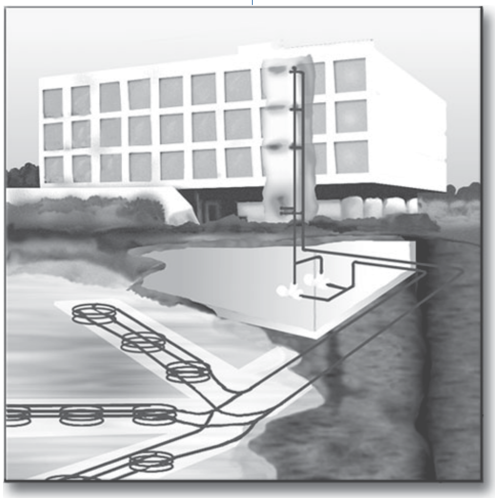
FEMP
Technology Focus
A New Technology Demonstration Publication
DOE/EE-0291
Federal Energy Management Program

Leading by example, saving energy and taxpayer dollars in federal facilities

Geothermal Heat Pumps Deliver Big Savings for Federal Facilities

An update on geothermal heat pump technologies and the Super ESPC

Energy-efficiency improvements at federal facilities must enhance support for the agency's critical missions while also saving energy and money. Geothermal heat pumps (GHPs, also known as ground-source heat pumps or GeoExchange systems) can do both, and can help meet energy-conservation, emissions-reduction, and renewable-energy goals.



Geothermal heat pump surface water loops.

GHP technology is now well known as a proven, reliable, efficient, and cost-effective choice for space heating, cooling, and water heating in federal facilities. Federal facilities have invested more than $200 million in GHPs since 1993.

GHPs achieve high energy efficiency by using a geothermal resource (the ground, groundwater, or surface water) instead of ambient air as a heat source and heat sink. The temperature of this resource is generally cooler than ambient air in the summer and warmer than ambient air during the coldest months, so GHPs operate over a smaller temperature lift—and therefore more efficiently—throughout the year.

Although the industry is growing quickly, many federal energy and facility managers are still unfamiliar with GHP technology. The Federal Energy Management Program (FEMP) offers technical and financing assistance to make GHPs just as easy to implement in federal facilities as the more conventional, less efficient alternatives (see textbox on following page).

Advantages of GHPs

Proven Efficiency and Energy Savings

Replacing conventional heating and air conditioning systems with GHPs typically saves 15–25 percent of total building energy use in nonresidential buildings; in residential buildings savings can be as high as 40 percent. GHPs reduce peak load as well. An evaluation of a 4000-home comprehensive GHP retrofit at the U.S. Army's Fort Polk in Louisiana showed that the GHPs reduced summer peak electric demand on the post by 7.5 MW, or 43 percent, and reduced electricity consumption in post housing by 33 percent, while eliminating natural gas consumption altogether (Hughes and Shonder 1998).

GHPs can also contribute to meeting emissions reduction goals because they use less electricity than conventional equipment to provide the same amount of cooling and heating.

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Improved Comfort—Better Humidity Control, Zone-Level Temperature Control, Quiet Operation, Reliability

Besides their intrinsic efficiency, GHPs offer other benefits that are highly valued at federal facilities. At several U.S. military installations, GHP retrofits have cut the energy use of family housing units by about 30 percent, and is also seen as an investment in the troops' morale and quality of life. Residents are more comfortable in their homes because the new GHPs operate reliably and quietly and provide better humidity control.

Nonresidential buildings can benefit from GHPs as well. Typically, each zone is provided with its own unit, which can be controlled separately to maintain occupant comfort.

Lower Maintenance Costs

The low cost of maintaining GHPs contributes significantly to their cost-effectiveness. The technology is simpler and inherently less prone to malfunction, requires less maintenance, and has a longer service life than air-source heat pumps. GHPs have no outdoor equipment to be tampered with, filled with leaves or other debris, or buffeted by the weather.

GHPs are generally charged with refrigerant and sealed at the factory—a feature that reduces required labor for installation and maintenance and benefits the environment as well. Spills of refrigerant are eliminated and overall costs are lower because installers don't have to handle refrigerants during installation and leaks are extremely rare. GHPs typically use 25 percent less refrigerant than other air-conditioning equipment.

An analysis of 1996–1998 maintenance records for the Lincoln, Nebraska, school district shows that annual corrective maintenance (repair) costs for four GHP-equipped schools averaged 2.1 cents/ft^2, compared to 2.9 to 6.1 cents/ft^2 for conventional systems in 16 other schools. Another analysis by the Geothermal Heat Pump Consortium found average total (preventive and corrective) maintenance costs for 25 GHP-equipped buildings to be

Financing through GHP Super ESPCs or UESCs

Federal agencies can use energy savings performance contracts (ESPCs) to finance their energy projects, allowing them to reduce their energy use and costs without depending on congressional appropriations to fund the improvements. Using FEMP's Super ESPCs, agencies can partner with prequalified, competitively selected energy service companies (ESCOs) and use an expedited contracting process to implement their projects quickly.

Federal facilities worldwide can use a Technology-Specific GHP Super ESPC, which offers financing and private-sector expertise specifically geared to GHP projects. Energy utility companies have also been strong proponents of GHPs, and many offer financing and services to federal agencies through utility energy service contracts (UESCs).

FEMP Project Facilitators

Using a FEMP Project Facilitator is your best insurance for achieving a successful energy project with persistent savings. Agencies that use FEMP project facilitators benefit from having an expert consultant on contractual, financial, and technical issues, and an experienced guide through the entire process of developing, implementing, and verifying savings from an energy project. FEMP project facilitation services for Super ESPC projects are free through the initial proposal stage and reimbursable thereafter.

Unbiased, Authoritative Technical Assistance from FEMP's GHP Core Team

The FEMP GHP Core Team provides agencies with the most authoritative technical assistance on GHPs available anywhere. FEMP project facilitators supported by specialists from the core team have the practical engineering design and construction experience to ensure that the job is done right. Some of the technical information and resources offered by the core team are available at www.ornl.gov/femp/. The FEMP GHP Core Team lead is John Shonder, (865) 574-2015, shonderja@ornl.gov.

For More Information, Visit FEMP's Web Site

To learn about ESPCs and UESCs, go to www.eere.energy.gov/femp/financing.

For contact information for the FEMP representatives in a DOE Regional Office near you, who will help you get started and get assistance from FEMP Services, go to www.eere.energy.gov/femp/financing/espc/getting_started.html.

about 11 cents/ft^2—16 to 30 cents/ft^2 less than for conventional systems. Both studies are published by ASHRAE (Cane et al. 1998; Shonder et al. 2000).

GHP Efficiency Saves Energy and Money

GHPs save energy and money because they operate more efficiently than conventional equipment. A compressor operates much more efficiently in a water-source heat pump than in an air-source unit. In addition, air needs to be circulated on only one side of the GHP, and less power is needed to move the water (or anti-freeze mixture) on the other side than would be needed to move air.

The temperature of the geothermal source/sink is far more stable than outdoor air, with much less severe highs and lows. Unlike air-source units, GHP systems do not use extra energy to power defrost cycles. In most locations there is no need for backup electric resistance heat.

Common-loop GHPs recover heat as part of their design. In cooler weather, the heat pumps serving the building perimeter extract heat from the common loop to provide space heating, while units serving core areas are cooling space and rejecting heat to the common loop. Under many operating conditions, the common loop is in balance, no net heat exchange with the ground is required, and the offset between heating and cooling units reduces the thermal load on the ground heat exchanger.

Recovered heat in GHP systems is also used to heat water. Desuperheaters are commonly installed with GHPs in military family housing to transfer heat from the heat pump into the water heaters. Dedicated water-to-water units are also found in many larger GHP systems.

GHPs were determined to be the most cost-effective option available to replace the old, ineffective HVAC system in Marston Pavilion, a historic building and community center for a U.S. Marine Corps base. The new GHP system costs 60 percent less to operate than the old system and provides excellent air quality and thermal comfort for the building.

Application and Feasibility of GHP Technology for Federal Sites

GHP System Types

GHPs are adaptable to almost any type of building and can be configured to fit a wide variety of sites and circumstances. Designing GHP systems to optimize efficiency and cost-effectiveness depends on choosing the configuration most effective and economical for the application. GHP systems are not feasible in every case, but their intrinsic efficiency and the wide range of design options makes them the most cost-effective choice for many situations.

The common denominator among all GHP systems is that they move heat between the geothermal source/sink and a building via water-source heat pumps to provide space heating and cooling, water heating, or refrigeration. A GHP system may have one or many water-source heat pumps, depending on the application. For example, in military family housing, each residence might be served by one heat pump with its own vertical-bore ground heat exchanger. Larger, nonresidential facilities might have many heat pumps on a common loop with a central variable-speed pumping station and one large geothermal source/sink.

Hybrid systems use a combination of geothermal resources and ambient air as heat sources/sinks, and are often the most economical approach where cooling needs are significantly larger than heating needs.

Important Factors in Determining Feasibility

Detailed estimates of costs and savings are required to determine the feasibility of any given project. However, there are some guidelines that can be used to screen potential projects before deciding whether to proceed with a feasibility study.

Building Function. In general, the most promising applications for GHP retrofits are buildings that are maintained at reasonably comfortable temperature setpoints (68–78°F) for at least 40 hours per week.

Equipment to be Replaced. It is not usually economically feasible to replace highly efficient, recently purchased equipment. There is more potential for savings when GHPs replace older, less efficient equipment that is more than about ten years old.

Energy Costs. In general, higher energy costs tend to improve the economics of GHP retrofit projects, but this is not always the case. For example, in a climate with significant heating requirements and high electricity rates, it may be more economical to heat with natural gas, regardless of the efficiency of the GHP.

GHP retrofits in military family housing are valued for their energy and cost savings and for improving the quality of life for the troops and their families.

The economics of any GHP project can be improved by utilizing the waste heat generated during the cooling cycle. For buildings with high water heating loads (e.g., residences, hotels, laundry facilities), GHPs can provide hot water at essentially no cost during the cooling season. Project economics are also improved if other energy conservation measures with relatively short paybacks are included with the installation of GHPs.

Maintenance Costs. GHPs generally cost less to maintain than conventional heating and cooling equipment, and this savings can sometimes mean the difference between a feasible project and an unfeasible one.

Retrofit Strategy. As with any retrofit measure, the capital cost is reduced if portions of the existing system (e.g., ductwork) can be used in the GHP system.

Local Water and Well Regulations. The installation of the ground-coupling system may be subject to local codes and regulations governing wells, water, and protection of water quality. Regulations affecting open-loop systems are common and variable, some requiring reinjection wells rather than surface drainage, for example. Some states require permits to use even private ponds as geothermal resources.

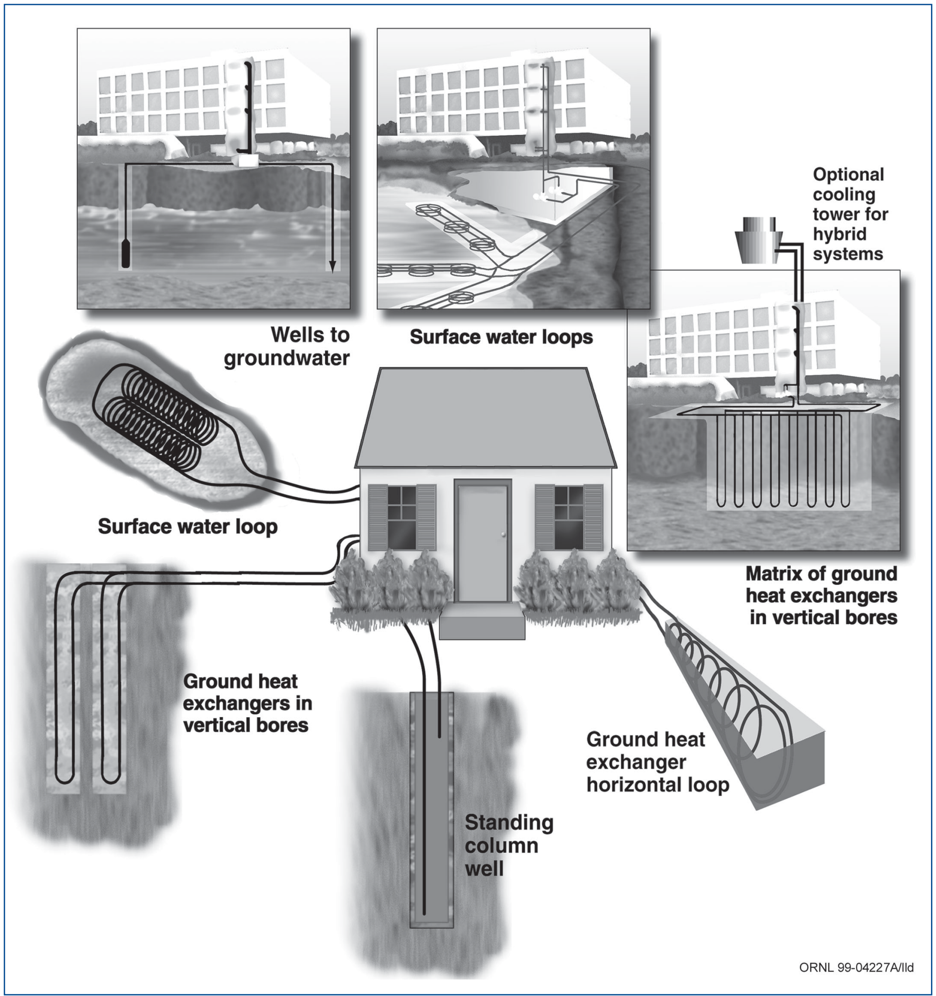
Geothermal Resources and GHP Systems

The type of geothermal resource that is available near the building is a primary determinant of the type of GHP system that will be most economical at any particular site.

Ground heat exchangers (or ground loops). Heat exchange with the ground using vertical or horizontal loops may be an economical option if there is enough land area near the building to accommodate ground heat exchangers. Horizontal loops require considerably more land area than vertical-bore heat exchangers, but may be less expensive to install, depending on the types of soil and rock formations encountered in drilling.

Ground heat exchangers are an option almost anywhere and are by far the majority among currently operating GHPs. However, as the industry matures and experience in the field grows, GHPs using surface water or groundwater for heat exchange are slowly gaining prominence. These other geothermal options may be even more economical than ground-coupled systems and should be considered where they exist.

Groundwater already being pumped. Some federal sites pump groundwater to the surface, treat it, and reinject it as a part of groundwater remediation projects. Tapping into groundwater that is already being pumped to the surface could be an extremely economical approach. Typically a plate-and-frame type heat exchanger is used to transfer heat between the groundwater and a common loop serving water-source heat pumps in nearby buildings. In years after the remediation project is completed, pumping on the groundwater side of the heat exchanger can be reoptimized for the HVAC application and continued using the same supply and reinjection wells.



The wide range of design options makes GHPs the most cost-effective choice for many applications.

Stationary surface water. Where large volumes of stationary surface water are near buildings, they may be economical resources for heat exchange. A common loop to serve water-source heat pumps in a nearby building can be submerged directly into a surface water impoundment such as a reservoir, runoff retention basin, reflecting pool, pond, or lake. If the water is used for recreational or other purposes that might interfere with this approach, an on-shore pump house with a heat exchanger and protected intake from and discharge to the body of water could be considered.

Moving surface water. A large river with reliable flow and modest current could be an economical heat exchange resource for nearby buildings. An on-shore pumphouse with a heat exchanger and protected intake from and discharge to the river might be advisable. Issues such as historical high and low water conditions, debris flow, and commercial and recreational traffic would be serious considerations.

Wastewater streams. Large-volume, reliable, flowing wastewater streams can be used to condition a heat exchanger. Maintenance of the heat exchanger and the stability of the missions of the facilities that are the source of the wastewater would be considerations.

Groundwater. Groundwater may be an economical heat exchange resource if large quantities are available at a reasonable depth, along with an acceptable and economical means of disposal. Poor water quality might require the use of expensive heat exchanger materials, and in some formations additional maintenance and aquifer reinjection might be expensive.

Standing-column well. Standing-column-well GHP systems are similar to standard groundwater GHPs, but because water is recirculated between the well and the building, only one well may be required (larger projects may have several wells in parallel). Standing-column wells are feasible in areas with near-surface bedrock. Deep bores are drilled, creating a long-standing column of water from the static water level down to the bottom of the bore. Water is recirculated from one end of the column to the other. To reduce required bore length, the system can be designed to bleed part of the water rather than reinjecting it all during peak heat rejection or extraction periods, causing water inflow to the column from the surrounding formation to cool or heat the column as needed.

References

Cane, E., A. Morrison, and C. J. Ireland, 1998. "Maintenance and Service Costs of Commercial Building Ground-Source Heat Pump Systems," ASHRAE Transactions, 104, pt. 2, 1998.

Hughes, P. J., and J. A. Shonder, 1998. "The Evaluation of a 4000-Home Geothermal Heat Pump Retrofit at Fort Polk, Louisiana: Final Report," ORNL/CON-460, Oak Ridge National Laboratory, 1998. (Available at www.ornl.gov/femp)

Shonder, J. A., M. A. Martin, P. J. Hughes, and J. Thornton, 2000. "Geothermal Heat Pumps in K-12 Schools: A Case Study of the Lincoln, Nebraska, Schools," ORNL/TM-2000/80, Oak Ridge National Laboratory, April 2000. (Available at www.ornl.gov/femp)

GHP and ESPC Information and Resources

DOE Geothermal Energy: www.eere.energy.gov/geothermal

FEMP GHP Technology-Specific Super ESPCs: www.eere.energy.gov/femp/financing/espc/technologies.html

FEMP GHP Resources: www.eere.energy.gov/femp/financing/espc/ghpresources.html

FEMP GHP Core Team: www.ornl.gov/femp

Geothermal Heat Pump Consortium: www.geoexchange.org

International Ground Source Heat Pump Association: www.igshpa.okstate.edu

About FEMP's New Technology Demonstrations

The Energy Policy Act of 1992 and subsequent Executive Orders mandate that energy consumption in federal buildings be reduced by 35% from 1985 levels by the year 2010. To achieve this goal, the U.S. Department of Energy's Federal Energy Management Program (FEMP) sponsors a series of activities to reduce energy consumption at federal installations nationwide. FEMP uses new technology demonstrations to accelerate the introduction of energy-efficient and renewable technologies into the federal sector and to improve the rate of technology transfer.

As part of this effort, FEMP sponsors the following series of publications that are designed to disseminate information on new and emerging technologies:

Technology Focuses—brief information on new, energy-efficient, environmentally friendly technologies of potential interest to the federal sector.

Federal Technology Alerts—longer summary reports that provide details on energy-efficient, water-conserving, and renewable-energy technologies that have been selected for further study for possible implementation in the federal sector.

Technology Installation Reviews—concise reports describing a new technology and providing case study results, typically from another demonstration program or pilot project.

Other Publications—we also issue other publications on energy-saving technologies with potential use in the federal sector.

Federal Energy Management Program

The federal government is the largest energy consumer in the nation. Annually, the total primary energy consumed by the federal government is 1.4 quadrillion British thermal units (quads), costing $9.6 billion. This represents 1.4% of the primary energy consumption in the United States. The Federal Energy Management Program was established in 1974 to provide direction, guidance, and assistance to federal agencies in planning and implementing energy management programs that will improve the energy efficiency and fuel flexibility of the federal infrastructure.

Over the years, several federal laws and Executive Orders have shaped FEMP's mission. These include the Energy Policy and Conservation Act of 1975; the National Energy Conservation and Policy Act of 1978; the Federal Energy Management Improvement Act of 1988; the National Energy Policy Act of 1992; Executive Order 13123, signed in 1999; and most recently, Executive Order 13221, signed in 2001, and the Presidential Directive of May 3, 2001.

FEMP is currently involved in a wide range of energy-assessment activities, including conducting new technology demonstrations, to hasten the penetration of energy-efficient technologies into the federal marketplace.

FEMP

A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

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Technology-Specific GHP Super ESPC

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