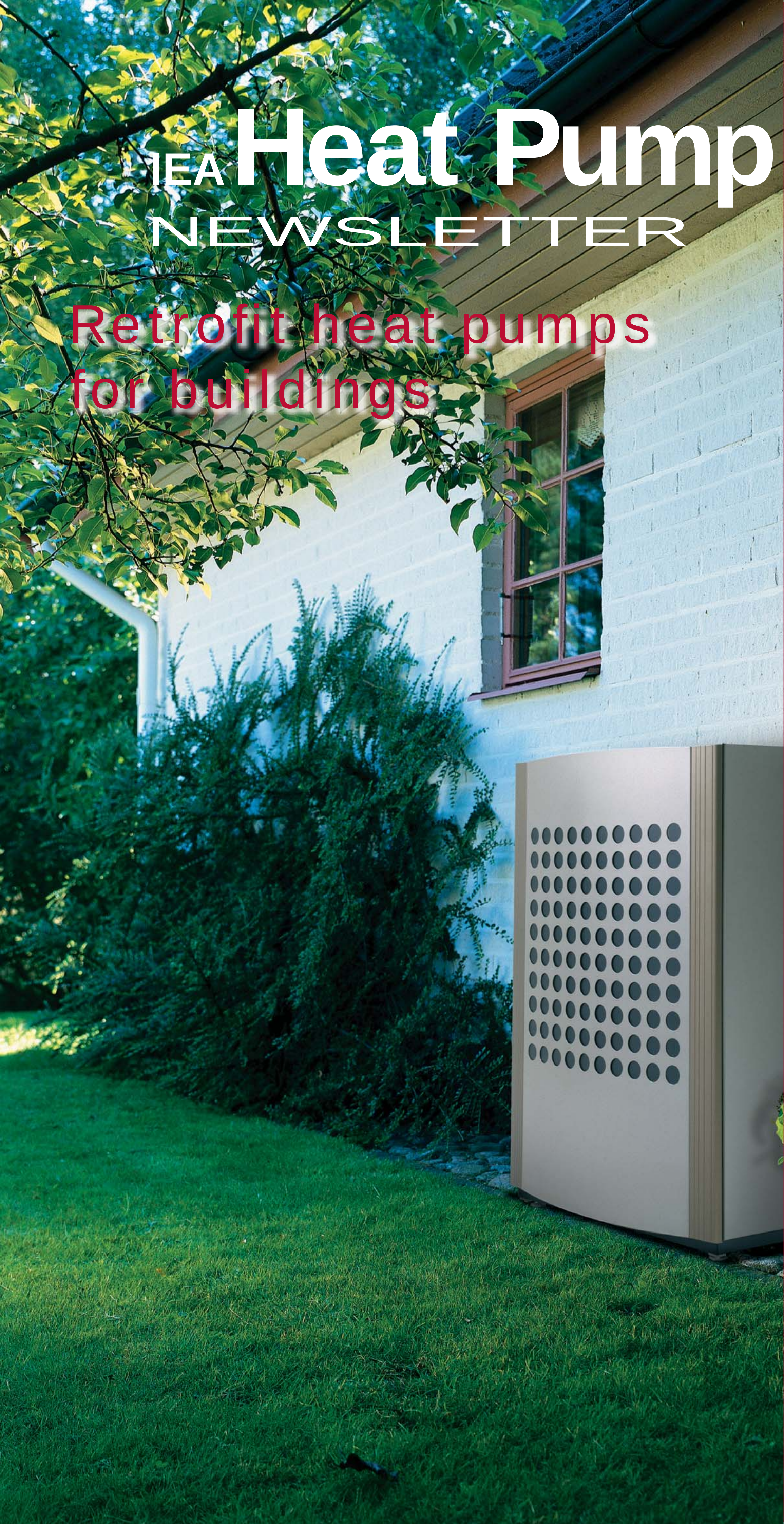
IEA Heat Pump CENTRE
NEWSLETTER
Volume 24
No. 4/2006



Retrofit heat pumps for buildings

Fort Polk Installation Demonstrates Retrofit Potential of Geothermal Heat Pumps

Jeff Hammond, USA

A recent independent study prepared for the U.S. Department of Energy by Oak Ridge National Laboratory (Hughes, et al, 1998) demonstrates that geothermal heat pumps (GHPs) provide substantial benefits to the end user, the electric utility industry and the environment. A comprehensive 4,003-home retrofit project was conducted at Fort Polk, Louisiana where the existing heating and cooling systems (560 gas furnace/electric air-conditioner systems and 3443 air-source heat pump systems) were replaced by GHPs with desuperheater water heaters. In addition existing incandescent lighting fixtures were replaced by high-efficiency fluorescent or compact fluorescent fixtures, and existing shower heads were replaced by low-flow shower heads. Evaluation of this massive retrofit showed that it reduced electrical consumption in the 4003 residences by 26 million kWh (33%) while altogether eliminating consumption of 27,425,000 Mj of natural gas. Peak demand was reduced by 7.5 MW (43%), and the power factor was increased from 0.52 to 0.62 . Emissions of CO_2 have been reduced by an estimated 20,321,000 kg per year at the Ft Polk site. The GHPs alone are credited with 66% of the electricity savings and all of the natural gas savings (Hughes and Shonder, 1998) accounting for about 14,900,000 kg of the total annual CO_2 emissions reduction

Introduction

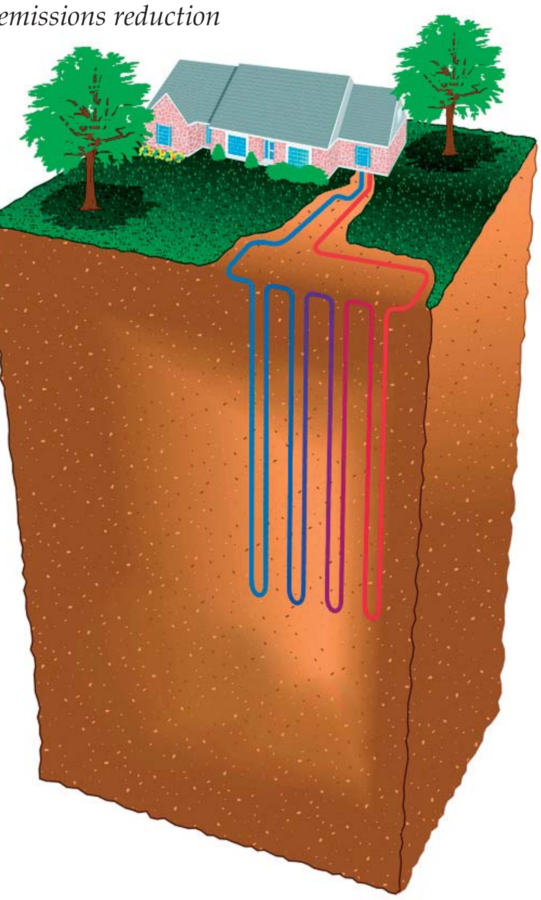
Fort Polk, the world's largest installation of geothermal heat pumps, was funded by $18.9 million in private capital, with no investment by the U.S. federal government except for procurement and administrative costs. Private investors, through an ESCO (Energy Services Company), realized that GHPs inherently pay for themselves. The U.S. Army and the ESCO share the cost savings over the life of a 20-year contract, allowing Fort Polk to exceed the mandate for 35% reduction in energy use by 2010, outlined in the Energy Policy Act of 1992. With heating, air conditioning, and water heating responsible for 74% of residential energy use (and 50% of commercial energy use) on a national basis (in the U.S.), widespread use of GHP systems could generate significant savings for energy utilities and end users.

GHP systems consist of simple, proven components. The technology is not new. The first recorded system was shown in a 1912 Swiss patent. Ground water or "open loop" heat pumps have been used successfully since the 1930s. The Edison Electric Institute (EEI) sponsored closed loop research (like the Fort Polk application) in the 1940s and 1950s, although the lack of suitable material for closed loop piping slowed interest. U.S. researchers (Oklahoma State University, among others) began investigating geothermal closed loop systems again in the 1970s with the advent of polyethylene pipe, which is ideal for the application. GHP systems have been gaining in popularity every since.

GHP Systems

In general, GHP systems consist of three components, (1) a geothermal (or water source) heat pump, (2) a heat source/sink (closed loop piping system) and (3) a distribution system (forced air ductwork or hydronic piping). A geothermal heat pump "moves" energy to or from the ground, instead of to or from the air like traditional heat pumps, giving the GHP system the advantage of working with a very mild heat source/sink – the ground.

[1] Power factor is the ratio between power (in Watts) and V-A (Volt-Amps), which is important to the electric company, since the company bills for Watts, but supplies V-A to the customer. The closer the power factor is to 1, the less power factor correction is necessary via capacitors or inductors, thus lowering power generation and transmission costs.



The heat source/sink consists of polyethylene pipe (usually 19mm or 25mm diameter), arranged according to the geography of the land. One loop piping system is not better than another; the loop is tailored to the available land space, with loop length adjusted accordingly (e.g. horizontal loops require more piping than vertical loops, due to the more shallow

burial depth). A water and antifreeze solution is pumped through the piping system. The water/antifreeze solution transfers heat from the earth to the heat pump refrigeration circuit (or from the heat pump refrigeration circuit to the earth), which transfers heat to or from the distribution system.

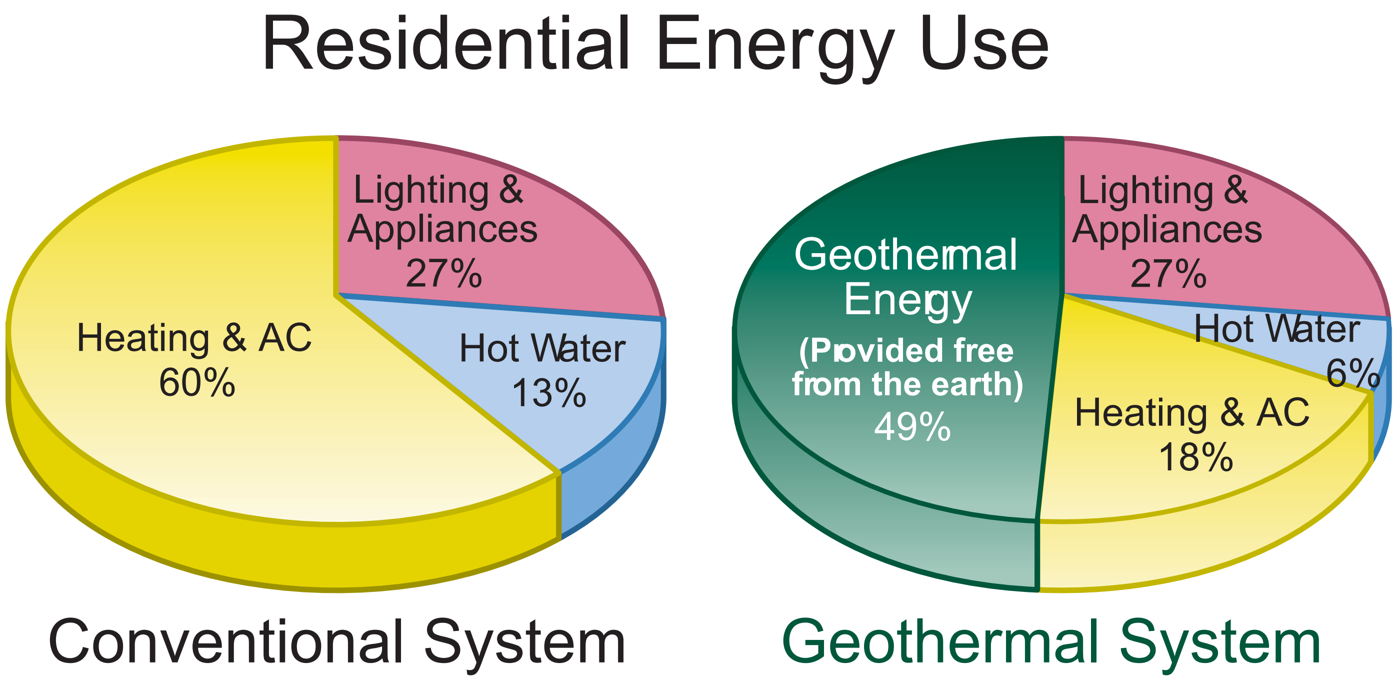
The distribution system consists of forced air ducting or hydronic piping. A forced air ducted system uses a fan and ductwork to deliver heated or cooled air via registers and grilles to the structure being conditioned. GHPs offer warmer air temperatures in heating for forced air systems than traditional air-source heat pumps due to the milder heat source they use. In cooling, GHPs provide excellent dehumidification and cool, refrigerated air. A hydronic distribution system may be used instead of a forced air system. Some examples include radiant floor heating, fan coil units and snow melt.

Diverse Applications for GHPs

Almost any building can benefit from a GHP system. Schools, assisted living communities, office buildings and residential homes are but a few examples. Any building that has an available space for loop piping of 0.1 to 0.3 m^2 per kW is a good candidate for a GHP system, even if the available space is under a parking lot or under the building. Where a retention pond is required for parking lot runoff, a GHP system can become not only the most efficient HVAC system, but may even be the lowest first cost (installed) system.

GHP systems can drastically reduce utility power generation requirements when compared to other systems. At Fort Polk, 0.32 kW peak demand reduction was realized for every installed kW of cooling capacity. This equates to peak demand reduction of 285 kW for every 9,290 m^2 building or for every 71 homes. If GHP systems were implemented on a widespread basis, power companies could avoid building new power plants. Using the figures from Fort Polk, a 400 MW gas turbine generator could be redirected for use elsewhere for every 99,500 homes or for every 1,400 buildings of 9,290 m^2 converted to GHP. In the past ten years since Fort Polk was started, heat pumps have become even more efficient, some with almost twice the efficiency, further enhancing generating capabilities (peak reduction). The increase in load factor with GHP systems helps level peaks and increase generating efficiency.

GHP systems are environmentally friendly. Based upon data supplied by the U.S. Department of Energy (NREL 1998), if just 100,000 additional homes in the US converted to a GHP system, CO_2 emissions could be reduced by over 200 million kg per year!



Residential GHP systems generally cost more to install than other HVAC systems. The additional cost is primarily the ground loop piping system, since the heat pump and distribution system are similar in cost to other technologies (e.g. furnace/air conditioner or air source heat pump). Initial cost for commercial GHP systems really depends upon a base system comparison. For example, GHP system initial cost is higher than a constant volume packaged rooftop unit, but the same or less than a 4-pipe VAV (variable air volume) system. Depending upon a base system comparison, peak demand and kWh savings will vary. However, GHP systems still have the most favorable operating cost and load profile of any HVAC system.

GHP systems have a proven track record for reducing operating costs for end users, lowering peak demand/improving load factor for utility companies and creating a more environmentally friendly heating and cooling system for society in general. The independent study of the Fort Polk GHP retrofit installation provides a benchmark for the endless possibilities of applying the technology on a widespread basis.

Conclusions

In conclusion, Fort Polk, the world's largest geothermal installation, demonstrates that retrofitting GHP systems makes economic sense, and also contributes to a better environment for future generations. In this study, the retrofit of 4,003 residences with geothermal heat pumps reduced electrical consumption for space heating, space cooling, and water heating by 17 million kWh per year. In addition, the GHPs eliminated consumption of 27,425,000 Mj/y of natural gas for space heating and water heating. The GHP retrofit has reduced CO_2 emissions by an estimated 14,900,000 kg per year.

References

Hughes, Shonder, White, and Huang. 1998. "Methodology for the Evaluation of a 4000-Home Geothermal Heat Pump Retrofit at Fort Polk, Louisiana," Oak Ridge National Laboratory, ORNL/CON-462 (March).

Hughes and Shonder. 1998. "The Evaluation of a 4000-Home Geothermal Heat Pump Retrofit at Fort Polk, Louisiana: Final Report," Oak Ridge National Laboratory, ORNL/CON-460 (March).

NREL 1998. "Environmental and Energy Benefits of Geothermal Heat Pumps," National Renewable Energy Laboratory (NREL), a DOE (U.S. Department of Energy) National Laboratory, DOE/GO-10098-653 (September).

Jeff Hammond
Director of Marketing
ClimateMaster, Inc.
7300 SW 44th Street, Oklahoma City, OK 73179, U.S.A.
jhammond@climatemaster.com
+1-405-745-6000, ext. 348