Big Savings from the World's Largest Installation of Geothermal Heat Pumps at Fort Polk, Louisiana

GHPs Pay for Themselves

The world's largest installation of geothermal heat pumps has proven that this technology can deliver big energy and maintenance cost savings as the centerpiece of a comprehensive energy-efficiency retrofit.

This massive project at Fort Polk, Louisiana—the largest-ever federal ESPC at the time—was funded by $18.9 million in private capital, with no investment by the federal government except for procurement and administrative costs. The improvements will be paid for over 20 years by the energy and maintenance cost savings resulting from the retrofit.

Geothermal heat pumps (GHPs) were installed in a comprehensive energy-efficiency retrofit at Fort Polk in 1995–1996. The project was a joint effort of the Army and Co-Energy Group, an energy services company (ESCO), and was carried out under an energy savings performance contract (ESPC).

New "Super-ESPCs" implemented by the U.S. Department of Energy (DOE) in late 1998 are available to all federal agency facilities nationwide for procuring GHP-centered energy-efficiency projects. The ESCOs competitively selected to develop and implement projects under the Super-ESPCs have all proven their qualifications to build and finance successful GHP-centered projects.

(Geothermal heat pumps are also known as ground-source or water-source heat pumps. The technology is often called "geo-exchange.")

Measures of Success

An independent evaluation conducted by the Department of Energy's Oak Ridge National Laboratory (ORNL) found that the Fort Polk project was a success by many measures:

• **Energy Savings** • The energy retrofit reduced overall electrical consumption in Fort Polk family housing by 26 million kWh per year (33%) while eliminating altogether annual natural gas consumption of 260,000 therms.

• **Peak Demand** • Summer peak electrical demand was reduced by 7.5 MW (43%).

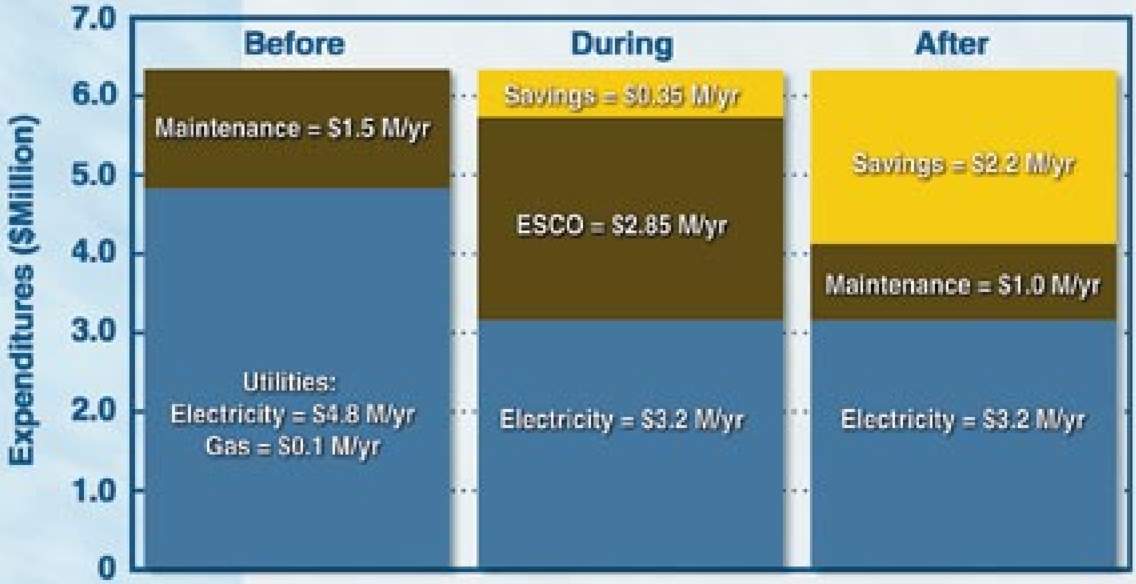
• **Load Factor** • Electrical energy savings and reduction of peak demand have dramatically improved the annual electric load factor —from 0.52 to 0.62—which may allow the Army to negotiate lower rates for the entire base.

• **Cost Savings** • Fort Polk saves about $345,000 annually for 20 years (the life of the contract). After the contract expires, the Army continues to reap the benefits of the GHPs' energy efficiency—about $2.2 million per year—during any remaining GHP service life.

• **Cleaner Air** • CO_2 emissions are reduced by 22,400 tons per year.

The Hammer Award

For their trailblazing project at Fort Polk—renewing the heating and cooling systems in 4,003 homes and lowering operating costs, without tapping government capital appropriations—Fort Polk, the Army Corps of Engineers, and Co-Energy Group were awarded Vice President Gore's Hammer Award on July 15, 1997. The Hammer Award recognizes work that makes government "work better and cost less" and symbolizes efforts to "hammer away" at unnecessary bureaucracy and costly inefficiency.



The value of the Fort Polk ESPC shows in the Army's annual cash flow for energy and energy-related maintenance for family housing before, during, and after the 20-year contract term.

The Performance Contract: A Winner for Fort Polk

The Army and Co-Energy Group will share the dollar value of the cost savings realized through the energy retrofit over the 20-year life of the contract. Co-Energy Group is responsible for maintenance of the GHPs and for providing ongoing measurement and verification (M&V) to ensure that cost and energy savings continue to be delivered to the Army.

The Fort Polk performance contract spells out big benefits that begin immediately for the Army:

• **No capital investment by the Army and no cost to the federal government** • The ESCO arranged $18.9 million in private financing and is paid back over time from savings in operating budgets.

• **Capital renewal** • Fort Polk gets new equipment for heating, cooling, water heating, and lighting in 4,003 apartments, plus low-flow shower heads. Attic insulation was installed where needed.

• **Maintenance headaches banished** • For Fort Polk, the history of the lowest bidder taking on the job and getting overwhelmed by peak-season service calls is over. For the next 20 years the maintenance burden belongs to the ESCO.

• **Executive Order 12902** • The Energy Policy Act of 1992 requires the government to become more energy efficient. President Clinton, by Executive Order 12902, reinforced the law by mandating a 30% reduction in energy use by federal agencies by 2005, compared to a 1985 baseline. Fort Polk took a giant step toward achieving the mandated energy savings with its GHP-centered ESPC. By exceeding the 30% reduction mandate in family housing, which represented about 40% of base-wide energy consumption before the project, Fort Polk can easily meet its overall savings mandate by taking a few other well-targeted actions elsewhere on the base.

Federal agencies must use 30% less energy in 2005 than they did in 1985.

DOE Regional Support Offices

Seattle
Cheri Sayer (206) 553-7838
Curtis Framel
(206) 553-7841

Chicago
Sharon Gill (312) 886-8573

Boston
Paul King
(617) 565-9712

New York
Bill Klebous
(212) 264-0691

Philadelphia
Leah Boggs
(215) 656-6976
Claudia Marchione
(215) 656-6967

Denver
Randy Jones
(303) 275-4814

Atlanta
David Waldrop
(404) 347-3483
Doug Culbreth
(919) 782-5238

For more information about National Geothermal Heat Pump Super-ESPC contracts, contact your DOE Regional Support Office.

Super-ESPCs Available to All Federal Agencies

The happy outcome of this project for Fort Polk, though impressive, is just the beginning of the story. ORNL's verification of actual energy and maintenance cost savings builds a solid foundation of confidence in GHP technology; and energy savings performance contracting is a vehicle that is proving its advantages in public and private facilities nation-wide. (Turn the page for a brief discussion of how ESPCs and ESCOs work.)

The success at Fort Polk demonstrated how current state-of-the-art GHP technology can provide significant financial benefits to the federal government, and created the momentum to promote GHPs and ESPCs in the federal sector. FEMP (the DOE Federal Energy Management Program) has implemented National Geothermal Heat Pump "Super-ESPCs" to streamline the procurement process and encourage federal sites to capture the great potential energy and costs savings of GHP-centered ESPCs.

Beginning in late 1998, federal agencies can contract with ESCOs who have been competitively selected and pre-approved by FEMP to develop GHP-centered energy-efficiency projects at federal sites anywhere in the U.S. under the Super-ESPC. Delivery orders can be awarded in 4 to 8 months, and customers can be assured that any of these ESCOs are fully qualified to deliver top-quality GHP-centered energy-efficiency projects.

Benefits of the GHP Super-ESPC for Federal Agencies

- Gain new GHP heating, cooling, and water-heating systems and other energy-efficiency retrofits without capital appropriations.
- Get a guarantee that cost savings will exceed ESCO payments each year.
- Shed the burden of maintaining heating, cooling, and water-heating systems if desired.
- Reduce energy consumption in training facilities, family housing, barracks, office buildings, and other facilities by 33% or more.
- Free operating budgets from high energy costs and escape the downward spiral of deferred maintenance.
- Provide healthier, more comfortable, and more productive indoor environments for building occupants.
- Achieve the energy savings mandates of Executive Order 12902.

"*The beauty of the [Fort Polk] ESPC is that the onus to save Btu's is on the contractor. I'm a happy camper knowing that I have a single entity that I am going to deal with over the next twenty years, an entity with a profit motivation for saving energy and maintenance dollars.*"

— Jim Kelley, Manager of Engineering and Planning, Public Works, Fort Polk

ESCOs and ESPCs – The Basics

Energy savings performance contracting is a mechanism for expediting partnerships to finance and implement energy projects such as the GHP-centered retrofit at Fort Polk. The goal is to renew energy-consuming systems using private investment, realize energy and maintenance cost savings, and repay the financing from savings.

Energy service companies, or ESCOs, provide the expertise and financing to develop, build, and maintain energy-efficiency projects for customers, and their compensation is tied to the level of energy and maintenance cost savings realized for the customer by the project. Energy savings performance contracting differs from conventional contracting in four key respects—integration of services, management of risk, timing of payments, and structural incentives. In performance contracting, ESCOs take on a much wider spectrum of responsibilities and risks than is common in conventional contracting.

Integration of Services

ESCOs survey buildings to document the existing systems and to identify potential energy-cost-saving measures (ECMs). They verify the economic feasibility of ECMs and obtain customer approval for their selections of ECMs, equipment, and subcontractors. They propose a fixed price for their services, such as financing, installing, and maintaining the ECMs, to be paid from savings over the life of the contract. After agreement with the customer is reached, ESCOs bond and finance the project, engineer the ECMs and obtain customer approval of the designs, order the equipment, install and commission the project, and train customer personnel for their negotiated role in operating and maintaining the project, if any. After the project is built and accepted by the customer, the ESCO performs its negotiated services such as maintenance and measurement and verification (M&V) of savings during the term of the performance period. Some ESCOs also provide energy procurement services to ensure that customers obtain the most favorable prices for the energy commodities they buy.

Management of Risk

ESPC customers avoid the risks of conventional contracting because the ESCO is willing and able to carry them. In conventional contracting, equipment suppliers, consulting engineers, and construction contractors are paid fees upon delivery of their goods or services, and the customer has no assurance that the project as built in its facilities will generate cost savings as estimated. In energy savings performance contracting, the customer's only up-front costs are for procurement and administration; the ESCO uses its own or third-party financing to develop and install the project, and in federal projects the ESCO always assumes the permanent financing obligation after the project is built.

Timing of Payments

Under ESPCs, payments for ESCO services and debt service start after the project is installed, commissioned, demonstrated to have the potential to deliver the guaranteed level of savings, and accepted by the customer. Payments are tied to M&V, which determines whether the project is delivering the guaranteed level of savings. The ESCO reimburses the customer for savings shortfalls.

Structural Incentives

Several features of conventional contracting are well known to work against the customer's interests and must be skillfully worked around to design and build successful energy efficiency retrofit projects. When the engineering fee is a percentage of the mechanical construction cost, it can be an incentive to produce designs calling for higher construction costs. A fixed mechanical design fee may be an incentive to

The structure of the Fort Polk shared energy savings ESPC (and of the new "hybrid" federal ESP with guaranteed savings).

minimize time spent on the design, perhaps by adapting a design from a previous project, for example. These and other structural disincentives are avoided in performance contracting by better alignment of customer interests and ESCO interests. In federal energy savings performance contracting the customer makes no payments to the ESCO until after a project is built and accepted by the customer, and any payments must come from energy and related operation and maintenance cost savings. This creates a strong incentive for the ESCO to consider all potentially cost-effective ECMs, to recommend a package of ECMs that meets customer needs, and to design and implement them as expeditiously as possible. As with any negotiated business transaction, however, customers must be sufficiently educated and supported with objective technical assistance to ensure that a win-win agreement is reached.

Forms of Performance Contracts

The Fort Polk ESPC is a *shared energy savings contract* in which the ESCO arranges the financing and repays the debt from the stream of payments from the Army. The ESCO is paid a fixed share of the savings monthly, so payment amounts can vary. The shared energy savings contract has been replaced in the federal sector by the energy savings performance contract, which is described below.

In the guaranteed savings contract, which is commonly used by customers other than federal agencies, the customer signs one agreement with the ESCO and one with the financier of the project. The ESCO implements the project and typically guarantees that annual cost savings will exceed the customer's annual payment on the debt. This structure is especially attractive to state and local government entities because of the tax advantages to them of borrowing directly.

Recent federal projects follow the new energy savings performance contract structure [codified at 42 USC 8287 as amended by the Energy Policy Act of 1992 (P.L. 102-486, Section 155) and associated final rule 10 CFR Part 436.] This ESPC is a hybrid of the traditional *shared savings* and *guaranteed savings* contracts. The ESCO arranges the financing and repays the debt, but also guarantees the level of savings per year, receives fixed-amount payments from savings, and repays the customer for any savings shortfall.

"Project organizers say that one of the most appealing aspects of the contract—from the Army's standpoint—is that it enables the base commander at Fort Polk effectively to cap maintenance costs and turn the responsibility for maintenance over to a third party. . . . Co-Energy has a strong vested interest in performing regular preventive maintenance . . . , whereas the Army had frequently left HVAC maintenance at Fort Polk unfunded or deferred to the following year."

— *Energy Design Update,* September 1997

Advantages of GHPs

– for Federal Agency Sites

• Lower energy costs because of lower energy consumption.

• Lower energy costs because of improved energy use patterns.

• A simple system that requires no "operators" or specialized service contracts.

• An inherently low-maintenance system and lower maintenance costs.

• A more comfortable building, and greater productivity among occupants.

• Possible future cash benefits from emissions allowances, and "green" bragging rights in the meantime.

• GHPs have a lower life-cycle cost than any other space-conditioning system in many applications.

• Renovated buildings may actually gain usable space by making mechanical rooms smaller, because most GHP components are underground or distributed around the building.

– for Facility and Energy Managers

• Less labor is required to run buildings.

• Simple preventative maintenance can be performed by custodial staff.

• Maintenance staff are freed up to maintain other buildings.

• Less staff time off the job for O&M training, and less retraining needed because of staff turnover.

• Fewer service calls from occupants who feel uncomfortable even though the HVAC equipment is functioning as designed (e.g., two-pipe systems with seasonal switchover).

• No above-ground outdoor equipment to be vandalized or clogged with leaves or dirt.

• When space utilization is modified, it is relatively easy to add or move heat pumps to correspond to the new layout.

– for Building Occupants

• Improved comfort levels, indoor air quality, and productivity in many cases.

• No semiannual periods of discomfort associated with the seasonal switch of central HVAC systems between heating and cooling.

• Greater comfort control for occupants, with thermostats in each zone.

• The system can heat and cool separate zones simultaneously.

• No feeling that the system is "blowing cold air" in heating mode.

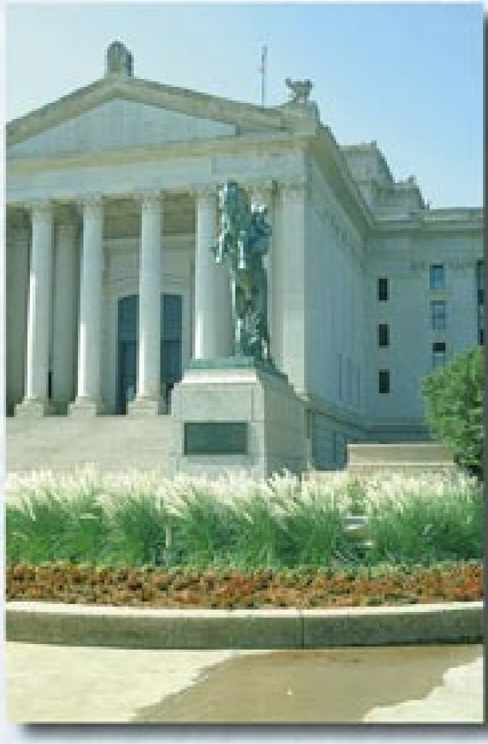
Advantages of GHP-Centered Projects Under the GHP Super-ESPC

– for Federal Agency Sites

• Using the Super-ESPC ensures correct alignment with ESPC statutory authority and full compliance with all federal procurement regulations that apply to performance contracting.

• Using the Super-ESPC saves time and resources: delivery orders can be awarded in 4 to 8 months, whereas individual site-specific ESPC procurements can take 2 to 3 years.

• The GHP Super-ESPC contracts were awarded to high-powered, financially stable ESCO teams that can offer financing at the lowest possible rates.



GHP systems are adaptable to virtually any kind of building, and nearly 10,000 GHPs have been installed in U.S. federal buildings. GHP technology is saving money in the Oklahoma State Capitol (right), as well as in many other state and local government buildings, over 400 schools, and thousands of low-income homes and apartments nationwide.

• Every ESCO operating under the Super-ESPC is motivated to make each project a success, because FEMP tracks agency satisfaction, and a poorly performing ESCO won't get a second chance.

• Competitive site-specific ESPC procurements to select an ESCO carry the risk of losing time and money if a rejected ESCO decides to lodge a protest with the OMB—a risk that the Super-ESPC eliminates completely.

• Project facilitators from FEMP Service Network (FSN) will lead agency site acquisition teams through the GHP Super-ESPC process for a modest fee, which can be paid at the beginning of the project or over 5 years.

• All projects under the GHP Super-ESPC contracts must center on GHPs, so agency sites can be assured that ESCOs awarded these national contracts will spend the extra time necessary to seriously consider GHPs for their facilities.

• All ESCOs that were awarded GHP Super-ESPC contracts were required to provide a rigorous demonstration of their GHP capabilities through past projects and a specific proposal for a large initial project, which eliminates the risk that GHPs may be misapplied if agency sites use these contracts.

• New GHP heating, cooling, and water-heating systems can be acquired at no capital cost; improvements are paid for out of energy and maintenance cost savings.

• Total costs are lowered by a combination of converting HVAC systems to GHP, eliminating other energy waste, decreasing maintenance costs, changing energy use patterns, and obtaining lower rates from current energy suppliers or finding lower-cost energy suppliers.

• Adequate operating budgets are guaranteed: ESPC project cost savings are guaranteed to exceed payments to the ESCO for services and debt retirement.

• GHP-centered ESPCs can conserve scarce capital resources for investment in core mission activities.

• If outsourcing of functions related to energy procurement, facility management, operations, or maintenance is part of the strategic plan, GHP-centered ESPCs provide a means to do so.

• The contract, through M&V, offers hard numbers on energy savings—important if emissions-allowance-trading systems are established.

– for Facility and Energy Managers

• GHP-centered ESPCs use future energy and maintenance savings to get resources to fix problems now.

• GHP-centered ESPCs lighten the workload of beleaguered O&M staff by renewing systems with inherently low-maintenance GHP technology and, if needed, by supplementing O&M resources.

• GHP-centered ESPCs tap expertise not available in-house to develop, finance, install, and operate GHP-centered projects.

• With performance contracting, GHP projects can be accomplished even in environments where energy projects are not a high priority.

• GHP-centered ESPCs provide broad integration of services; the customer deals with one ESCO rather than a number of consultants, contractors, drillers, and suppliers.

• GHP-centered ESPCs provide a structure that aligns the interests of the ESCO with those of the customer and shifts the risks to the ESCO.

• In-house staff may be trained to operate and maintain GHPs and other ESCO-installed systems, and those skills can be applied in other buildings, even those not part of the ESPC project.

– for Building Occupants

• ESPCs can provide new GHP heating, cooling, and water-heating systems that improve comfort, indoor air quality, and productivity.

• ESPCs motivate ESCOs to educate building occupants and keep them happy, because occupants affect energy consumption.

• ESPCs can take the strain off tight budgets, freeing up tenants' capital for investment in core mission activities.

"The service people who live in [Fort Polk] housing are substantially more comfortable than they were before. For the first time ever, the equipment servicing those units is properly engineered and sized. In the cooling mode, it can bring the humidity down to 45%, which means more comfort and no mold and mildew."

— Brian Haggart, President, Environmental Group/ClimateMaster

Geothermal Heat Pump systems can be configured for all kinds of buildings.

The type of ground loop that is most economical for the building site depends on available land area, soil and rock type, and hydrology.

Geothermal heat pumps take advantage of the earth's relatively constant temperature to provide clean and efficient heating and cooling year round.

One or more loops of piping circulate water or other fluid, transferring heat from the ground (or groundwater or surface water) to warm the building during winter. During the summer, the system transfers heat from the building to the ground to provide cooling.

The Fort Polk Story–Developing the World's Largest Installation of Geothermal Heat Pumps

The Fort Polk Joint Readiness Training Center in west-central Louisiana is a 200,000-acre Army base where military and civilian personnel are trained for airlift, close-air support, resupply, and battlefield combat missions. Altogether some 23,000 military personnel and family members live on the base; about 12,000 people live in Fort Polk family housing.

Family housing at Fort Polk consists of 4,003 living units in 1,290 buildings. New heat pumps, energy-efficient lighting, and low-flow shower heads were installed in each unit. Attic insulation was added where needed.

Maintenance Headaches

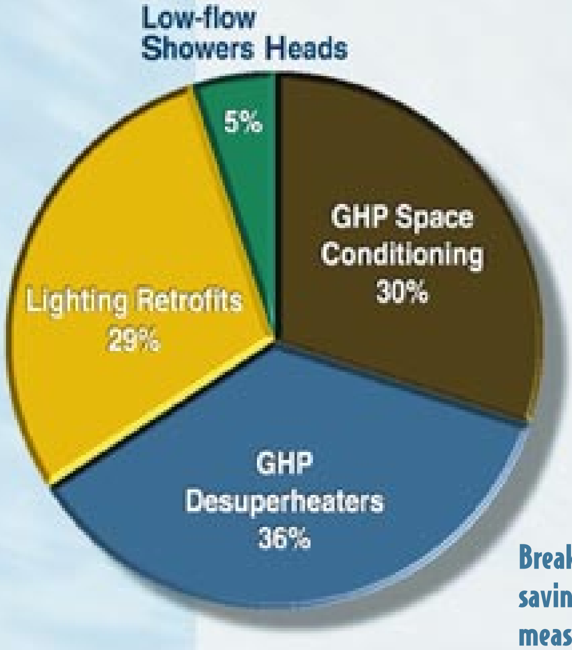
At Fort Polk, acute and worsening maintenance headaches were the primary motivation for seeking a package deal that would allow the Army to shed maintenance responsibilities and to renew the heating and cooling systems. The HVAC equipment in family housing was a hodgepodge of minimum-efficiency units selected on the basis of low bids, often misapplied in terms of sizing, and suffering from poor-quality installation. In the face of increasing service requests, the base had outsourced family housing maintenance to a series of the lowest-bidding contractors. As service calls increased and the difficulty of stocking parts and training technicians for the miscellaneous units overwhelmed the contractors' budgets, the net result was poor service for the residents and financial difficulties for some contractors. By the early 1990s all of these problems, aggravated by aging equipment, made the situation intolerable. In July of the last year before the retrofit, there was an average of 90 service calls per day and over 100 calls on the worst days.

Budget Constraints

Fort Polk also faced budget constraints familiar to federal agencies nationwide: No one knew when a capital appropriations request might be approved, and some feared that when funding for renewal did become available, it would be phased so that the history of piecemeal upgrades would repeat itself. Still, the energy-savings mandates of Executive Order 12902 would have to be met. The deficit reduction mood in Congress also meant that Fort Polk's $13 million annual energy budget—in which family housing represented a 40% and rising share—would be flat at best, so that any growth in energy costs would have to come out of training or salary dollars.

The Solution

It became clear that an ESPC could be the solution at Fort Polk. Instead of using a big capital expenditure, an ESPC could accomplish the needed construction and be paid for out of cost savings without adding to the operating budget, and the maintenance headaches would be cured.

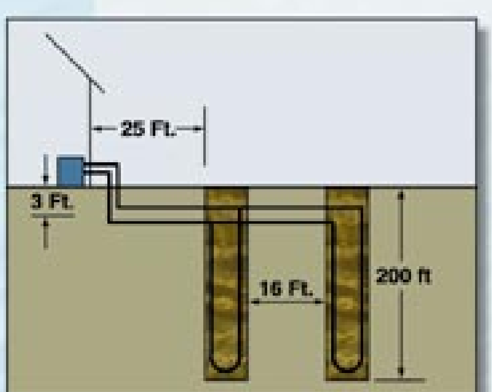


Breakdown of energy savings by conservation measure (Feeder 1).

The U.S. Army Engineering and Support Center, Huntsville, the Army's center of excellence for performance contracting, was paid about $140,000 to support project development and implementation, including determining feasibility, developing the RFP, and negotiating and awarding the contract. The RFP conveyed a preference, but not a requirement, for GHPs.

Only one ESCO, Co-Energy Group, bid for the project. At that time the maintenance savings advantage of GHPs was a well-kept secret. If the Fort Polk RFP were issued today, now that the word is out, more ESCOs would bid.

Co-Energy Group agreed to bear all the up-front costs of the project and assume responsibility for maintenance in exchange for a 77.5% share of the energy savings and a fixed price for maintenance equal to 77.5% of the Army's projected cost for maintenance without the energy retrofit. Co-Energy Group would replace 4,003 HVAC systems with GHPs and also install other energy- and water-conservation features that had proven cost-effective in similar projects.



Each apartment's heat pump is linked to two U-shaped ground heat exchangers that are in $4^1/_8$-inch vertical bores.

The Fort Polk GHP Systems

The GHP configuration implemented at Fort Polk is a closed-loop, vertical-borehole ground heat exchanger system. The heat exchanger, heat pump, and other components of the system were designed for easy installation, compact size, maximum efficiency, long life, low maintenance cost, and to provide a more comfortable environment for residents.

At Fort Polk, the ESCO bears the actual cost of maintenance of the installed equipment while being paid a fixed price, which is a powerful motivation for the ESCO to ensure long-term reliability and control maintenance costs. Energy efficiency is an equally high priority. And any ESCO experienced in housing projects knows that Rule No. 1 is to keep the occupants happy, because they can have a major influence on energy use. More comfortable homes and the financial success of the Fort Polk ESPC were the natural outcomes of careful and innovative design and engineering that capitalized on the inherent efficiency of GHPs.

New GHP Design for Efficiency and Low-Cost Installation

When Co-Energy Group was developing the project, none of the 1.5- to 2-ton GHPs on the market had high enough efficiency and low enough installation costs to make the project feasible. Co-Energy's partner, the GHP manufacturer ClimateMaster, overcame that obstacle by redesigning some of its smaller units to project specifications. This is one of the reasons that Co-Energy Group was able to bid the project while others were unable to find savings sufficient to cover costs.

The heat pump is a packaged water-to-air unit that is factory-charged with refrigerant, which avoids the problems associated with field-charged, split-system refrigeration systems. Since there is no interface to outdoor air, there are no defrost controls to maintain. And because the units are not outdoors or exposed to the weather, performance degradation resulting from

"Where you have a lot of air conditioning combined with electric water heating, desuperheaters are a real winner. It's like getting free hot water for half the year."

— Gary Phetteplace
U.S. Army Cold Regions Research Laboratory

corrosion, vandalism, or clogging with leaves or mud, for example, is not an issue.

Installation costs were reduced significantly by building the pump and valves that circulate water through the ground loop, along with controls, into the unit. This avoids the expense of mounting components on walls and making multiple power and plumbing connections. It also saves valuable floor space and makes for a more aesthetic installation.

The heat exchanger's underground piping is high-density polyethylene, which is often guaranteed by the manufacturer for 50 years. The pipe was purchased in "uni-coils" (preassembled U-bend loops sized for the bore length), which can be installed quickly. All joints are thermally fused, and with uni-coils, the only field-installed fusion joints are near the surface.

In heating mode GHPs deliver air to the registers at about 105ºF, which is 10-15ºF warmer than air-source heat pumps will do, and warm enough to preclude complaints about the system "blowing cold air."

The Supporting Cast of Energy Savers

Seventy-five percent of the new heat pumps utilize desuperheaters, which recover waste heat from the GHPs and transfer it into the water heater. (In 25% of the living units, the heat pumps and water heaters were too far apart to make desuperheater installation practical.) Co-Energy Group also installed attic insulation where needed, low-flow shower heads, and compact fluorescent lights. Weather-stripping and storm windows were not installed because the housing units were already fairly tight and the potential energy savings did not justify the investment. So, too, with duct sealing work, except in cases where leaks were large enough to cause serious performance or comfort problems. Window treatments were upgraded in some apartments to allow use of smaller heat pumps.

The Importance of Engineering and Project Management

The quality of engineering and project management that went into the Fort Polk project was certainly key to its success. Observers of the project have applauded the remarkable project management and coordination achievements of Co-Energy Group and the thorough engineering performed by Applied Energy Management Techniques, a subcontractor to Co-Energy Group. ClimateMaster also contributed significantly to engineering efforts, and other advisors were consulted as well. The magnitude of the project demanded second and third opinions.

The engineering tasks included: (1) developing models of energy consumption and performing design calculations to size heat pumps and ground heat exchangers for 4,003 apartments; (2) engineering the other retrofits for each apartment, and (3) estimating overall energy savings.

About 686 miles' worth of piping was installed in the heat exchangers at Fort Polk. The pipe was preassembled and installed as "uni-coils," so the only fusion joints in the piping are near the surface—one of several measures to control installation and maintenance costs.

Construction

The major challenge in project construction was drilling and installing over 8,000 borehole heat exchangers. To keep the project on track, local Louisiana drilling crews were joined by crews from Texas, Oklahoma, and Arkansas. At the peak of the drilling phase, 27 drill rigs were on site installing 100 borehole heat exchangers per day to depths of about 200 feet. Some of the crews were water-well drillers; others were shothole seismic prospectors, as they're known in the oil industry, who use explosives to find oil when they're not installing GHPs.

Before construction began, Co-Energy had taken over maintenance and hired in the core staff of the last of Fort Polk's maintenance contractors. These people were trained to lead indoor installation crews, and others were hired to staff the crews. At the peak of the work, 20 heat pumps were being installed per day. Other crews had already installed the lighting, showerhead, and attic insulation retrofits.

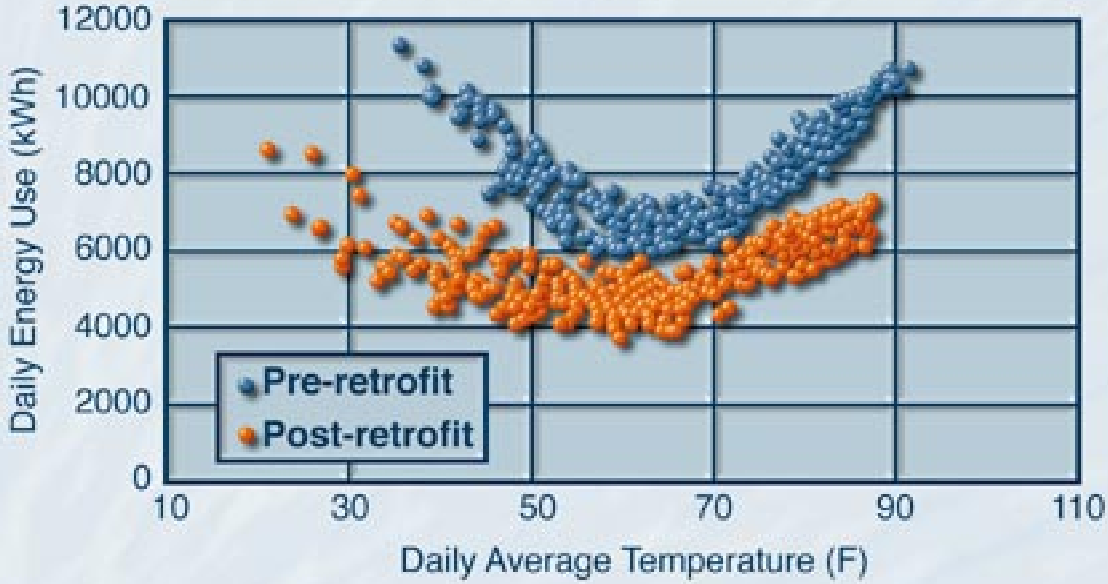
The Results: Dramatic Energy Savings

The Fort Polk retrofits are producing dramatic savings. According to ORNL's evaluation, annual electricity consumption in Fort Polk family housing dropped by about 26 million kWh, a 33% reduction. Natural gas consumption for space and water heating of 260,000 therms per year was eliminated completely. These savings result in an estimated reduction in CO_2 emissions of 22,400 tons per year. Summer peak electrical demand has been reduced by 7.5 MW, a 43% reduction, equivalent to a decrease of almost 2 kWh per house. The electrical energy and demand savings correspond to an improvement in annual electric load factor from 0.52 to 0.62.

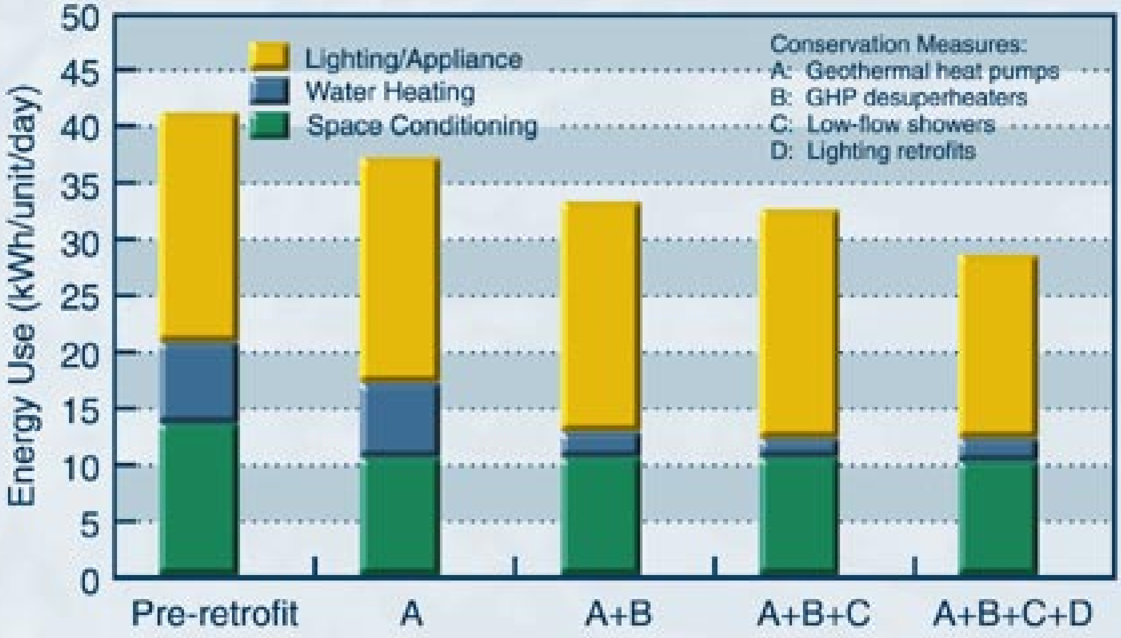
This overall 33% reduction in electricity use was achieved even though electric-powered GHPs replaced natural-gas-fueled furnaces and water heaters in 20% of the apartments. As expected, the average electricity savings in housing units that were originally all-electric was substantially higher than the savings in units that had used natural gas before the retrofit, measuring 35% and 14%, respectively. In apartments that were all-electric before the retrofit, the GHPs were found to save about 42% of the pre-retrofit electrical consumption for heating, cooling, and water heating. The proportion of total energy savings attributable to the new GHPs—through the heat pumps themselves and through the desuperheaters for water heating—was a whopping 66% in 200 apartments on Feeder 1 that were all-electric before the retrofit.

Energy and maintenance cost savings to the Army amount to $345,000 per year during the 20-year contract and over $2 million annually thereafter for as long as the GHPs last.

A total of 1.8 million feet of $4\frac{1}{8}$-inch bore was drilled for installation of 3.6 million feet of high-density polyethylene pipe for over 8,000 ground heat exchangers.



The project at Fort Polk reduced annual electricity use in family housing by about 33%. This plot shows pre- and post-retrofit daily electricity use on Feeder 1, which served housing that was all-electric before the retrofits.



Impact of retrofits on electricity use for space conditioning, water heating, and lighting and appliances (Feeder 1).

ORNL's reports on the evaluation of the Fort Polk project are available to the public from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161 (703-487-4650) and to DOE and DOE contractors from the Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831 (423-576-8401). Ask for:

• The Evaluation of a 4000-Home Geothermal Heat Pump Retrofit at Fort Polk, Louisiana: Final Report, Report ORNL/CON-460 (1998), by P. J. Hughes and J. A. Shonder, and

• Methodology for the Evaluation of a 4000-Home Geothermal Heat Pump Retrofit at Fort Polk, Louisiana, Report ORNL/CON-462 (1998), by P. J. Hughes et al.

ORNL's Evaluation Methodology

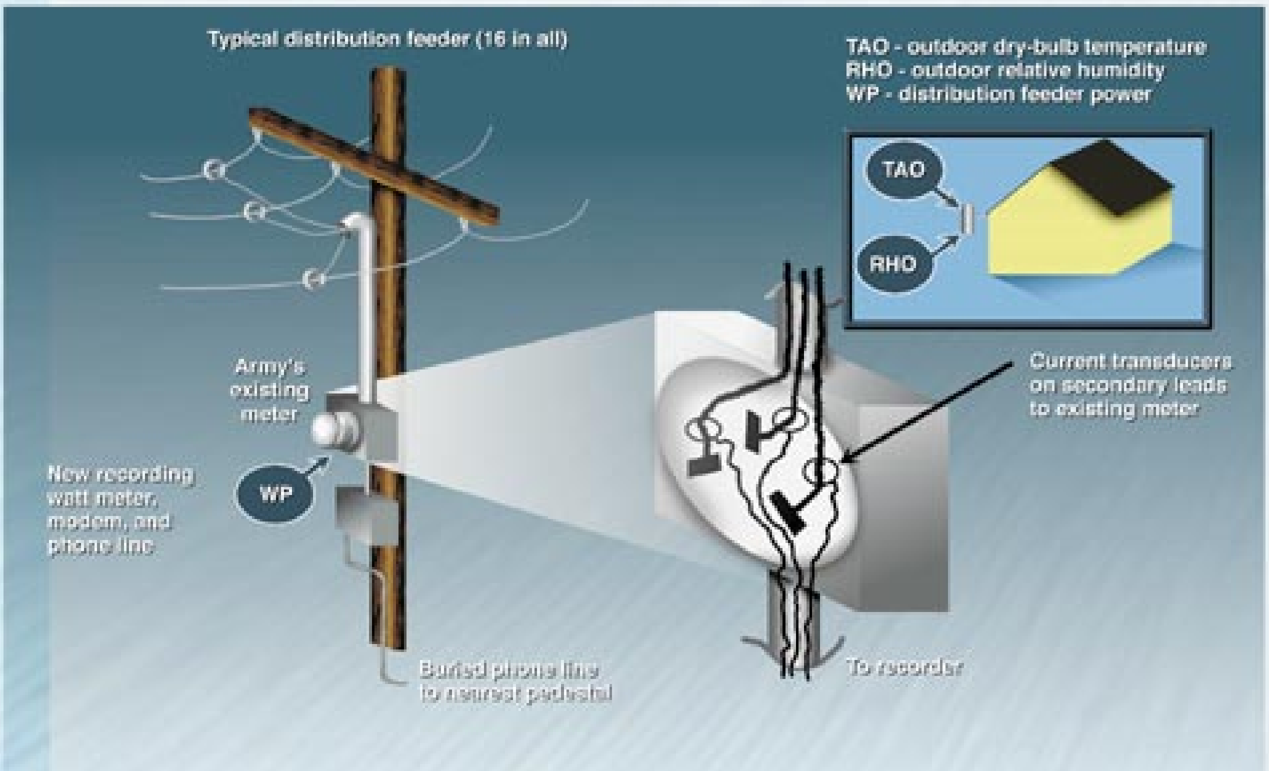
For ORNL's evaluation of the Fort Polk project, data were collected to show electricity consumption per feeder (Level 1), per apartment (Level 2), and per water heater and heating/cooling system (Level 3). "Energy balance" data were collected from one building.

Researchers from ORNL analyzed the impacts of the Fort Polk retrofit project on energy use, electrical demand, and maintenance costs. The evaluation was based on a three-tier data collection strategy. Data were collected to show electricity consumption per feeder (Level 1), per apartment (Level 2), and per water heater and heating/cooling system (Level 3).

The most aggregated level of data—Level 1—was taken at 14 of 16 electric distribution feeders supplying the family housing areas. Feeder 1, for example, serves the electrical loads in 200 apartments in 46 buildings, as well as streetlighting in the neighborhood.

The evaluation addressed maintenance costs by developing an estimate of the maintenance cost baseline (i.e., maintenance costs that would have occurred had the project not been done). An actuarial approach was used to estimate equipment replacement rates over the 20-year contract term, based on a census of the age of existing HVAC equipment. Estimates of service call frequency, required maintenance actions, and required labor were derived from apartment service records from the last year before the retrofit.

The reports on the Fort Polk evaluation document the details of ORNL's analyses of energy savings, maintenance savings, calibrated models for estimating energy savings, and methods for designing GHP systems and performing M&V.



Data on electricity use were collected from submeters on the electrical feeders. Temperature and humidity data were also collected at 15-minute intervals at four different locations in family housing.

Lessons Learned at Fort Polk

• Quality Engineering • The thorough engineering of the Fort Polk project before installation was a key reason for its success, and quality engineering is important for any ESPC project. The optimal design of a GHP system will minimize cost and maximize effectiveness, and accurate predictions of energy savings can reduce risk and decrease financing costs.

• Engineering Models to Predict Energy Savings • For very little effort beyond that needed to properly size the GHPs, engineering models of the pre-retrofit facilities can be calibrated to pre-retrofit consumption data, the retrofits can be implemented in the models to estimate post-retrofit energy consumption, and accurate estimates of retrofit energy savings can be derived by applying the modeled post-retrofit percentage savings to the pre-retrofit consumption data. ORNL predicted the measured energy savings on Feeder 1 to within 1% using this technique.

• The Best GHP Configuration • The vertical borehole ground heat exchanger is only one of many GHP configurations. Considering all the options will lead to the most cost-effective GHP configuration for the application.

• Maintenance Savings • In GHP-centered projects, maintenance savings may be of the same order of magnitude as energy savings. A realistic maintenance baseline is important in determining financial outcomes.

• Engineering Models • Computer models of GHP systems in building energy analysis tools are orders of magnitude better now than they were when the Fort Polk project was developed.

• Sizing Methods • ORNL found that five different methods used to size vertical-borehole ground heat exchangers yielded widely varying results when the Fort Polk project was developed. Since then new versions of some of these methods have been introduced, and agreement across methods is substantially improved.

• Thermal Properties • A critical input to vertical-borehole ground heat exchanger sizing methods is the thermal properties of the soil/rock formation of the bore field. New commercial services have emerged that will install one or more vertical-borehole ground heat exchangers on site for pre-project testing and reliably determine soil/rock properties. This information allows more precise designs and tighter bidding by drilling contractors.

• Thermally Enhanced Grouts • Bentonite grouts used as bore backfill material offer the advantages of effectively sealing the bore to prevent potential groundwater contamination from vertical movement of water, and of providing a solid conduction path between the pipes and the bore wall. However, the thermal conductivity of bentonite grout is low and the grout acts as a pipe insulator, resulting in the need for longer bore lengths. In areas with only one aquifer, rather than several at different depths, a grout plug at the surface can protect groundwater, and backfilling the bore with pumped sand or thermally enhanced grout can improve thermal performance and result in more economical designs.

• The M&V Options • ORNL's analysis of the four major measurement and verification (M&V) options, along with the experience at Fort Polk, leads to the conclusion that there is no one best approach to M&V, and that all options or even combinations of options may be appropriate for GHP-centered ESPC projects. Customers and ESCOs need to balance cost against precision as they evaluate and agree on methods for their projects.

• The M&V Balance • M&V is a project cost that must be covered by the savings generated by the project. Overly zealous M&V may require sacrificing some energy conservation measures or lengthening the contract term.

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Resources for learning more about Geothermal Heat Pumps and Energy Savings Performance Contracts:

Oak Ridge National Laboratory
Julia Kelley 423-574-1013
Fax: 423-574-9329
e-mail: kellyjs@ornl.gov

International Ground Source Heat Pump Association (IGSHPA)
490 Cordell South
Oklahoma State University
Stillwater, OK 74078-8018
405-744-5175 or 800-626-4747
Fax: 405-744-5283
http://www.igshpa.okstate.edu

Geothermal Heat Pump Consortium, Inc. (GHPC)
701 Pennsylvania Ave., N.W.
Washington, DC 20004-2696
202-508-5500 or 888-All-4-GEO
Fax: 202-508-5222
http://www.ghpc.org/

DOE Federal Energy Management Program (FEMP)
http://www.eren.doe.gov/femp/

DOE FEMP GHP Page
http://www.eren.doe.gov/femp/financing/tecspec.html
(click on Geothermal Heat Pumps)

DOE Regional Support Offices

Western Region: Seattle
Cheri Sayer 206-553-7838
cheri.sayer@hq.doe.gov
Curtis Framel 206-553-7841
curtis.framel@hq.doe.gov

Central Region: Denver
Randy Jones 303-275-4814
randy.jones@hq.doe.gov

Midwest Region: Chicago
Sharon Gill 312-886-8573
sharon.gill@hq.doe.gov

Southeast Region: Atlanta
Dave Waldrop 404-347-3483
david.waldrop@hq.doe.gov
Doug Culbreth 919-782-5238
carson.culbreth@hq.doe.gov

Northeast Region:
CT, ME, MA, NH, RI, VT
Paul King 617-565-9712
paul.king@hq.doe.gov

Northeast Region:
NJ, NY
Bill Klebous 212-264-0691
william.klebous@hq.doe.gov

Mid-Atlantic Region:
DE, DC, MD, PA, VA, WV
Leah Boggs 215-656-6976
leah.boggs@hq.doe.gov
Claudia Marchione 215-656-6967

Oak Ridge National Laboratory
Buildings Technology Center
Julia Kelley
P.O. Box 2008
Oak Ridge, TN 37831-6186

Oak Ridge National Laboratory

U. S. Department of Energy
Office of Energy Efficiency and Renewable
Energy, Geothermal Heat Pump Program

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