$

CONSUMPTION CHARGE:

$$391.2 \cdot 100 \text{ FT}^3 \cdot .60 \text{ ¢/100 FT}^3 = 235 \text{ ¢/YR}$$

TOTAL OPERATION COST.

$$235 + 60 + 154 = \underline{\underline{449 \text{ ¢/YR}}}$$

R-19 ROOF, R-19 FLOOR, R-19 WALL, DBL GLASS, @ 15" W. WALL, H500 F 2
 .75 C14/14C INFL. 5000 DD $t_{in} = 68^{\circ}$ $t_o = 19^{\circ}$

HEAT LOSS

HEAT LOSS

WINDOW	-	$(25 \cdot 2 \cdot 3) + (60 \cdot 2 \cdot 3) \cdot 15 \cdot 65 \cdot (68 - 19)$	=	6497	Btu/hr	
WALL	-	$(25 \cdot 2 \cdot 3) + (60 \cdot 2 \cdot 3) \cdot 204 \cdot \frac{1}{19} \cdot (68 - 19)$	=	2991		
FLOOR	-	1500	$\frac{1}{19} \cdot (68 - 19)$	=	3863	
ROOF	-	1500	$\frac{1}{19} \cdot (68 - 19)$	=	3863	
INFIL	-	$(1500 \cdot 3) \div 60 \cdot 1.08 \cdot 75 \cdot (68 - 19)$	=	7938		
				<u>25152</u>	Btu/hr	

MAINTENANCE

RULE CONSTRUCTION @ 2% INST COST

$$.02 \cdot 2000$$

$$= 40$$

STANDARD NATURAL GAS @ 1 1/2% INST COST

$$.015 \cdot 690$$

$$= 10$$

ELECTRIC RESISTANCE @ 1 1/2% INST COST

$$.015 \cdot 550$$

$$= 8$$

WATER TO AIR HEAT PUMP FROM KUTTERS

$$.75 \cdot 83 =$$

$$= 62$$

CAPITAL COST OF WATER TO AIR HEAT PUMP w/ WELLS

2 - 150' WELLS @ 30% ROCK - 275 \$/IN. FT

70% SOFT - 1.10 \$/IN. FT

$$1.10 \cdot 150 \cdot 5 \cdot .70 = 573$$

$$275 \cdot 150 \cdot 5 \cdot .30 = 186$$

$$\text{CASING } 4" \text{ @ } 5.00/\text{FT} = 750$$

$$\text{CEMENT PNEUM SEAL} = \underline{260}$$

$$1774 \times 2 = 3548$$

$$\text{WELL PUMP - 1hp} - 650$$

$$\text{CUTTER} - 70$$

$$\text{TANK, CURB} - 240$$

$$\text{CASE} - 400$$

$$\text{INSTALLATION} - \underline{500}$$

$$1860$$

$$\text{PIPING TO HOUSE - } 30' \text{ @ } 12 \$/\text{FT} = 360$$

$$\text{FROM HOUSE - } 100' \text{ @ } 12 \$/\text{FT} = \underline{1200}$$

$$1560$$

$$\text{TOTAL COST WELLS} = 6968$$

POWER COST - WELL PUMP @ 10' @ 1/3.0 COP

$$36,706,726 \text{ BTU/YR} \div 36,000 \text{ BTU/kWh} = 1020 \text{ kWh/YR}$$

$$10 \cdot 2.33 \cdot (40 / 1.433) \cdot .5 = 330.5 = .466 \text{ IP} \cdot 746 = .343 \text{ kW}$$

$$.343 \cdot .25 = .409 \text{ kW}$$

$$.409 \cdot 1468 \text{ kWh/YR} = 601 \text{ kWh/YR} \times .043 = 25.3 \$/\text{YR}$$

MAINT WELL PUMP @ 1 1/2% YR

$$.015 \cdot 1860 = 27.9 \$/\text{YR}$$

SINGLE FAMILY RESIDENTIAL

(1) HEAT PUMP SYSTEM COMPARED TO NATURAL GAS @ 75% EFF

INCREMENTAL CAPITAL - 9378

" MAINT - 52

NATURAL GAS (FURNACE) - 340 \$/yr

ELECTRICITY (HEAT PUMP) - 1.80 \$/yr

(2) HEAT PUMP SYSTEM COMPARED TO NATURAL GAS @ 90% EFF

INCREMENTAL CAPITAL - 8068

" MAINT - 22

NATURAL GAS (FURNACE) - 283 \$/yr

ELECTRICITY (HEAT PUMP) - 1.80 \$/yr

HEAT PUMP SYSTEM COMPARED TO ELEC RESISTANCE

INCREMENTAL CAPITAL - 9518

" MAINT - 54

ELECTRICITY (RESIST) - 461 \$/yr

ELECTRICITY (HEAT PUMP) - 1.80 \$/yr

(3) CITY WATER HEAT PUMP VS NATURAL GAS FURNACE

INCREMENTAL CAPITAL - 2410

" MAINT - 52

NATURAL GAS (FURNACE) - 340 \$/yr

ELECTRICITY (HEAT PUMP) - 154 \$/yr

WATER BILL (HEAT PUMP) - 295 \$/yr

RESIDENTIAL SYSTEM COSTS - (1931 \$)

A. AIR-TO-AIR

3TON UNIT INSTALLED	-	2200	
SUPP. ELEC HEAT	-	160	
REFRIG LINES 25'	-	170	
PAD (OUTSIDE)	-	40	
CONTRAS	-	120	
POWER WIRING	-	250	
COND. DRAIN	-	40	
		<u>2980</u>	

B. ELECTRIC FURNACE

FURNACE w/wiring	-	1450	635
POWER WIRING	-	175	120
3TON A/C COND UNIT	-	1425	-
LINES 25'	-	170	-
CONTRAS	-	120	30
PAD	-	25	-
		<u>2330</u>	<u>835</u>

C. GAS FURNACE

FURNACE 50/36	-	2125	735
GAS PIPING 25' 5/4"	-	125	125
3TON COND UNIT	-	1425	-
WIRING	-	120	30
CONTRAS	-	120	30
LINES & PAD	-	<u>210</u>	-
		<u>4125</u>	<u>1070</u>

D. FUEL OIL FURNACE

FURNACE 34/36	-	2225	1000
OIL TANK	-	300	300
OIL LINE 50' 5/4"	-	250	250
3TON COND UNIT	-	1425	-
WIRING	-	120	30
CONTRAS	-	120	30
LINES	-	170	-
PAD	-	40	-
		<u>4650</u>	<u>1710</u>

WATER TO AIR HEAT PUMP	
3 TON HEAT PUMP	- 1425
Supp. Elec HT	- 160
WATERS	- 250
PIPING TOE 9.00	- 450
WIRING	- 150
DRAIN	- 40
	<hr/> 2475

WHOLESALE COST OF COMPONENTS

AIR P AIR HEAT PUMP	3 TON	- 1636
ELECTRIC FURNACE		- 323
GAS FURNACE		- 446
OIL FURNACE		- 595
WATER TO AIR HEAT PUMP	34 msh	- 1306
A COIL	36,000 + ENCLOSURE	- 190
HTG T-STAT		- 13
HTG & COOL T-STAT		- 22
T-STAT WIRE	.058 \$/FT 40'	- 2.32
15' REFRIG LINE		- 71
20' 10-2 W/GND		-
COND DRAIN	15' 3/4" 2" to PVC Sinks	- 9
3 TON COND UNIT		- 795
SUPPLEMENTARY Elec HT	10kw	- 130

MINIMUM UNITARY COSTS FOR HEATING FUEL OIL FURNACES AND NATURAL GAS FURNACES

CONTRACTOR ESTIMATES

AIR-TO-AIR	1	2	3	MEANS	AVG
3 TON SPLIT	2100	3000		2518	
5 TON ROOF-UP	3000	4200		3576	
SHW ELECTRIC FURNACE	500	600		753	
50K GAS FORCED AIR		5700			
W/ 3 TON SPLIT	2240	2100		2432	
W/O " "	530	900		584	
7 1/2 TON GAS/ELEC	6500	5500		5537	
35K FUEL OIL FORCED AIR					
W/ 3 TON SPLIT	2760	3300		2546	
W/O " "	1100	1500		1144	
WATER-TO-AIR					
3 TON SPLIT	2100	4000		1631	
6 TON SPLIT	4800	4800		2461	

CONTRACTOR REPLY SHEET

Note: Estimates are for equipment only, along with necessary piping, wiring and controls. Do not include allowances for ductwork, humidifiers, electrical air cleaners, etc. Use values for high efficiency or good quality equipment. Feel free to leave any areas blank which deal with equipment you don't normally handle.

<u>Units</u>	<u>Heating & Air Conditioning</u>	<u>Heating only</u>
Air-to-Air Heat Pumps		
3 ton - split system	\$3,000. ⁰⁰	XXX
5 ton - roof top system	\$4,200. ⁰⁰	XXX
Electric Furnace, 15 kW	\$600. ⁰⁰	
Gas Forced Air Furnace, 80,000 output Btu/hr	\$900. ⁰⁰	
3 ton - split system	\$2,700. ⁰⁰	
7 1/2 ton Roof Top Gas/Electric	\$5,500. ⁰⁰	XXX
Fuel Oil Forced Air Furnace, 85,000 output Btu/hr		
3 ton - split system	\$1,500. ⁰⁰	
	\$3,300. ⁰⁰	
Water-to-Air Heat pump		
Single package - 3 ton	\$4,000. ⁰⁰	XXX
Single package - 6 ton	\$4,800. ⁰⁰	XXX

Jm
CONTRACTOR REPLY SHEET

Note: Estimates are for equipment only, along with necessary piping, wiring and controls. Do not include allowances for ductwork, humidifiers, electrical air cleaners, etc. Use values for high efficiency or good quality equipment. Feel free to leave any areas blank which deal with equipment you don't normally handle.

<u>Units</u>	<u>Heating & Air Conditioning</u>	<u>Heating only</u>
Air-to-Air Heat Pumps		
3 ton - split system	2100 ⁰⁰	XXX
5 ton - roof top system	3000 ⁰⁰	XXX
Electric Furnace, 15 kW	500 ⁰⁰	500 ⁰⁰
Gas Forced Air Furnace, 80,000 output Btu/hr	600 ⁰⁰	550 ⁰⁰
3 ton - split system	1500 ⁰⁰	
7 1/2 ton Roof Top Gas/Electric	6500 ⁰⁰	XXX
Fuel Oil Forced Air Furnace, 85,000 output Btu/hr		
3 ton - split system	1000 ⁰⁰	
Water-to-Air Heat pump		
Single package - 3 ton	2100 ⁰⁰	XXX
Single package - 6 ton	4800 ⁰⁰	XXX

in the surrounding area, nor will the potential development of adjacent lands be impeded.

- f) That there are adequate provisions for the maintenance of open space and common areas, that if developments are done in phases that the early phases have the same or higher ratio of amenities as proposed in the entire development.
- g) That the total energy needs of the development have been considered and are as little as is economically feasible, and the maximum use is made of renewable energy sources, including solar, where practical.
- h) That all other applicable City ordinances have been complied with.

APPENDIX B —

STANDARDS AND METHODS OF ACHIEVING BONUSES

Any combination of the bonuses below may be used to achieve the maximum bonus allowed for any development. However, at least 5% must be earned from three separate categories before any bonuses are awarded. Categories 1 and 2 may not both be used in achieving this minimum threshold for bonus densities.

I. Energy-Efficient Housing

A. Energy-Efficient Guidelines - Mandatory items for all units

1. Minimum insulation requirements

Roof - R- 38

Walls - R-19

Floor - R-19 batts or R-11 perimeter insulation with vapor barrier, or R-7 insulation on slabs

Window - double-glazed

2. Summer shading requirements

All windows facing south or west must be 80% shaded at noon on August 21, and 80% shaded at 3:00 p.m. on August 21.

Shading may be by:

- a) External opaque shutters
- b) External opaque shades
- c) External plants or trees
- d) Internal opaque shades, which, when closed, provide an air-tight seal, and are equal to R-6 in insulation value

3. Summer venting requirements

The building must be designed for:

- a) Operable windows along two opposite sides of the building, or
- b) Mechanical ventilation which can provide at least 15 air changes per hour ducted to the exterior.

3.000 cfm - 15.000

B. Prescriptive Path for Bonus Points

1. Solar collector

- a) Each structure shall provide at least 10% of the conditioned floor area in glazing oriented within 20° of south.
- b) Up to 4% of the floor area may be provided in east- or west-facing glazing; the glazing may replace the south-facing requirement at a ratio of 1 sq. ft. of south-facing glazing to 3 sq. ft. of east-facing glazing.
- c) If night insulation is to be provided, it must be tight-fitting as to create a seal against the window and be of at least R-6 insulation value.

2. Thermal storage

- a) An amount sufficient to store at least 30 BTU/°F shall be provided for each square foot of south-facing glazing. This is equivalent to the following:
 - 3 sq. ft. of 4-inch thick brick wall
 - 3 sq. ft. of 4-inch thick slab
 - 1 cu. ft. of concrete, masonry, or rock
 - 3.5 gallons of water
- b) Location - The thermal storage must be located within the insulated shell of the building, and must receive direct solar radiation during part of the heating season, or have radiation reflected on it from a light-colored surface (Munsell of at least 8). The masses may not be covered with carpet or other material with an insulation value of greater than R-1.

- c) Thickness - Thermal masses may not be more than 12 in. thick nor less than 3 in. thick for solid masses. For water storage, the container may not be less than 6 in. thick. There is no maximum thickness for liquid storage media.
- d) The collectors and storage masses must be located in the living room, dining room, family room, or other similar rooms which have the majority of daily activity.

3. Bonus

If the above conditions are met, then the following performance levels and density bonuses shall be allowed:

<u>Housing Type</u>	<u>Performance Level</u>	<u>Bonus</u>
1 story, detached, no NI	3.22 BTU/DD/FT ²	18%
1 story, detached, w/ NI	2.82	22%
1 story, 1 common wall, no NI	2.84	22%
1 story, 1 common wall, w/ NI	2.44	26%
2 story, detached, no NI	3.02	19%
2 story, detached, w/ NI	2.61	24%
2 story, 1 common wall, no NI	2.64	24%
2 story, 1 common wall, w/ NI	2.25	27%
1 story, 2 common walls, no NI	2.76	23%
1 story, 2 common walls, w/ NI	2.37	26%
2 story, 2 common walls, no NI	2.34	27%
2 story, 2 common walls, w/ NI	1.97	30%

NI means night insulation of an insulation value of at least R-6.

2 story means at least 40% of the total floor area is directly over or under other conditioned space.

1 common wall means that at least 20% of the exterior wall surface is directly attached to other conditioned space.

2 common walls means that at least 40% of the exterior wall surface is directly attached to other conditioned space.

C. Performance Path for Bonus Points

Any solar system, passive or active, may be used to gain a density bonus. It should meet the mandatory requirements of

this section, or otherwise demonstrate that the system will not experience unwanted summer heat gain and can be adequately vented.

It must also demonstrate that adequate thermal storage is provided to provide nighttime heating.

Solar systems shall be evaluated using the following methods:

1. For passive solar systems, the solar load ratio method devised by the Los Alamos Scientific Laboratory shall be used to determine the annual solar heating fraction.
2. For active systems, the F-chart method shall be used to determine the annual solar heating fraction.
3. Any other method may be used if it:
 - a) Is generally accepted as a more accurate estimate of solar heating fraction than the above methods.
 - b) Computes the solar heating fraction based on an annual heating cycle, not on design day criteria.

Bonus points for performance path

The rating shall be determined by the following formula:

$$\frac{(\text{Total annual heat needs}) - (\text{Internal gains} + \text{Usable solar heat})}{(\text{Degree days}) (\text{Square feet of conditioned area})} = \text{RATING}$$

All heat energy is expressed in BTU's; all degrees are Fahrenheit.

<u>Rating</u>	<u>Bonus</u>
Less than 4 BTU/DD/FT ²	10%
Less than 3.5 "	15%
Less than 3 "	20%
Less than 2 "	30%
Less than 1 "	40%

II. Common Open Space - 0-15% (1% for every 2% of the project area in open space)

For common open space to be counted, it should be suitable for use either passively or actively. It should also be landscaped in such a way as to be accessible to the members of the homeowners' association. Common open spaces should be screened from incompatible uses wherever practical. The common open space should be designed so that it can be used year-round as much as possible and should be comfortable in all weather conditions, again as much as possible and practical.

D. Appendix D - Commercial

From the desk of

DICK WANDERSCHIED

Kevin,

Here's a new rate card
hot off the press. (They
take effect on June 1.).
Don't forget to add the
25% Electric Users tax
on to the kWh rate. Give
me a call if you need help

482-3211 x280

Dick

AKHLAND WAREHOUSE -

OUTSIDE DESIGN - 19°F

INSIDE DESIGN - 68°F (OCCUPIED AREA)

INSIDE DESIGN - 60°F (WAREHOUSE AREA)

HEAT LOSS :

ASSUME DOOR GLASS, 2" INSULATION (R-7) ROOF/WALL;
UNINSULATED GLASS, .75 CM/IN IN OCCUPIED AREAS
1.5 CM/IN IN WAREHOUSE. R-11 WALL/GLASS IN
OCCUPIED AREAS ASSUME FULL 2-LAYER CONSTRUCTION

LARGE OCCUPIED AREA :

WALLS	-	1832	•	.091	•	49	=	8169 BTU/HR
GLASS	-	240	•	.59	•	49	=	6938
EDGE	-	240	•	.50			=	12000
GLASS	-	5760	•	.091	•	49	=	25683
INFIL	-	576	•	1.08	•	68	=	42501 30483
BACK WALL	-	220	•	.143	•	13	=	4759
							<u>99850</u>	BTU/HR
							33032	

WAREHOUSE AREA :

WALLS	-	1712	•	.143	•	36	=	8813 BTU/HR
GLASS	-						=	0
DOORS	-	288	•	1.20	•	36	=	12442
ROOF	-	17880	•	.143	•	36	=	92046
(1.5) INFIL	-	2160	•	1.08	•	36	=	83981
GAIN	-						=	(5940)
							<u>191333</u>	BTU/HR

SMALL OCCUPIED AREA :

WALLS	-	672	•	.091	•	49	=	2996 BTU/HR
GLASS	-	64	•	.59	•	49	=	1850
ROOF	-	1600	•	.091	•	49	=	7134
EDGE	-	94	•	.50			=	4700
INFIL	-	160	•	1.08	•	49	=	8467
BACK WALL	-	640	•	.143	•	13	=	1190
							<u>26337</u>	BTU/HR

TOTAL 317520 BTU/HR

(2)

ANNUAL ENERGY REQUIREMENTS
 DEMAND - 4886 DD (SEPT-MAY)
 CO - .89

OCCUPIED AREA:

$$\frac{4886 \cdot 24 \cdot 126187}{49} \cdot (.89)$$

$$= .269 \times 10^9 \text{ BTU/YR}$$

WAREHOUSE AREA:

$$\frac{(6214 \cdot 4886) \cdot 24 \cdot 191333}{41} \cdot (.89)$$

$$= .3056 \times 10^9 \text{ BTU/YR}$$

FOR GAS HEATING:

ASSUME EFF = .80

$$.5746 \times 10^9 \text{ BTU/YR} : 100000 \div .80 = .7182 \text{ TH/YR}$$

FOR ELECTRIC RESISTANCE

$$.5746 \times 10^9 \text{ BTU/YR} \div 3413 \text{ BTU/KWH} = 168356 \text{ KWH/YR}$$

CONVENTIONAL SYSTEM

ASSUME NO A/C IN WAREHOUSE

GAS FIRED UNIT HEATER SYSTEM:

4 - 60 MMH OUTPUT UNITS @ 360

FLUE @ 20' DIA WALL 20' EA @ 11.55 \$/LF

GAS PIPING 20' 1" @ 5.4 \$/LF

CONTRACT & ELEC @ 250 \$/EA

$$\begin{array}{r} - 1440 \\ - 924 \\ - 648 \\ - 1000 \\ \hline 4012 \end{array}$$

OCCUPIED AREA:

ZONE 1 20,000 BTU/HK HTG 3 FC A/C

ROOF TOP GAS ELECTRIC UNIT

2 FC / 60 MMH

GAS PIPING 40' @ 5.4 \$/LF

RIGGING

$$\begin{array}{r} - 1690 \\ - 216 \\ - 150 \\ \hline 2056 \end{array}$$

DUCT WORK 1200 LF @ 3.7 \$/FT
 50' @ 3.7 \$/FT 214.6 \$ - 3.10 \$/FT

$$- 655$$

OCCUPIED AREAS (CONT.)

(3)

ZONE 2 : 4800 ft^2 - 68000 Btu/hr / 10 TON

10 TON / 200 MASH HIGH REX PIP

GAS PIPING, 60' @ 6.15 ¢/LF

Ductwork 4000 cfm 2000 W4. 20' @ 5.9 ¢/LF

200 $\times$ 5.9 = 1180 ¢ - 2.57 ¢/4

Registers

1000 - 6675

- 369

- 2237

- 300

10377

ZONE 3 : 2240 ft^2 - 31850 Btu/hr 5 TON

2000 cfm 1000 W4. 14' @ 4.5 ¢/LF

60 $\times$ 4.5 = 270 ¢ - 3.10

Registers

GAS PIPING, 60' @ 6.15 ¢/LF

1000 - 3000

- 337

- 150

- 369

4356

TOTAL SYSTEM

- 23041

GROUND WATER HEAT PUMP SYSTEM - 65 F :

Zone 1 2 TON WATER TO AIR

UNIT

CONTROL VALVE

WATER PIPING 1" PVC 100' @ 6.50

2300

150

650

Zone 2 10 TON WATER TO AIR

UNIT

CONTROL VALVE

WATER PIPING 1 1/2" PVC 100' @ 6.30

8500

150

830

Zone 3 5 TON WATER TO AIR

UNIT

CONTROL VALVE

WATER PIPING 1" PVC 100' @ 6.50

3923

150

650

MAIN WATER DISTRIBUTION

300' BURIED 2" PVC

300' - 37

DIAN HUNG IN MCG
150' 2" PVC @ 8.85

-132

TOTAL INCREMENTAL COST EXCLUDING WELLS \$5677

Pr + 3500

- Calculate amount available per well/pump.

COP 3.2

ANNUAL ENERGY USE

$$269 \times 10^9 \div 3.2 \div 3413 = \frac{24,637}{33786} \text{ kWh/yr}$$

FLOOR PANEL SYSTEM

ASSUME 80° DWT 1" PLASTIC PIPING 1" BRON SURFACE
68° AIR

$$\frac{.135}{1.25} + \frac{1}{9} + \frac{1}{1.65} = .1064 + .1111 + .6061 = .8236$$

$$\begin{aligned} \left(\frac{.1064}{.8236} \right) \cdot (80 - 68) &= 1.55 \\ \left(\frac{.1111}{.8236} \right) \cdot (80 - 68) &= 1.62 \\ \left(\frac{.6061}{.8236} \right) \cdot (80 - 68) &= 8.83 \end{aligned}$$

FLOOR SURFACE TEMPERATURE

$$= 80 - (1.55 + 1.62) = 76.8^\circ \text{F}$$

222

$$9.0 \text{ BTU/hr} \cdot \text{ft}^2 \cdot ^\circ \text{F} \cdot 1.96 = 8.64$$

$$\Delta t = 80 - 76.8 = 3.17^\circ \text{F}$$

PIPE SPECIFIC OUTPUT =

$$3.17 \cdot 8.64 = 27.4 \text{ BTU/hr} \cdot \text{ft}^2$$

$$1" \text{ PVC} = .344 \text{ ft}^2/\text{LF}$$

HEATING REQUIREMENT OCCUPIED AREAS

$$\text{HEAT LOSS } 126,187 \text{ BTU/hr}$$

$$\text{FLOOR AREA } \frac{2544}{14.7}$$

$$14.7 \text{ BTU/hr} \cdot \text{ft}^2$$

SPACING REQUIREMENT

$$14.7 \text{ BTU/hr. Ft}^2 \div 27.4 \text{ BTU/hr. Ft}^2 = .536 \text{ Ft}^2/\text{Ft}^2$$

$$.536 \text{ Ft}^2/\text{Ft}^2 \div .344 \text{ Ft}^2/\text{L.F.} = 1.55 \text{ L.F./Ft}^2$$

$$12" \div 1.55 = 7.69" \text{ C-C} \quad \underline{\underline{\text{say } 8"}}$$

FOR WAREHOUSE AREA.

$$\text{HEAT LOSS} = 19133 \text{ BTU/hr}$$

$$\text{FLOOR AREA} = 2,488 \text{ Ft}^2$$

$$\text{SPECIFIC LOSS} = 54.8 \text{ BTU/hr. Ft}^2$$

SPACING @ ABOVE CONDITIONS:

$$54.8 \div 27.4 = 1.99 \text{ Ft}^2/\text{Ft}^2$$

$$1.99 \div .344 = 5.8 \text{ L.F./Ft}^2$$

$$12 \div 5.8 = 2.04" \text{ C-C} \quad \text{say } 2" \text{ TOO CLOSE}$$

@ 55°F FET POINT

$$\left(\frac{.1064}{.8236} \right) \cdot (80 - 55) = 3.23^\circ$$

$$\left(\frac{.1111}{.8236} \right) \cdot (80 - 55) = 3.37^\circ$$

$$\left(\frac{.6061}{.8236} \right) \cdot (80 - 55) = 15.4^\circ$$

FLOOR SURFACE TEMPERATURE

$$80 - 6.6 = 73.4^\circ\text{F}$$

$$6.6^\circ \cdot 9.0 \cdot .96 = 57.0 \text{ BTU/hr. Ft}^2$$

$$\text{LOSS} = 54.8 \text{ BTU/hr. Ft}^2$$

$$\underline{\underline{12" \text{ C-C}}} \text{ @ } 80^\circ \text{ AWT}$$

FLOW REQUIREMENT FOR FLOOR PANEL SYSTEM

@ 85 RESERVE / 10° ΔT

$$317520 \text{ BTU/hr} \div 400 \cdot 10 = 63.5 \text{ gpm.}$$

CALCULATE ANT. AVAILABLE FOR WEL

PIPING LENGTH REQUIREMENT.

OCCUPIED AREA 6" C-C

$$8800 + 2280 + 1520 = 12,600'$$

WAREHOUSE AREA 12" C-C

$$4800 + 2640$$

$$= \underline{\underline{7440'}}$$

$$20,040'$$

+ 5%

$$\underline{\underline{21,042'}}$$

COST OF FLOOR PANEL SYSTEM -
 21042' @ .33 \$/ft

= 6944

EDGE INSULATION

= 1000

TIES

= 200

LABOR 9 man-days @ 20 \$/hr

= 2160

OUTSIDE PIPING FROM HT PIP COATS.

= 2310

MISC MATH AND ELEC.

= 1500

PUMP ASSUME

1111

100 pumping level 60% u-w eff.

$$(63.5 \times .33) \cdot (100 + 40) \div .60 \div 33000$$

$$= 3.7 \text{ IP say 5HP SWS.}$$

= 3500

17160

OPERATING COSTS

MAINT 3% Equip

$$.03 \cdot 4000$$

$$= 120$$

$$.001 \cdot 6344$$

$$= 6.3$$

- 189

Elec. Use

$$(3.7 \cdot .746) \cdot .73 \cdot 1500 \cdot .04$$

- 178

Summary

GAS/ELEC VS WATER TO AIR HEATPUMP
 * INCREMENTAL CAPITAL COST
 INCREASED ELECTRICAL USE 29020E.04
 NATURAL GAS SAVINGS 3537E.60
 MAINT. ASSUMED SAME

9157
 1163
 2152
 —

DOES NOT INCLUDE PROD. & INJ WELLS

GAS/ELEC VS FLOOR PANEL
 * INCREMENTAL CAPITAL COST
 INCREASED ELECTRICAL USE
 NATURAL GAS SAVINGS
 MAINT. ASSUMED SAME

1089:
 178
 430:
 —

ASHLAND WAREHOUSE (REVISED)

PEAK LOAD OCCUPIED AREAS

114369 BTU/Hr

PEAK LOAD WAREHOUSE AREA

191333 BTU/Hr

ANNUAL ENERGY - OCCUPIED AREAS

496600 (OCT-MAY) C_o .60 (LOWER THAN ORIG FOR INT GAIN)

$$\frac{114369 \cdot 24 \cdot 496600}{49} (.60) = .1669 \times 10^9 \text{ BTU/YR}$$

ANNUAL ENERGY - WAREHOUSE

70° is original value

$$\frac{191333 \cdot 24 \cdot (496600 \cdot .89)}{41} (.80) = .396 \times 10^9 \text{ BTU/YR}$$

ENERGY CONSUMPTION - NATURAL GAS

$$.5629 \times 10^9 \div (.75 \cdot 1000000) = 7505 \text{ TH/YR}$$

ENERGY CONSUMPTION - HEAT PUMP

$$.5629 \times 10^9 \div (3413 \cdot 3.0) = 54976 \text{ kWh/YR}$$

CAPITAL COSTS:

AREA 1 - GAS HEATER

3TON UNIT

2000

GAS PIPING

220 (FROM ORIG EST)

2220

WATER TO AIR

DIFFERENCE 1530

3TON UNIT

3100

WATER PIPING

650

3750

AREA 2

GAS HEAT

10 TON UNIT

7600

GAS PIPING

370

8270

WATER TO AIR

DIFF 1060

10 TON UNIT

8500

WATER PIPING

830

9330

AREA 3

GAS HEAT

5 TON UNIT

3500

GAS PIPE

370

3870

WATER TANK

UNIT - 4800

DIFF - 1580

WATER PIPE - 650
5450

WAREHOUSE AREA (NO 210)

GAS HEATING - 4100

WATER TO AIR

DIFF - 11050

2-7 1/2 TON - 11150

DUCTWORK - 2400

PIPING - 1400
15150

TOTAL INC. EQUIP - 12060

WELL COST

ASSUME 2 - 150' WELLS

FLOW REQUIREMENT FROM WUDCO DATA @ 60°

3 TON - 5 5

5 TON - 8 8

10 TON - 16 16

7 1/2 TON - 12 .2 24

53 gpm TOTAL - 6" WELL

WELL COST (70/30)

150 .1 .1 .7 .70 = 808

150 .275 .3 .7 = 806

Casing 6" @ 14/ft = 2100

CEMENT, PACKING ETC = 400

4174.5 x 2 = 8349

Pump

53 gpm @ 80' RL - 5 HP

w/CONTROLS & TANK = 2000

BURIED PIPING 150' 2" PVC @ 10 %/ft

- 1500

BUDG PIPING @ 0.25 %/ft 150'

- 1527

SUBTOTAL

13199

TOTAL 25250

OPERATING COSTS

MAINTENANCE - ASSUME NO INCREMENTAL MAINT. ON HEAT PUMPS

WELL PUMP @ 2% INST COST

$$.02 \cdot 2000 = 40$$

40 \$/yr

INCREASED ELEC - WELL PUMP.

$$Z.P. .7 + 6 = 1.492 \text{ kW @ } 1466 \text{ hrs/yr}$$

$$1466 \cdot 1.492 \text{ kW} = 2190 \text{ kWh/yr @ } .0541$$

118 \$/yr

INCREASED @ 1/2% INC. INST COST

$$.005 \cdot 25255 =$$

126 \$/yr

FUEL COSTS

$$\text{NATURAL GAS } 7505 \text{ T/yr @ } .6112 \text{ $/T} = 4587 \text{ $/yr}$$

$$\text{ELECTRICITY @ } 54976 \text{ kWh/yr @ } .05624$$

E. Appendix E - Industrial

TAXABLE

HEAT PUMP VS INDUSTRIAL ^{NAT. GAS} BOILER

800,000 BTU/yr. 25% ANNUAL LOAD FACTOR

CAPITAL COSTS

HEAT PUMP - BOILER - 47,000 - 6000 = 41,000

6" PRODUCTION WELL 400' $(400 \div 20) + (1000) = 9000$

PUMP 120 gpm @ 100' - 7.5 FT = 6000

PIPING 4" PVC @ 10\$/FT 300'

59000

59000

+10%

64900

MAINT.

$$TP/BOILER 3\% (0.03)(47,000) \left(\frac{64.9}{53} \right) = 1551$$

$$PIPE @ 1\% (0.01)(9000) \left(\frac{64.9}{53} \right) = 66$$

INS = 1/4%

$$0.005 \cdot 64900$$

$$\frac{66}{1617} - 195 = \frac{1422}{324} \text{ \$/yr}$$

ENERGY USE

$$.25 \cdot 800,000 \cdot 1.75 \text{ kWh} = 1.75 \times 10^3 \text{ kWh/yr}$$

$$1.752 \times 10^3 \text{ kWh/yr} \div 10^6 = 1.752 \times 10^3 (10^6 \text{ kWh/yr})$$

$$0.05406 \text{ \$/kWh} \cdot 1.0 \text{ CO}_2 - 3.75 \text{ \$/10}^6 \text{ kWh} = .22 \text{ \$/10}^6 \text{ kWh}$$

$$1.752 \times 10^3 \cdot (3.75 + .22) =$$

$$= 6955 \text{ \$/yr}$$

SAVINGS

$$1.752 \times 10^3 (10^6 \text{ kWh/yr}) \cdot 9.20 \text{ \$/10}^6 \text{ kWh}$$

$$= 14366 \text{ \$/yr}$$

SUMMARY OF DATA FROM G.T.C. HEAT PUMP PROJECTS

~~Elmer~~ Indian Springs, Pine Bluff, Ark. ~~for~~
~~Stennis~~ Stennis, Mt. Lake, ~~Stennis~~,
 Ephraim, Othello, Yakima P.O., St. Elmer, La.

yr	Capacity	Source	well	Cost	Est. cost	$\$/10^6 \text{ B.T.U.}$
1/31	1.4×10^6	60	140	62,000 ^I	71,000	48
		70	140	57,500 ^I	66,000	44
		93	140	42,600	49,000	33
	TPB 060			29,100 ^m	33,000	-
	TPB 050			50,000 ^m	57,000	-
1-79	2.379×10^6		190°	100,000 ^I	205,000	87 2nd
11-79	2.379×10^6		140	93,000 ^I	120,000	50
1-81	320,000	70	140	27,510 ^m	31,500	98 -
7-80	540,000	65		19,251 ^m	23,500	43 -
	2.25×10^6			22,000 ^m	100,000	44
	2.11×10^6			25,500 ^m	91,000	43
	670,000	4		24,000 ^m	29,000	43 -
	5.61×10^6	65	140	146,000 ^m	177,000	31.6
3/30	594,000	80	150	30,000 ^I	36,400	61.3 -
10/20	550,000	85	140	22,500	25,000	45 -
	1.339×10^6	60	120	39,000	43,500	32.50
	1.209×10^6	60	140	43,000	49,000	37
		75	120	35,000	40,000	34
		85	120	35,500	40,000	31

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