

Geothermal Heat Pumps: Environmental and Economic Benefits for Public Schools*

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Introduction

Geothermal heat pumps (GHPs) have the potential to play a significant role in improving the quality of our indoor air, increasing the energy efficiency of our buildings and homes, providing significant savings for building owners (such as school districts), and promoting the overall sustainability of our utility distribution systems. The U.S. General Accounting Office estimates that widespread adoption of GHP systems could easily save the country billions of dollars in energy costs each year (GAO, 1994). Their initial higher costs have restricted their growth, however, with consumers, architects and engineers typically opting for less expensive and less efficient heating and cooling systems.

Heating and cooling accounts for 40% of utility consumption in the United States (UNEP, 2004). Improvements in utility efficiencies in this sector could have many benefits for our society, including: reductions in utility expenses, a reduction in negative environmental impacts resulting from the burning of fossil fuels and subsequent emissions of greenhouse gases; improved health of our citizens by reducing the amount of particulate matter in the atmosphere and within our buildings; and reduced energy requirements during peak demand time.

Schools in the United States spend more than \$6.0 billion on energy each year, with an average school district spending at least \$400,000 on utility bills. The U.S. Department of Energy has found that, for most districts, utilities are second only to payroll as a percentage of overall operating expenses (DoE, 2002). Geothermal heat pumps utilize a two-way, electric fan and the stable temperature of the Earth's crust to power a process that is so simple and easy to operate that it is the most energy efficient HVAC appliance in existence (L'Ecuyer, 1993). If all schools converted to GHPs, the 25 to 40% savings estimate would translate into a \$1.5 to \$2.4 billion utility savings.

The simple design of the GHP system translates into lower maintenance and repair requirements when compared to other systems. Typically, maintenance and repair costs for GHPs are approximately 20% to 40% of those of conventional HVAC equipment, costing an average of \$.06-.12 per square foot as compared to \$.30 per square foot (DoE, 1998 & ASHRAE, 1998). GHPs are not only simpler; they are significantly smaller than, for example, the traditional boilers and rooftop air conditioning units that power many of our buildings. GHP units can be placed in closets or hung above ceiling tiles thus eliminating the need for basement boiler rooms entirely.

The combined energy and maintenance savings means that projects easily offset the higher upfront costs. This expense avoidance allows for a payback term for GHP retrofits that is typically less than ten years. Conversion to GHP systems would provide a boost to operational budgets and go a long way to protecting the school districts against the volatility of the ever-rising prices of natural gas, oil and propane. In practice, a GHP uses only one unit of electricity to move three units of heat (DoE, 1998). To put this another way, GHPs deliver more than three times more energy than they consume (EGI, 2001).

Life Cycle Analysis

This life cycle cost comparison pits a conventional HVAC system against a GHP system as they relate to a project is going out to bid by the San Cayetano School in Fillmore, California. The school has a total of 37 classrooms. Fifteen are located in four original classroom buildings

and 11 modular buildings house the other 22 classrooms. Also included in the project scope are two separate buildings housing administration offices and a cafeteria, respectively. The original buildings are typically heated with forced-air natural gas fired horizontal furnaces mounted at the back of the classrooms.

The conventional rooftop systems first costs were estimated at \$342,842. This corresponds to \$2,833 per ton or \$9.91 per square foot. The GHP systems first costs were estimated at \$583,138. This cost corresponds to \$4,819 per ton or \$16.85 per square foot of conditioned floor area. Though the GHP option costs 41% more, there are several distinctions that should be made.

While the average life expectancy for conventional systems is 15 years, GHP systems can be expected to last 25 years, an increase of 60%. Though the financial analysis provided below does not address the life expectancy of the conventional system, it could be appropriate to include the cost of a replacement system at year 2019. Were the unfinanced, one-time cost of such a project tacked onto the spreadsheet on the GHP side of the equation, it would create additional positive cash flow savings for that year of more than \$370,000.

Further long-term financial efficiencies for GHP systems come from analysis of the ground loop system. Manufacturers offer a 50 year warranty for the material, meaning that the loop can be expected to function through two GHP systems. The cost of the ground loop system is \$282,136, or 48% of the total cost of the system. Looking ahead 25 years at the potential replacement cost of the system, this cost of a ground loop can be subtracted from future project estimates. Using the original quotes for the project, this means that while the conventional system costs \$342,842 to replace, the GHP replacement would only cost \$301,002, 12% less than the conventional system.

The GHP system provides a 27.5% reduction in energy demands. By applying a base electric cost of \$0.16/kWh, this translates to a savings of \$28,305 in the first year. Though the upfront cost of the GHP system is approximately 41% higher than the conventional system, the utility savings allow the extra cost of the GHP system to be recaptured after only eight years. Were utility costs to increase more than the built-in assumptions (8% per year increase for heating and a 3% increase for cooling), the savings would increase and the time for pay back would further shorten.

	Air Source Heat Pump	GHP
System Cost:	\$342,842	\$583,138
<u>Energy Use</u>		
Cooling (kWh):	292,020	242,498
Heating (kWh):	<u>351,618</u>	<u>224,231</u>
Total:	643,638	466,729
Annual Energy Costs:	Air Source Heat Pump	GHP
Electricity	\$102,982	\$74,677

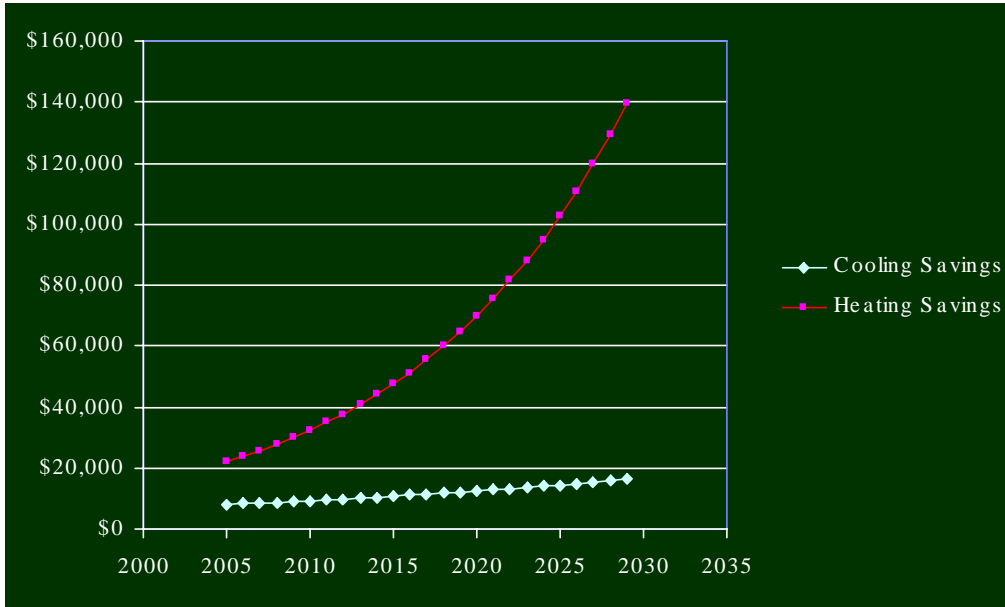


Table 1. Energy savings (adapted from GHPC, 2004)

The combination of utility efficiency and low maintenance costs make the GHP system the best choice. The life cycle cost analysis shows that the Geoexchange system saves a little over \$2 million in heating and cooling and maintenance expenses over its lifetime. It does not factor in the possibility of having to replace the conventional system only 15 years into the future, which would provide substantial additional savings.

Poor Indoor Air Quality (IAQ) and Schools

Old buildings with aging HVAC equipment, new buildings that are sealed so tightly that outdoor air has no means to enter, and overcrowded classrooms with high humidity and CO2 concentrations are just a few of the common problems affecting schools and creating environments with unhealthy indoor air. Other issues include mold, dust mites and airborne chemicals, such as formaldehyde that leaches from furniture and carpeting. How common a problem is this for schools? Studies in 1995 and 1996 found that 20% of schools suffer from poor IAQ and 36% of schools report that their HVAC system is more of a hindrance than an asset when it comes to maintaining a functioning and healthy school environment (GAO, 1995 & 1996).

Regardless of the end-use of a building or its air quality issues, problems related to poor IAQ are generally due to HVAC systems (Armstrong, 1992). Poor humidity control, lack of fresh air and inadequate design and maintenance of the HVAC system are the top causes of poor indoor air quality. These defects encourage both moisture and water damage which then encourage growth of microbial pollutants (IOM, 2000 & Bornehag, 2001). Temperature and humidity control are achieved by GHPs without risk of associated microbial pollutants. The small amount of electricity consumed by a GHP means that the unit can cycle constantly and still use significantly less energy than other systems. Due to this constant cycling, GHP systems are able to maintain good ventilation rates and control the temperature without sending blasts of dry, hot or cold, damp air into the classroom. They are thus able to maintain humidity and temperature in the ideal range of approximately 40% to 60%.

Because GHP systems are all-electric, there is no onsite combustion associated with their operation. The only emissions associated with GHP operation take place at the power generation plant. If petroleum products used to run conventional boilers and heaters were redirected to supply power for electric heat pumps such as GHPs, 35% to 50% less fuel would be needed to heat and cool. This reflects the greater efficiency of power plants and electric appliances compared to combustion-based HVAC units. The associated decrease in fuel consumption would lead to an equivalent reduction in greenhouse gas emissions (IEA, 2004).

Conclusion

In California, the Public Employees' and Teachers' Pension Funds own a combined 160 million square feet of office space. An energy efficiency initiative proposed by the California State Treasurer would invest \$200 million to perform physical retrofits of these buildings to improve energy efficiency. Upon completion, estimated annual energy savings are expected to be \$40 million per year, providing a pay back on the investment in only five years (OST, 2004).

The San Cayetano project demonstrates the long-term financial feasibility of GHP retrofits. Consumers, including school districts, have typically installed less efficient, though more familiar, equipment. The lower initial costs of such systems are appealing to cash-strapped school districts which find themselves with reduced budgets year after year. With utility costs continuing to rise and old equipment requiring replacement, school districts will be forced to look beyond traditional HVAC equipment in search of more efficient options.

Though poor IAQ is also of concern, its impacts are still being debated and seemingly of less urgency than utility costs. Fortunately, decisions that reduce utility consumption, such as installation of GHP systems, frequently provide additional benefits to indoor and outdoor air quality. Though the installation of GHPs makes excellent sense financially, they also provide our communities with improved indoor air quality, reduced emissions of pollutants, and healthier citizens.

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