TECHNICAL AND MARKET RESULTS OF MAJOR U.S. GEOTHERMAL HEAT PUMP PROGRAMS

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ABSTRACT

The term geothermal heat pumps (also known as GHPs, ground-coupled heat pumps, and GeoExchange systems) refers to a family of systems that meet heating, cooling, and water heating needs while using 20 – 40% less energy than conventional space-conditioning systems. The GHP industry evolved from a few refinements in commercially available water-source heat pump and natural gas distribution pipe technology. Closed-loop ground heat exchangers made of high-density polyethylene, in combination with water-source heat pumps modified to operate over an extended range of entering water temperatures, enabled GHP systems to operate cost-effectively for both residential and commercial/institutional buildings in virtually any climate. Electric utilities in the United States, led initially by the rural electric cooperatives, embraced GHPs as a means to reduce utility peak loads, improve load factors, and gain market share. Policy makers took notice and estimated that widespread use of GHPs would enable the United States to save as much as 2.7 quads of energy, or over 3% of the nation's total. As part of the U.S. Department of Energy's overall GHP effort, several programs were launched to support mainstreaming the use of GHPs — including the National Earth Comfort Program and the Federal Energy Management Program's GHP technology-specific program. This paper describes these two major GHP programs, reviews their technical and market results, and discusses the lessons learned.

1. INTRODUCTION

The term geothermal heat pumps (also known as GHPs, ground-coupled heat pumps, and GeoExchange systems) refers to a family of systems that meet heating, cooling, and water heating needs while using 20 – 40% less energy than conventional space conditioning systems. GHP systems accomplish this by tapping heat sources and sinks that are near the buildings served — such as the ground, groundwater, surface water, wastewater streams, or potable water supplies (where allowed) — via water-source heat pumps (DOE FEMP 1999). These heat sources/sinks have moderate temperatures compared to outdoor air, the heat source/sink for conventional space-conditioning systems. GHPs are a renewable energy technology because the natural processes that sustain the sources/sinks at friendlier temperatures than outdoor air are always at work.

Water-source heat pumps (WSHPs) have been manufactured as a commercial product in the United States since the late 1950s (Hughes 1990). The original markets for WSHPs were primarily residential. The first market was in southern Florida, and these early systems used groundwater or canal water as the energy source/sink. Water was pumped from the source and discharged directly through the heat pump to the surface (canal, ditch, etc.).

In the early 1960s, systems for commercial and institutional applications using separate heat pumps for each zone, but connected to a common water loop, began to appear on the U.S.

West Coast. Referred to as the California heat pump system, the closed common loop was conditioned with an indirect closed-circuit water cooler for heat rejection and a boiler for heat addition to keep WSHP entering water temperatures within design limits. This concept quickly spread to the East Coast and elsewhere in North America. Today this system configuration is commonly referred to as the water-loop heat pump (WLHP) system (Pietsch 1988), and the market is primarily commercial office buildings but includes institutional buildings such as schools as well.

In the late 1970s and early 1980s the GHP industry began evolving from the older WSHP industry. With minor refinements WSHPs were made operable over an extended range of entering water temperatures. This enabled closed-loop ground heat exchangers to replace groundwater "pump and dump" as the geothermal source/sink in residential applications, and enabled ground heat exchangers to replace the boilers and towers in commercial and institutional applications.

The vast majority of GHPs in the United States are installed with the closed-loop system using continuous high-density polyethylene pipe buried in the earth, either in vertical or horizontal configuration. The closed-loop technology permits GHPs to be applied effectively almost anywhere, and this universal applicability was one of the keys to rapid growth in recent years.

The GHP industry started with very industrious entrepreneurs, including contractors and manufacturers, who built viable enterprises before any government or utility involvement. Since the early 1980s the utility industry has sponsored many modest but successful GHP programs in their service territories that clearly boosted the small industry in some localities. The U.S. Department of Energy (DOE), dating back to 1978, and utilities and their associations [the National Rural Electric Cooperative Association (NRECA) and the Electric Power Research Institute (EPRI)] sponsored modest R&D efforts in support of the fledgling GHP industry.

Some of the earliest and perhaps most widespread utility support of the GHP industry came from rural electric cooperatives (RECs) because of their unique circumstances. Most RECs are electric distribution companies that buy their power from statewide generation and transmission cooperatives (G&Ts) or investor-owned utilities (IOUs) on the wholesale market. The aggregate pattern of the electric loads they serve influences how economically RECs can procure wholesale power for resale to their customers. Lower peak demands and higher annual load factors are preferred. This pricing signal often encouraged RECs to seek ways to shave the peak loads — one of the main reasons the authors believe that hundreds of RECs helped the industry promote GHPs. A number shaved peak loads by 5 – 10 MW, others improved load factors by over 10%, and some even got directly into the GHP sales, installation, and service business.

Support of the GHP industry by IOUs came later, but their resources were orders of magnitude larger than RECs', so even a few successful IOU programs could have a noticeable impact. Since they could simply roll the cost of new power plants into the rate base, IOUs had less incentive to aggressively reduce peak loads. An informal review of utility programs, including both RECs and IOUs, found that the successful utilities often focused on a combination of commercial buildings, schools, and residential. One of the most successful GHP programs was developed by a utility that hired a vice president of marketing from a private-sector company. A benchmarking study found that utilities, which were regulated enterprises inexperienced in competitive business practices, often struggled as they ventured into the competitive market arena of GHPs and energy services (DOE 1997).

By the 1990s policy makers in Washington, D.C., noticed GHPs. DOE's Energy Information Administration (EIA), in a report supporting development of the National Energy Strategy, estimated GHP energy savings potential at 2.7 quadrillion Btu by 2030, up from less than 0.01 quad in 1990 (U.S. DOE 1990). A study by the U.S. Environmental Protection Agency (EPA) comparing the major HVAC options for residential applications determined that GHPs were the most energy efficient and environmentally benign option (EPA 1993). It became recognized that if — a *big* if — GHP technology were commonplace throughout the nation, the energy savings and emissions reductions would be significant. This set the stage for initiation of several major GHP programs, which are the topic of this paper.

In October 1993 the Clinton administration launched the Climate Change Action Plan as well as the voluntary Climate Challenge, a partnership between DOE and major electric utilities who pledged to reduce their greenhouse gas emissions. The Climate Challenge attracted over 50 utilities, whose chief executive officers sent letters to the Secretary of Energy stating their intent to either stabilize their greenhouse emissions at or below their 1990 levels or reduce their emissions to a different measurable performance level (DOE 1993). The Edison Electric Institute (EEI), supported by the NRECA and EPRI, selected GHPs as one of its five initiatives under the President's Climate Change Action Plan.

At about the same time DOE's Federal Energy Management Program (FEMP) was formed "to reduce the cost and environmental impact of the government by advancing energy efficiency and water conservation, promoting the use of renewable energy, and improving utility management decisions at Federal sites."

2. DESCRIPTION OF MAJOR U.S. GHP PROGRAMS

2.1 NATIONAL EARTH COMFORT PROGRAM

In 1994 DOE, EEI, NRECA, EPRI, the International Ground Source Heat Pump Association (IGSHPA), EPA, and several utilities initiated a collaborative effort for GHP market mobilization and technology demonstration called the National Earth Comfort Program (GHPC 1994). This program was supposed to build upon the GHP activities already underway led by industry, IGSHPA, DOE national laboratories, universities, EPRI, and NRECA. The program goals were to (1) reduce greenhouse gas emissions by 1.5 million metric tons of carbon annually by the year 2000, (2) increase GHP annual unit sales from 40,000 to 400,000 by the year 2000, saving over 300 trillion Btu annually, and (3) create a sustainable market for GHPs, a market not dependent on utility-provided rebates or government incentives.

Program objectives were to reduce the barriers to widespread customer acceptance of GHPs. The program developers saw three primary market penetration barriers: (1) GHPs cost \$2,000 – \$5,000 more per unit installed than conventional residential HVAC systems; (2) the benefits and advantages of GHPs are generally unknown to customers and opinion leaders; and (3) the infrastructure needed to reduce front-end costs and ensure customer satisfaction existed in only a few places.

The Geothermal Heat Pump Consortium, Inc. (GHPC) was formed to implement the National Earth Comfort Program and was registered as a non-profit corporation (GHPC 2001). The GHPC was organized around three operating committees, with each expected to address one of the three primary barriers to market penetration. These committees were (1) First Cost Competitiveness Committee, (2) Technology Confidence Building Committee, and (3) Infrastructure Strengthening Committee.

The three operating committees were responsible for planning, budgeting, proposing, and then subcontracting and overseeing projects in their areas. Electric utilities selected by the board were responsible for assigning qualified utility employees to assume the leadership roles on all operating committees. Below are overviews of the perceived barriers addressed by each operating committee and actions contemplated to address them at the outset of the program.

First-Cost Competitiveness. The biggest barrier for *any* energy-efficient technology, especially in the residential market, is its first-cost premium over standard-efficiency technology. This was true for GHP systems, which had a first-cost premium of $2,000 – $5,000 in residences, as well as cost premiums in most commercial applications. Program designers identified several ways in which this barrier could be addressed (GHPC 2001):

- Financing. Alternative financing options to move first-cost components into a financing stream, allowing the customer to achieve a positive cash flow by paying for the financing through the energy and maintenance savings.
- DSM programs. Model utility demand-side management (DSM) programs to increase market activity in a region and increase competition, thereby leading to lower prices for GHP systems.
- Drilling technology enhancements, expected to lead to lower costs for ground heat exchangers.
- System performance R&D, expected to lead to performance enhancements, or at least market recognition of the already-superior performance characteristics of the technology, to help overcome first-cost problems.

Technology Confidence Building. Although GHPs had by 1994 been *technically* proven, customers, developers, builders, architects, engineers, HVAC contractors, utility program personnel, environmental regulators and building code officials were still generally unaware of its existence. Those who did know of the technology were often aware of its first-cost barrier, without having any confidence in its ability to save on energy and maintenance costs and to perform reliably over time. Program designers believed that such confidence could only be created by real market experience. The mechanisms that were identified to address the lack of awareness of and confidence in GHP technology were the following (GHPC 2001):

- DSM programs. Investment by utilities in strong regional DSM programs highlighting GHP, beginning with high-level utility executive buy-in and involving strong public awareness and trade ally development programs.
- National public awareness campaign. This campaign, leveraged by the regional utility DSM programs, would educate end-users through regional and national media, public relations campaigns, and disseminated materials, information, and tools.
- Technology transfer. Communication of successful program designs among utilities, starting with at least six strong regional programs and spreading to other utility service territories as lessons are learned and success is demonstrated.

Infrastructure Strengthening. Initially GHP shipments were estimated at about 40,000 units per year. A subsequent DOE-EIA survey established 1994 baseline sales at only 28,094 (DOE 1999). This represented about 0.5% of national sales of HVAC equipment (boilers, furnaces, air conditioners, and heat pumps). Such a low level of market penetration, coupled with low awareness and higher first cost, resulted in a very weak infrastructure of residential and commercial marketers, designers, and installers. In many areas, the supply infrastructure was essentially non-existent. Measures that were identified to strengthen market infrastructure were (GHPC 2001):

- Technology awareness. Improve awareness of and support for GHP technology among state and local regulators, and standardize regulations and codes that affect GHP installations (drilling regulations in particular).
- Training and certifying installation technicians. Increase participation in the industry and improve system performance and reliability; also increase the industry's responsiveness to marketing opportunities and servicing needs.

- Tailored materials, data and tools. Developed to incorporate the latest research, in order to help architects, engineers, developers, builders, and installers produce optimal system designs at the lowest possible cost without compromising performance and reliability.
- Developing equipment and installation standards and rating systems. Facilitate market acceptance of GHP technology.

The original concept for funding of this public/private partnership went as follows: Subject to sufficient annual appropriations by Congress, DOE was to provide $35 million to the overall GHP program, including the National Earth Comfort Program, to be matched with $65 million in private (primarily utility) funding over the seven-year program term. The funding plan assumed that some of the utility funds would come to the GHPC to help sponsor national operations, but that by far most utility funds would be spent directly by utilities on market mobilization programs within their service territories. Table 1 summarizes the original spending plan.

Table 1. Original plan for funding the overall GHP program including the National Earth Comfort Program

Fiscal year	DOE funding ($ millions)	Private funding ($ millions)	Total program funding ($ millions)
1994	0.0	6.0	6.0
1995	6.5	13.0	19.5
1996	9.0	13.0	22.0
1997	8.5	14.0	22.5
1998	5.5	8.0	13.5
1999	4.0	7.0	11.0
2000	1.5	4.0	5.5
All years	35.0	65.0	100.0

To raise funds to help sponsor national programs, GHPC formulated a membership dues structure that initially focused on utilities as the primary source of private-sector funding. Annual dues for utilities were set at $0.10 per residential meter, with a cap of $50,000. This meant that utilities with more than 500,000 residential meters paid the same level of membership dues each year.

2.2 FEMP'S GHP TECHNOLOGY-SPECIFIC PROGRAM

DOE's Federal Energy Management Program (FEMP) is one of the sectors within DOE's Office of Energy Efficiency and Renewable Energy (EERE). The primary mission of all the sectors within EERE except for FEMP is technology R&D. FEMP's mission is multi-faceted, but its most relevant aspect to this report is its effort to help U.S. federal agencies meet their mandates to reduce energy use in the 500,000 U.S. federal buildings (President Clinton 1999).

U.S. federal energy goals are expressed in terms of energy intensity (site usage in Btu per building area). The goals for 2005 and 2010 are 30 and 35% reductions in energy intensity, respectively, in comparison to 1985 energy consumption. To meet the 2010 goal federal facilities need to reduce their site energy consumption by an estimated 50 trillion Btu per year during the 2001–2010 period.

FEMP has many strategies for assisting agencies. These include design assistance to help agencies design and construct new buildings right the first time and guidelines making it easy for agencies to select equipment from among the most efficient available in each product category when making purchases. However, over 80% of the required annual savings of 50 trillion Btu is expected to come from retrofits of existing buildings. These projects include energy conservation measures (ECMs) such as lighting upgrades, insulation improvements, motor and drive upgrades, building control improvements, and HVAC equipment replacements. Because agencies rarely have all the appropriations they need to develop and fund energy-efficiency projects, FEMP supports agencies in the use of private-sector vehicles for project development and financing such as Energy Savings Performance Contracts (ESPCs) and Utility Energy Services Contracts (UESCs).

FEMP's agency customers are mandated to reduce building energy use, and they spend billions of dollars per year on new building construction, equipment purchases, major building renovations, energy, and energy-related operations and maintenance expenses. Therefore, it is not surprising that another FEMP mission is to help federal agencies lead by example in the use of advanced EERE technologies developed by DOE, industry, or partnerships between the two. FEMP is always looking for technologies that are commercially available, that are proven but underutilized, that save energy and money, have strong constituencies and momentum, and are wanted by, but not readily accessible to, agencies. GHPs met these criteria, so FEMP initiated a technology-specific program.

DOE's ongoing GHP programs sponsored by the Office of Power Technologies (specifically the Geothermal Division within OPT), including the National Earth Comfort Program and other initiatives, were essential contributing factors in preparing GHPs to meet FEMP's criteria. These programs created the initial interest in GHPs among agencies, and convinced FEMP that large public and private investments of other people's money would enable FEMP, with its very modest resources, to effectively help agencies gain access to the technology.

Perhaps most responsible for generating agency and FEMP interest in GHPs was a statistically valid evaluation study by Oak Ridge National Laboratory of a 4000-home GHP retrofit at Fort Polk, Louisiana. Under one of the first major federal energy savings performance contracts (ESPCs) in the United States completed in 1996 the energy services company (ESCO) installed GHPs, upgraded attic insulation, compact fluorescent lights, and low-flow shower heads. The results were significant: overall electricity consumption was reduced by 26 million kWh per year (33%) even though use of 260,000 therms per year of natural gas was also eliminated; the summer peak electric demand was reduced by 7.5 MW (43%); and the annual electric load factor increased from .52 to .62. (Hughes et al. 1998). In another study of about 50 schools in the Lincoln Nebraska school district, 4 of which had GHPs, it was determined that based on actual experience competitive first cost and energy and maintenance cost savings made GHPs the district's lowest life-cycle-cost HVAC option (Shonder et al. 2000).

Feedback from FEMP's agency customers indicated that DOE's GHP programs had stimulated their interest, but their efforts to move toward project development had proven frustrating. The sources of agency frustration were more related to shortcomings in the GHP delivery infrastructure than to problems with the technology. Shortcomings mentioned were lack of credible documentation of GHP benefits; no guides for surveying or auditing facilities and performing analyses to quickly determine whether GHPs were feasible; poor or no representations of GHP systems in the building energy analysis software programs used by agencies; no guides for construction or maintenance cost estimating of GHP systems; multiple ground heat exchanger design tools that gave conflicting recommendations and that required design inputs that were not readily available; lack of engineers willing to consider GHPs in their designs; and lack of quality (or any) GHP installation, commissioning, and service contractors in the area.

In short, federal sites were interested in GHP technology, were expecting to have all of the delivery infrastructure for GHPs that was available for mainstream ECMs, and were frustrated to learn that it did not yet exist. Even more frustrating, in some cases where all of the technical barriers were overcome for particular GHP projects, the agencies lacked sufficient capital appropriations for implementation.

FEMP designed its GHP program to address these issues. The goal was to, within a few years, foster the transition of GHP technology from its status as a proven-but-underutilized technology into a mainstream ECM routinely considered for agency projects. There was no GHP unit or capacity shipment goal. Instead FEMP maintained its ongoing role as an unbiased, trusted federal advisor to its federal agency customers, available to help agencies apply GHP systems where they were economical and desired by the agency. There was no promotion of GHPs as part of FEMP's program. That was left to the providers of GHP systems and existing advocacy organizations such as the GHPC and IGSHPA.

FEMP did not reinvent itself or even seek incremental appropriations to sponsor its emphasis on GHPs. Instead, it allocated a small portion of its existing funding to help agencies implement GHPs through its ongoing agency assistance programs. For example, existing building retrofit projects were the largest opportunity for GHPs, and the ESPC and UESC vehicles were emerging as the dominant means for implementing such projects. Some agencies have strong preferences for ESPCs or UESCs, so FEMP has ongoing outreach, education, and project facilitation programs to support both financing mechanisms. FEMP was able to cost-effectively support agency use of GHPs in ESPC and UESC projects by supplementing the existing FEMP ESPC and UESC teams with GHP technical experts.

FEMP geared its assistance to large commercial and institutional GHP projects. Observers noticing the military family housing emphasis may think otherwise, but when housing units are retrofitted by the hundreds or thousands, those projects share all the characteristics of large commercial and institutional projects. Why large projects? ESPCs and UESCs are best suited for multi-million-dollar projects because fixed transaction costs can be spread over a larger base and financing can be obtained at lower interest rates. Large projects enable bundling of GHPs with ECMs having shorter paybacks, increasing the number of feasible GHP projects under the ESPC and UESC vehicles where the project must be paid for by the cost savings generated by the retrofits. Small GHP projects require as much FEMP assistance as large ones, so large projects provide more leverage for FEMP's limited resources. Lastly, large GHP projects can bear the cost of attracting the necessary installation and service infrastructure to sites where none existed locally.

When FEMP's GHP program was being planned, only a small percentage of federal sites were served by electric utilities offering GHP projects through UESCs. And FEMP was not sure that the regional "all purpose" energy service companies (ESCOs) offering ESPC projects would emphasize GHPs either. Therefore, FEMP decided to include a special worldwide GHP Super ESPC procurement as a component of its GHP technology-specific program.

The GHP Super ESPC competitive procurement resulted in awards in 1999 of indefinite-delivery, indefinite-quantity contracts to five ESCOs who demonstrated expertise in the application of GHP systems through past performance and proposals for a specified project. This step ensured that every federal site worldwide would have access to several quality sources for development, financing, and implementation of GHP projects. Since every delivery order project implemented under these umbrella contracts must include GHPs, these ESCOs were also highly motivated to find agency sites where pay-from-savings GHP projects were feasible.

FEMP supported a few engineers at DOE's Oak Ridge National Laboratory (ORNL) to serve as its "GHP core team." The team's unique qualifications included involvement with GHP technology since the late 1970s, a technical leadership role in implementing FEMP's Super ESPC program, intimate knowledge of FEMP's UESC and design assistance programs, and knowledge of the cultures and design and construction practices at many different federal agencies. The GHP core team provided technical support to the DOE procurement officials who competitively awarded the GHP Super ESPC contracts. Then through FEMP's ongoing ESPC, UESC, and design assistance programs, the core team provided direct assistance to agency customers or the ESCOs/utilities and their subcontractors who were implementing GHP projects.

Since comparable resources are available for every other mainstream HVAC option, federal agencies and other building owners expect the GHP technical resources listed in Table 2 to be available for GHPs. The GHP core team's top priority is to provide direct assistance to federal GHP projects. However, any remaining level of effort is applied toward using GHP project experience to advance the development of the tools listed in Table 2 that are as yet unfinished. The core team seeks partners and cost-sharing for all that it does. For example, core team members work within the technical community at ASHRAE — defining R&D work statements and serving on contractor selection and monitoring committees — because ASHRAE is currently the only sponsor of GHP R&D in the United States.

Table 2. GHP technical resources essential to achieving mainstream status by major project development stage – progress toward developing them.

Stage	Technical Resource	Progress
1. Credible evidence of benefits stage (evaluations)	a. Military Family Housing	(Hughes et al. 1998)
	b. Other Commercial/ Institutional	(Shonder et al. 2000)
2. Survey/audit stage	a. GHP Survey Guide—expandable for each GHP family member	To be completed in FY 2002
	b. GHP Survey Training—based on the GHP Survey Guide	
3. Feasibility/ decision-making stage	a. GHP Construction Cost Estimating Guide—expandable for each GHP family member	Enough vertical closed loop data is in the database to support statistically valid construction cost algorithm development, in progress. http://public.ornl.gov/BTC_MIC/logon.cfm
	b. GHP Maintenance Cost Estimating Guide—expandable for each GHP family member	Enough vertical closed loop data is in the database to support statistically valid maintenance cost algorithm development, in progress. (subset from ASHRAE 1998)
	c. Proven GHP Representations in (at least one, and hopefully all, commonly used) Building Energy Analysis Methods—expandable for each GHP family member.	Proven GHP representations now in research-grade software for use as a benchmark. Will begin testing commercial-grade software in FY 2002. Hope to find at least one commonly used method that is acceptable.
	d. GHP Feasibility Study Guide—expandable for each GHP family member	To be initiated in FY 2002
	e. GHP Feasibility Study Training—based on GHP Feasibility Study Guide	
4. Design stage	a. Proven In-Situ Tests for Soil/Rock Formation and Vertical Bore Backfill Thermal Property Determination	New method for analysis of in-situ test data developed and field tested (Shonder et al. 2000). ASHRAE Research Project 1118RP completed (Kavanaugh 2001)
	b. Proven Vertical Borehole Ground Heat Exchanger Design Tools	Technical papers documenting the comparison of available design methods and models calibrated to data, in ASHRAE Transactions (Shonder et al. 1999; Shonder et al. 2000). A report consolidating this information is in progress.

	c. Proven Borehole Completion Methods	ASHRAE Research Project 1016RP completed (Nutter 2001)
	d. Proven Standing Column Well Design Tools	ASHRAE Research Project 1119RP in progress (Spitler 2002)
	e. Proven Surface Water Loop Design Tools	ASHRAE work statement written but not yet approved for funding
	f. GHP Design Training	ASHRAE Short Course and ASHRAE Professional Development Seminar ongoing (ASHRAE 1997, ASHRAE 1995)
5. Implementation stage	a. GHP Guide Specifications—expandable for each GHP family member	GHP guide specifications have been developed for closed-loop and groundwater systems: http://www.eren.doe.gov/femp/financing/espc/ghpspecs.html
	b. GHP Guide Covering GHP System Commissioning, Preventive Maintenance, and System Trouble-shooting—expandable for each GHP family member	(ASHRAE 2002)

To maximize GHP system acceptance, the various guides and training courses need to be developed, published, and offered to the public in accordance with the policies and procedures of the most recognized professional societies or associations in that mainstream field of endeavor. For example, designers of HVAC systems for large commercial and institutional projects generally turn to ASHRAE for their technical information needs; therefore the design items should be developed, published, and offered through ASHRAE. The Association of Energy Engineers (AEE), the National Ground Water Association (NGWA), and other groups may be the most appropriate mainstream organizations for some of the other items on the list. Of course IGSHPA continues to be the only industry association totally focused on GHP technology and applications.

The FEMP investment in GHP core team activities is summarized in Table 3. During the first year the team provided technical support to the DOE procurement officials who competitively awarded the GHP Super ESPC contracts. During subsequent years the core team's top priority has been to provide direct assistance to GHP projects. Remaining resources were applied toward using the GHP project experience to advance the development of the tools listed in Table 2.

Table 3. Federal Energy Management Program (FEMP) GHP Technology-Specific Program Funding

Fiscal year	DOE funding ($ millions)
1998	0.10
1999	0.25
2000	0.35
2001	0.35
All years	1.05

3. RESULTS OF MAJOR U.S. GHP PROGRAMS

3.1 NATIONAL EARTH COMFORT PROGRAM

The full \$100 million funding was never raised from federal taxpayers, utility ratepayers or shareholders, or the GHP industry. A total of \$23.7 million flowed directly through the GHPC, 80% from DOE. It is believed that utilities directly spent an additional \$37 million on GHP market mobilization programs in their service territories, bringing total program spending to about \$60 million (GHPC 2001). The GHPC has continued to operate after the last of the funds received from DOE in 1999 were utilized.

Many aspects of the GHPC program contributed to its success. These included monitoring, training of contractors and architects and engineers, national public awareness campaign, R&D, financing, and marketing activities. Utility market mobilization programs were the core strategy for increasing GHP shipments ten-fold over the program period. When they did not go as planned, a major mid-course change was made in the GHPC business model, starting in part at the 1998 strategic planning session. It was decided to target commercial and institutional markets with two time-honored approaches — strategic outreach and design assistance.

Utility Market Mobilization Programs. The original National Earth Comfort Program plans called for 6–12 large regional utility market mobilization programs, cost-shared by the GHPC but heavily leveraged by electric utility investments. The nation would be split into six regions and two lead demonstration utilities would be chosen for each of the six national regions. A special task force, consisting of at least six highly trained individuals, would be sent to assist these utilities in successfully deploying model marketing programs as rapidly as possible. The task force would work with the utility team to identify and "sell" key groups such as subdivision developers, school districts, or national accounts. Since smaller utilities had already developed strong GHP programs with 1000–2000 GHPs installed annually in residential and school markets, the theory was that this approach could be transferred to major utilities. It was envisioned that major utilities, operating in large cities and states, would sell as many as 25,000 GHPs per year in their service areas. Once a number of major utilities had demonstrated success this would be shared with other utilities who would develop their own programs without GHPC cost sharing. Program success would be measured on the basis of the number of GHPs sold annually and the number of utilities that joined the program without cost-sharing.

These GHP market mobilization concepts had been successful during the DSM era of the late 1980s and early 1990s. But by the time major support from the utilities and government was developed for the National Earth Comfort Program in 1995, the restructuring of the U.S. electric utility industry was already underway. Top management of utility companies became cautious while they worked to sort out basic strategic issues such as — What businesses do we want to be in after restructuring? What reorganizations and mergers and acquisitions are required to get there? How are we going to recover our stranded costs?

With restructuring pending, utilities largely backed away from implementing the DSM programs that their regulators had approved. The utilities feared that the coming regulatory changes that would implement restructuring would result in DSM costs becoming stranded costs not recoverable from rate payers. Rebates, common for GHPs, were scaled back or canceled, and marketing managers were reassigned or laid off in the effort to prepare for competition. Some utilities were unable to make multi-year commitments because of uncertainty about corporate roles after restructuring. Others focused on merging with or acquiring other utilities, or investing in new unregulated enterprises such as heating, ventilating, and air-conditioning (HVAC) companies, ESCOs, or even fiber optics. Although utilities liked GHPs, they were concerned that after restructuring their generation companies would lose the loads to competitors and the benefits to the utility would be short lived.

Nonetheless, GHPC went through several competitive cycles in which utilities requested cost-sharing from the National Earth Comfort Program for the GHP market mobilization programs they planned to mount within their service territories. Given the prevailing regulatory uncertainty, most of the requests were for cost-sharing on small pilot projects rather than the large market-moving programs originally envisioned. A total of 29 utility programs were approved for cost-sharing. During 1995 – 1999 about $7.8 million was transferred from GHPC to utilities to cost-share their programs. Had these programs all been implemented as characterized in the original requests, the utilities would have spent about $37 million on market mobilization in addition to the GHPC funding. However, some utilities did not mount programs of the magnitude originally planned and others pulled out before starting, so it is difficult to determine how much was actually spent.

The secondary leveraging originally envisioned, whereby many other utilities would follow without GHPC cost-sharing once a number of co-funded utilities had demonstrated success, never materialized. Widespread adoption of model programs by co-funded partners did not occur (GHPC 2001).

Strategic Outreach. GHPC subcontracted several market-sector experts to work directly with trade allies and utilities. Their jobs were to communicate GHP benefits to customers and influential players in their market segments. They were to utilize existing contacts, develop new leads, and respond to GHPC leads. Their mission was to help potential customers or market influencers (builders, developers, engineers, architects, etc.) become comfortable with GHP. They were not to make direct sales, but rather to open doors, qualify leads, and lay the foundation for trade allies to close deals. The fact that the trade allies — either the manufacturers or their representatives or distributors, or utilities, or ESCOs — would be required to step in and make an investment of effort if any opportunities were to be turned into real projects meant that GHPC costs per ton installed could potentially be low. Over the 1995 – 1999 time period GHPC spent about $2 million on strategic outreach.

Design Assistance. An essential complement to strategic outreach for commercial and institutional markets is design assistance. The GHPC strategic outreach subcontractor may create some genuine interest in a developer or building owner, and the manufacturer's representative or other trade ally may build on that foundation, but sooner or later the owner's independent and trusted design engineer must be educated and convinced.

GHPC found that providing small grants to pay for GHP design experts to mentor engineers in design had several benefits and settled on that approach. First, it eliminates the need to overcome the inertia of a designer who would rather not bother to get formal training on something new when he or she is already aware of off-the-shelf solutions (especially if the training requires travel, takes several days, and is on their own dime). Second, even when engineers receive formal training they often do not gain enough knowledge to account for all relevant factors when performing a feasibility study or enough confidence to actually apply GHPs in a real project design. Third, the customer's engineer gets a thorough education on GHP feasibility analysis and design in the context of his or her own project. Fourth, the designers may see their own business advantage in learning the skills. Some engineers exposed to the program began to work on additional GHP projects on their own initiative.

Again, the fact that the trade allies — either the manufacturers or their representatives or distributors, or utilities, or ESCOs — had to step in and make an investment of effort if any opportunities were to be turned into real projects meant that GHPC costs per ton installed could potentially be low. Over the 1995 - 1999 time period GHPC spent about $1.2 million on design assistance. An owner could first learn of GHP from the strategic outreach subcontractor. Then one or more trade allies could further educate the owner to the point where the owner was serious enough to bring in his or her own engineer for an opinion. If the owner's engineer was clueless about GHP then a design assistance request may have been in order. While individual projects could be influenced by strategic outreach, design assistance, or both, most of the sales cycle effort was to be provided by the trade allies (GHPC 2001).

National public awareness campaign. GHPC initially thought it would have the resources to attack head-on the widespread lack of awareness of GHPs among customers, developers, builders, architects, engineers, HVAC contractors, utility program personnel, environmental regulators, and building code officials. According to the original program design, one of the key strategies for leveraging public awareness resources called for GHPC to take a national lead on the development and implementation of resource materials, public relations efforts, and other key elements of a national campaign. These efforts would be complemented by the utility market mobilization programs, which would concentrate public awareness and market infrastructure development efforts within their service territories. It was even hoped that groups of utilities would team together on regional efforts.

When utility market mobilization programs did not go as planned, GHPC redirected its national public awareness campaign to be more focused along lines that would support the new emphasis on strategic outreach and design assistance to commercial and institutional markets. GHPs were promoted as an emerging green technology that was superior for space heating and cooling and water heating. The target application segments were schools, offices, large retail establishments, assisted living facilities, and military installations. The target influencers were builders, mechanical contractors, architects, and engineers. Materials, public relations, and editorial board outreach was directed at each segment and the general public. Between 1995 and 1999 GHPC spent about $4.5 million on the national public awareness campaign (GHPC 2001).

Bottom Line Results. Three measurable components of the National Earth Comfort Program — utility market mobilization programs, strategic outreach, and design assistance — were tracked in the form of GHP capacity shipments resulting in or influenced by program activities. According to the GHPC's final report to the DOE these totaled about 150,000 tons over the 5-year period 1995 – 1999 (GHPC 2001).

Government tracking of industry shipment data provides an independent means of verifying the GHPC estimate of National Earth Comfort Program impact. Data from DOE EIA based on a manufacturer's survey methodology are summarized in Table 4 (DOE 1999, DOE 2001). In the 1994 baseline year GHP capacity shipments were placed at 109,231 tons. Assuming shipments would have remained at the 1994 level without the program, 169,333 tons of above-baseline GHPs were shipped during the years 1995 – 1999. Therefore, it is theoretically possible that 150,000 of the 169,333 tons, or 89% of the above-baseline shipments, were influenced in some way by the GHP program.

The GHPC asserts that through continuing strategic outreach and design assistance, the GHP capacity shipments influenced by them have grown about 33% per year for 2000 and 2001 bringing the total from 150,000 to 260,000 tons (Abnee 2002). According to Table 4 the 1999 GHP tonnage increased 33% over 1998 totals, so a continuation of that growth is also theoretically possible. EIA no longer tracks GHP shipments so industry growth during these years cannot be verified. The program spent a total of approximately $60 million in years 1995 – 1999 and is believed to have influenced about 150,000 tons, which translates to an average of $400 per ton. For years 1995 – 2001 if 260,000 tons is the right number and total spending remained $60 million, the cost per ton is $230.

Table 4. Annual GHP shipments according to EIA

Calendar year	Unit shipments (no.)	Capacity shipments (tons)
1994	28,094	109,231
1995	32,334	130,980
1996	31,385	112,970
1997	37,434	141,556
1998	38,266	141,446
1999	49,162	188,536

3.2 FEMP'S GHP TECHNOLOGY-SPECIFIC PROGRAM

Since FEMP launched its GHP emphasis program in late 1998, the annual federal investment in GHPs has grown from $6 million in FY 1999, to $33 million in FY 2000, to $76 million in FY 2001, as indicated in Figure 1 (Shonder 2002). FY 2001 investment includes about $49 million under ESPCs, $23 million under UESCs, and $4 million funded by appropriations.

The trend is going strong, with another $70 million worth of federal GHP projects under development so far and potentially awardable in FY 2002. It is apparent from the investment trend shown in Figure 1 that essentially all of the increased activity results from the large financed "pay-from-savings" ESPC and UESC projects that FEMP is mostly involved with. FEMP examined the contract documents for the ESPCs and interviewed agencies with UESCs to determine that about 24,000 tons of GHPs were placed in these projects from FY 1999 through FY 2001.

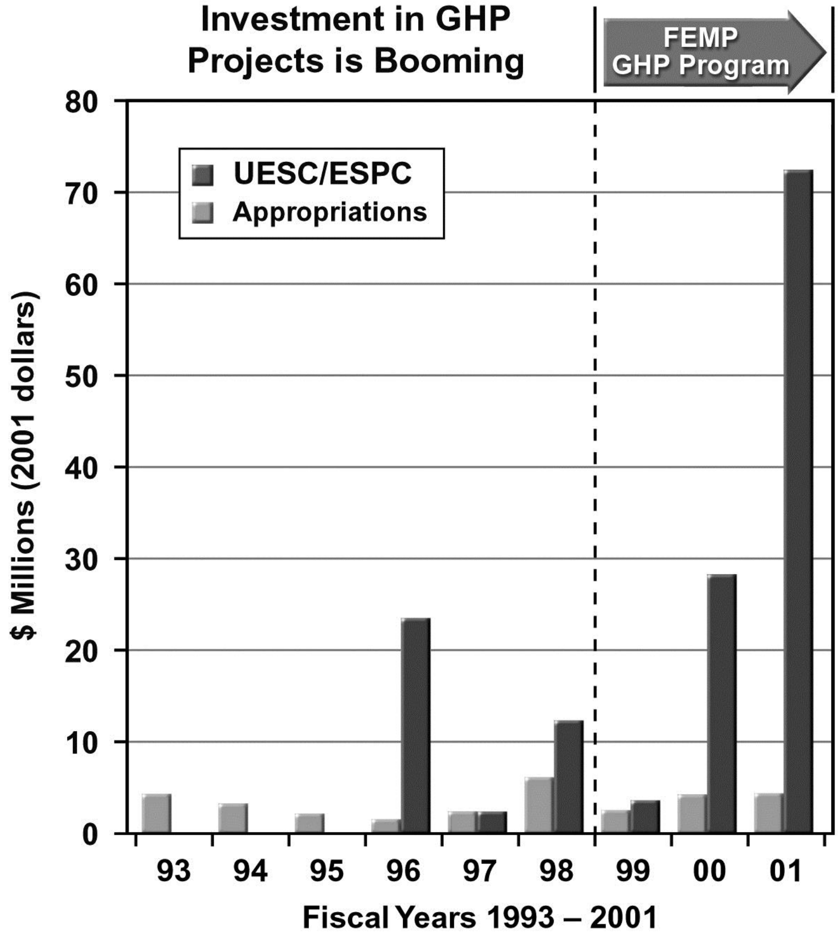

Figure 1. Federal investment in federal GHP projects for fiscal years 1993 – 2001. (UESC/ESPC numbers include the $19 million Fort Polk ESPC project in 1996 and the $9.4 million UESC project at Little Rock Air Force Base in 1998.)

As for progress on development of the GHP technical resources that building owners expect for any mainstream HVAC option, FEMP has been a victim of its own success. There has been so much demand for direct GHP project assistance that progress on the tools has been slower than hoped. Nevertheless, significant progress has been made, as summarized in the right-hand column of Table 2.

As indicated in Table 3, FEMP has spent $1,050,000 on its GHP technology-specific program through FY 2001. With GHP capacity shipments of 24,000 tons, this corresponds to about $44 per ton. In addition FEMP and others have caused substantial progress to be made toward development of the GHP technical resources that both public- and private-sector building owners expect for any mainstream HVAC option.

However, in the view of FEMP and its agency customers, the primary motivation for embracing GHPs was to have another ECM useful for making progress toward their building energy use reduction goals. Based on the subset of GHP projects implemented under FEMP's Super ESPC program, agencies are saving, on average, 5000 site Btu annually for every dollar invested. For comparison, agencies save 7000 site Btu annually for every dollar invested under Super ESPC in general. Federal agencies will soon be moving on to "leading by example" with the next technology, and how well GHPs do will depend totally on their merits. To sustain federal market share the GHP industry will need to continue to improve its value by reducing costs, improving performance and reliability, and doing a better job of bundling GHPs into projects with other ECMs having shorter paybacks.

4. DISCUSSION OF LESSONS LEARNED

Many actions and program components contributed to the success of the overall GHP program. Information received from the GHPC indicates that GHP capacity shipments influenced by GHPC strategic outreach and design assistance are growing about 33% per year. GHP equipment and pipe manufacturers have reported very strong growth rates boosted partially by the rapidly growing federal sector demand influenced by the FEMP program. Many of the lessons learned can be summed up in the following summary.

4.1 NATIONAL EARTH COMFORT PROGRAM

Adaptive Management of a Portfolio of Strategies. Credible market assessments enable identification of multiple market segments or niches to target, each with its own realistic goals, barriers, and strategies to overcome barriers at a quantifiable cost. The cost per ton to develop shipments to niches can be estimated, actual experience tracked, strategies for the niches adjusted, and resource allocations adjusted. Markets change and the allocation of resources needs to change along with them so that resources go to the lowest cost per ton strategies and niches. The GHPC program emphasis changed from residential to commercial/institutional. Strategic outreach and design assistance became the primary strategies to reach commercial/institutional markets. The national public awareness campaign was changed to better support the new strategies.

Funding Never Reached the Projected Levels. The original DOE funding levels of about $8-9 million per year for the second and third years as planned by the GHPC were never reached. Without these levels in the second and third years it was very difficult for utilities to justify investment in major market mobilization programs as the matching funds were simply not available. Instead smaller programs, without long-term critical mass, became the norm. About two or three years into the GHP program EEI was asked what new initiatives DOE should start for Climate Change II and they replied "Finish what we agreed to do in the GHPC program."

Uncertainty in Utility Deregulation. The utilities were uncertain about what direction to pursue under the on-again, off-again deregulation thrust in the United States. Also, the lack of effective price signals to utility customers, such as time-of-use or real-time pricing, results in failure of markets to encourage peak load reduction — one of the strengths of GHP. With the technology available today load management in response to accurate price signals is clearly possible, without requiring any involvement of building occupants, even for residences. It is possible today to build a house which has a zero summer peak load during the serving utility's two-hour peak, but in most places there is no economic incentive for the homeowner to do so (Pratsch 2002).

Public–Private Partnerships. There are many lessons to be learned from these programs. Partnership programs should be built around established expertise and organizations to be as cost-effective as possible. Customer needs should be front and center — the customers are paying the ultimate bill. Technologies seeking to gain market share from entrenched products need to target small market niches where the barriers can be cost-effectively overcome first, and build from there. If that means focusing initially on large, financed, retrofit projects in commercial/institutional facilities such as those owned by the federal government or schools (it is believed that over 750 schools have GHP systems in the United States), so be it. If customers need providers to bring the necessary GHP delivery infrastructure and financing with them, it is important to ensure that as many customers as possible have access to such providers to achieve economies of scale.

4.2 FEMP'S GHP TECHNOLOGY-SPECIFIC PROGRAM

Save Money by Building Programs Around Established Expertise and Organizations. When DOE's Geothermal Division, as part of its overall GHP program, decided to explore opportunities to expand application of GHPs in the federal sector, it partnered with FEMP. FEMP already had a keen understanding of its federal agency customers, had respected ongoing programs that provided technical assistance and supported agencies' use of project financing, and had the infrastructure at DOE regional offices and national laboratories to support agency projects nationwide. FEMP also had as part of its team a few engineers at ORNL with a history of involvement with GHP technology since the late 1970s, intimate knowledge of FEMP's financing and technical assistance programs, and knowledge of the cultures and design and construction practices at many different federal agencies. By choosing partnership over reinvention, DOE's Geothermal Division found a partner able to motivate GHP projects and help mainstream the technology for $44 per ton and willing to do so with its own funds.

Meet Customer Needs. Federal sites were interested in GHP technology, were expecting to have all of the delivery infrastructure for GHPs that they had for mainstream ECMs, and were frustrated to learn that it did not yet exist. FEMP designed its program to address the concerns of its agency customers. FEMP maintained its ongoing role as a trusted and unbiased federal advisor to its federal agency customers, available to help agencies apply GHP systems where they were economical and desired by the agency.

Large Projects Solve Many Problems. Large GHP projects can bear the cost of attracting the necessary installation and service infrastructure to sites where none existed locally. Federal agencies lack the funds they need for their projects and rely on partners to finance them via the ESPC and UESC vehicles. ESPCs and UESCs are best suited for multi-million-dollar projects because fixed transaction costs can be spread over a larger base and financing can be obtained at lower interest rates. Large projects also enable bundling of GHPs with ECMs having shorter paybacks, increasing the number of feasible GHP projects under the ESPC and UESC vehicles where "pay from savings" is required. Small GHP projects require as much FEMP assistance as large ones, so large projects provide more leverage for FEMP's limited resources.

Ensure Universal Access. When FEMP's GHP program was planned, only a small percentage of federal sites were served by electric utilities offering GHP projects through UESCs. And FEMP was not sure that the regional "all-purpose" ESCOs offering ESPC projects would emphasize GHPs either. Department of Defense and Department of State facilities around the world had no access to GHP systems. Therefore, FEMP decided to include a special worldwide GHP Super ESPC procurement as a component of its GHP technology-specific program. The ESCOs holding these contracts are motivated to find GHP project opportunities because all projects they do must include GHPs. There is plenty of evidence that utilities and regional ESCOs are now offering GHP projects to defend their markets. Federal agencies love options, and competition is good for the customer.

5. CONCLUSIONS

Researchers, working closely with engineers and entrepreneurs, made a few refinements to commercially available technology, and the GHP industry was born. Closed-loop ground heat exchangers made of high-density polyethylene, in combination with water-source heat pumps able to operate over an extended range of entering water temperatures, enabled GHP systems to operate cost-effectively for both residential and commercial/institutional buildings in virtually any climate, worldwide. Electric utilities in the United States, led initially by the rural electric cooperatives, embraced GHPs as a means to reduce utility peak loads, improve load factors, and gain market share. Policy makers took notice and estimated that widespread use of GHPs would enable the nation to save as much as 2.7 quads of energy, or over 3% of total U.S. consumption. As part of DOE's overall GHP effort several programs were launched to support mainstreaming the use of GHPs.

In 1994 the National Earth Comfort Program was established with pledges of \$100 million, \$35 from DOE and \$65 from the electric utility industry. Although the program's goal — to increase the annual unit sales of geothermal heat pumps from 40,000 to 400,000 units by 2000 — was not achieved, the efforts may have staved off a decline due to the withdrawal of the utility industry support of R&D, rebates, and marketing. Under this program annual sales of GHPs nearly doubled from 1994 to 1999, clearly accelerating the growth of the industry.

Building on the earlier efforts of DOE's overall GHP program, including the National Earth Comfort Program and others, FEMP established its GHP technology-specific program in late 1998. GHP shipments to the federal market increased more than ten-fold from FY 1999 to FY 2001. Possibly the most cost-effective component of the overall DOE GHP program, FEMP's GHP technology-specific program remains active today.

GHPs remain possibly the best technology available today for reducing energy consumption from space heating and cooling and water heating. Managing Btu's with GHPs — that is, moving them from room to room, from air conditioning to water heaters, or storing them in the ground for the winter — is a more prudent use of energy than dumping thermal energy into the air as virtually all conventional air conditioning does today. While this industry will continue to grow, its growth is slower and resulting energy savings less than it might be if supported prudently by government programs, public–private partnerships, or tax credits.

Technologies developed or encouraged by DOE save energy and reduce pollutant emissions only if they achieve widespread adoption. Yet most governments focus virtually all of their resources on R&D. A much higher return on government investment to save energy and the environment could be derived from investing about 10% of the R&D funds on expanding adoption of EERE technologies that are commercially available, proven but underutilized, substantially reduce energy and emissions, are cost-effective, have a credible base and momentum, and are wanted by customers but to which access is not easy. It is clear from the GHP experience that even when EERE technologies meet these criteria, much research still needs to be done to help a fledgling technology grow. Applications research is needed to provide customers with all the guides and tools to make GHP projects no more difficult to develop and implement than conventional HVAC projects. And market assessment and research is needed to target the market niches where the barriers to GHPs can be most cost-effectively overcome.

ACKNOWLEDGMENTS

This work was funded by the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Federal Energy Management Program, and prepared by Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, which is managed by UT-Battelle, LLC, for the U.S. Department of Energy under contract no. DE-AC05-00OR22725. This paper represents the views of the authors and does not necessarily represent the views of DOE. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

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