

COST CONTAINMENT FOR GROUND-SOURCE HEAT PUMPS

FINAL REPORT

SUBMITTED TO THE

ALABAMA UNIVERSITIES-TVA
RESEARCH CONSORTIUM (AUTRC)

AND THE

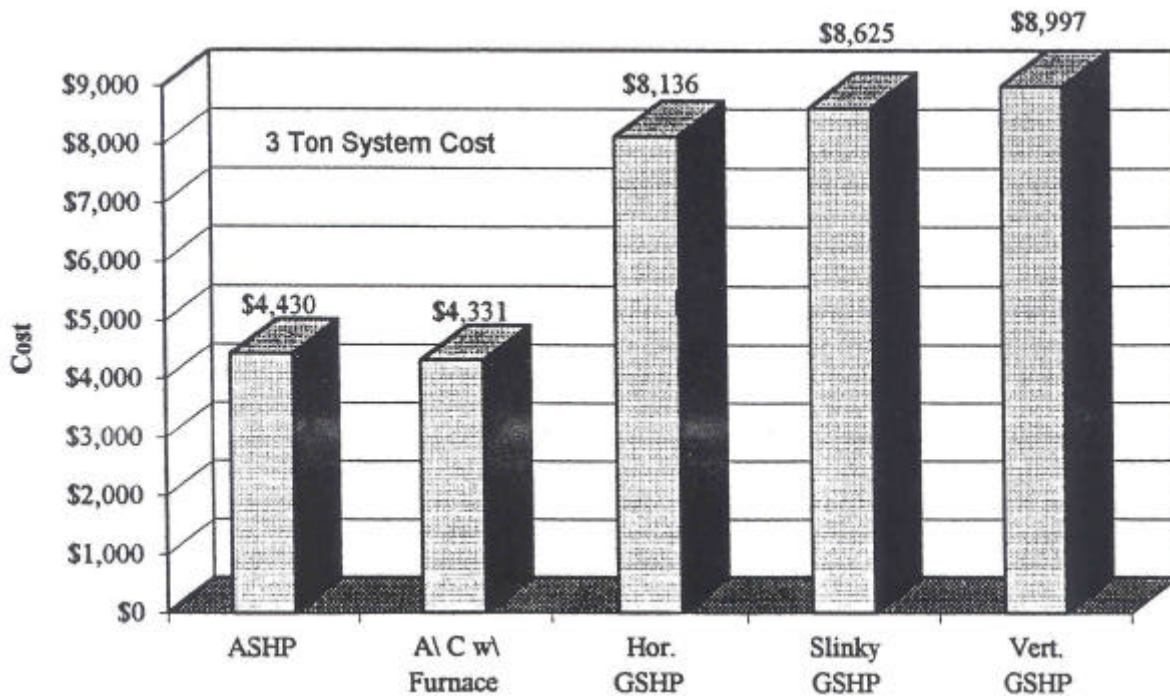
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December 1995



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EXECUTIVE SUMMARY

High installation costs have been identified as a major barrier to wider application of ground-source heat pumps (GSHPs), often referred to as geothermal heat pumps. The primary reason cited for higher cost is the ground loop. Other factors may be high costs of GSHP heat pump units and supplies, interior installation, and limited competition.

A project has been sponsored by the Alabama Universities-TVA Research Consortium and the Technology Advancement Division of TVA to:

1. Identify current total and component cost of GSHPs.
2. Compare the cost of GSHP equipment and installation with similar industry cost.
3. Identify cost containment measures used by the conventional building industry.
4. Prioritize and evaluate potential conventional GSHP cost containment methods.

National Rural Electric Cooperative Association (NRECA) Market Research was subcontracted to develop and conduct a mailed survey to establish a national norm for the cost of purchasing and installing GSHPs. A total 547 surveys were mailed and 285 were returned for a response rate of 57%. The average cost of ground-source heat pump systems ranged from \$2,360 per ton (5-ton horizontal) to \$3,000 per ton (3-ton vertical). Compared to 3-ton conventional equipment, added cost was \$1,250 to \$1,550 per ton. The costs have been subdivided by components.

| | |
|---------------------|------------------|
| Ground loop | = 27.2% to 34.2% |
| Heat pump | = 27.3% to 30.2% |
| Indoor installation | = 19.2% to 21.1% |
| Ductwork | = 13.5% to 14.5% |
| Pumps | = 6.2% to 6.9% |

Horizontal loops averaged \$741 per ton, slinky coils \$904 per ton and vertical U-tubes \$1,028. Based on a 3-ton system, component potentials to reduce total price are:

- | | |
|--|---------------|
| 1. Reduce water-to-air heat pump cost (EER = 13.5) | \$880 |
| 2. Reduce indoor installation cost | \$540 |
| 3. Reduce pump costs (esp. desuperheater pump) | \$280 |
| 4. Reduce ground loop cost below \$2,200 | \$220 - \$360 |

A demonstration project was conducted that converted an \$800 packaged terminal heat pump (PTHP) with a 9.2 EER to a 1.5-ton GSHP unit with a 14.4 EER at ARI 330 conditions. Since PTHPs have production levels and components similar to GSHP units, cost should be in line. The Cost Survey indicates GSHP unit costs are double PTHPs.

Recommendations are to concentrate on reducing the cost of the components with the greatest potential (heat pumps, indoor installation, pumps), avoid overemphasis of low-cost loops at the expense of quality, emphasize cost containment in training and publications, and share the cost of training and market development with manufacturers. Additional suggestions are to involve experienced contractors in loop research and development, spur competition of the development of optimized units, (“golden carrot” initiatives), and encourage involvement with “affordable housing” projects.

COST CONTAINMENT FOR GROUND-SOURCE HEAT PUMPS

CHAPTER 1 - INTRODUCTION

1.1 Background and Objectives

Ground-source heat pumps (GSHPs), often called geothermal heat pumps (GHPs), are recognized as an excellent heating, cooling, and water heating alternative. They provide high levels of comfort, homeowner satisfaction and high efficiency (1). The relatively low demand characteristics of GSHPs are an advantage to many utilities. An EPA report encourages the use of them as a highly desirable method of reducing greenhouse gas emissions and ozone depletion (2). Many electric utilities have implemented marketing incentives and training assistance to encourage wider use of GSHPs. In several regions of the U.S., these programs have been successful in improving acceptance and installation quality. However, GSHP cost in most regions in the U.S., including the TVA service area, remain high.

Reductions in GSHP system cost, improvements in installation quality, greater competition, and improved market penetration have occurred primarily in the areas that have been involved with GSHPs for several years. The first cost of GSHPs in areas that do not have established contractors and designers is often prohibitively high. These relatively high costs cannot be economically justified by many potential customers. Thus, the GSHP heat pump industry in these areas does not develop sufficiently to support loop and HVAC contractors who will invest in the equipment and training necessary to install GSHPs effectively.

The reasons for these higher costs and lost market opportunities **appear** to be:

1. High cost of ground loops.
2. Higher cost for GSHP heat pump equipment and supplies.
3. Higher cost of HVAC installation.
4. Limited competition.

The **objectives** of this project are to:

1. Identify current total and component costs of GSHPs.
2. Compare the cost of GSHP equipment and installation with similar industry cost.
3. Identify cost containment measures used by the conventional building industry.
4. Prioritize and evaluate potential conventional GSHP cost containment methods.

1.2 Literature Review

In addition to the EPA (2), several organizations have identified GSHPs to be a very attractive means of reducing energy consumption, lowering utility costs, and reducing pollution. These include the National Rural Electric Cooperative Association (3), the Department of Energy (4), and the Electric Power Research Institute (5). These agencies and others have identified high loop cost as the number one reason for lack of market penetration. Several projects have been supported by

NRECA, EPRI, and the local utilities to reduce this cost. These include the development of the “Slinky” coil ground heat exchanger, the development of angle drilling equipment, and market programs, such as the TVA Promotion, that reduce cost by bulk purchase of supplies and rebates.

In 1991, TVA initiated a program that offered customers of participating power distributors “free” ground loops. TVA provided the piping materials and the power distributor paid for loop installation if the customer agreed to cover the cost of the heat pump equipment, ductwork and indoor installation. As of February 1993, 219 customers were participating (6).

The customer costs for an average size home (1,600 sq ft with a 3-ton heat pump) was \$5,400. TVA cost was \$435; while, the distributor cost was \$870. Thus, the total cost for a 3-ton GSHP is \$6,705 (or \$2,235 per ton). This would not include any overhead and profit for the loop installation component since it is subsidized by the utility. Reference (7) estimates the savings in the southeast to be approximately \$300 per year for a GCHP. Using a typical installation cost of \$4,000 for a conventional system, simple payback time is 4.7 years with the utility supplements and 9.0 years without.

Many customers are very reluctant to participate in the program even with the 4.7 year payback. Since little activity has occurred without supplements, it is likely that very few customers would be eager to participate with the 9-year payback.

While loop cost appears to be a major reason for higher first cost, the \$5,400 “indoor” equipment cost should be approximately the same as the \$4,000 typical first cost of a conventional system given the essentially equal complexity of the equipment and installation. If this “indoor” installation cost could be brought in line with the measures suggested by this proposal, payback time could be reduced to 4 years without utility supplements and zero years with supplements. Thus, the goals of increased market penetration could be realized to a much greater extent.

A detailed study of vertical geothermal heat exchanger installation methods concluded that the cost of vertical loops could be greatly reduced (8). The survey found a range of cost of vertical loops to be \$750 to \$2000 per ton in 1993. The author suggest that actual cost should be less than \$540 per ton. Major assumption of this cost is that loop contractors will use efficient and well controlled business practices to reduce overhead, competition will drive the cost down, test holes will be drilled at the contractors expense before bidding, and the GSHP technology will proliferate. The \$540 per ton price does not appear to consider the seasonal and periodic variations in project opportunities, equipment maintenance, increasing cost of environmental compliance, and the expenses associated with drilling for long periods of time in locations that are a great distance from the home base of the contractor.

Reference (9) summarizes a great deal of information regarding case studies and utility programs. Twenty-seven case studies were sighted with simple payback (SPB) periods. Paybacks verses ASHPs ranged from 2 to 9 years with an average of 6 years. SPB versus natural gas ranges from 4 to 24 years with the average being 10 years.

A variety of ground heat exchanger designs have been proposed and demonstrated as cost cutting alternatives. These include the Geo-Bag, large diameter bore holes with spiral coils, variations of the slinky coil, variations of multiple pipe arrangements, standing column wells, direct expansion with copper coils, direct expansion with reinforced polyethylene, dual source (air and ground) coils and others. The purpose of this project is **not to evaluate the effectiveness of these alternatives**, but to look at the cost of the most common **closed loop** GSHP coils, related equipment and supplies.

This project will also use information available in the construction industry that closely relates to GSHPs. A source of cost information widely used by estimators and planners is the R.S. Means cost data publications (10, 11, 12, 13, 14). These data will be used as a baseline for actual cost and what is realistic in terms of reductions.

Many of the supplies and equipment used in the GSHP industry are used elsewhere. Catalogs and pricing are widely available (in addition to the cost given in R. S. Means). The cost found in the GSHP survey will be compared to the cost given to the public in sources such as Johnstone Supply and W. W. Graingers.

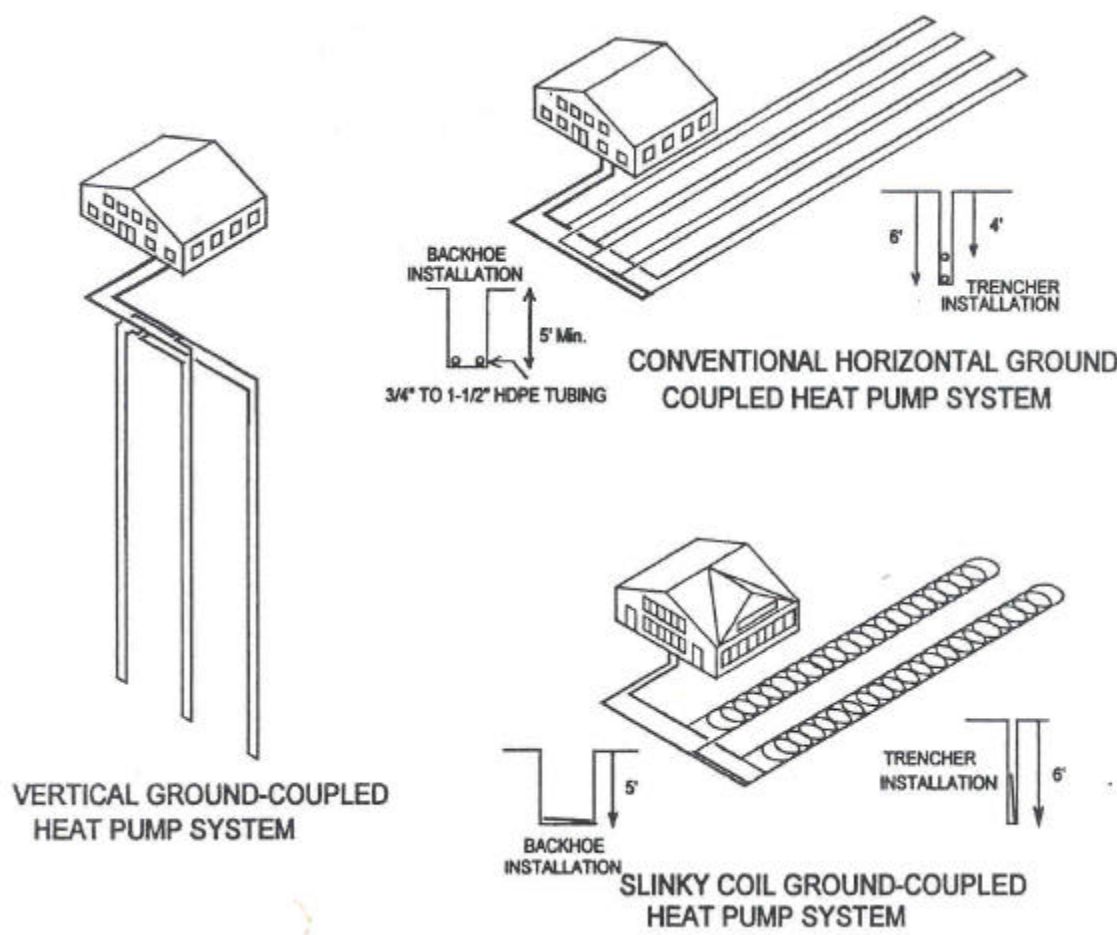


Figure 1.1 Conventional GCHP Systems

CHAPTER 2 - GSHP COST SURVEY

2.1 Survey Description

As a component of this project, National Rural Electric Cooperative Association (NRECA) Market Research was subcontracted to develop and conduct a mailed survey to establish a national norm for the cost of purchasing and installing ground-source heat pumps. Five hundred forty-seven surveys were mailed to various companies and individuals associated with GSHPs. Names were taken from a spectrum of sources that included the International Ground Source Heat Pump Association (IGSHPA) Membership Directory, participants in previous NRECA surveys, volunteers who were aware of the survey, and TVA personnel associated with GSHPs. A copy of the survey is included in Appendix A.

Two-hundred and eighty-five surveys were returned for a response rate of 57%. The 285 total was made up of electric cooperative employees (40.7%), other electric utilities (19.2%), contractors (16.8%), distributors or manufacturers (9.2%), engineers or consultants (6.0%), educators (2.1%), others (2.8%) and respondents refusing to identify affiliation (3.0%).

Detailed statistical results were provided in a separate report by NRECA (15). Data were presented in graphical and tabular form. Comments from respondents were extensive and are included in Appendix B. The survey results have been condensed and presented in new graphical form in the sections that follow.

2.2 GSHP Component Descriptions and Costs

Many of the respondents were unable to answer all the questions in the survey. Only 108 of the respondents answered the detailed component portion of the survey. Figure 2.1 shows the percentage of respondent that installed the various loop types. For example, 62% of the respondents installed slinky loops. Multiple responses to this question were possible. Some respondents installed all four of the primary loop types shown in the figure. The number of respondents installing other types included groundwater (11), standing column (3), bag (1), direct expansion (1), and large bore (1).

Figure 2.2 presents details concerning the methods used to install various loop types. Twenty-seven of the respondents use single pipe horizontal loop with an average length of 414 ft per ton. Thirteen of the respondent use multiple pipe loops installed with a chain-type trencher with the average trench length being 332 ft per ton. The data is unclear on this point, but the majority of installations appear to be 2-pipe. More respondents used a backhoe to install multiple pipe loops. Data indicates a combination of two or more pipes per trench since the average trench length is 218 ft per ton, but the average ft per ton of pipe is 700 (or 3.2 ft of pipe per ft of trench). Slinky coils were installed with a chain-type trench at an average of 806 ft of pipe per ton and 217 ft of trench per ton (or a pitch of 3.7 ft of pipe per ft of trench). This indicates extended slinky coils are the dominant choice of the respondents. More respondents used backhoes for slinky installations and placed slightly more pipe (970 ft per ton) in a slightly shorter trench (207 ft per ton). Vertical installations average 174 ft per ton of bore with single U-tubes.

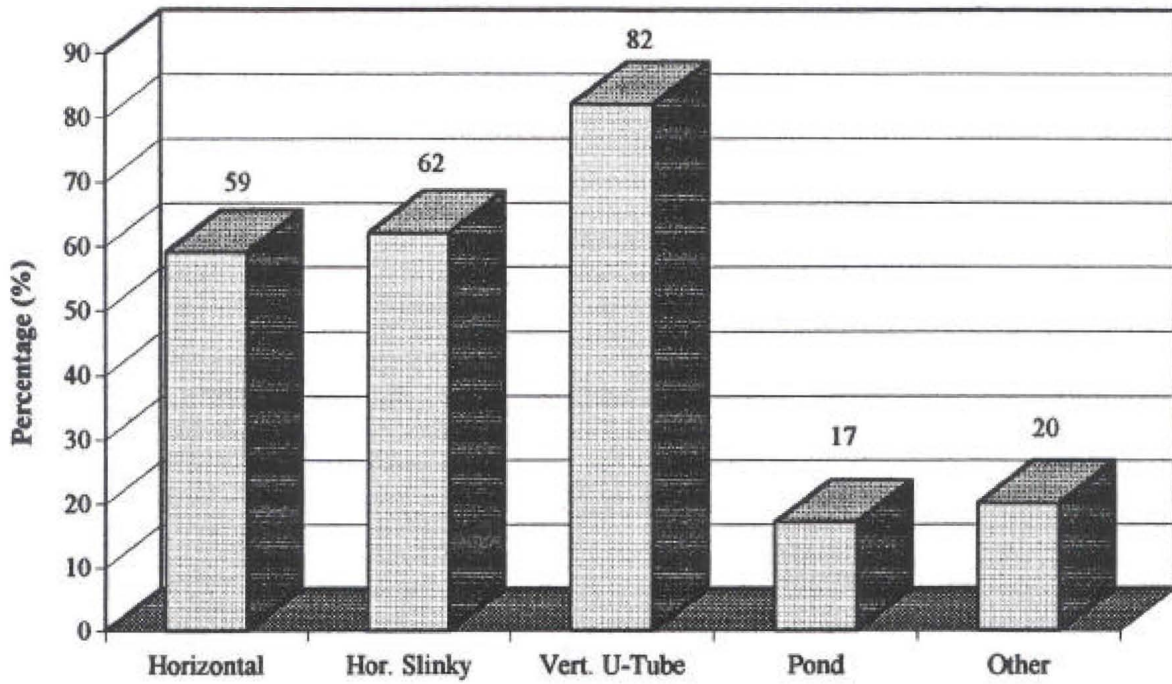


Figure 2.1 Percentage of Respondents Installing Various Loop Types

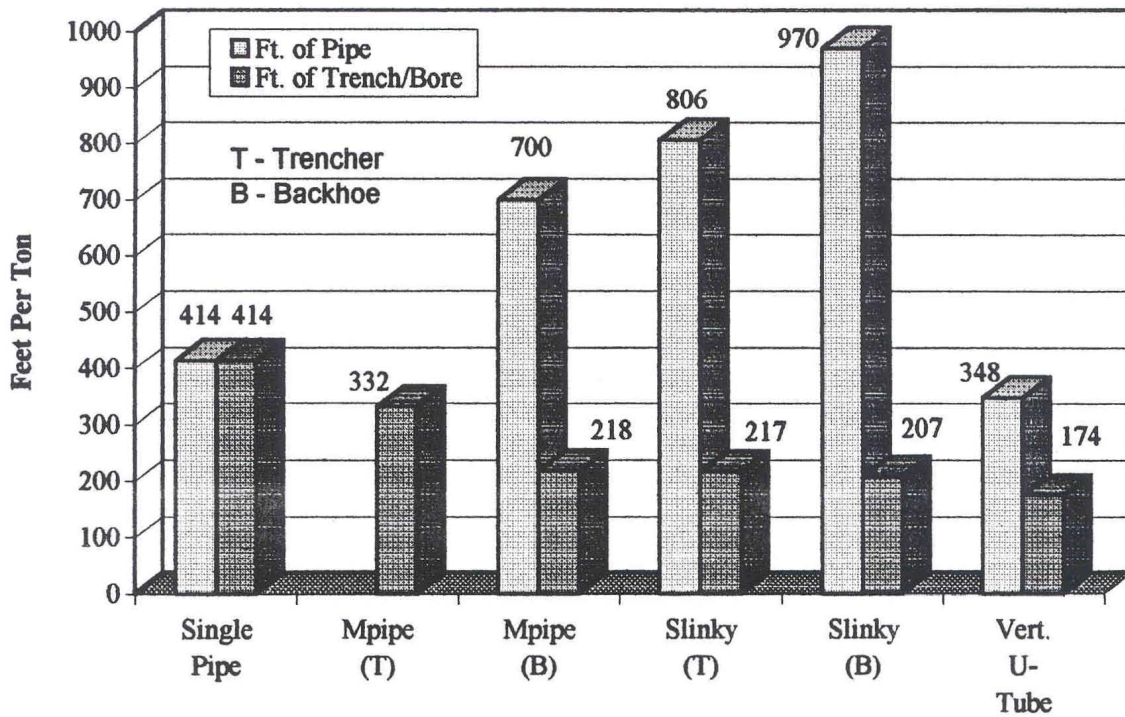


Figure 2.2 Average GSHP Length per Ton of Pipe and a Trench (or Bore)

Figure 2.3 summarizes the cost of the three primary loop types. The costs of horizontal and slinky loops with trenchers and backhoes are combined. The survey did not ask for pond loop or other types of loop costs. Loop costs are not out of line with what is to be expected. The only surprise is the difference in the cost of straight pipe horizontal and slinky loops which were expected to be nearly equal. Figure 2.4 may explain some of the difference. The variation in the cost of 3/4-in. polyethylene pipe was large. Several respondents paid well above the average costs which caused the cost of 3/4-in. pipe to be higher than for 1 inch. If these respondents were installing slinky coils, which is normally 3/4 inch, the higher average slinky loop cost shown in Figure 2.4 may result. The survey suggests respondents paid significantly more for larger diameter piping when it is classified as header piping rather than being used for the ground loop. The reason for this appears to be that larger quantities are purchased when 1-1/4-in. and 1-1/2-in. piping are used for the loop field and cost per ft is lower.

Much of the effort in reducing GSHP cost has concentrated on loop cost. Figure 2.5 indicates some effort is warranted in other areas. The figure presents all system cost exclusive of the ground loop. The figure also shows system costs without the ground loop and without the ductwork. Some economy of scale is realized since the average for the smaller 3-ton unit is \$1,974 per ton (with duct/without loop) and the 5-ton average is \$1,620 per ton.

Included in the totals is the cost of the water-to-air heat pumps as shown in Figure 2.6. The bulk of the units are in the 11 to 14 EER range (ARI 330). The respondents were asked for the manufacturer, model, and EER. Answers indicated the respondents believed the units' EERs were slightly higher than the published ARI values. Most of the units appear to include heat recovery coils (desuperheaters). There is some economy of scale with the larger units (\$720 per ton) compared to the smaller units (\$860 per ton).

Figure 2.7 gives the cost of pumps used in GSHP applications. These are generally high-head wet rotor circulator pumps. The pump kits include valves for purging the ground loop assembled on the pump(s) in a single package. Respondent overwhelmingly used the 1/6-hp pump(s) since the added cost and rated input power (245 watts) are only slightly larger than the smaller 1/12-hp pump (205 watts input). Respondents generally use a single-pump kit for 3-ton and smaller systems, and the 2-pump kit for larger units. The higher cost of the smaller heat recovery (desuperheater) pumps is somewhat surprising.

Figure 2.8 is graphic indicator of the major barrier to GSHPs. The survey polled respondents for the **total installed system** cost of two competing technologies, the air-source heat pump (10 SEER) and the electric air conditioner (10 SEER) with a natural gas furnace (78% AFUE). The cost of the GSHPs were generated by adding the base cost of a 3-ton system without the loop (\$5,913 from Figure 2.5) to the loop costs (for a 3-ton system) given in Figure 2.3 for the horizontal, slinky, and vertical loops. A minimum value of 10 SEER for the heat pump and A/C were chosen since this represents an equivalent performance to a 13 to 13.5 SEER GSHP heat pump (ARI 330). Details for this assertion can be found in Appendix C.

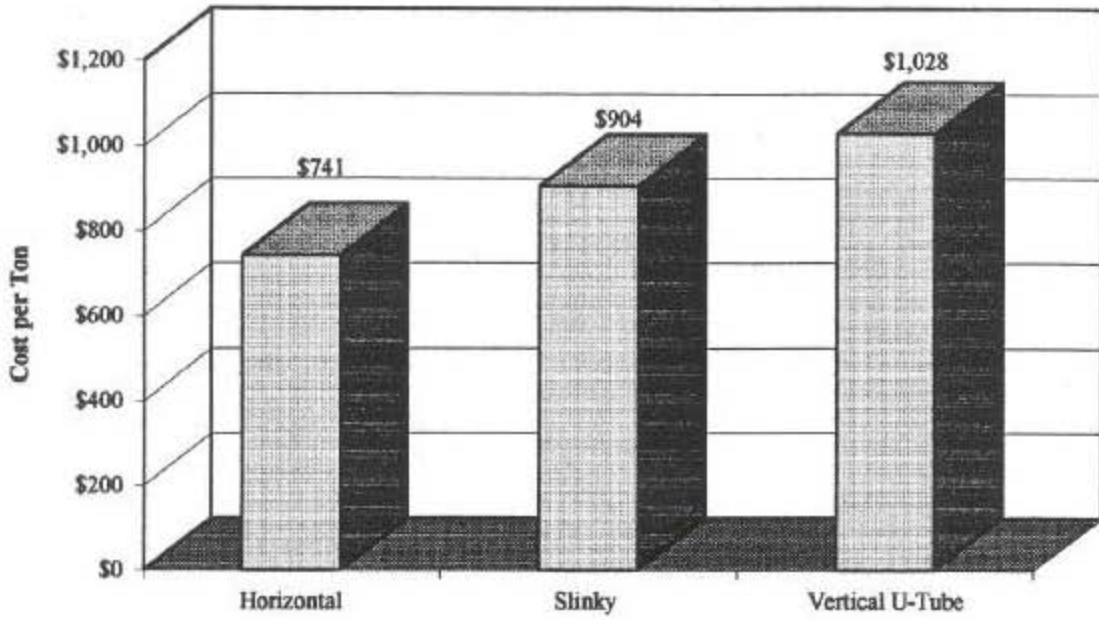


Figure 2.3 Installed Loop Cost Per Ton

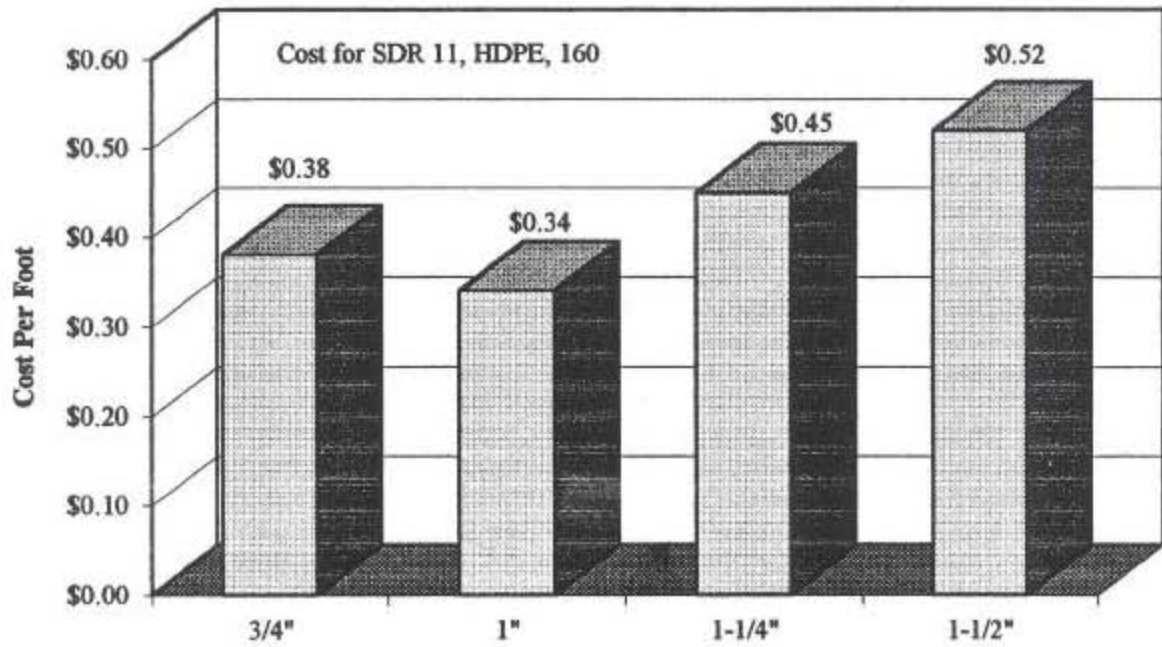


Figure 2.4 Cost Per Foot of Ground Loop Piping

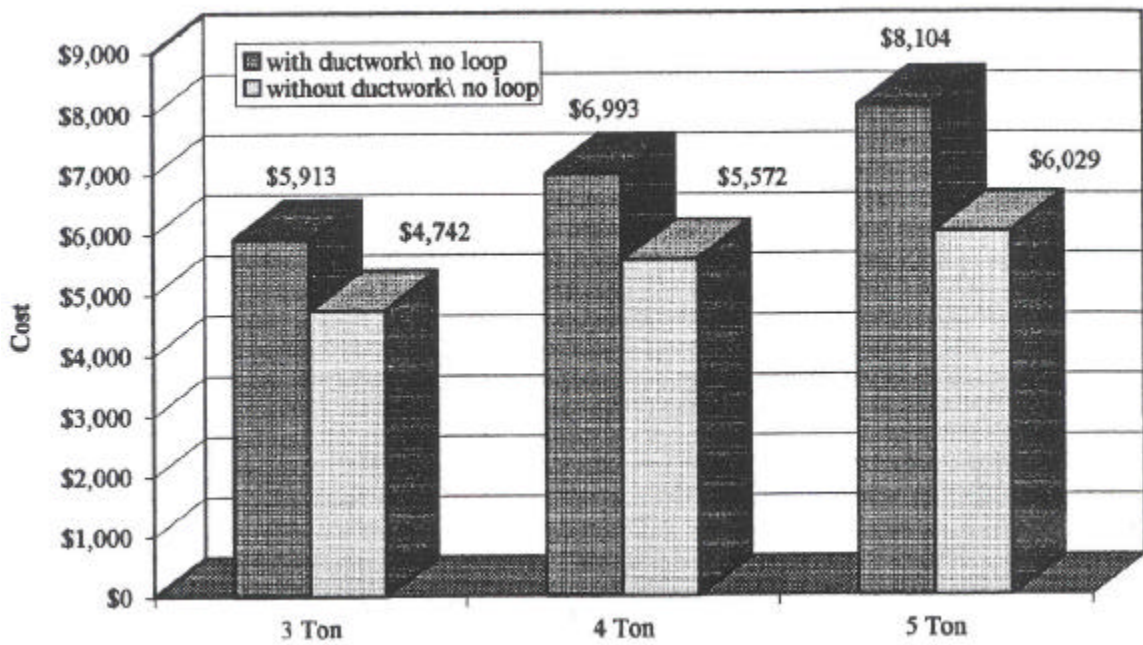


Figure 2.5 Cost of Equipment, Supplies & Interior Installation without Loop

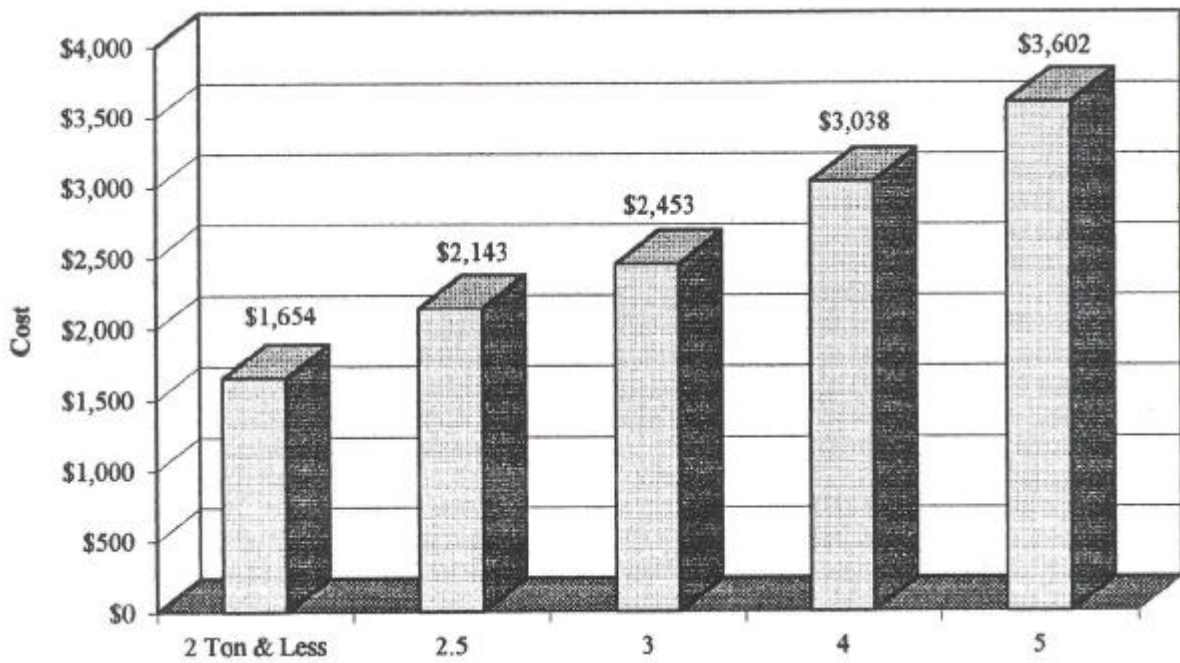


Figure 2.6 Cost of Water-to-Air Heat Pump Units.

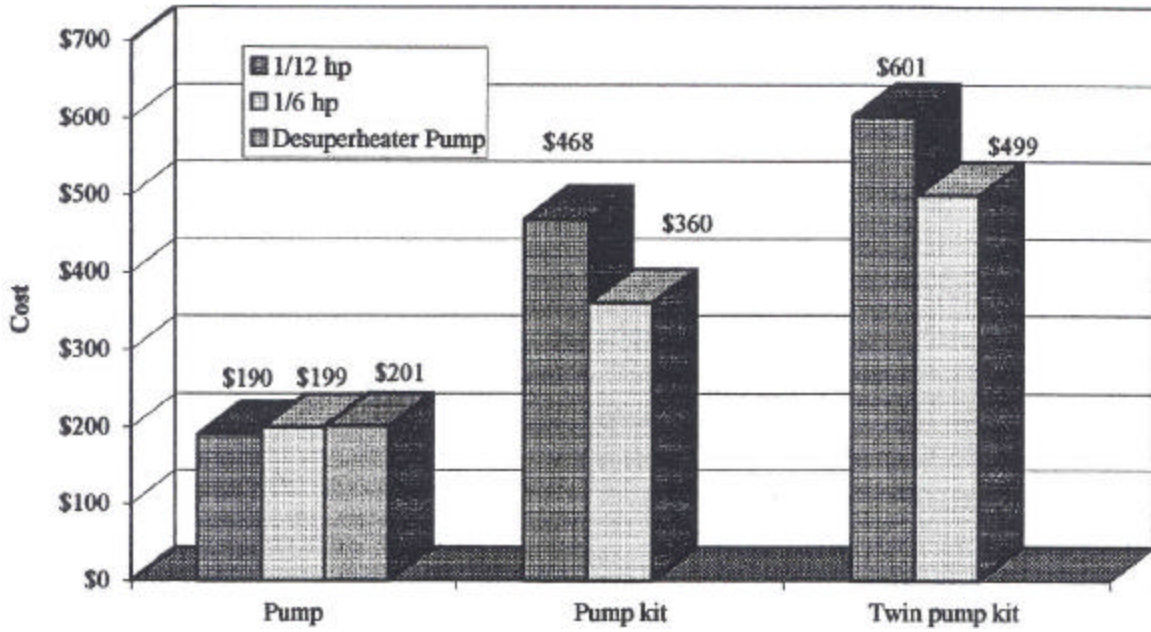


Figure 2.7 Cost of GSHP Pumps

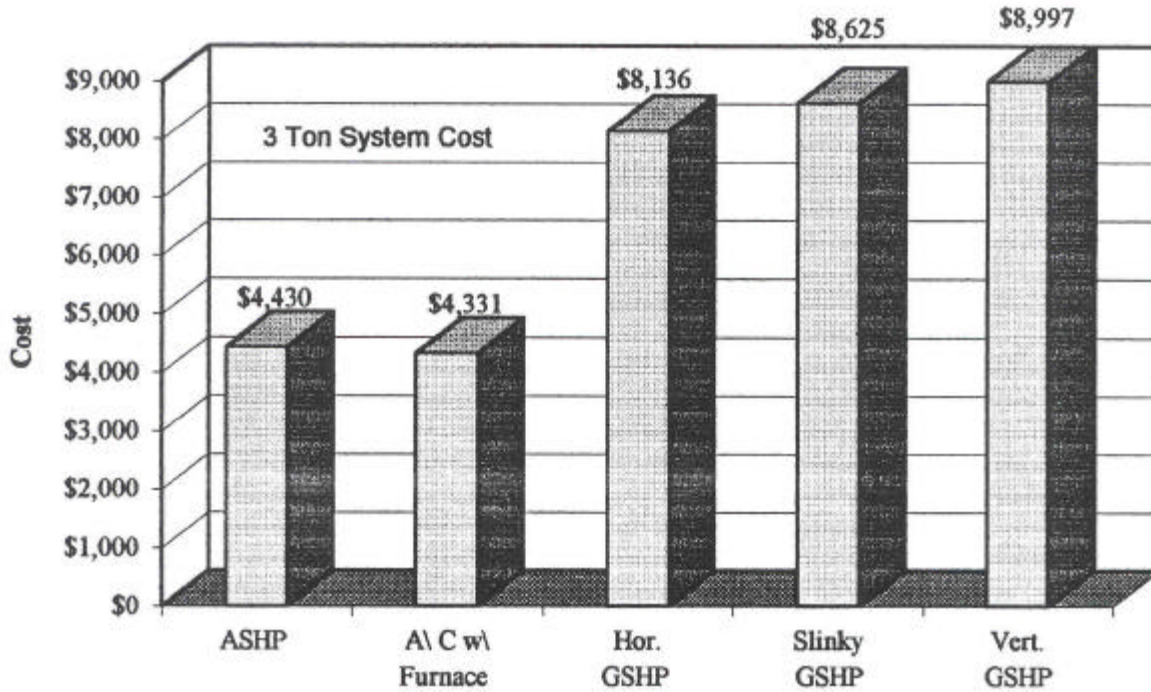


Figure 2.8 Total Installed Cost for Conventional and GSHP Systems

The assumption has been the loop costs were the major contributing factor to higher GSHP cost. However, since the total cost for a 3-ton system is \$1,270 to \$1,555 per ton higher than an A/C with a gas furnace and loop costs are only \$741 to \$1,028 per ton, other added cost are significant. Since loop installation is a labor intensive activity requiring significant capital investment and maintenance for installation equipment, the potential for cost reductions below \$741 per ton is possible but not outstanding. It appears that an additional \$500+ per ton reduction is possible if the cost of the interior portion of the system is brought in line with conventional equipment.

Figure 2.9 shows the effects of rebates upon system cost. Many have advocated higher rebates in order to lure potential GSHP customers. Figure 2.9 may indicate this may be counter-productive, since system cost have found to be higher for higher rebates. Figure 2.10 is a more detailed breakdown of component cost of the three types of 3-ton GSHPs. In showing the individual costs and the amount each contributes to the total, the merit of attempting to optimize cost in each area can be evaluated and prioritized.

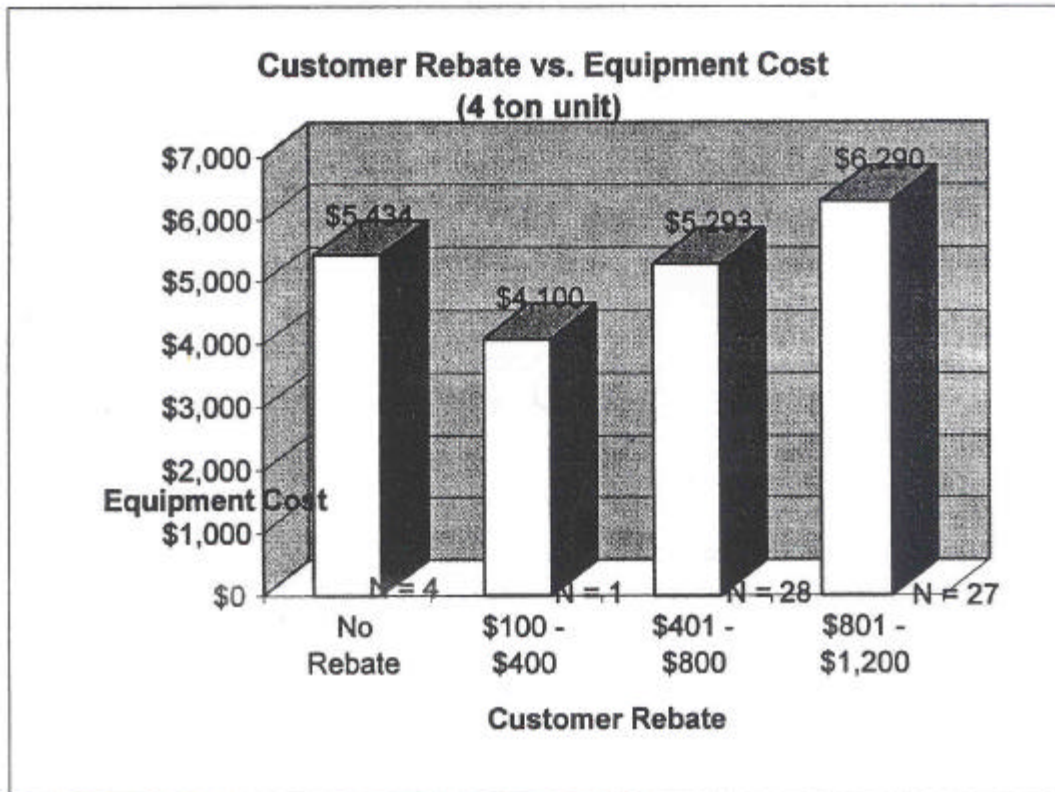


Figure 2.9 Impact of Rebate Upon System Cost GSHP (without Loop & Duct)(Sample Size of No. Rebate and \$100-\$400 Insufficient).

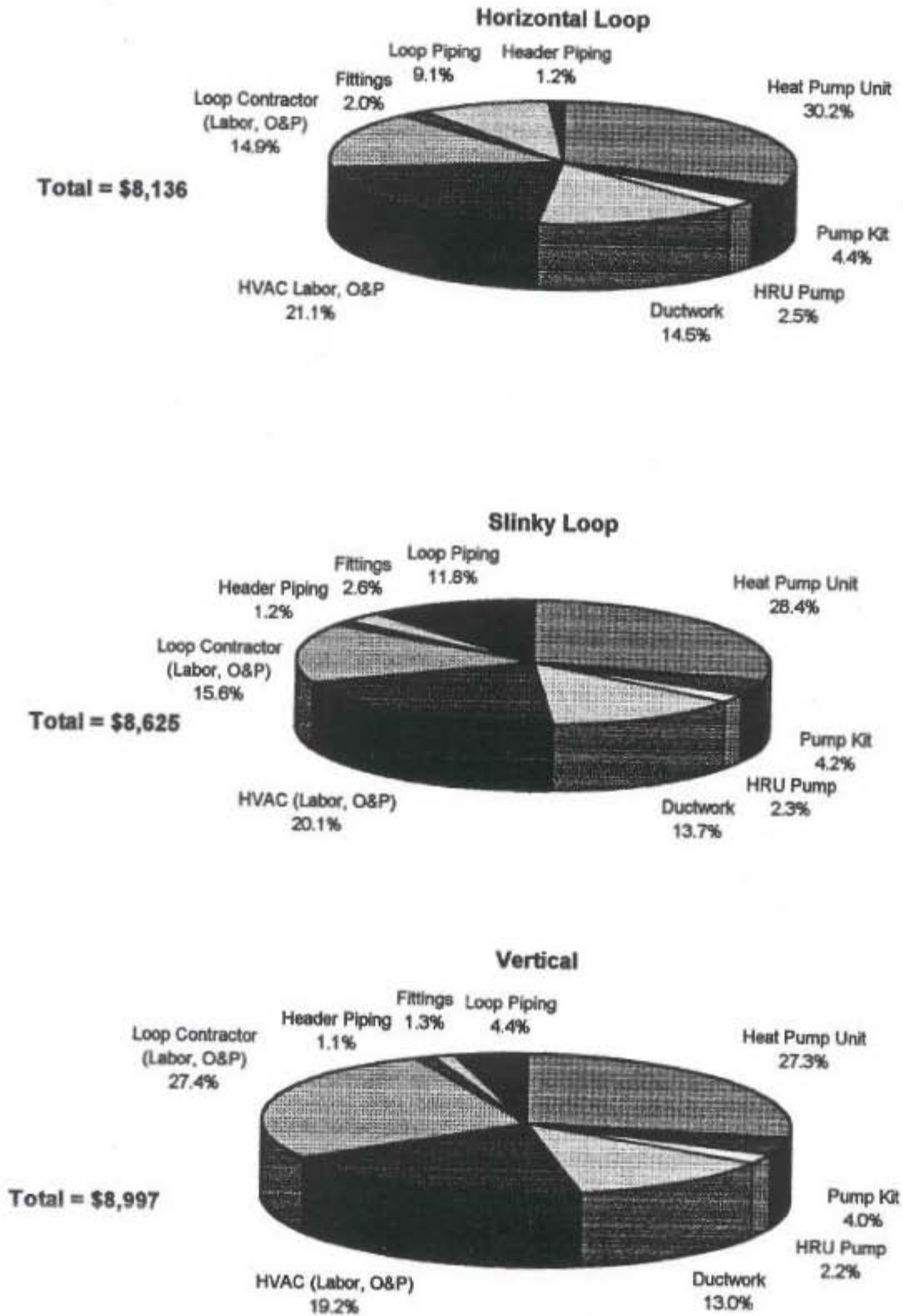


Figure 2.10 Component Costs of 3-Ton GSHP Systems.

CHAPTER 3

COMPARISON OF GSHP COST TO EQUIVALENT CONVENTIONAL COST

Several sources have been consulted for the cost of similar equipment and labor activities in the building industry. The primary resource is the 1994 Mechanical Cost Data (11) and related publications. This publication breaks down equipment, labor, and overhead for a variety of building components. Although the information can be regionalized, it is presented for the national average values.

3.1 Ground Loop Cost

The most closely related activity to a horizontal ground loop is installation of high density polyethylene (HDPE), 160 psig water pipe. The Means Data cost of 3/4-in. HDPE is 20¢ per ft, which is significantly lower than the 38¢ per ft average (Figure 2.4) reported in the GSHP Survey. However, the net cost for installing 3/4-in. HDPE when labor, overhead and profit are included is \$1.76 per ft. taking the average single pipe length of 414 ft per ton (Figure 2.2) and multiplying it by the Means' cost, yields a total of \$728 per ton. If the cost of header piping is included, the cost exceeds the \$741 per ton value found in the survey (25 ft per ton) and this is coupled with the Means cost of installing 1-1/2-in. HDPE (\$3.28 per ft), \$82 per ton is added to the loop piping cost. Thus, the total would be \$810 per ton.

- **It appears the cost for installing a ground loop in a single-pipe horizontal pattern is in line with the building industry cost to install similar water lines even though the price per ft of 3/4-in. GSHP piping is 90% higher than water piping with similar specifications. If 3/4-in. pipe was 20¢ per ft, savings would be \$74 per ton.**

Trenching cost are much more difficult to identify since the values found in Means' cost include removal of native soil and adding backfill from a stockpile. The net cost per for digging a 2-ft wide by 6-ft deep trench is \$4.68. However, only 46% of this cost is related to excavation and compaction. The total for trenching ground loops would be \$2.15 per ft. To this subtotal, pipe cost must be added. For a 2-pipe horizontal loop using 3/4-in. HDPE at the Means cost of 20¢ per ft, the total would be \$2.55. The average length of trench for the 2-pipe horizontal is 332 ft per ton or \$846 per ton for the loop piping. This total becomes \$928 per ton when the header cost is included.

- **It appears the cost for installing a ground loop in a 2-pipe horizontal pattern is in line with the building industry cost to trench and purchase piping even though the price per ft of 3/4-in. GSHP piping is 90% higher than water piping with similar specifications. Cost reductions of \$120 per ton are possible if pipe prices are equal to Means' cost.**

The Means' cost data do not include costs for activities similar to installing slinky coils or vertical U-tubes. While the possibility does exist for reducing installation cost with these loop types, it does not appear the potential exists for reductions much greater than the current horizontal costs are possible.

- i ***Projected savings using conventional HVAC costs/methods = \$220 to \$360 for 3-ton***

3.2 Heat Pump Unit Costs

The Means equipment costs for air-source heat pumps agree with the GSHP Survey results, but water-to-air heat pump prices are significantly lower than those in the Survey. Average Means' costs are \$1,275 for a 3-ton unit (compared to \$2,453 in the GSHP Survey), \$1,675 for a 4-ton (compared to \$3,038 in the GSHP Survey), and \$2,025 for a 5-ton (compared to \$3,602 in the GSHP Survey). Results can not be directly compared since the units in the Means' data are water loop models that do not normally include heat recovery coils, use less expensive expansion devices, and usually have slightly lower efficiencies. However, upgrading the efficiencies of this type of equipment to match the values typically used in GSHPs would cost far less than differences between the Means cost and the GSHP Survey costs.

A 3-ton GSHP unit with an EER of 13.5 (ARI 330) could be attained by modifying standard water source heat pump (ARI 320 EER = 11.0) by:

1. Using a compressor with an ARI 520B EER of 10.8 at an added cost of \$31.
2. Upgrading from a nominal 36,000 Btuh to a 42,000 Btuh water coil at \$20.
3. Adding a bi-flow thermostatic expansion valve at \$25 plus \$10 added labor cost.
4. Adding a desuperheater coil at \$33 plus \$15 added labor cost.
5. Upgrading from a 500 watt input to 400 watt input PSC fan motor at \$15.

Total cost of upgrade = \$149 + 100% manufacturer/distributor mark-up = \$298

Thus, the cost of an equivalent 3-ton unit would increase from to Means' cost of \$1,275 to \$1,573.

- **It appears the costs of water-to-air heat pumps found in the GSHP Survey is significantly higher compared to the cost of equipment with slightly lower quality in the Means Cost Data.**

i ***Projected savings using conventional HVAC costs/methods = \$880 for 3 ton GSHP***

3.3 Ductwork Costs

It is difficult to match the low cost for ductwork found in the GSHP Survey. Consider a small home with a central duct system made with the lowest cost components (i.e., flex duct and ductboard). A 18-in. by 12-in. rectangular main duct 30 ft in length (150 ft²) has a Means cost of \$550. Short duct runs of 7-in. round flexible duct would cost \$487 with eight diffusers at \$20 each and a 5-ft² filter-grill \$117 would bring the total to \$1,314 which includes overhead and profit. This is close to the \$1,171 found in the GSHP Survey, which does not include HVAC contractor overhead and profit.

- **It appears the costs of ductwork found in the GSHP Survey is in line with the values in the Means Cost Data.**

i **Projected savings using conventional HVAC costs/method = \$0**

3.4 Pump Costs

The 1994 Means Mechanical Cost Data does not include the cost of wet rotor pumps. A substitute is to consult HVAC supply catalogs. The 1994 Fall/Winter Johnstone Supply Catalog lists costs for the most commonly used GSHP wet rotor pumps to be \$143 for a 1/16 hp, \$129 for a 1/12 hp, and \$56 for a 1/25 hp domestic hot water circulator. The costs appearing in the 1994 W. W. Graingers Catalog (#385) are equivalent. This catalog offers 1 inch, full port, two-way, brass valves for \$15. Four valves would be needed to substitute for the two three-way valves in a pump kit. Two brass three-way valves can also be purchased for less than \$20 each.

- **It appears the costs of the main circulator pumps are 30% to 40% higher in the GSHP Survey than the price available from wholesale HVAC supply houses. The average cost for heat recovery pumps (desuperheater) is more than double supply house cost.**
 - **It appears the costs of pump kits in the GSHP Survey can be improved upon by purchasing pumps and valves from HVAC supply houses and paying for one to two hours of labor to assemble these components.**
- i *Projected savings using conventional HVAC costs/methods = \$280 for 3-ton GSHP*

3.5 Indoor (HVAC) Installation Costs

The unaccounted costs in the GSHP Survey were \$1,750 or 19.2% (vertical systems) to 21.1% (horizontal systems) of the totals. These costs include thermostats, auxiliary heat, wiring, unit connections, non-loop related labor, overhead and profit. This would include overhead and profit related to ductwork; since, it does not seem to appear in the \$1,171 ductwork cost found in the GSHP Survey. If the ductwork overhead and profit of \$340 (from Means Data) were deducted from the \$1,750 HVAC costs along with \$95 for a set-back thermostat, a value of \$1,315 remains for HVAC installation.

The 1994 Means Mechanical Cost Data list an average labor cost for installing a 3-ton water-to-air heat pump as \$291 plus \$384 for overhead and profit. A cost for installing the pumps (main loop and heat recovery pumps) must also be included at \$25.50 each (labor) and \$23 each for overhead and profit. Means' costs include the price of supplementary heating. Thus, the total would be \$772 compared to the \$1,315 found in the GSHP survey.

- **It appears the costs of installing the indoor portion of a GSHP system and related supplies are 70% higher in the GSHP Survey than costs of installing similar equipment in the conventional HVAC industry.**
- i *Projected savings using conventional HVAC costs/methods = \$540 for 3-ton GSHP*

3.6 Reduction Potential GSHP Components

A ranking of potential areas of cost containment measures can be listed. This listing assumes the GSHP industry brings its costs/charges in line with the values found in the Means Mechanical Cost Data for equivalent supplies, equipment, and labor. The Means Mechanical Cost Data applies to large commercial or industrial projects, large multi-family, or custom single-family projects. These data were chosen as a basis for comparison rather than Means Residential Cost Data because they reflect costs associated with the higher-end homes currently choosing GSHPs.

Based on a nominal 3-ton GSHP system, the cost containment measures can be ranked according to potential to reduce total price.

| | | |
|----|---|-----------------|
| 1. | Reduce water-to-air heat pump cost (EER = 13.5) | \$800 |
| 2. | Reduce indoor installation cost | \$540 |
| 3. | Reduce pump costs (esp. desuperheater pump) | \$280 |
| 4. | Reduce ground loop cost below \$741 per ton* | \$220 - \$360 |
| 5. | Reduce ductwork cost below \$1,171 (no OH&P) | \$ <u>0</u> |
| | Total | \$1,920-\$2,060 |

* This considers the potential of reducing costs for loops installed using conventional technology. While the possibility of reducing costs does exist, most of the highly touted, novel loop configurations and equipment have failed to live up to initial expectations for a variety of reasons. The potential for improvement (in terms of performance and lower costs) must be evaluated thoroughly before the industry's limited research resources are unwisely expended. Alternatives should have the following characteristics.

1. Be very durable during and after installation.
2. Be able to be installed with low cost, low maintenance, and compact equipment.
3. Require moderate volumes of antifreeze solutions in cold climates.
4. Must not require heat pumps with larger refrigerant charges, complicated controls or complex refrigerant circuits.
5. Be evaluated based on long periods (one year) with higher than average loads.
6. Be constructed of materials that can be fabricated with conventional materials that will not decay in soils.
7. Be able to be installed and serviced by technicians with moderate skills.

CHAPTER 4 LOW-COST GSHP UNIT DEMONSTRATION PROJECT

4.1 Cost of Equivalent Equipment with Similar Sales Volumes

Manufacturers have cited low sales volume as a reason for higher GSHP heat pump costs. The 1994 shipments of water-source heat pumps was 104,000 units (16). Estimates of the total water-source units applied to GSHPs range from 20,000 per year in 1992 (17) to 40,000 (4) in 1994 by the Geothermal Heat Pump Consortium (GHPC). If the higher estimate is true, then total number of water loop units would be only 64,000. If the manufacturer's claim of higher GSHP unit cost being a result of low sales volumes, then the cost of a 3-ton water loop heat pump should be much higher than the 1994 Means Cost Data amount of \$1,275.

A product with shipment levels near GSHP numbers is the packaged terminal heat pump (PTHP). 59,000 PTHPs, often called through-the-wall heat pumps, were shipped in 1994 (16). These units are primarily used in hotel, nursing home, and office type applications as a more efficient alternative to packaged terminal air-conditioners (PTACs) with electric resistance heat. They represent a product with components and packaging similar to water-to-air heat pumps. The Means Cost Data do not give 1994 cost for PTHPs. However, the cost of a 15,000 Btu/h cooling/13,900 Btu/h heating capacity PTAC is \$960, which is assumed to be a heat pump. Cost given for larger PTACs are obviously air-conditioners with electric resistance heat.

A 17,500 Btu/h (cooling) PTHP was purchased at a cost of \$802 for the purpose of demonstrating the potential for lower cost equipment. The unit had a cooling EER of 9.2 and a heating COP of 2.8.

4.2 Conversion of a Low-Cost PTHP to a GSHP Unit

The conversion of the PTHP to a water-to-air heat pump in the laboratory was not difficult. Most of the components were similar to those used in standard water-to-air units. Most of the components were similar to those used in standard water-to-air units. The rotary compressor, reversing valve, blower wheel, indoor coil, piping, cabinet, and power wiring were appropriate for the conversion. The two most radical changes were the replacement of the outdoor air-to-refrigerant with a tube-in-shell water-to-refrigerant coil, and the change to a thermostatic expansion valve (TXV). The reason for using a tube-in-shell coil rather than a co-axial design was availability. It was in stock in the lab and near the correct size. The TXV is standard with a refrigerant charge in the bulb that gives best performance with evaporator temperatures in the 20°F to 50°F range. It was not specifically designed for bi-flow (heat pump) operation, but the manufacturer approves this application.

Other modifications are shown in Figure 4.1. The original 1/4-hp, double-shaft fan motor was replaced with a 1/6-hp single-shaft, since the converted heat pump only has one fan. Standard water-to-air controls for low voltage thermostat operation replaced the line voltage PTHP controls. Two holes were cut in the cabinet to accommodate the liquid lines to the water coil. Water was

provided to the unit by a pump on a constant temperature tank in the test lab. The pump power penalty to the system was made according to ARI 330 (18).

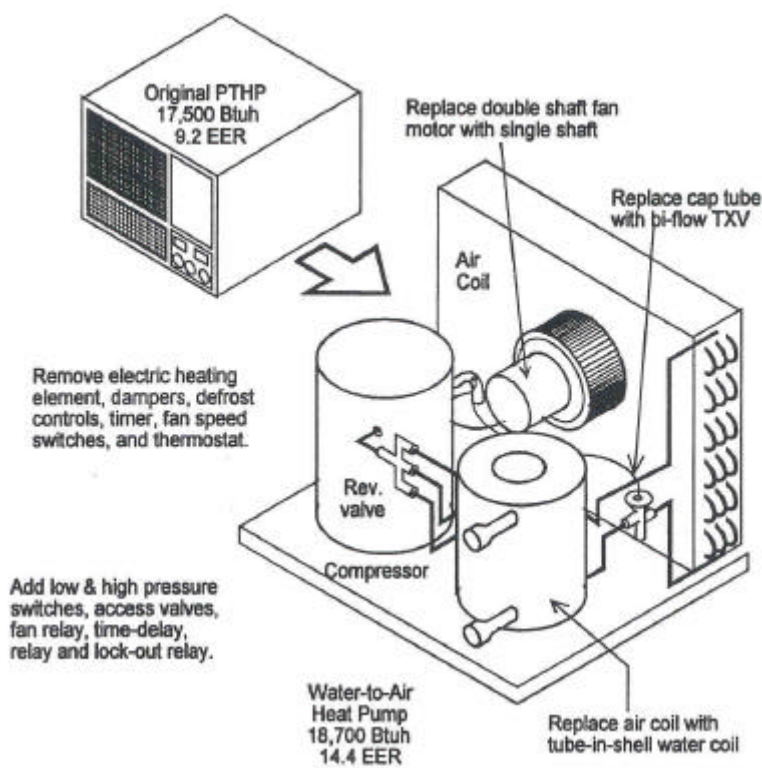


Figure 4.1 Conversion of an Air-to-Air PTHP to a Water-to-Air Heat Pump

4.3 Test Results of Converted PTHP

The converted unit was set up in a psychrometric test facility. The lab is constructed according to ASHRAE Standard 37-88 (19) specifications for cooling. The conditions in the lab were set as specified ARI 330-93.

Inlet Air: 80°F dry bulb, 67°F wet bulb
 Inlet Water: 77°F
 Pump Penalty: Watts = $0.8 \times \text{gpm} \times [\Delta h \text{ (ft water)} + 17]$ = 89 watts
 Water flow was set at 5 gpm and air flow at 530 cfm.

Average test results for a series of runs were:

$t_{a_o} = 57^\circ\text{F}$ dry bulb, $t_{a_o} = 55.8^\circ\text{F}$ wet bulb, $t_{w_o} = 86.2^\circ\text{F}$
 $W_{\text{comp}} = 940$ watts, $W_{\text{fan}} = 270$ watts, $\Delta h_{\text{coil}} = 5.2$ ft water
 $P_{\text{comp. out}} = 170$ psig, $P_{\text{comp. in}} = 72$ psig, $t_{\text{comp. out}} = 180^\circ\text{F}$, $t_{\text{comp. in}} = 52^\circ\text{F}$

The resulting ARI 330 efficiency of the converted PTHP was:

EER = 14.4 Btu/whr with a net cooling capacity of TC = 18,700 Btu/h

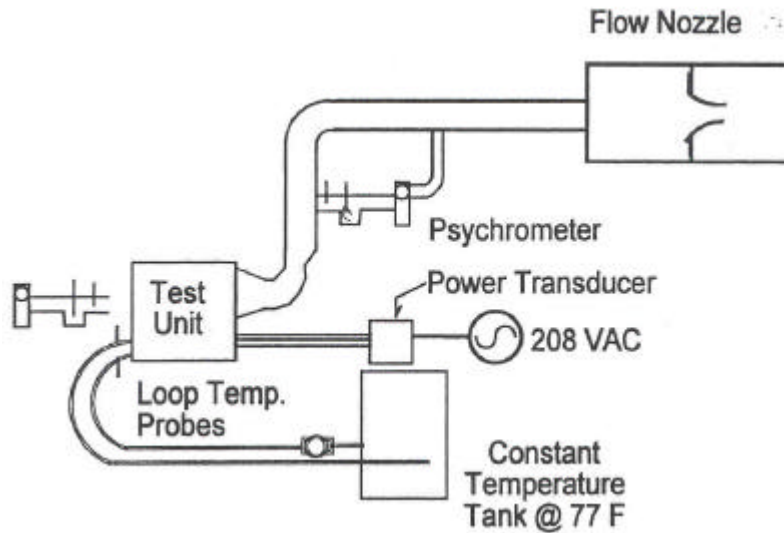


Figure 4.2 Converted PTHP in Psychrometric Test Facility

4.4 Potential of Reducing GSHP Equipment Cost

The performance of the converted PTHP unit (which has similar components and sales volumes) indicates there is potential for producing and marketing equipment at a much lower cost than the values found in the GSHP Cost Survey. Given the improved efficiency of all types of compressors (rotary, scroll and reciprocating) on the market today, simple and well designed water-to-air heat pumps can be produced with ARI 330 EERs in the 13.5 to 14.5 range. These units do not require advanced controls, expensive motors, or multiple-speed compressors. A middle ground can be found to achieve the often conflicting goals of low cost and high efficiency by:

1. Using high efficiency compressors [ARI 520B (20) EER = 10.8+].
2. Using water coils with a 15°F to 18°F approach in cooling ($t_{\text{cond}} - \text{EWT}$).
3. Using large face area, low pressure loss air coils (i.e., 0.75 ft²/ton, 3 row, 12 fpi).
4. Using TXVs that maintain reasonable superheat temperatures.
5. Using high efficiency, low speed PSC fan motors with properly sized blowers.
6. Limiting water coil head loss to 10 ft of water or less at 3 gpm per ton.
7. Using simple controls in the unit that can be interfaced with simple thermostats or more complex external energy management systems.

Water-to-air heat pumps, with components of quality equal to 10 SEER air heat pumps, can have ARI 330 EERs between 13 and 14. This is because the ARI rating conditions result in condensing temperatures 20 to 25°F lower than the temperatures of air heat pumps rated at ARI 210/240 (21) conditions. Additionally, the ARI 330 pump penalty should be much lower than the outdoor air fan demand of an air heat pump. A more detailed computation is shown in Appendix C.

CHAPTER 5 COST CONTAINMENT CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

- * The average cost of ground-source heat pump systems (loop, unit, duct, installation) ranged from \$2,360 per ton for a 5-ton horizontal loop to \$3,000 per ton for a 3-ton vertical ground loop.
- * Compared to 3-ton conventional systems added cost was \$1,250 to \$1,550 per ton.
- * The costs have been subdivided by components,

| | |
|---------------------|-----------------|
| Ground loop | = 27.2 to 34.2% |
| Heat pump | = 27.3 to 30.2% |
| Indoor installation | = 19.2 to 21.1% |
| Ductwork | = 13.5 to 14.5% |
| Pumps | = 6.2 to 6.9% |
- * Availability of larger rebates tends to increase system costs.
- * The potential for reducing cost appears to be (greatest potential first):
 1. Lower heat pump cost.
 2. Reduce cost of indoor installation (Setting unit; Connecting controls, electrical, duct, pumps, water heater, and ground loop; Purging loop).
 3. Lower pump cost.
 4. Reduce ground loop cost. (This considers only conventional loops).

5.2 Recommendations for Loop Cost Reductions

A good deal of effort has been focused on lowering the cost of ground loops since they are such a large portion of total GSHP cost. However, this study indicates that loop costs have lower potential for reduction than several other GSHP components. Ground loop installation is a labor intensive activity that requires relatively expensive and high maintenance installation equipment. This study indicates the labor, overhead and profit in horizontal loop installation is actually lower than the prevailing cost of equivalent activities in the construction industry. To expect loop contractors to reduce cost below \$741 per ton using current networks, technology and pricing, may ultimately drive potential GSHP partners away from the industry or diminish the system reliability that has been an important factor in GSHP success.

Short-term recommendations are to seek piping at a reasonable cost. The GSHP Cost Survey found a wide variation in the average cost of 38¢ per foot of 3/4-in. HDPE pipe. There may be alternative sources of black, high density PE 3408 pipe that meets IGSPHA recommended specifications (22), such as distributors that handle gas pipe. Since these firms handle larger volumes of pipe, mark-up may be lower. However, users are encourage to follow IGSPHA specifications; make sure the tubing is OD controlled (SODR, Sch. 40, etc.) rather than ID controlled (SIDR); insure the tubing is thermally fused; and consult other GSHP partners by word-of-mouth regarding pipe quality.

Longer term recommendations are to investigate alternatives methods of loop contractor support in the forms of:

1. Networking with contractors (locating jobs, training, financing heavy equipment, employment during slow seasons, etc.).
2. Development of specialized loop installation equipment.
3. Alternative ground loop systems.

Loop contractors are a critical component of a healthy GSHP industry. They have not traditionally had a level of influence proportional to their value. Therefore:

Efforts to improve installation techniques with an emphasis toward loop cost reductions should include the input of experienced loop contractors (minimum of 3 years and 100 systems). Projects should include a high percentage of this type of contractor in formulating the project, evaluating performance, and conducting the actual research and development project.

Item 3 above has received a large amount of attention and support. However, the GSHP Survey indicates the two most widely used loop types are the traditional vertical U-tube and the multi-pipe horizontal. While there may be less expensive ways to install GSHP loops, these remain the backbone of the industry because they are **reliable, durable, and allow efficient system performance for extended periods under heavy loads.**

Any proposed ground loop alternatives should:

1. Be very durable during and after installation.
2. Be able to be installed with low cost, low maintenance and compact equipment.
3. Require moderate volumes of antifreeze solutions in cold climates.
4. Not require heat pumps with large refrigerant charges, complicated controls or complex refrigerant circuits.
5. Be evaluated based on long periods (one year) with higher than average loads.
6. Be constructed of materials that can be fabricated with conventional equipment that will not decay in soils.
7. Be able to be installed and serviced by technicians with moderate skills.

RADICAL RECOMMENDATIONS

1. Committee members, consultants and other associated with making recommendations regarding loop first-cost reductions should live in dwellings heated and cooled by a GSHP.
2. It is also recommended they be required to work in the field with a loop contractor for an entire system installation and contact the homeowner or building owner to determine the customer's satisfaction with their work.

5.3 Recommendations for Heat Pump Cost Reductions

The costs of water-to-air heat pumps represent a percentage of total GSHP approximately equal to loop cost. However, the potential for reduction appears to be much greater. This statement is based on comparative cost of similar equipment used of water loop applications and the cost of packaged terminal heat pumps. These types of equipment have similar components, sales volumes, packaging and complexity (or lack of complexity). Means Cost Data indicate water-to-air heat pump cost lower than air heat pump cost can be expected.

Short- and long-term recommendations for reducing heat pump cost are:

1. Education of the public regarding comparative equipment cost.
2. Encourage manufacturers and distributors to share the burden of lower GSHP cost with contractors with a goal of higher sales volumes.
3. Spur competition by educating and encouraging non-GSHP manufacturers regarding the simplicity of designing and producing units with good (EER = 13.5) to excellent efficiency (EER = 15+) water-to-air heat pumps.
4. Partnering to relieve the burden on those manufacturers and distributors who are currently training contractor and designers.
5. Reduce (and restructure) the number of ARI ratings for water-to-air heat pumps from three to one in order to lower the financial burden upon manufacturers, especially small and new companies. (Note, there is only one ARI standard for both air heat pumps and cooling-only equipment).
6. Encourage designers and contractors to obtain several quotes and continuously review the most recent ARI Directory of Applied Products (23) in order to obtain the best economic value (cost vs. efficiency).

RADICAL RECOMMENDATION

1. Conduct a mini-golden carrot competition for water-to-air heat pumps that include cost to produce, ease of installation, EER, and COP as evaluation criteria.

5.4 Recommendations for Interior Installation Reductions

The overhead and profit of contractors installing the interior portion of GSHP systems appears to be higher than those installing conventional HVAC systems. GSHP systems require contractors, especially in the residential sector, who provide installations with above average quality. For this reason, some reasonable premium can be expected. However, the GSHP Cost Survey indicates the HVAC interior installation is approximately 20% of the total GSHP cost which may be excessive.

Short- and long-term recommendations for reducing interior installation cost are:

1. Improve training that includes a **heavy emphasis** on methods and supply sources that lower installation time and cost.

2. Have electric utilities subsidize or finance training and installation equipment purchase for new contractors in lieu of current rebate practices.
3. Educate contractors by publishing columns in national GSHP publications that concentrate on innovative cost reduction methods written by experienced individuals in the field.
4. Spur competition by educating non-GSHP contractors regarding the dependability and customer satisfaction of GSHPs.

5.5 Recommendations for Water Pump Cost Reductions

The survey indicates there is some potential to lower GSHP cost by reducing the Cost of pumps and pump kits. **Short-term recommendations** are:

1. Purchase equivalent and acceptable pumps, valves and fittings from traditional HVAC and plumbing supply houses and distributors.
2. Evaluate the cost of assembling pump kits or pump mounting devices in-house during slow periods or bad weather.
3. Educate contractors by publishing columns in national GSHP publications that concentrate on innovative pump cost reduction methods written by experienced individuals in the field.

5.6 Recommendation to Dispel Myth of GSHPs are for High Incomes Only

Recent market surveys indicate that homeowners with GSHPs are predominately from upper income brackets. This is not surprising since the GSHP Survey indicates the cost at \$2,400 to \$3,000 per ton. However, this does not have to be the case in well designed, moderate structures. A demonstration project should be launched to dispel the myth that GSHPs are for high income building owners GSHPs only by:

1. Designing well insulated, moderate-size homes with minimum ventilation rates as prescribed by ASHRAE Standard 62-1989a (24).
2. Limiting heat pump costs to the costs of equivalent sized PTHPs.
3. Sizing ground loop to meet building load, which is small if item 1 (above) is followed.
4. Sizing the piping loop so that circulation can be provided by a single 1/12-hp or smaller pump.
5. Keeping the interior system simple to insure low first-cost and low maintenance.
6. Assuming the small added cost of the GSHP in a long-term loan (i.e., home mortgage) which is affordable since monthly utility expenses are low.
7. Working with existing organizations that have a proven track record of providing affordable housing such as Habitat for Humanity.

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APPENDIX A - SAMPLE SURVEY FORM

NRECA MARKET RESEARCH GROUND-SOURCE (GEOTHERMAL) HEAT PUMP SURVEY

The following survey is being conducted by NRECA Market Research in conjunction with the University of Alabama and the Tennessee Valley Authority. The purpose of this survey is to determine a national norm for the cost of purchasing and installing Ground-Source Heat Pumps. It is intended that the development of a national norm for the cost and installation of a Ground-Source Heat Pump will help all of those involved in the selling and installation process. Please take a few moments to complete and return this survey in the postage-paid envelope. Your input is vital to the success of this project.

1. Do you sell Ground-Source Heat Pump systems? Yes No
(If No) Please skip to question #11.
(If Yes) How many ground-source heat pumps has your company sold during the last two years?

What type of Ground-Source Heat Pump loops do you sell? (CHECK ALL THAT APPLY)
 Straight horizontal Horizontal-Slinky Vertical Other (Specify) _____

What percentage of your sales are:
a. Straight horizontal? Less than 10% 10-25% 26-50% 51-75% 76-100%
b. Horizontal-slinky? Less than 10% 10-25% 26-50% 51-75% 76-100%
c. Vertical? Less than 10% 10-25% 26-50% 51-75% 76-100%
d. Other _____ Less than 10% 10-25% 26-50% 51-75% 76-100%
2. Please indicate how many of each of the following loop type of ground-source heat pumps have been installed in your service area within the last two years:
 # Single-pipe horizontal
 # Multiple-pipe horizontal with trencher
 # Multiple-pipe horizontal with backhoe
 # Slinky installed with trencher
 # Slinky installed with backhoe
 # Vertical U-bend
 # Other _____
3. Please indicate how many feet of trench (or bore) per ton were typically installed in your service area within the past two years for each of the following loop type of ground-source heat pumps?

Feet of trench (or bore) per ton:
 Feet per ton Single-pipe horizontal
 Feet per ton Multiple-pipe horizontal with trencher
 Feet per ton Multiple-pipe horizontal with backhoe
 Feet per ton Slinky installed with trencher
 Feet per ton Slinky installed with backhoe
 Feet per ton Vertical U-bend
 Feet per ton Other _____
4. Please indicate how many feet of pipe per ton were installed in your service area within the last two years for each of the following loop type of ground-source heat pumps:

Feet of pipe per ton:
 Feet per ton Single-pipe horizontal
 Feet per ton Multiple-pipe horizontal with trencher
 Feet per ton Multiple-pipe horizontal with backhoe
 Feet per ton Slinky installed with trencher
 Feet per ton Slinky installed with backhoe
 Feet per ton Vertical U-bend
 Feet per ton Other _____

5. Please indicate how many systems were installed in your service area in the last two years in each of the following size categories:

System Size:

| | |
|--------------------------|-----------------------------|
| _____ # Less than 2 tons | _____ # 4 tons |
| _____ # 2-1/2 tons | _____ # 5 tons |
| _____ # 3 tons | _____ # Greater than 5 tons |

6. For each of these size categories, please indicate the average cost of the equipment installed within the past two years both with ductwork, and without ductwork, and the loop cost installed:

| <u>System Size</u> | <u>Average Installed Cost</u> | | <u>Loop Cost Installed</u> |
|---------------------|-------------------------------------|----------------------------------|----------------------------|
| | <u>With Ductwork / Without Loop</u> | <u>Without Ductwork and Loop</u> | |
| Less than 2 tons: | \$ _____ | \$ _____ | \$ _____ |
| 2-1/2 tons: | \$ _____ | \$ _____ | \$ _____ |
| 3 tons: | \$ _____ | \$ _____ | \$ _____ |
| 4 tons: | \$ _____ | \$ _____ | \$ _____ |
| 5 tons: | \$ _____ | \$ _____ | \$ _____ |
| Greater than 5 tons | \$ _____ | \$ _____ | \$ _____ |

7. Do these costs include a desuperheater (heat recovery unit)? ____ Yes . ____ No.

8. Please indicate how many ground source heat pump units you have sold and/or installed in each of the following energy efficiency rating (EER) categories:

_____ Less than 11 EER
 _____ 11 to 13 EER
 _____ 13 to 15 EER
 _____ Greater than 15 EER
 _____ Don't know

(IF DON'T KNOW)

What are the manufacturers names and models of the ground source heat pump equipment you typically use? _____

9. Please indicate the approximate cost of the following conventional central air equipment in your area:

| | <u>With Duct</u> | <u>Without Duct</u> |
|---|------------------|---------------------|
| 3 ton 10 SEER air conditioner with 78% AFUE furnace | \$ _____ | \$ _____ |
| 3 ton 10 SEER air source heat pump | \$ _____ | \$ _____ |

10. Are rebates on ground source heat pumps available to customers or installers? ____ Yes. ____ No.
 (IF YES) How much? \$ _____

11. Do you install Ground Source Heat Pumps? ____ Yes. ____ No.
 (IF NO) Please skip to questions #24.

12. Why type of loop systems do you typically install? __ Straight Horizontal. __ Horizontal - Slinky. __ Vertical.

13. What is the average cost per ton for each type of system to install the loop?

| | <u>Cost to Install Loop (per ton)</u> |
|---------------------|---------------------------------------|
| Straight horizontal | \$ _____ per ton |
| Horizontal - Slinky | \$ _____ per ton |
| Vertical | \$ _____ per ton |
| Other _____ | \$ _____ per ton |

14. How many ground source heat pumps has your company installed during the last two years? _____

15. How often have you installed Polyethylene pipe within the last two years (in ground piping only)?
 ____ Less than 10% of the time. ____ 10 - 25% of the time. ____ 25 - 50% of the time. ____ 50 - 75% of the time.
 ____ 75 - 100% of the time. ____ None of the time.

16. How often have you installed Polybutylene pipe within the last two years (in ground piping only)?
 ____ Less than 10% of the time. ____ 10 - 25% of the time. ____ 25 - 50% of the time. ____ 50 - 75% of the time.
 ____ 75 - 100% of the time. ____ None of the time.

20. What is the approximate percentage of fitting cost to total pipe cost?
 Less than 10%. 10 - 25%. 26 - 50%. 51 - 75% 76 - 100%
21. Please indicate how often you install the following pump and Valve arrangements:
- a. Pump kit with flush valves mounted in package?
 Less than 10% of the time. 10 - 25% of the time. 25 - 50% of the time.
 50 - 75% of the time. 75 - 100% of the time. None of the time.
- b. Pump kit without flush valves (valves installed by contractor)?
 Less than 10% of the time. 10 - 25% of the time. 25 - 50% of the time.
 50 - 75% of the time. 75 - 100% of the time. None of the time.
- c. Pump and flush valves mounted and installed by contractor?
 Less than 10% of the time. 10 - 25% of the time. 25 - 50% of the time.
 50 - 75% of the time. 75 - 100% of the time. None of the time.

22. Do you install the following pumps:
- Yes. No. Pump kit - Two 1/6 hp pumps with flush valves?
 (IF YES) What is the approximate cost? \$ _____
- Yes. No. Pump kit - Two 1/12 hp pumps with flush valves?
 (IF YES) What is the approximate cost? \$ _____
- Yes. No. Pump kit - One 1/6 hp pump with flush valves?
 (IF YES) What is the approximate cost? \$ _____
- Yes. No. Pump kit - One 1/12 hp pump with flush valves?
 (IF YES) What is the approximate cost? \$ _____
- Yes. No. 1/6 hp pump?
 (IF YES) What is the approximate cost? \$ _____
- Yes. No. 1/12 hp pump?
 (IF YES) What is the approximate cost? \$ _____
- Yes. No. Desuperheater (heat recovery) pump?
 (IF YES) What is the approximate cost? \$ _____

23. How many years have you been involved with Ground Source Heat Pumps?
 2 years or less. 3-5 years. 6 to 10 years. Over 10 years.

24. Which of the following best describes your company type:
 Electric Cooperative. Electric G&T. HVAC Contractor. Loop Contractor.
 Loop and HVAC Contractor. Other (Specify) _____

25. What is your title and/or job description?

26. Do you have any comments you would like to make about ground source heat pump costs?

THANK YOU FOR TAKING THE TIME TO COMPLETE THIS SURVEY. PLEASE RETURN THIS SURVEY IN THE ENCLOSED POSTAGE-PAID ENVELOPE TO NRECA MARKET RESEARCH.

APPENDIX B - COMMENTS OF RESPONDENTS

- ID
- 001 A plastic plate type of ground heat exchanger that could reduce loop installation time by 50% AND COSTS BY 30%. It is called the Geo-Bag.
- 002 It seems to me that manufacturers nation wide are gouging their dealers.
- 003 The cost per ton for vertical systems is about \$2,500 to \$2,600 per ton. Many installers want to install larger units compared to air source heat pumps. This makes the \$600 to \$800 more per ton become larger because you have ½ to 1-1/2 more tons, plus the additional cost per ton.
- 004 So, far in our area, they have not been competitive. Cheap gas and high efficiency furnaces dominate. Utah residents are amazingly comfortable with evaporative cooling so the AC benefits are minimized. Savings of \$100 - \$200 per year make an investment of \$5,000 - \$7,000 seem ridiculous.
- 005 The system is cost effective and has a payback of an estimated seven years on our system. We would see more installations if the cost of the loop were less.
- 006 I wish the cost was more competitive to air source units which are the consumers' choice for my area. The additional costs, even with rebates (which are small due to limited impact on revenue), don't stir member interest.
- 007 They can be lowered. Great technology will soon be involved in some yet undetermined way.
- 008 I won't say what everybody else says: "Costs are too high" because you would or should expect to pay Cadillac prices for a Cadillac system. Prices will NEVER be lower, but they need to be MORE REALISTIC!
- 009 In our service territory, they cost twice as much to install as air-to-air. Due to increased activity costs to install loops, they have dropped 25% in 1994.
- 010 Please send me a copy of the results. We are considering developing a program to promote this technology. We also plan to participate in the National Earth Comfort Program
- 011 I would like a copy of the study results.
- 013 I would like information about the survey results.
- 014 They are a very good source of heating and cooling in new homes and in energy-efficient homes.

COMMENTS
(continued)

ID

- 015 There is competition with experienced, trained contractors. We're kept very busy by utility ads. There's little competition without experienced, trained contractors occasionally installing systems.
- 018 We do provide members \$600 to install geothermal. Vertical loops cost in this area are too high.
- 019 Our costs are not far from conventional systems (without loop). Paybacks are typically 3-6 years. The biggest problem is a lack of or wrong information out in the world. As gas prices increase, so will the understanding of the public.
- 020 Heat Pump systems will have to be much more cost competitive to gain market share.
- 021 It's a great product, but the initial cost is too high.
- 022 In our service area, there is not enough competition or infrastructure to make the first cost issue competitive with fossil fuel burning equipment.
- 023 If we could find a way to reduce the cost of installing the loop, we would do a brisk business with ground source heat pumps. Someone needs to invent a small, affordable drilling machine to drill for vertical installations.
- 024 We find that cost seems to be no problem. Has no problem producing the units, but we worry about having enough qualified dealers to do correct installations.
- 029 We support this type of system. However, we rely on our contractors to sell and install them.
- 031 Installed costs vary widely, depending on soil conditions and how large the home is. However, our customers "love" their systems, and ALL would buy them again.
- 033 We agree with the National Earth Comfort Program that first-cost competitiveness hinders market growth and penetration for geothermal systems. We are aggressively looking for ways to lower the initial cost and make geothermal systems the obvious choice for customers.
- 036 Six years ago, I installed a ground source vertical three-ton in my home and am very satisfied. I hope to have this system the rest of my life. It's ideal comfort.
- 039 There are too many installed too cheaply.

COMMENTS
(continued)

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- 040 An emphasis must be made to provide a better understanding of the appropriate installation methods and the subsequent reduction in front-end cost. Further work should be done on hole/trench completion methods.
- 046 They still seem to be considerably higher when the only difference in cost should be the loop installation.
- 047 The units installed in northeast Missouri are currently \$2,000 - \$3,000 higher in cost than other high-efficiency systems. Most dealers will not market the systems because they can make more profit selling and installing gas systems. They don't want to deal with a new product line.
- 048 The manufacturers of GSHP equipment have got to find a way to lower their cost. It is not the cost of the labor that has driven up the price of the ground source heat pump.
- 049 I feel the unit is too expensive and not in line with air-to-air heat pumps.
- 056 At the present time, I am installing an Econair heat pump with a polyethylene slinky ground loop in my own home.
- 058 The initial cost is too expensive by \$3,000. Dealers and manufacturers must reduce their costs. Rebates or utility incentives aren't enough to mitigate the high initial cost.
- 063 The cost of installing is very high. The payback is too long in coming to justify the cost of installation.
- 064 Information on costs of commercial ground source heat pump systems would be very helpful to me in "selling" the system to owners.
- 065 I feel the cost is a major issue holding these out of the market. The added cost causes the buyer to look/purchase an alternative system. Utilities, well drillers, and dealers must work toward offsetting this in order for these systems to compete and prevail as the best system for commercial and residential buildings.
- 066 Some power companies believe that the prices we receive for vertical loops are excessive. They should look at the economics of geothermal before making a blanket assumption concerning drilling costs.
- 069 We have helped install inside units to the charged system on approximately ten systems in the last two years.

COMMENTS
(continued)

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- 070 Typically, they are overpriced. Contractors are using their normal mark-up. Because of additional equipment costs, profits per job are very high - \$2,000 - \$3,000 per job. If it was \$1,000 per job, we would see a large increase in installation.
- 072 The difference in price between air-to-air and geothermal heat pumps needs to be reduced somehow. Manufacturers' rebates, in addition to other incentives, may be the answer.
- 073 I would like to see the cost come down, but not out of the installer's pocket.
- 074 Loop costs need to come down.
- 075 I would like to see lower installation costs, but co-ops need to market ground source heat pumps on their merit, i.e., high efficiency, lower operating costs, cleanliness, quiet, etc. People will pay more if they are educated regarding these factors. The system is worth the money.
- 078 The average cost of the ground source heat pumps runs between \$2,500 - \$2,000 per ton for a turn-key job.
- 082 Drillers in the Northwest charge too much per foot to make vertical loops competitive.
- 083 We provide all the materials to the contractor for a closed loop and essentially a free loop to the end-use consumer.
- 084 We are a wholesaler for ground source heat pumps and sell to contractors and other co-ops in western North Dakota.
- 085 Acceptance of the cost to install a ground source heat pump by the member is our stumbling point. Also, contractors don't want to take the time to learn about the system. They tend to take the "comfortable zone".
- 086 Offer a \$1,000 rebate and finance a maximum of \$7,000 for 7 years with 5% interest.
- 088 The price is normally too high for the average consumer to buy a ground source heat pump. In this area, we also lack expertise in installing and repairing them.
- 091 System costs in the Northeast seem to be significantly higher than in other areas of the country.

COMMENTS
(continued)

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- 093 The high initial cost of ground source heat pumps has inspired me to try to promote using city water, discharging used water to sotrm sewers. This uses simple, low cost, easy installation equipment. It fits best where water is plentiful and available at a low cost.
- 099 We have a lot of interest in geothermal, but at an average cost of \$3,000 per ton installed, this has discouraged most buyers.
- 100 There aren't enough qualified earth couple installers to provide a true competitive market. I would like the results of this study.
- 101 The current installation cost is an obstacle in itself. The lack of recognition of the benefit of these systems, however, is the greatest hurdle, overshadowing all the others.
- 107 Loop costs are too expensive to allow us to compete with gas systems. Our loop rebates are \$1,500 per system.
- 108 We work with heating and cooling contractors to install these. We talk to our consumers with the contractors. The contractor sells the heat pump and duct work. DS&O REC installs the loops.
- 109 The pipe and fittings for the earth loops can't be squeezed down any further unless there are compromises to the current standards allowed.
- 111 We are interested in promoting ground source heat pumps where they are cost-effective solutions and alternatives to electric resistance heat. We need to see more stability in the installation costs. In Montana, the ground loop cost estimates jump all over the place, especially up.
- 113 We do offer a \$350 per unit rebate.
- 114 We started installing in 1987 and now have 7% of the members with ground source heat pumps. It's a great program for REC's and the members.
- 115 We promote the concept; however, the initial cost is a significant barrier. The numbers work out better on large community systems. We have been successful in this market.
- 116 Interest is on the rise.
- 117 We only have one or two dealers who are installing closed loop systems. The cost is 50% - 100% more so it is a really hard sell. You have to convince the buyer of substantial long-term yearly savings to be able to sell closed loops.

COMMENTS
(continued)

- ID
- 122 If needed, I can provide a summary of information collected when people apply for rebates, such as brands installed and percentage of open vs. closed loops.
- 123 The mild climate here in California makes it hard to justify the higher initial cost of ground source heat pumps as compared with other parts of the country.
- 125 It's a good product!
- 127 We don't sell or install heat pump systems. We do, however, use heat pump software to assist members with selection. We also provide the first year of electric usage for the heat pump only at no charge to encourage installations. All installed heat pumps are working very well on our system.
- 128 The biggest obstacle is cost. We need to make them more affordable. Financing is the key.
- 129 The general consensus from customers is that equipment costs are too high when compared to air source heat pumps.
- 132 We find they are competitive with LP gas systems in our area.
- 133 We need to get the cost down.
- 134 Why not use more active solar?
- 137 Higher efficiency heat pumps can cost-effectively reduce the size of the loop field.
- 143 They are high in our area - \$2,500 or \$2,800 per ton. That includes the piping.
- 144 The loop cost is the only premium. Inside equipment should be a wash with equipment, efficiency, air source heat pumps, or air conditioning, not gas equipment. Loops cost currently run about \$850/ton.
- 145 Some contractors have a tendency to increase prices as rebate dollars are increased.
- 148 We face a somewhat difficult time with high initial costs even though there are very good paybacks. Contractor support has been spotty
- 150 Well drillers charge water well prices for loop wells. They're killing the market.

COMMENTS
(continued)

- ID
- 151 The under-floor installations have greatly reduced our costs. Around here, vertical bores cost \$12 - \$18 per foot whereas the under-floor is mainly the cost of pipe and backfill material with only about \$200 extra excavation costs, if that.
- 154 If contractors, suppliers, and manufacturers don't make a reasonable profit, there will be no ground source industry.
- 157 Our installations are up over 1,000% in the last two years.
- 162 The costs are high in New England.
- 163 I have seen an increasing amount of interest in people wanting to put in ground source heat pumps, but the initial up-front cost of the loop field changes their minds.
- 164 We currently pay rebates to customers who have ground source heat pumps installed by a participating HVAC contractor.
- 165 I would like to see more emphasis on vertical standing water column (VSWC) systems in those areas where possible, mostly in the north.
- 167 The usual thought is that geo is more expensive.
- 168 We are very interested in research that will allow the cost of geothermal installations to decrease. Our members are convinced of the efficiency and the dependability of the geothermal heat pump, but when they compare the up-front cost difference, a large percentage choose the air-to-air heat pump. A 12 SEER heat pump is installed for \$1,200 per ton in our area.
- 169 We promote ground source heat pumps and provide a rebate for each unit installed on our member cooperative lines.
- 171 Although I could not contribute to the survey, we are very interested in this kind of data to provide consultants to potential customers.
- 172 Ground source heat pump sales in our area have been excellent, and satisfaction has been high. Because we offer rebates, we have been able to dictate the proper installation. As a result, both dealers and customers have been very happy, and much of the recent growth in sales is directly related to word-of-mouth from people who have them. Complete installations in our area average around \$2,500 per ton.

COMMENTS
(continued)

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- 175 Much more experimentation needs to be done on ground loop installations to develop lower costs and more productive installation processes.
- 176 I applaud your efforts to help us establish a “normative” price for these ground source systems. However, it is important to also differentiate the quality of the product specified in this survey. Typically, a higher quality product (one which performs reliably with normal maintenance and at least as efficiently, if not more so, than other alternative products and lasts at least as long, if not longer) can be expected to cost more at the initial purchase than an inferior product.
- 177 Contractors in our area include and
- 181 Across our four operating areas, the average cost per ton for new installation is \$2,407, and retrofit is \$2,270. Installed costs vary widely from a low of \$4,000 for a 1.5 ton retrofit to a high of \$25,770 for a 6-ton retrofit.
- 183 We hope this industry grows. I would like a financing program for ALL co-ops.
- 184 You’re asking the wrong questions on this survey. Cost of systems is not the problem. The poor quality of HVAC installations overall is the underlying problem.
- 186 They are coming down as the competition increases. The cost of the units themselves must be reduced.
- 187 The manufacturer of the heat pump needs to get more aggressive in marketing. There is very little support. The loop costs are coming down. We encourage our customers to only work with certified installers.
- 189 In the metro area, the high cost of ground source heat pumps makes it prohibitive when compared to other available commercial HVAC systems. Ground coil costs will have to come down.
- 190 Encourage free enterprise. Charge a fair price that’s agreeable to both parties. Please don’t use the survey results to artificially fix low prices as part of the Marketing Agreement.
- 192 I would like to try different loops, perhaps a bag.
- 194 The costs are too high.
- 195 We are seeing more than a 100% annual increase.

COMMENTS
(continued)

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- 198 The installation costs are the only deterrent to a greater use of the ground source system.
- 200 Installers are still trying to make too much profit per job, which reduces the number of jobs they could do.
- 201 The cost is often not a factor to those who are knowledgeable about the technology and its benefits.
- 202 Costs need to come down across the board, from manufacturers to installers.
- 203 Ground loop pump kits are all priced too high! A single kit sells for \$397, and a double kit is \$591.00.
- 204 Our costs will range from \$3,200/ton on small units to \$2,200 per ton on larger units fro new construction. We do all of our own horizontal loops.
- 207 We are interested in getting into the program, but we are uncertain at what level.
- 208 It's the "only way to fly".
- 209 I would like to see ground source heat pump costs (including loop costs) made more affordable.
- 210 Don't "undersell" the true, long-term value of the system.
- 211 With the introduction of the slinkly, the cost of a horizontal earth loop has been reduced approximately one-third.
- 213 I would like more details.
- 214 Have rebates that promote them. Have a heat pump inspector to make sure they're installed correctly.
- 215 Direct expansion represents an opportunity to reduce costs and increase efficiency. It requires less training and no specialty tools for the average HVAC contractor. I can also be very flexible in most installation settings.
- 216 In our area, it would help marketing this system if power companies offered rebates to have them installed in homes.
- 217 Just like your feet, they can't be beat! It's very, very good heat.

COMMENTS
(continued)

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- 219 They would sell like hotcakes if the initial installation cost was not so high.
- 220 Dealers are placing too high a margin/warranty reserve. We need to fully develop the ground looping industry and technology.
- 221 I would like to see a report on these results.
- 223 We install about 30 per year, and the majority are open systems.
- 224 Hopefully, the cost of the heat pumps will come down along with the cost of installing the loop fields.
- 225 Our input is perhaps of little value as the questions seem to indicate you are residential-oriented. We did only commercial systems until very recently.
- 226 I don't think the cost of the heat pump is excessive, but when you add in the cost of the loop, the cost doubles. That makes the cost excessive for the complete package.
- 229 It's an excellent system.
- 230 I would like to see a lower cost for vertical systems.
- 231 The cost is not our main problem. The problem is getting quality work. The loop cost is about \$1,000 per ton. We rebate \$437 per ton. The price of equipment is increased because they don't want to put it in so they sell air source heat pumps.
- 232 Our co-op used to install heat pumps. However, our serviceman chose to go out on his own. We gave him the heat pump customers. We do make loans for energy efficient heat pumps to our customers.
- 233 Ground source heat pumps are too expensive! Too much time is spent on reducing loop costs when it is the unit's cost which poses our greatest problem. In most cases, a complete gas system with duct work costs the same and often less than a ground source heat pump without duct work. Saving \$500 on a loop doesn't cut it.
- 234 More competition is needed. Dealers are drastically oversizing equipment and loops. Dealers say they want to install geo, but they prefer gas because they make more money and don't tie-up cash flow.
- 235 Hopefully, costs will come down more in the future to allow more customers to take advantage of the benefits and savings.

COMMENTS
(continued)

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- 236 In nearly two-thirds of the country, wells are less costly and more efficient. Why do you close your eyes to that advantage? How can you make a “national norm” on something so variable with geology?
- 237 They are very reasonable and well in line with other types of heating and cooling equipment. Reduced maintenance, long life, and energy savings are pluses when considering that the lifetime cost will be well below other types of systems.
- 240 It is priced according to what it does, not what it costs. I can buy an air source package unit for \$1200 (4 ton). A water source package unit cost with pumps is 300% of that.
- 243 They are still too high! Also, we need to do some studies on operating costs in schools. They are high because of refrigerated cooling rather than commercial ventilation.
- 244 Closed loop commercial system initial costs are TOO HIGH for the general market, particularly in our market area with low natural gas costs and high electrical rates. Some jobs (commercial) have gone closed loop because of utility rebates and government assistance. This support is not going to be available any more. The standing column well system has made us fairly competitive with all the great advantages of the heat pump.
- 252 We heavily promote earth coupled heat pumps and rely on a dealer network to make the sale and do the installation.
- 254 We actively promote ground source heat pumps and work with dealers and co-op contractors to reduce the cost associated with ground source heat pumps.
- 259 Until this year, we installed ground source heat pumps. At that point, we found two things which made us reconsider our position on ground source heat pumps. First, the pipe manufacturer was changing from polybutylene to polyethylene which meant we would have to buy more tools. Secondly, the heat pump manufacturer had rerated the heating side of the heat pump. This meant we would have to install a larger heat pump to meet the heating requirements of the home, plus have three times too much air conditioning in the summer. This made the cost prohibitive to our customers and the operating costs would not allow any savings.
- 261 The cost of the earth couple is too high.
- 262 Both the systems and the wells are too high. This is the biggest problem we have trying to promote it.
- 264 Sometimes I don't have time for questions like these that are going to change anyway!!!

COMMENTS
(continued)

- ID
- 266 Pricing strategies per foot of pipe or trenching do not reflect the actual cost basis incurred, and discourage use of longer ground loops to reduce demand and operating costs.
- 268 I would like a copy of the results of the survey. We are now working in the commercial sector and see good potential for penetration into schools, health care, prisons, and municipal buildings.
- 269 The prices are too high in our area (about \$3500 per ton).
- 270 Until we can make the consumer realize the benefit of these units, it will always be an up-hill battle.
- 271 It is an up front investment with a lifetime return.
- 273 I am concerned about reducing the initial costs, especially on the ground side of the installation. As a utility, we are committed to promoting and supporting increased numbers of geothermal installations. However, builders and buyers are hesitant, despite a favorable life cycle, benefit/cost analysis. Please send a copy of the completed survey results.
- 274 It is a fantastic system, but must be designed for efficiency first, not necessarily cost first.
- 276 The average cost per ton in our area is around \$2800 to \$3000.
- 279 The ideal solution for consumers and co-ops would be if the initial cost could be lower.
- 282 We need more quality HVAC contractors involved in geothermal to supply the growing demand.
- 285 GSHP equipment costs are competitive, but the outside costs are a little high. We need more support to get going here, as people like the system and are trying to find a company that they can afford.

APPENDIX C
COMPARISON OF HEAT PUMP EFFICIENCIES FOR EQUIVALENT
COMPONENTS - AIR SOURCE AND GROUND SOURCE

Air-to-air heat pump design procedure for 82°F outdoor air/ 80°F indoor air (ARI 210/240 conditions)

1. Start with Copeland CR35K6-PFV compressor with 45°F evaporating and 120°F condensing temperatures: $q_{\text{evap}} = 38,700 \text{ Btu/h}$ $w_{\text{comp}} = 3050 \text{ watts}$
2. Reduce superheat to from 20 to 10°F: $q_{\text{evap}} = 39,900 \text{ Btu/h}$ $w_{\text{comp}} = 3050 \text{ watts}$
3. Indoor fan must provide 1200 cfm: Use 1/3 hp, 60% eff. $\Rightarrow 415 \text{ watts}$
4. Outdoor coil must be 7 ft², 2-row, 10 fpi with 2700 cfm (or equal) to condense at 120°F
5. Outdoor fan must be 1/4 hp, 60% eff. $\Rightarrow 310 \text{ watts}$
6. Total Cooling (TC) = $q_{\text{evap}} - q_{\text{fan}} = 39,900 \text{ Btu/h} - 3.412 \text{ Btu/whr} \times 415$
 $TC = 38,400 \text{ Btu/h}$
7. **EER = TC/ w_{total} = TC/ ($W_{\text{comp}} + W_{\text{in.fan}} + w_{\text{o. Fan}}$) = 38,400/(3050+415+310) = **10.2 Btu/whr****

Water-to-air heat pump design procedure for 77°F entering water / 80°F indoor (ARI 330 conditions)

1. Start with Copeland CR35K6-PFV compressor with 45°F evaporating and 100°F condensing temperatures: $q_{\text{evap}} = 39,200 \text{ Btu/h}$ $w_{\text{comp}} = 2210 \text{ watts}$
2. Reduce superheat to from 20 to 10°F: $q_{\text{evap}} = 40,400 \text{ Btu/h}$ $w_{\text{comp}} = 2210 \text{ watts}$
3. Indoor fan must provide 1200 cfm: Use 1/3 hp, 60% eff. $\Rightarrow 415 \text{ watts}$
4. Water coil is nominal 3-ton capacity with 9 gpm to condense at 100°F with 12 ft. of water head loss.
5. Pump Penalty (ARI 330) = $0.8 * \text{gpm} * (\text{hd. loss} + 17) = 0.9 * 9 (12+17) = 210 \text{ watts}$
6. Total Cooling (TC) = $q_{\text{evap}} - q_{\text{fan}} = 40,400 \text{ Btu/h} - 3.412 \text{ Btu/whr} \times 415$
 $TC = 38,900 \text{ Btu/h}$
7. **EER = TC/ w_{total} = TC/ ($W_{\text{comp}} + W_{\text{in.fan}} + w_{\text{o. Fan}}$) = 38,900/(2210+415+210) = **13.7 Btu/whr****