TRENDS IN “GREEN” DESIGN – MAKING GROUND SOURCE HEAT PUMPS THE SYSTEM OF CHOICE

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Abstract

Ground source heat pump systems have been around for nearly 50 years. The efficiencies that can be achieved today are difficult to match with any other type of heating and air conditioning system. With the familiarity of the system, installed costs have become very reasonable, and in some cases have been the same or less expensive than other comparable systems.

Given all this, the question remains – why aren't more of these systems being proposed and installed? This report will investigate some of the reasons why and what can be done to remedy them. Major issues include professional education, availability of research and design material, industry or governmental incentives, and education in our K-12 schools and universities. Certainly all participants in the design process, from the designer to the owner, play a part in this dilemma. Recommendations will be made that address key hurdles this industry faces regarding making ground source heat pumps the system of choice.

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CHAPTER 1 - Energy Use and Reduction

Current Consumption

Because of the current upward trends in fuel, natural gas and electricity costs, the United States is without a doubt on a new path toward maximizing energy efficiency in both residential and commercial buildings. Newer building materials, added insulation levels and tighter structures have produced building skills that are considerably more energy efficient than those of even five to 10 years ago. Energy efficient appliances, HVAC equipment and lighting systems used in today's buildings consume substantially less energy than those in the past. Programmable thermostats, DDC automatic control systems, occupancy lighting controls and daylighting control for buildings can now provide ways to limit energy consumption in almost every type of occupancy.

Various programs initiated by Federal and State government require designers and developers to construct buildings that exceed energy standards developed as recent as 2004. When designing or constructing these buildings, professionals are constantly trying to push the envelope and find ways to squeeze every dollar they can out of the energy budget.

In 1994, the U.S. Green Building Council began as a quest to encourage sustainable design in building construction. Their concept, initiated in 1998 using the LEED (Leadership in Energy and Environmental Design) scoring system, encouraged ways to reduce the energy consumption in buildings, including HVAC systems, water and lighting systems. It took approximately seven years for USGBC to register the first 1,000,000,000 square feet of space. From June to November of 2007, approximately 2.3 billion square feet were registered, indicating the growth of the concept and current public acceptance[15].

Even with all this work toward energy efficiency in building construction and operation, the consumption in the U.S continues to rise. Projections by the U.S. Energy Information Administration indicate a 37 percent increase in energy consumption over the next 20 years. In comparison, the world's energy consumption is expected to increase 53 percent in the next 20 years, and 70 percent by 2030[14].

Information published in ENR Magazine shows approximately 39 percent of the energy consumed in the U.S. is related to commercial and residential buildings. 35 percent of that is directly related to HVAC systems. Energy consumed per residential household and per square foot of commercial space rose dramatically from 1990 to 2007[1].

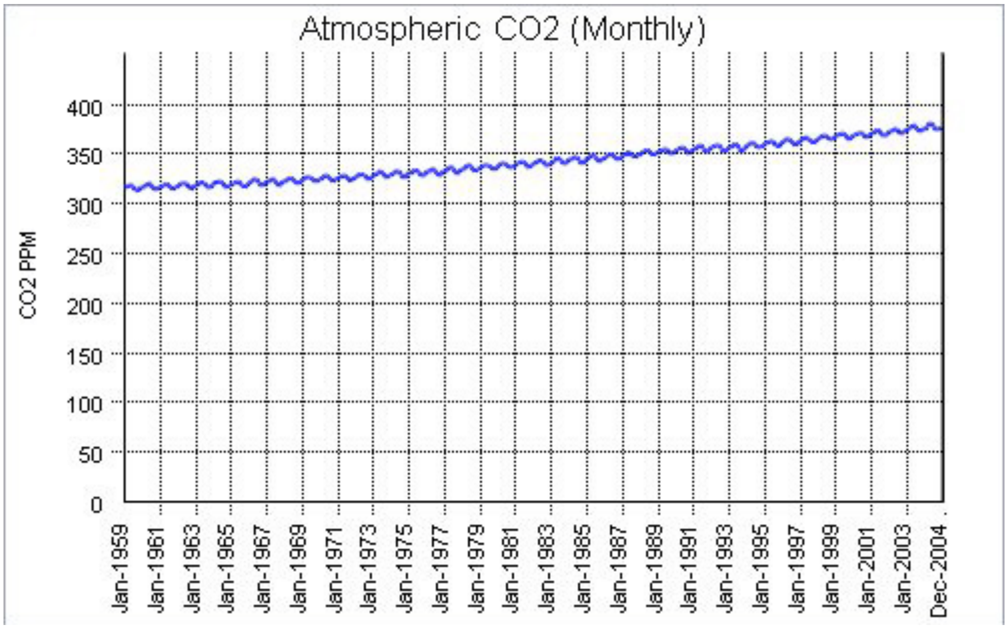
Based on information from the U.S. Department of Energy, the current trends indicate a 40 percent increase in U.S. commercial energy consumption by 2030. It will be important to continue the search for even greater energy efficiencies in building operation in order to stop or slow this upward trend.

Greenhouse Gas Emissions

CO_2 and other greenhouse gas contributions to our atmosphere almost certainly have a detrimental affect on the earth's ozone. While there may be debate as to whether these gases are a result of manmade or natural occurances, we certainly know that the need for electricity and the use of fossil fuels contributes a significant quantity of these products to our atmosphere. The industry is obligated and capable of pursuing all options to reduce the consumption of these energy sources, and in turn, greenhouse gas emissions..

Work by C.D. Keeling and T.P. Whorf with the Scripps Institute of Oceanography at the University of California has included monthly CO_2 measurements since 1959. Figure 1-1 shows a 19 percent increase from 1959 to 2004 in the concentration of CO_2[2]. Based on the past trends and current consumption of fossil fuels, the Energy Information Administration projects a 1.9 percent annual increase through 2025, mainly from developing countries, while the industrialized countries are projected to have only a slight increase[3].

Figure 1 – Atmospheric Concentration



On December 11, 1997 at the International Framework Convention on Climate Change, the Kyoto Protocol was agreed upon. Entered into force on February 16, 2005, this agreement was intended to stabilize the greenhouse gas emissions worldwide. The U.S. was a signer to the protocol but has never ratified it because it did not include targets for developing countries and it only involved monitoring and reporting.

The American Institute of Architects (AIA) has developed a program called Architecture 2030. This program sets a goal for reducing building carbon equivalent emissions in new buildings 100 percent by 2030.

The USGBC has set similar goals in regards to its LEED rating system. Certified buildings would have 50 percent reduction in carbon-equivalent emissions, Silver at 75 percent, Gold at 80 percent and Platinum at 100 percent.

Another entity, the American Society of Heating and Refrigerating and Air Conditioning Engineers, has set its own recommendations for energy independence. ASHRAE 90.1-2010 is intended to require a 30 percent reduction in consumption compared to 90.1-2004. Their goal would be to see net zero energy use in new buildings by 2020.

Basis of Report

While this paper is not intended to cover such a broad topic as U.S. and world energy consumption trends, this information is important when establishing a basis for encouraging the use of ground source heat pumps (GSHPs). Our society is at a point where we will be required to do everything we can to reduce our consumption of energy and eliminate the contributions of greenhouse gases to the environment.

Many things can be done to accomplish this, but a large one is making our heating and cooling systems as efficient as possible, both residentially and commercially. The industry is familiar with the savings available through the use of GSHPs but has been slow to fully accept and apply the system. Why that is and what can be done to improve this situation is the basis of this report.

CHAPTER 2 - USGBC

The U.S. Green Building Council (USGBC), founded in 1984, continues to lead the way when it comes to sustainable design and encouraging energy efficiency. Its mission is "to transform the ways buildings and communities are designed, built and operated, enabling an environmentally and socially responsible, wealthy and prosperous environment that improves the quality of life[4]." Their LEED green building rating system was initiated in 1998 as a way for business and industry to measure and illustrate the many facets of how building construction can use sustainable concepts and in many cases limit the consumption of energy.

The USGBC has played a lead role in the encouragement of sustainable design via its LEED rating system. Certifications of compliance are available for new construction, commercial interiors, existing buildings, core and shell, single-family, residential and residential neighborhood development. All of these certifications contain points that can be earned relative to the HVAC system selected and applied.

Table 1, listed below, shows the two items that are uniquely related to the use of GSHP systems[9].

Table 1 – USGBC LEED Points Contribution

Optimized Energy	GSHP systems are one of the most energy efficient systems. Up to 10 points are available for systems that energy efficiencies greater than ASHRAE 90.1-2004.
Enhanced Refrigerant Management	Most GSHPs are now manufactured standard with HFC-410A, which is a zero ozone depletion refrigerant.

In addition to the two specific items in table 2.1, the use of ground source heat pumps can help with many other LEED certification categories. While not unique to GSHPs, they are equal to or exceed the abilities of other HVAC systems to gain points toward certification. A list of those issues is as follows[9]:

- Water Use Reduction – Systems without a cooling tower can reduce the amount of water used by not having evaporation at the tower.
- Minimum Energy Performance – All GSHPs easily meet the minimum efficiency requirements of ASHRAE 90.1-2004.
- Fundamental Refrigerant Management – CFC-based refrigerants were originally used in GSHPs, but all manufacturers now offer units with non-CFC-based refrigerants.
- Measurement and Verification – It's easy to track the performance of a GSHP system through the use of electric metering and a central building management system (BMS).
- Minimum IAQ Performance – GSHPs can be coupled with energy recovery equipment to deliver ventilation air quantities to meet ASHRAE 62.1-2004.
- Outdoor Air Delivery Monitoring – Using a dedicated outside air system consisting of an energy recovery device attached to a GSHP, it is easy to measure and monitor the quantity of outside air delivered to the space.
- Increased Ventilation – GSHPs coupled with energy recovery equipment can be designed to exceed the amount of outside air ventilation in the breathing zones of buildings.
- Controlability of Systems – GSHPs inherently can provide zone control down to a level of 1 ¼ tons. Occupants in shared spaces can adjust the desired control setpoints through thermostats connected to the BMS.
- Thermal Comfort – Many GSHPs can provide relatively tight temperature and humidity control because of their ability to heat or cool at any time. Reheat options also allow precise dehumidification. The use of GSHP systems have proven to be more acceptable to building occupants so verification of thermal comfort is not difficult.

The use of GSHP systems would appear to be a good choice when designing a building to achieve LEED certification. There are many categories that directly relate to the attributes of the system and allow the designer to earn points toward a goal. While the USGBC does not suggest or recommend specific systems, it seems like GSHPs correspond nicely with many of the categories and would be an excellent choice for the HVAC system.

CHAPTER 3 - Codes and Standards

General

There really is no distinction, in terms of codes and standards, between the design of a GSHP system and any other HVAC system. The codes and standards used to design a GSHP system will still contain certain basic requirements, including acceptable indoor air quality, thermal comfort, system installation, and energy efficiency.

ASHRAE 62.1-2007, Ventilation for Acceptable Indoor Air Quality, describes the process and standards for the use of outside ventilation air in commercial buildings. The amount of air needed is directly related to the type and quantity of occupants, although there are different methods of obtaining the correct answer. Most GSHP systems will utilize some type of dedicated outside air unit to deliver the required amount of ventilation air to the occupied spaces. These outside air units will also typically contain heat recovery equipment to pre-treat the air before applying heating or cooling via another water-to-air heat pump.

The standard for indoor space conditions is ASHRAE 55-2004, Thermal Environmental Conditions for Human Occupancy. As with many other HVAC systems, a GSHP system will be able to provide heating, cooling and dehumidification to provide proper space conditioning and satisfy most occupants. The heat pumps would provide zone control for relatively small spaces, increasing the likelihood that the building users will be comfortable. Because the controls are relatively simple, those using the space will also feel like they have control over space setpoints.

Adopted codes such as the Uniform Mechanical Code and International Mechanical Code are applicable to the design and installation of GSHP systems, just as they are for more typical HVAC systems. These codes give requirements concerning equipment operation, duct systems, serviceability, piping and controls.

Energy Codes

Almost all states have adopted some type of energy code in the past few years. The two most common are the International Energy Conservation Code (IECC) and ASHRAE 90.1-2004, Energy Standard for Buildings Except Low-Rise Residential Buildings. These codes are similar and generally describe “minimum prescriptive and performance-related regulations for the design of energy-efficient structures,” according to IECC 2003. They are applicable to existing and new buildings.

A major component of the IECC and ASHRAE 90.1-2004 is the minimum building skin R-values, which vary from one area of the U.S. to another. The selection of an HVAC system has no effect on this issue, so the application of GSHPs would certainly not complicate the design.

Information in these codes that does affect HVAC system selection is minimum equipment efficiencies. These efficiencies are listed for both heating and cooling equipment of all types and sizes. GSHPs far exceed the minimum values listed, and in most cases will represent the most efficient type of system available.

The other item in these two codes that directly relates to HVAC system selection is controls. When GSHPs are applied to a project, it is easy to meet these control system requirements. Items such as thermostat zone control, setpoint overlap, night setback, energy recovery and outside air shut-off are all things that can be specified with a GSHP system.

At issue, related to the IECC and ASHRAE 90.1-2004, is not whether a GSHP system can meet the minimum requirements. What is important is how far can GSHPs exceed the minimum requirements. The USGBC LEED rating system and other similar programs put a great deal of emphasis on designing and installing systems that exceed the minimum code requirements by a substantial amount. If the goal is to provide sound sustainable design, then these energy codes are really only used as a benchmark to compare how far certain HVAC systems exceed a standard of design.

CHAPTER 4 - Development of GSHPs

General Development

The development of ground source heat pump systems is not new. In fact, there are commercial systems currently in operation that are nearly 50 years of age[5]. More conventional heat pump systems that utilize a heating plant and cooling plant are even older than that.

A ground source heat pump system is one where indoor, reversing cycle, water to air heat pumps are coupled to the earth or water body. The earth or water body is used to dissipate the heat or provide heat to the building. This heat rejection or absorption is accomplished through the use of a closed loop circulating to each of the indoor heat pumps.

System Descriptions

There are several ways in which this connection to the earth or water body can take place. Each has its own advantages and applications, depending on the location, soil conditions and available site. The most common options are discussed below.

The method most commonly used involves vertical drilled wells, 150-300 feet deep. High-density polyethylene pipe is inserted into the wells with a U-bend at the bottom. This piping up and down the well is then grouted to ensure complete compaction and proper heat transfer. A typical drilled well can deliver approximately 1-2 tons of cooling based on the soil conditions.

Another method that involves earth contact uses coiled piping set in a shallow vertical trench. This method is easier because most contractors can create the 4-8 foot deep trenches using conventional equipment, but it takes considerably more site square footage to develop the same tonnage. The coils of piping are also backfilled or grouted into place to create the heat transfer.

Systems that utilize a body of water in lieu of the earth are also quite plentiful. Here, piping or piping coils are submerged at a point where the water temperature is relatively constant. Proximity of the building to the water body is important and care must be taken to avoid freezing of the piping loop.

All of these systems discussed would then have a closed piping loop that connects the heat sink to the indoor heat pumps. This loop would be installed below grade outdoors and pumps could be located in a mechanical space inside the building. There are a variety of pumping methods that can be applied to a loop of this type, depending on the building size and construction.

The circulated water is then used by the heat pumps to heat or cool the indoor space. During this process, heat is extracted or added to the closed loop. Each heat pump unit can operate independently and it is possible for different heat pumps to heat and cool simultaneously. Heat pumps are selected and located to respond to the required zoning of the building. Typical sizes range from 1¼ to 25 tons.

Heat pump systems are utilized throughout the U.S. and geothermal systems are no exception. Buildings in cold weather climates are just as good candidates as those in mild or warm weather.

System Efficiencies

Heat pump systems are attractive primarily because of their efficiency. The term COP (coefficient of performance) describes the efficiency of heating equipment such as this. COP states the amount of energy delivered per electricity consumed. Currently COPs range from 2.5 to 5.0 for most commercially available equipment. Those at the upper range can achieve these high numbers because they have been redesigned using R410a refrigerant. Few other types of equipment can match the COPs of these ground source heat pumps.

On the cooling side of the efficiency discussion, heat pump manufacturers catalog energy efficiency rates (EER) that quantify Btuh output/watt input. These EER numbers range from 14.0 to 19.0, depending on the entering air and water conditions. Compared to DX rooftop units and split systems, heat pumps are significantly better.

Energy Studies

It is important to show that the potential energy savings through the use of GSHP systems are significant. There have been several studies performed that document these savings and some of them are summarized below. Life cycle cost analysis comparing GSHPs to other systems is also a part of the studies presented here.

In May of 2007 and 2008, ASHRAE Design Competition classes in the Architectural Engineering/Construction Science and Management Department of Kansas State University analyzed several HVAC systems for a specified commercial building[11]. The students, supervised by Fred L. Hasler, P.E., and Julia Keen, P.E., concluded in each report that GSHP systems were the most efficient and had the least life cycle cost. Their reports recommended the use of GSHPs because of these costs and other factors related to sustainability, control, and affect on the architectural aspects of the building.

Jerrad Boyle, a student in the same program at Kansas State University, performed a system comparison of an existing LEED Silver building located in Manhattan, Kansas[12]. This analysis was intended to compare the energy costs of the installed DX/gas-fired rooftop design to one that utilizes GSHPs. His results showed a 52 percent savings in space conditioning energy costs per year by using a GSHP system. This savings was not only significant from a cash basis, but implementation of the GSHP system could have contributed to a higher LEED rating.

Image Engineering Group, Ltd. In Grapevine, TX has been involved in more than 100 GSHP projects since 1992 and has found huge energy savings and paybacks in their work. One of the projects that has received acclaim is Bird High School in North Richmond, Texas. This 300,000 square foot facility is realizing energy costs approximately one half of similar buildings with conventional HVAC systems. When coupled with the first cost savings, reduced maintenance and equipment life expectancy, the district believes the payback to be almost immediate.

CHAPTER 5 - Applications

Important Criteria

A ground source heat pump system can be applied to a wide variety of building types. Schools, offices, retail, churches, institutional and residential housing are all occupancies where GSHPs have been applied, but virtually every type of building could be equipped with this system and be successful.

There are three primary factors to be considered when trying to adapt a ground source heat pump system to a particular building. They include HVAC zoning, availability of a heat sink, and locations for heat pumps and associated piping. Each is discussed in the following paragraphs.

HVAC zoning is an important consideration when it comes to system selection. This involves determining what level of temperature control is needed and which spaces are to be grouped, or zoned, to respond to that temperature control. Heat pumps are available in many sizes, from 1 ¼ to 25 tons. Because of this wide range of unit sizes, heat pumps can easily provide the required zoning to meet just about any requirement.

The next critical item to be analyzed when considering a ground source heat pump system involves the availability of an acceptable heat sink. If an earth contact system is envisioned, then there must be sufficient square footage of site to support vertical drilled wells or horizontal trenches. Spacing of wells and trenches is critical in order to be confidant the earth can absorb the heat from our system, and do so repeatedly for many years. When considering a body of water, it must be deep enough and in close proximity to the building in order for it to perform properly and be cost effective.

Finally, there must be sufficient floor space and/or ceiling plenum to locate the heat pumps and associated piping. These units are generally shallow, so they will fit within most ceiling plenums, but generally a 24-inch high plenum free of obstructions is needed. Space to run the piping and mount the required pipe accessories and valves is also necessary. A ground source heat pump system will generally take up less building square footing because central plant equipment and large air handling equipment is not necessary.

Simplicity of the System

One of the more appealing aspects of a ground source heat pump system is its simplicity. There is no boiler or chiller, therefore eliminating the "central plant" engineers are so accustomed to designing around. While many different types of pumping systems can be applied, it is usually very similar to those of traditional hot/chilled water systems. Temperature controls for these heat pumps can be stand-alone for each unit, or the units can be grouped onto a DDC central building management system.

If owners are trying to locate the typical mechanical room with boilers and maybe a chiller, it won't be found on a ground source heat pump project. The earth or nearby body of water are doing all of the work of creating or rejecting heat. An equipment room on a GSHP project might consist of piping entering the building from outdoors and a few small pumps. This obviously eliminates a great deal of maintenance, but it also requires much less building square footage that could add up to significant first costs. Having a system consisting of pumps and heat pumps is something that can be serviced by just about any level of contractor in any location.

Temperature controls are typically the part of the system that gives owners so much trouble. Control schemes for boilers, chillers and all handling units can become so complicated that most owners are not able to understand or actively monitor and modify the systems. Controls for heat pumps are usually quite simple, relying on a space thermostat to operate a single unit in order to satisfy the room temperature set point. It is possible to group many heat pumps under a building-wide DDC system, but its only purpose is to provide data collection, troubleshooting or group functions such as night setback control.

Heating and Cooling Simultaneously

Another benefit of a ground source heat pump system is its ability to provide heating and cooling simultaneously throughout the building. Each heat pump connected to the water loop can heat or cool based on the signal from the space thermostat. Typical water temperatures throughout the year can support heating or cooling at any time. It is also possible that under certain conditions the heat added to the water loop equals the heat extracted and it is not necessary to even utilize the outdoor wells or water body.

There are other conventional systems that can provide heating and cooling capabilities simultaneously, but they do so at a poor efficiency. VAV reheat systems rely on an electric or hot water coil at the VAV box to reheat air that has already been cooled. 4-pipe fan coil unit systems can deliver hot and chilled water at the same time, but the boiler and chiller are sometimes active when no load exists, wasting resources and energy.

System Advantages

Several of the advantages of applying GSHPs to a project have been disucussed, but it is prudent to list more here to provide support for choosing this system. Table 2, below, is a summary of these issues.

Table 2 – Summary of GSHP System Advantages

1. Limited amount of equipment mounted on the roof or ground outdoors.
2. Long equipment life because compressors are operating indoors.
3. Dramatic energy savings in comparison to other system types.
4. HVAC zoning can be as small as one office or room. This increases comfort levels and occupant satisfaction.
5. Heat pumps coupled with energy recovering equipment provides a low cost way to introduce outside air at low moisture content.
6. They can be applied to just about any project occupancy, in any location.
7. The system is simple to understand, operate and repair.
8. It’s a proven system that has been refined over the last 50 years.
9. It requires considerably less building floor space than other systems.
10. Easy to meet industry standards and codes for energy efficiency.

CHAPTER 6 - Design Professional Issues

Familiarity and Understanding

One of the major roadblocks to making ground source heat pump systems more popular is the process design professionals go through when selecting an HVAC system for a particular building. While this process can be theoretical and calculating in most instances, there are other issues that come into play. This chapter will identify what many of the issues appear to be, and what process designers use for system selection.

Practically all engineering firms will utilize a prescribed approach to HVAC system analysis and selection, but many times their work is incomplete or unsupported. It benefits designers and consultants when their clients are happy, so selecting a system that is low cost, energy efficient and simple to use is usually important. The products and resources available for engineers to use when selecting HVAC systems has been limited in the past and probably didn't have enough of a data base to accurately determine first and life cycle costs.

An issue that undoubtedly comes into play is an engineer's understanding and familiarity with the system. Engineers are trusted to deliver an HVAC system that meets the needs of their clients. If they cannot fully understand or feel comfortable with the system and explain it to the client, then the likelihood it will be recommended or even considered is not very good. These systems have been around for quite some time, but their appreciation has been limited for a variety of reasons. Most engineers have no experience or limited experience with GSHP systems. It's human nature to stay with what we know and continue to do the things that have proven to be successful in the past.

Design firms develop expertise by working with specific clients or hiring engineers with experiences different from their own. If a firm has designed many projects using large VAV air handling units and VAV boxes, then it may be hesitant to change direction and move to a ground source heat pump design. A certain level of design efficiency is achieved by repeating the same design and change could cause a decrease in the profitability of the firm. Many firms will target potential hires based on the expertise they posses. In this way, they can immediately create the needed expertise without having an effect on the efficiency and profitability.

Many of the issues described previously also can affect the potential risk and liability a design firm wishes to accept. When an engineer or design firm does work that is beyond their area of expertise there can be dire consequences. Most firms also want some level of comfort that the proposed systems are proven in the industry, and that the firm has the expertise to avoid errors and omissions.

Potential liability issues and litigation can be the result of firms doing work outside their area of expertise or "comfort zone." The pressure to provide a design that is accurate as well as fast has become intense in this industry. While the quantity of suits may have leveled off in the recent past, engineering firms remain one of the most active defendants in our society[6]. The bottom line is that firms will stay with what they know best and will be hesitant to venture into HVAC designs that can expose themselves to potential errors and litigation.

"Does this system really work as well as advertised?" This is the question most engineers unfamiliar with ground source heat pump systems would ask themselves when the subject is presented to them. Designers want to apply proven concepts that they know will satisfy their clients' needs. There are many who wish to be out there on the "cutting edge," but the liability issues described previously hold them back from trying new things.

Cost of Design

This paper has discussed the issues surrounding an engineer's expertise and familiarity with certain types of HVAC systems. One of the issues dealt with how efficient a firm can be when it comes to design and the production of construction documents. That efficiency can have a big effect on the firm's profitability, which is obviously crucial.

The profitability or "cost of design" is an important factor when a design firm is considering what type of HVAC system to apply. It is necessary for the firms to have in-house talent that can design systems efficiently, expertly and accurately. Without that expertise, the possibility of profit decreases dramatically. Obtaining that talent can also be costly, whether it is developed from within or brought in from the outside.

Talent, or expertise, is the crucial factor when considering the possible profit a firm might generate. Factors consist of risk to reward analysis, accepting a certain learning curve for the long-term goals, and the cost to obtain talent not currently present. Whatever the issue, it is reasonable to believe that “design cost” and profitability will play a part in the decisions designers make when selecting an HVAC system for a particular building.

Research and Design Support

Another thing that engineers and designers need to have is a source of design guides and research that can support their selection process and development of HVAC designs. It gives them resources that can educate and supplement the expertise and experience they hold. This quantity of resources related to ground source heat pumps has grown significantly and will continue to do so as these types of systems gain popularity.

ASHRAE has always been an entity that considered research and resource publications a high priority. They currently publish many standards, design guidelines, books, papers and articles relating to ground source heat pump systems and related topics. These publications are available to members and non-members alike. At any national or regional ASHRAE meeting there are also a number of technical sessions addressing the use and application of GSHP systems.

The International Ground Source Heat Pump Association (IGSHPA) was formed in 1987, as a non-profit organization to advance GSHP technology and encourage its use. This organization not only publishes design and installation manuals; they offer software packages and training seminars for all levels of designers and installers. The IGSHPA is an entity that specifically targets GSHPs, and provides very detailed publications and education that can be used by design firms and contractors to increase their level of expertise.

As discussed earlier, the USGBC and its LEED rating system can provide a set of guidelines for an engineer to follow when incorporating sustainable design into a project. The ability to design HVAC systems that are extremely energy efficient can be crucial in obtaining a certification for a building. A portion of the materials presented for each subject include approach and implementation guidelines and design assistance. These guidelines and suggested strategies can be used by designers as guideposts when comparing system efficiencies and effectiveness.

Education

Educational opportunities for professionals is also a critical issue for engineers and designers. These opportunities can come in several forms and from different sources but they must provide practical information that an engineer can use on future or current projects. Practically all states in the U.S. require some type of continuing education in order for registered professional engineers to maintain their license, so it has become common for engineers to regularly attend these types of seminars.

Manufacturers of heat pumps and related equipment have a vested interest in putting as much information as possible in front of the design community. The more their product is used as a basis of design by the engineers, the greater the likelihood that they will sell the product. Whether it's lunchtime sessions in design firms' offices or formal seminars at neutral places a great deal of information and comfort with the system can be gained.

ASHRAE and IGSHPA are also sources of education that can be used to learn more about GSHP systems. They both present seminars and technical sessions on this topic routinely at regional and national conventions and meetings. Many times those educational sessions are given by professionals who have a great deal of experience and bring a lot of practical application to the attendees. When engineers can hear from others experienced with the design and have an opportunity to interact with them personally, the comfort level of actually trying the systems themselves increases.

Many universities are also trying to bring more exposure of GSHPs to as many engineers as possible. A good example is Oklahoma State University, the home of the IGSHPA. Their Certified GeoExchange Designer Courses are offered each year to design professionals. An annual technical conference and expo is also sponsored by them to allow those in the industry to gather, learn and spread the word about GSHPs. The IGSHPA has also developed an elementary school curriculum that is free and helps to explain to these students what GSHPs are about and how they work. Several software programs are also made available to the design industry.

In 2007, Arizona State University established one of the first study programs in the country related to sustainable design – the Global Institute of Sustainability. The institute has developed and sponsors K-12 programs related to all types of sustainability subjects. It also offers a certificate in Sustainable Technology and Management that design, operation and management professionals can earn.

As part of the ASU Global Institute of Sustainability, there exists the School of Sustainability. Students can earn several B.A., B.S., M.A., M.S. and PhD degrees in sustainability. Each of these degrees has a different focus, but they all are created to further the concept of sustainable design and teach future designers and managers how to implement various architectural and engineering concepts to building construction.

Terry Townsend, P.E., President of Townsend Engineering, Chattanooga, Tennessee, and past ASHRAE president, was featured in a M/E Roundtable for Consulting-Specifying Engineers magazine regarding the current surge in GSHP design. Related to dealing with education, he said, "attending educational sessions or courses from ASHRAE is a good way to avoid mistakes. Using a mentoring consultant during the design sequence and utilizing design assistance provided by utilities is another good idea. Also, it's important for an HVAC designer to admit a lack of experience in geothermal-based designs and seek out the necessary guidance in order to produce a good system design[13]."

CHAPTER 7 - Owner Issues

First Cost

Owners of buildings have a much different set of issues and concerns when it comes to HVAC system selection and the possible use of GSHPs. These issues may track those of the engineer, but the "bottom line" plays a huge role in the owner's view of the system. Questions like "will it work?" "what will it cost?" and "what benefit will I receive from it?" are undoubtedly going to the basis of acceptance by the owner.

It is obvious from the length of time these systems have been in use and the documentation of numerous studies that a GSHP system will work. These systems work for a large variety of buildings in practically all U.S. climates. In many ways, it can be shown that a GSHP system not only will work, but it will outperform most other traditional systems. Many of the issues presented in chapter four can be used to educate owners on why it will work and how effective it can be.

The cost of a project will almost always be an issue for owners. How "cost" is defined can vary and be of different importance. "Cost" can be installed cost, life cycle cost, energy cost or maintenance cost. All of these can be important and it will be necessary for engineers to be able to show owners how GSHPs compare to other systems.

One challenge facing designers is convincing building owners that the premium to build a sustainable building is relatively minor. A 2003 study for California's Sustainable Building Task Force, "The Cost and Financial Benefits of Green Buildings," concluded that the 33 buildings studied only had a 2 percent premium cost over conventional designs[10]. Many other studies are coming to the same conclusion, which should help make this discussion easier for the design community.

Benefits that the owner could receive from GSHP systems are numerous. The more important ones include long-term financial gain from system efficiency, more effective employees because of better indoor air quality, simplicity of the system, and the fact that the owner can be perceived as being a good steward of the earth's resources. Typical life cycle costs each year in private sector offices have been found to be $200 per square foot per year for salaries, $20 per square foot per year for bricks and mortar, and $2 per square foot per year for energy[7]. An owner can add as little as 10 percent to the building construction cost of building and pay for it with only a 1 percent increase in employee productivity. Owners who are looking long term will realize that having happy and efficient employees can play a crucial role in the success of their business.

Incentive Programs

There are many states that offer some type of incentive program related to the use of GSHPs. The Database of State Incentives for Renewables and Efficiency (DSIRE) at *www.desireusa.org* lists these known incentive programs in a simplified format. Each program listed is linked to the utility provider or state program for detailed information.

A review of those listed for Kansas and several surrounding states indicates limited programs and incentives. The incentives typically fall into one of two categories. First, the utility providers may offer cash rebates or low-interest loans. Secondly, items offered by state and federal government include low-interest loans and tax credits.

Virtually all of the incentives investigated were focused toward residential construction and were severely lacking when it came to commercial buildings. While a $300-$1,000 rebate might seem attractive to a homeowner, it would not be significant to a commercial building owner, or encourage them to proceed with a GSHP system installation.

Incentive programs are designed by their authors to accomplish specific things. While reviewing those in this geographic area, it is clear that utility providers have some interest in limiting the growth of energy use and the subsequent need for additional production capability. This interest is modest at best and doesn't address at least half of the utility systems' potential consumption for commercial customers. The true intent or desire of utility providers may be more perception than accomplishment.

A summary of the incentives offered in Kansas, Nebraska, Oklahoma and Missouri that relate to the use of GSHPs are listed in Tables 3 through 6. The federal government also offers several incentive programs that are summarized in Table 7.

Table 3 – Kansas Incentives Related to GSHPs

- Kansas Energy Efficiency Program – 0 percent interest loan to income-qualified homeowners for home improvements
- Kansas City Power and Light, Commercial/Industrial Energy Efficiency Rebate program – Rebates up to $92 per ton, based on certain paybacks.
- Kansas City Power and Light Energy Optimizer Programs – Free thermostat for qualified customers

Table 4 – Missouri Incentives Related to GSHPs

- Energy Loan Program – Low interest loans for public and governmental buildings based on certain paybacks
- Columbia Water and Light, SuperSaver Loans – Low interest loans for high efficiency HVAC equipment
- 12 different utility providers – Rebates of $50-$350 per ton for heat pump installations (mostly residential)

Table 5 – Nebraska Incentives Related to GSHPs

- Dollar and Energy Savings Loans – Low interest loan for residential and commercial buildings.
- Omaha Public Power District, Commercial Heat Pump Program - $100 per ton rebate for GSHPs
- Omaha Public Power District, Residential Energy Efficiency Rebate Program – Rebates for various improvements
- Twin Valleys Public Power District, Residential Energy Efficiency Rebate – Rebates for various improvements

Table 6 – Oklahoma Incentives Related to GSHPs

- Energy Efficient Residential Construction Tax Credit – Up to $4,000 tax credit for efficiency beyond ECC 2003
- Community Energy Education Management Program – Low interest loans for public buildings with 6 year paybacks or less
- Energy Loan Fund for Schools – Low interest loans for schools implementing energy conservation measures.
- Edmond Electric, Residential Heat Pump Rebate Program - $150 per ton rebate for GSHPs

Table 7 – Federal Incentives Related to GSHPs

- Energy Efficient Commercial Buildings Tax Deduction – Corporate tax break for exceeding ASHRAE 90.1-2001
- Energy Policy Act of 2005 - $300 tax credit for GSHP residential and $1.80 per square foot for commercial improvements exceeding ASHRAE 90.1-2001

CHAPTER 8 - Recommendations

Encouraging the Design Community

There may be many owners who have been made aware of GSHP systems and their advantages, but the more likely origin for recommending them will come from the design engineers. Because of this, it is imperative that the design community have a sense of comfortability and confidence with the system. At issue then is developing a plan to raise awareness, provide education and support publications, and publicize the success of GSHP systems to designers.

Many more engineers are aware of GSHP systems today than 20 years ago, but there is a need to grow this familiarity exponentially. Everyone involved or who has experience with the systems is obligated to help get the word out. There are many organizations such as ASHRAE, IGSHPA and USGBC that can be used to publicize these systems to all types of design professionals. This needs to happen through the use of articles in newsletters and magazines, continuing education and local meetings.

Building owners, politicians and the general public also need to be made aware of GSHP systems and how they can be applied to most buildings. It might take an informed owner to push the issue with an unsure engineer to get a GSHP system installed. Politicians who are more familiar with the systems and their benefits can be more effective introducing legislation to encourage and reward the use.

Think about the progress that has been made over just the last 5-10 years regarding the general public's perception of "green/sustainable" design and other issues related to our world's environment. This can be duplicated for ground source heat pumps. If more and more people are aware of and behind the use of GSHP systems, then the chances of implementation by the design community will increase dramatically.

Education and providing the tools to analyze and quantify the GSHP system's advantages are also important when it comes to providing comfort to the design community. Opportunities for continuing education to professionals are still somewhat limited when it comes to GSHP systems. In addition to ASHRAE and IGSHPA, there needs to be a concentrated effort by universities, professional societies and manufacturers to offer the type of help the design community is looking for. Many of these workshops should also present information about the software packages available to help the engineers when it comes to system analysis and comparison.

A particular target group should be those who are LEED accredited professionals or members of USGBC. As stated in chapter two, the use of GSHP systems are a benefit when the goal is to achieve certification for a particular building. These designers need to be fully aware of the benefits of this system and how it can make the building certification an easier process. Manufacturers such as Climate Master have begun to advertise the LEED benefits of GSHPs, but it needs to be more widespread and originate from the design community[8].

The need to educate and provide support for the design community centers around the fact that the system design must be profitable and minimize professional liability issues. If designers have a good understanding of the system, know how to implement it, and feel comfortable that they can do so efficiently and accurately, then GSPHs will appear on more designs. One successful design will lead to another, and then the trend will head in the right direction.

The Part Owners and Government Play

The other two entities that must be made a part of this trend toward more geothermal system design are the building owners and government. As with the designers, owners may act cautiously when asked to accept a GSHP system design for their buildings. Local, state and federal governments must also play a role in encouraging the GSHP system use.

Chapter seven focused on the many issues facing building owners and what things would be important to them. It should be important that we expose as many people as possible to the financial benefits. This could easily be done by targeting associations that owners and building managers participate in. A presence at local, regional and national conferences and trade shows could do a lot to get the word out about how GSHP systems can help owners and operators achieve their goals. Potential first costs, utility savings, being part of a sustainable design and improving the effectiveness of their workforce must be clearly presented.

Most of the incentives available related to GSHPs come from the local utility providers and that must change. The potential for energy savings and reduction of greenhouse emissions is huge for the commercial and institutional building sector. If the U.S. is serious about these issues, then a serious effort must be made to provide the necessary incentives to get it done. Most owners want to do the right thing and they want to reduce their energy consumption, but help is needed to offset the initial first cost of installing these systems. Reasonable incentives could eliminate the argument surrounding the increased first cost of installing these systems and put the focus more on using less energy and reducing greenhouse gas emissions.

Projects for government buildings need to include provisions for the designers to seriously consider GSHPs. This would be another way to expose more designers to the system and its benefits. When GSHPs are part of the system selection analysis, then the results should support many more installed systems. If governments are reluctant to include wording directly related to a specific HVAC system type, then the requirements for system alternatives should at least include minimum efficiency targets that match those associated with GSHPs.

Tax rebates or breaks along with requiring GSHP systems in system selection processes could go a long way toward getting more systems installed. We need to move past the small breaks offered for residential installations and go after the huge market of commercial buildings. It wouldn't be necessary to continue these incentives forever because once everyone is familiar with the system and energy rates continue to rise, the use of GSHPs will sell itself.

Education is the Way to Go

Education systems throughout the U.S. will also need to play a large role in promoting the use of GSHP systems. This can include work at the K-12 level and enhanced education at the university level. While this education may not necessarily be technical in nature, it should generally describe how GSHPs can respond to our need to be more environmentally responsible.

Today, younger children are besieged with information about environmental issues and the potential affect greenhouse gases can have on our society and world. This is important because they will be our leaders in a short amount of time and by introducing it early in their life, it almost becomes second nature to them. We need geothermal HVAC designs to be a major part of that discussion and for the students to know the function and benefits that can be realized.

Middle and high school students are in a similar position, but they are also capable of having a better understanding of the nature and benefits of GSHP systems. Instead of simple eco-friendly concepts at the grade school level, these older children and youth should be exposed in greater detail to the system operation. The importance here is again trying to educate as many people as possible to the system, how it works and the benefits it presents.

Regardless of the students' age, it will be imperative that information be provided to teachers in a way that they can use to showcase GSHPs. This information must come from professional organizations and universities so that little is required of the teachers other than to present it in class.

The next level of education would be the work that vocational education facilities perform. A graduate of an HVAC specialty at one of these institutions needs to be as familiar with heat pumps as they are with traditional gas-fired furnaces. If designers and owners don't feel comfortable with the expertise available to them to provide routine maintenance or initial installation, then the systems will never be proposed or designed. This effort must involve many manufacturers and also the engineering professional organizations.

Finally, institutes of higher learning must be participants in this education process. Course offerings for programs and degrees that relate to the building industry must include a reasonable amount of instruction related directly to GSHP systems. Many times these are students who are on the brink of entering the job market and their familiarity with GSHPs and how to apply them is crucial to the overall goal of installing more systems. Students must be taught techniques for design and exposed to all of the issues related to installation, temperature control and specifying the systems.

More universities need to create studies directly relating to sustainable design or adapt these concepts to existing programs. It is easy to see that when more students are exposed to sustainable design the subject of GSHPs will come up. Applying these systems to both residential and commercial use must be an important part of this course of study.

CHAPTER 9 - Conclusions

A Proven System

There is no question that GSHPs must be considered a proven system to provide heating, ventilating and air conditioning for all types of buildings. The heat pumps have shown themselves to be comparable to other HVAC systems in terms of reliability and required maintenance. These systems have been around for nearly 50 years, giving the design community a sense of comfortability.

The accumulation of energy and efficiency data is growing substantially, and that data is proving just how good GSHPs are when it comes to reducing energy costs. When comparing the energy costs savings, first costs and maintenance costs, most analysis are showing very reasonable paybacks. Based on the pattern of increased utility costs, these paybacks will become even shorter in the future.

Sustainable Design

Engineers designing HVAC systems today must consider aspects of design that relate to proper use of resources, reducing greenhouse gas emissions, utilizing heat recovery equipment and providing systems that can be easily controlled. The LEED rating system presented by the USGBC will undoubtedly become more common in the industry and the use of GSHPs will allow the engineer to easily achieve certified buildings. GSHP systems can be viewed as the "green" design easier than most other conventional systems because of its use of one of our most common renewable resources, the earth itself.

Incentives

At least in the short term, it will be necessary to provide some types of incentives to building owners. It is important to provide whatever is possible in the way of tax breaks and rebates to owners in order to offset any differences in installed first costs. When the first cost issue is removed from the system analysis, the choice to use GSHPs could increase dramatically. These incentives are also necessary in order to show the general public that the U.S. is willing to support all of this sustainability discussion with real dollars. These are dollars that can reap huge benefits in the future when considering the energy saved.

Education

Probably one of the largest hurdles that must be overcome with regards to implementing GSHP designs is education. This education needs to start at the K-12 level in order to make a real change in the public's familiarity of GSHPs. Some programs have been implemented, but they need to be grown exponentially. Children who are exposed to the system and its benefits will grow up to expect its implementation. They will also unknowingly educate their parents and families, increasing the knowledge base of all U.S. citizens.

It is also crucial that educational opportunities are available at the vocational technical schools and universities. Those who choose to enter the building HVAC industry as installers, maintenance technicians or designers need to be familiar and comfortable with GSHPs. The support from manufacturers and professional associations can play a key role in providing the manpower and financial support necessary to develop these programs. University programs that teach HVAC design must include a reasonable amount of GSHP systems in a variety of classes, including energy analysis, system selection, system design, and other sustainability coursework.

The Final Word

The awareness, acceptability and enthusiasm for ground source heat pump systems must be increased dramatically in the near future. A goal should be to make these systems as well known as solar or wind energy and GSHPs can be the HVAC system that helps to solve the eventual energy crisis in the U.S. If the public, designers, building owners, utility providers and government agencies all come together under a common goal of reduced energy consumption and sustainable design, then ground source heat pumps will become the system of choice.

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