Office of the Secretary of Defense

REPORT TO CONGRESS

Ground-Source Heat Pumps at Department of Defense Facilities

Office of the Deputy Under Secretary of Defense (Installations and Environment)

January 2007

Executive Summary

Background

Section 2825 of the National Defense Authorization Act for Fiscal Year 2006 (Public Law 109-163) and the Joint Explanatory Statement to accompany H.R. 2863, Department of Defense Appropriations Act, 2006 (Public Law 109-148) requested a report on the use of ground-source heat pumps (GSHPs) at Department of Defense (DoD) facilities as follows:

- A description of the types of DoD facilities where GSHPs have been used;
- An assessment of the applicability and cost effectiveness of the use of GSHPs at DoD facilities in different geographic regions of the continental United States (CONUS);
- An assessment of the applicability of GSHP systems for new-construction and retrofitting DoD facilities; and
- Recommendations for facilitating and encouraging the increased use of GSHP systems at DoD facilities.

Summary of Findings

A GSHP system transfers heat to and from the earth or water by using specially designed heat exchangers. The technology has been in use in the United States since the 1970s for building heating and cooling. DoD has been installing GSHP systems on installations since the late 1980s. Today more than 52,000 tons of GSHP systems are operating on DoD installations. The most common application of GSHP technology in the Department has been in family housing units in the eastern half of the U.S. where GSHP technology has proven the most cost effective. GSHP systems have been installed in family housing, unaccompanied personnel housing, office buildings, and training facilities to name a few.

Analysis of DoD data shows that GSHP projects have been the most cost effective in the South, Southeast, Midwest, and Mid-Atlantic regions. To date, neither DoD installations nor the GSHP industry has widely used GSHP systems in other regions of CONUS. Computer modeling using three representative DoD buildings indicates that vertical-bore GSHP systems when hybridized[1] with conventional heating, ventilating and air-conditioning (HVAC) equipment are cost effective in the Northeast, Southwest, Western Mountain, Northwest, and West Coast regions of CONUS. However, within these regions, modeling shows that vertical-bore GSHP systems alone require many more favorable site conditions to be cost effective. Further analysis, such as detailed modeling, is needed to identify specific opportunities in these regions.

[1] The term "hybridized" refers to installing a GSHP system coupled with traditional HVAC equipment such as a cooling tower or a boiler.

Requirements such as section 109 of the Energy Policy Act of 2005 (EPAct 2005) require incorporating sustainable design practices into all federal new construction and retrofit projects as long as they are life cycle cost effective. GSHP systems can be an energy efficient alternative for federal facilities when designed and installed properly. Some specific parameters that affect the cost effectiveness of using GSHP technology for facilities under new construction or retrofit are:

- Climate and soil thermal properties;
- The GSHP technology type to be used;
- Size of system(s);
- Building characteristics;
- Local infrastructure supporting GSHP systems including experienced GSHP professionals;
- Feasibility of using GSHP hybrid design; and
- The cost and efficiency of the new or existing conventional HVAC equipment compared to a GSHP system.

To increase the usage of GSHP technology in DoD, this report recommends seven strategies that DoD can undertake.

- *Train Designers and Energy Managers*. Lack of knowledgeable GSHP designers was identified as a problem in past GSHP demonstration projects. This continues to be a potential problem impeding the greater use and the higher success rate of GSHP systems.
- *Design Assistance*. Establish a center of expertise either within DoD or in collaboration with one of the existing Department of Energy (DoE) laboratories to provide consultation at all levels from discussion of basic concepts to design reviews and troubleshooting of existing systems.
- *Specifications*. Conduct periodic reviews of DoD Unified Facilities Guide Specifications covering GSHP systems for consistency, applicability, and consideration of new technologies. This review could be the first tasking of the center of expertise.
- *Design Manual*. The American Society of Heating Refrigeration and Air-conditioning Engineers (ASHRAE) published their HVAC design manual in 1997. In an evolving field, such as GSHP, an updated design manual is critical.
- *Soil Thermal Properties Database*. Collect soil thermal properties data and maintain a database of this information. Among the most important site specific parameters in the design of GSHP are soil thermal properties. These properties are often completely unknown and the difficulty in obtaining them is relatively high.
- *Continue DoD Screening Feasibility Analyses*. Screening results can identify additional potential DoD installations where GSHP technology can be life cycle cost effective, particularly in areas of the CONUS where GSHP technology has yet to be proven or implemented.

- *Studies of Long Term Performance of Existing DoD GSHP Installations*. Although many GSHP projects have been constructed, aside from the GSHP project at Fort Polk, detailed studies have not been performed for most of these installations. Further assessment of installations with existing GSHP technology is needed to evaluate long-term performance.

GSHP can be a cost effective alternative in new construction and retrofitting of facilities. Lessons learned from various DoD installations with installed GSHP systems include:

- Correct GSHP system design and installation is paramount to ensuring system performance and energy savings are achieved;
- Experienced designers and installers are critical to ensuring GSHP systems are designed and installed correctly;
- Great care must be shown when planning GSHP system layout to ensure ground heat exchanger bore fields do not interfere with each other, with existing underground infrastructure (i.e. underground utilities), or future changes in the mission of the base;
- Education of GSHP system operation for maintenance staff and building tenants is critical to ensure that systems continue to operate properly; and
- Hybridizing GSHP systems can solve system underperformance issues and, in some instances, may be the most cost effective design option.

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1. Introduction

On January 6, 2006, the President signed into law the National Defense Authorization Act (NDAA) for Fiscal Year (FY) 2006 (Public Law 109-163). Section 2825 of the act states:

SECTION 2825. REPORT ON USE OF GROUND SOURCE HEAT PUMPS AT DEPARTMENT OF DEFENSE FACILITIES.

> (a) REPORT REQUIRED.—Not later than July 1, 2006, the Secretary of Defense shall submit to the congressional defense committees a report on the use of ground source heat pumps at Department of Defense facilities (DoD).
>
> (b) CONTENT.—The report required under subsection (a) shall include—
>
> (1) a description of the types of DoD facilities that use ground source heat pumps;
>
> (2) an assessment of the applicability and cost effectiveness of the use of ground source heat pumps at DoD facilities in different geographic regions of the United States;
>
> (3) a description of the relative applicability of ground source heat pumps for purposes of new construction at, and retrofitting of, DoD facilities; and
>
> (4) Recommendations for facilitating and encouraging the increased use of ground source heat pumps at DoD facilities.

Further, this requirement is defined by the Joint Explanatory Statement to accompany H.R. 2863, Department of Defense Appropriations Act, 2006 (Public Law 109-148). To satisfy the requirements, this report has been developed by the Naval Facilities Engineering Service Center (NFESC) in collaboration with the Army's Construction Engineering Research Laboratory (CERL) and Cold Regions Research and Engineering Laboratory (CRREL), the Air Force Civil Engineer Support Agency (AFCESA), and the Department of Energy's Oak Ridge National Laboratory (ORNL).

1.1 Background Information on Ground-Source Heat Pump Technology within the Continental United States

The basic physical law - that heat flows from a warmer medium to a colder one- cannot be reversed without the addition of energy. A heat pump is a device that enables heat to be forced in the direction opposite to basic physical law. Because energy must be added to accomplish reversal, the name heat pump is used to describe the device. A heat pump functions by using a refrigerant cycle to transfer heat energy. In the heating mode of a refrigerant cycle, a heat pump removes heat from a lower temperature medium, such as the ground, water, or air, and supplies that heat to a higher temperature sink, such as the heated interior of a building. In the cooling mode of a refrigerant cycle, the process is reversed and the heat is extracted from the cooler inside air and rejected to the warmer outdoor heat sink (e.g., ground, water, or air). For space conditioning of buildings, heat pumps that remove heat from outdoor air in the heating mode and reject it to outdoor air in the cooling mode are common. These are normally called air-source or air-to-air heat pumps. A common window-type air-conditioner functions similarly to an air-to-air heat pump, except it is not designed to reverse the cycle to provide heating. Ground-Source Heat Pumps (GSHP) use the ground, ground water, or surface water as a heat source or sink.

Several different terms have been used to describe GSHP systems, they include: Ground-Coupled Heat Pumps, Geothermal Heat Pumps, Earth Source Heat Pumps, Geo-source Heat Pumps, Geo-exchange systems, and Earth-Energy systems to name a few. All systems that embody the ground-source concepts have been grouped into a general category of GSHPs for purposes of this report. The GSHP industry uses a variety of names to connect with their targeted industrial market.

1.1.1 Ground-Source Heat Pump Types

There are three basic types of GSHPs: ground-coupled heat pumps (GCHPs), ground water heat pumps (GWHPs), and surface water heat pumps (SWHPs). Figure 1 shows the various types of systems currently being installed in the Continental United States (CONUS).

GCHPs use buried closed-loop piping, which exchanges heat with the ground to “couple” the heat pump systems with the ground. GCHP’s became widely used beginning in the mid-1980s. The process of heat exchange is accomplished by circulating a fluid, usually water or a water based antifreeze solution, between the heat pumps and the ground heat exchangers in a closed loop. The ground heat exchangers consist of either vertical (Figure 1a) or horizontal (Figure 1b) arrays of buried High Density Polyethylene (HDPE) pipe that form heat exchangers with the ground. Vertical heat exchangers are fabricated by drilling boreholes into the ground and inserting a "u-tube" into the borehole. The holes are then backfilled, usually with a grouting material, which has the purpose of improving thermal contact between the pipe and the ground and preventing surface runoff from contaminating groundwater. In addition to low land area requirements, vertical ground coupling has several other advantages: stable deep soil temperatures with greater potential for heat exchange, and adaptability to most sites. Among vertical ground-coupling’s disadvantages are potentially higher cost, problems in some geological formations, the challenge of properly classifying a site’s geothermal resource, and the need for an experienced driller and installer specializing in GSHP technology.

Horizontal heat exchangers may be installed in trenches excavated by trenching machines, backhoes, or excavators. Piping may be placed in the trenches either singly or in multiple-pipe arrangements. The primary advantage of horizontal systems is lower cost. Fewer requirements for special skills and equipment combined with lower uncertainty of the subsurface site conditions lead to lower design and installation costs. The disadvantages of horizontal ground coupling are its large land area requirements, its limited potential for heat exchange with the groundwater, and the wider temperature swings of the soil at the typical burial depths.

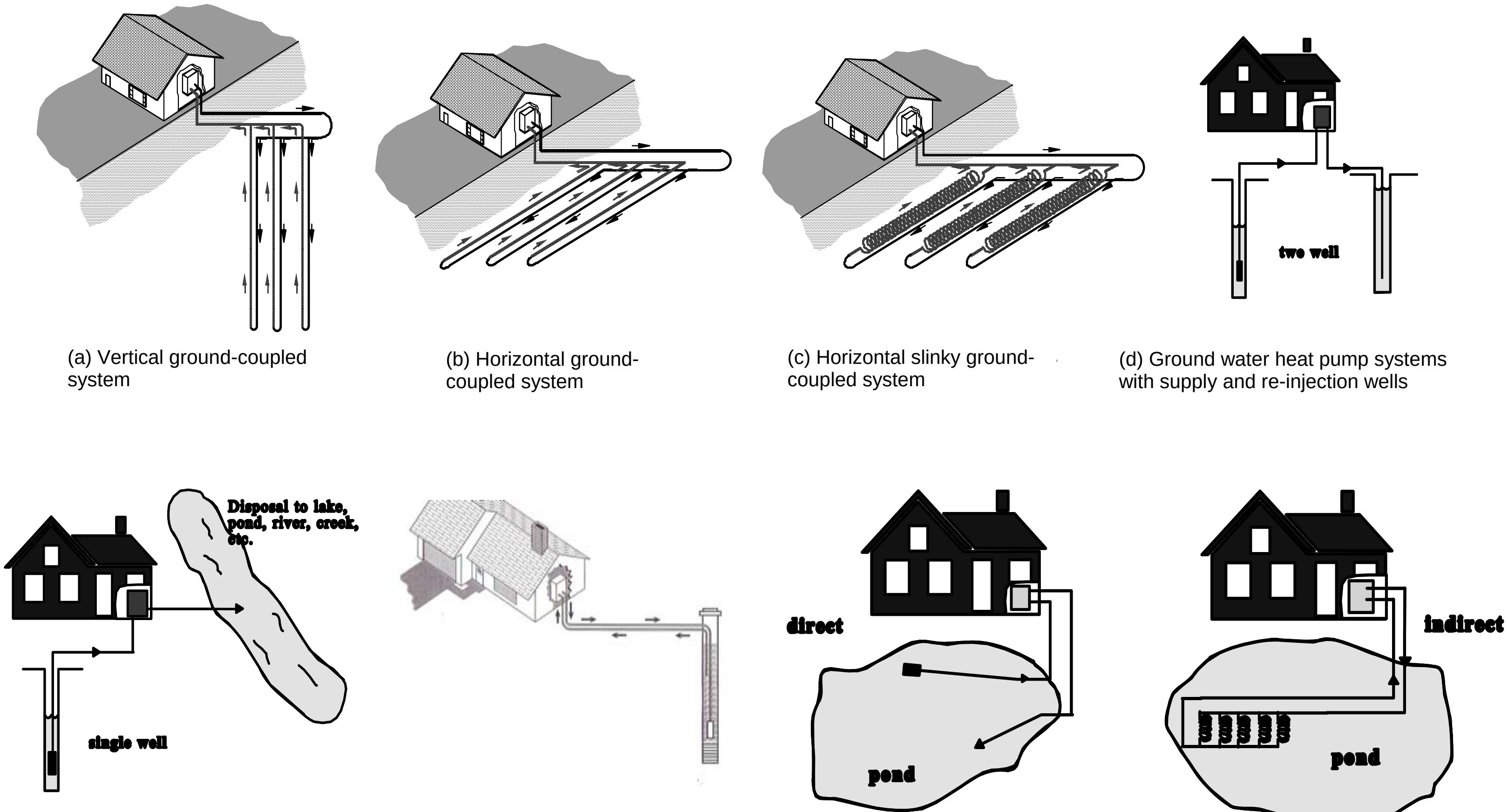
An alternate method of installing a horizontal heat exchanger is the "slinky" method (Figure 1c). When using the slinky method, a wide pit is excavated with a bulldozer, excavator, backhoe, or loader. The coils of plastic piping, rather than being uncoiled, are spread out in a spiral pattern. Usually a fixture is used to obtain uniform coil spacing before the coils are tied to one another to maintain the appropriate spacing. The material excavated is then carefully backfilled over the piping coils. It is also possible to use the slinky method with the coils placed vertically in trenches. Obtaining adequate compaction of the backfill can be difficult for the vertical slinky configuration. Slinky systems have the same advantages as conventional horizontal systems but require less land area and are adaptable to a wider range of construction equipment. One disadvantage to the slinky system is the additional time and cost associated with the installation. Another disadvantage of a slinky system is that the lower volume of ground involved in the heat transfer process, results in larger seasonal temperature swings and hence lower equipment efficiencies.

GWHP systems are the oldest form of GSHPs and became popular in the mid-1970s. These systems extract water from the ground, exchange heat with this water, and then return the water to the ground (Figure 1d) or dispose of it at the surface (Figure 1e) where permitted.

Another variation is the “standing column well” (Figure 1f). In general, systems of this type require special geology, which has limited them for the most part to the New England area. During normal operation, water from the standing column well is delivered to the heat pumps, and then returned to the same well in a closed loop. Heat is transferred to and from the geological formation surrounding the well through convection and advection. When the temperature of the water falls below a set point, a portion of the flow is bled off and ejected to the sewer or a surface water body. Net extraction of water from the well forces new water to flow in, thus allowing “thermal regeneration” of the well.

GWHP systems have the lowest installed cost in most cases, especially in larger applications. However, their use is limited by the availability of ground water and local area environmental regulations. For larger GWHP applications, heat exchangers isolate heat pumps from ground water resulting in reduced water quality requirements. Isolating heat pumps from ground water enables a system to be designed around a central heat exchanger for whole building applications. Plate and frame type heat exchangers are used, as they are not as difficult to clean. Avoiding contact between the ground water and the atmosphere (i.e. oxygen) is paramount to eliminating problems with GWHP systems. Failure to use the best design practice of specifying an isolating heat exchanger led to the premature failure of many early GWHP systems.

SWHP systems extract and discharge heat to surface water bodies. Heat transfer is accomplished by circulating water through the heat pump to and from the water body (Figure 1g). Another method transfers heat through “coupling” HDPE pipes submerged in the water body (Figure 1h). One other SWHP system, known commercially as the “Slim Jim,” transfers heat though stainless steel or titanium plate heat exchangers.



(a) Vertical ground-coupled system

(b) Horizontal ground-coupled system

(c) Horizontal slinky ground-coupled system

(d) Ground water heat pump systems with supply and re-injection wells

(e) Ground water heat pump systems with disposal at surface

(f) Standing Column Well

(g) Surface water heat pump system

(h) Surfact water system with indirect coupling

Figure 1: Various types of GSHP Configurations

Figures (a)-(h) provided by CRREL, except (f), (IGSHPA, 2000)

For buildings in CONUS, cooling loads often exceed heating loads, even for cooler climates in the Northern United States. The design challenge and the ideal GSHP design strategy is to balance heating and cooling requirements. The objective is to maintain a stable heat level by balancing heat extraction and rejection into the medium. In a ground system, when either heat extraction or rejection becomes imbalanced the average ground temperature will drift over years. Eventually the ground temperature will be outside a useable temperature range for either heat rejection or heat extraction. The result is that the geothermal resource becomes "spoiled." One solution is to add a conventional cooling tower to the GSHP system, to make a Hybrid GCHP system, to provide supplemental heat rejection capacity. The additional heat rejection capacity enables the heat rejection and heat extraction to be kept in balance.

Another type of ground-source heat pump system is the direct expansion GCHP. The direct expansion GCHP system circulates refrigerant directly to copper tubing buried in the soil rather than using water or an antifreeze solution as an intermediate heat transfer fluid. The direct expansion GCHP has the potential for higher efficiency than a GSHP system using water or an antifreeze solution as an intermediate heat transfer fluid. However, it lacks the prominent advantage of having the entire refrigerant contained in the factory-fabricated unit like the GSHP. To date, applications of direct expansion GCHP have been limited.

In general, determining the optimal GSHP system design will depend on a number of factors including: geothermal (including ground/surface water) resource(s) available, land availability, soil conditions, local regulations, and the type and status of the existing HVAC system (for an existing building). As for all other HVAC systems, a GSHP system designer weighs these factors and others in matching the best HVAC system to the application.

1.2 Current Status of GSHP Technology within CONUS

Table 1, reported in the World Geothermal Congress 2005, shows the total number of GSHP units installed and operating within CONUS by the end of the calendar year 2004. The Geothermal Heat Pump Consortium (GHPC) reports that by the end of 2005 there were more than one-million GSHPs installed in the United States. The GHPC estimates an increasing number of GSHPs installed at 20% per year. Still, this figure represents a small percentage (less than 1%) of all HVAC units within the United States.
Two organizations focus on developing the GSHP industry in CONUS, the Geothermal Heat Pump Consortium (GHPC) and the International Ground Source Heat Pump Association (IGSHPA). Additionally, there are academic organizations supporting GSHP technology. The Oregon Institute of Technology (OIT) currently runs the Geo-Heat Center (GHC) in Klamath Falls, OR. The University of Alabama runs the GeoCool laboratory. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) is the principal developer of design guidance for the industry. ASHRAE, through Technical Committee TC6.8 (Geothermal Energy Utilization), sponsors training programs as well as technical programs at their meetings that have resulted in the vast majority of the referred technical contributions to the literature in the GSHP field. On the Federal level, the Department of Energy's (DoE) ORNL is the lead

laboratory for DOEs GSHP technology specific Super Energy Savings Performance Contract (ESPC). The companies supporting GSHP design, installation, and maintenance are rapidly evolving.

Table 1. Geothermal (Ground-Source) Heat Pumps as of 31 December 2004 (Lund, 2005).

Locality	Ground or Water temp. (°C) [1.]	Typical Heat Pump Rating or Capacity (kW)	Number of Units	Type [2.]	COP [3.]	Heating Equivalent Full Load Hr/Year [4.]	Thermal Energy Used (TJ/yr)	Cooling Energy (TJ/yr)
States: Northwest 13% Midwest 45% South 36% West 8%	5-25	12.0	600,000	V=44% H=36% W=20%	3.5	1200	22,214	27,768
TOTAL			600,000				22,214	27,768

Notes:

1. Average ground temperature for ground coupled units or average well water or lake water temperature for water-source heat pumps.
2. Type of installation: V=vertical ground coupled, H=horizontal ground coupled, W=water source (well or lake water).
3. COP = output thermal energy/input energy of compressor.
4. Equivalent full load operating hours per year.

1.2.1 Software Tools Currently Available for GSHP Screening

GHPC hosts a website, www.geoexchange.org, which lists GSHP software. The website identifies software used as aids in determining the potential feasibility of GSHP systems using sites specific conditions.

1.3 Methodology

The methodology used to complete the GSHP analysis as required by Congress is based on defining climatic regions of the country as outlined by the DoE's climate classification system[2], which outlines CONUS into 15 zones[3]. Further, the methodology used to analyze both current and potential GSHP installations at DoD facilities is based on data collected on existing systems. The data on current systems provides a means to identify potentially successful applications. The project characteristics used to screen for potentially successful GSHP applications include identifying factors that contributed to an existing GSHP system performing well and identifying the causes of underperforming projects.

To determine the feasibility of using GSHP technology in regions of the country that do not use the technology currently, computer modeling analysis was used to screen potential at DoD facilities. For this task, DoD collaborated with ORNL. Using the results of the computer modeling, the output was analyzed to determine the potential for success of GSHPs applications. Section 3.3.2 discusses details of the analysis.

Chapter 4 includes the Federal requirements for new-construction and retrofit projects at federal facilities from the EPAct 2005 and corresponding DoD policy. Included in this

[2] Additional information on the DOE's climate classification system can be found at http://resourcecenter.pnl.gov/html/ResourceCenter/1420.html and http://www.energycodes.gov/implement/pdfs/climate_paper_review_draft_rev.pdf.

[3] One zone representing the extreme regions of Alaska was excluded from this analysis.

chapter are specific issues related to new construction and retrofit for three DoD facility types. Also included is a discussion on the feasibility of using GSHP technology to meet these requirements.

Chapter 5 provides conclusions and recommendations and addresses ways that DoD can further encourage GSHP usage at its facilities.

2. Current Inventory of GSHPs at DoD Facilities within the Continental United States

2.1 Development of Data Survey Sent to DoD Facilities

A data call was issued to relevant DoD installations on March 14, 2006. The data call requested general, technical, and economic information on all GSHP projects that have been implemented at DoD facilities. Appendix A provides the full results from the data call.

2.2 Database Accuracy

Quality control methods were used to check the accuracy of the collected data. Review of the data identified out-of-range and implausible values. The appropriate point of contact either confirmed or corrected the suspect data. The database incorporates the necessary corrections.

The ratio of the project investment cost per installed ton was calculated for projects that reported both project investment and GSHP capacity. Figures 5a and 5b compare the project investment cost with installed tons for commercial systems and residential systems, respectively. The two graphs identify that costs increase linearly per installed ton[4]. Linear regression analyses on both sets of data yield R^2 values close to unity, which also support linear trends. Furthermore, these installation cost values are close to that of similar systems installed in the private industry. For 2006, regression analyses of the data shows a cost per ton of around $7,000 for commercial systems and around $4,600 for residential systems.

Reported annual cost and energy savings were validated as well. Upper thresholds for annual cost savings and energy savings were calculated by using ASHRAE Technical Committee 6.8 Geothermal Energy Utilization research that estimates GSHP full load heating and cooling hours for various buildings and climates and by assuming GSHP pre-retrofit equipment efficiencies. Reported values that exceeded the thresholds were verified with the appropriate point of contact.

The reported annual cost savings are higher than the corresponding upper threshold for 84% of the projects that reported these values. Additionally, 58% of the reported annual cost savings have percent differences greater than 50% of the threshold value. The overall percent difference between the reported annual cost savings and the threshold value is 84%. These results indicate that the accuracy of the reported annual cost savings values are unreliable and, therefore, these values were not used in the analyses. Similarly, the reported annual energy savings are higher than the corresponding upper threshold for only 46% of the projects that reported these values. Additionally, only 20% of these values have a percent difference greater than 50% of the threshold value. The

[4] The cost data in Figures 5a and 5b was adjusted for inflation and location.

overall percent difference from the threshold value is -31%. These reported annual energy savings values are considered reasonable and were used in the analyses.

2.3 DoD Current GSHP Inventory and Analysis

Figure 2 shows the locations for GSHP systems in operation at DoD facilities, with climate zones overlaid. The zones are defined by DoE International Energy Conservation Code (IECC). GSHPs operating at DoD facilities primarily have been installed in the Southeast, Midwest, and Mid-Atlantic regions. A few GSHP systems have been installed in the Northeast and Southwest, while none have been installed along the west coast.

Two hundred sixty four DoD GSHP projects, both installed and planned, were reported (Table 2). Approximately 21,000 GSHP units have been installed to date, which equates to approximately 52,000 tons of installed GSHP capacity. Total installed capacity is likely to be higher considering that only 93% of reporting installations submitted this figure. Table 2 displays installed DoD GSHP tons broken down into different building classes using the DoD Real Property Classification System (RPCS)[5] two-digit class. This shows 79% of installed DoD GSHP capacity has been in Family Housing, 11% in Unaccompanied Personnel Housing (i.e. Barracks / Bachelor Officer Quarters (BOQs) / Bachelor Enlisted Quarters (BEQs)), 6% in Administrative / Office Buildings, 2% in Training Facilities, and the rest (~2%) in various other facilities.

The reported total annual energy savings from currently operational GSHP systems is 158,000 megawatt-hours. However, savings for some GSHP projects remain unreported. 59% of all projects reported annual energy savings and 55% reported annual cost savings. The low reporting rates and inaccurate reporting of energy and cost savings are likely due to the difficulty in determining actual energy and cost savings. Building energy use must be measured before and after a GSHP is installed in order to accurately determine these values. Unfortunately, energy consumption monitoring and processing can become cost prohibitive and impracticable if not planned for prior to GSHP installation. Therefore, it is speculated that the reported data resulted from estimations rather than from verified measurements.

Fifty-three percent of DoD GSHP projects are installed by fully funded contracts (Table 2). Thirty-six percent of projects have been financed through Utility Energy Service Contracts (UESC) and 11% through ESPC. Although making up only 47% of the total number of projects, more GSHP capacity has been financed on UESC and ESPC combined. Specifically, 42% of total GSHP capacity has been installed using UESC and 38% using ESPC.

Table 3 displays the average value and data range for particular technical and economic GSHP parameters requested in the data call. Investment cost and annual energy savings data have been normalized by dividing their values with the corresponding installed GSHP capacity of the project. Cost effectiveness of DoD GSHP projects is further discussed in Chapter 3.

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[5] More information on the DoD RPCS system can be found at http://www.acq.osd.mil/ie/irm/ProgramAnalysis_Budget/ToolAndMetrics/FPG/FPGQuickReference.htm

Figures 3 (a), (b), and (c) show DoD GSHP projects broken down in the different RPCS facility classes by projects and installed GSHP capacity. As the figures indicate, 64% of GSHP projects are installed and operated in family housing. The efforts being made to privatize family housing may pose a challenge to continuing implementation of GSHP technology within DoD.

Figure 4 shows the DoD rate of adoption of GSHP technology by tracking installed GSHP capacity from 1988 to the present year. Figure 4 indicates that GSHP systems at DoD facilities increased rapidly in the mid-90s and has continued to be installed with an average yearly installation of about 5,500 tons between 1996 and 2006.

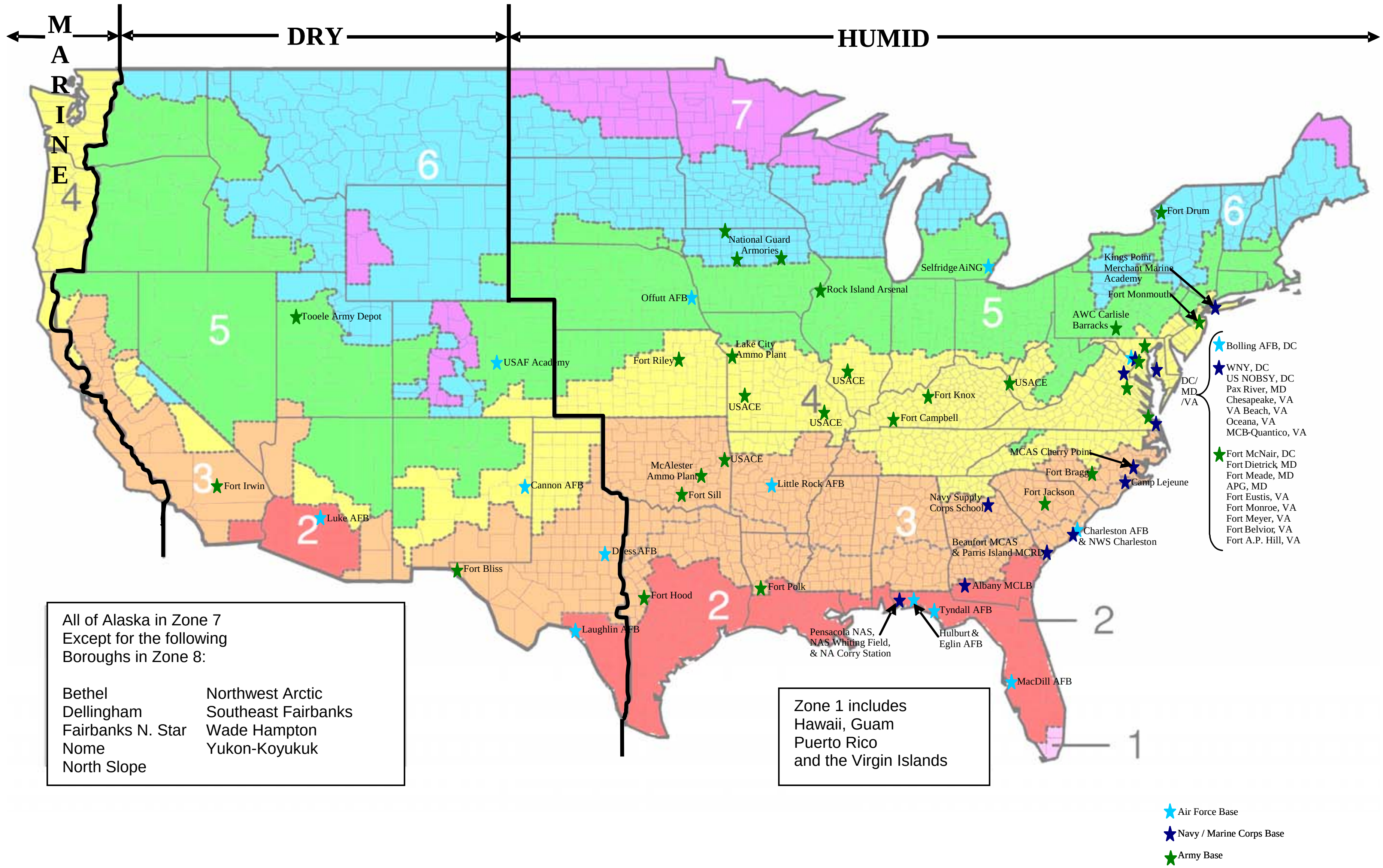


Figure 2: DOD Installations with GSHPs Currently Installed or Planned to be Installed (Shown on DOE IECC Climate Classification Map) (Briggs *et. al.*, 2002)

Table 2. DOD CONUS GSHPs Installed Pertinent Information

DOD Branch	Total # Of GSHP Projects Reported	Total Reported GSHP's Operational[1] (#) / (installed Ton Capacity)	% of GSHP installed Tons for Different RPCS Facility Class Buildings[2]														Total Reported Annual Savings[3] (kWh)	% Projects Per Finance Mechanism[4]		
			71	72	61	17	74	73	44	21	53	14	22	54	69	13		App / Other	UESC	ESPC
ARMY	193	9,534 / 22,553	68.7%	12.6%	10.9%	3.3%	0.8%	1.2%	0.7%	0.0%	0.0%	0.4%	0.1%	0.7%	0.0%	0.5%	77,748,424	58%	34%	8%
AIRFORCE	27	3,934 / 9,091	86.8%	12.5%	0.4%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	Not Sufficient Data to Report	50%	43%	7%
NAVY / MARINE CORPS	44	7,679 / 20,406	88.0%	7.8%	4.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	80,546,656	32%	43%	24%
TOTAL	264	21,147 / 52,050	79.3%	10.8%	6.4%	1.5%	0.3%	0.5%	0.3%	0.0%	0.0%	0.2%	0.0%	0.3%	0.0%	0.2%	158,345,080	53%	36%	11%

Notes:

Please note the above table is based on the data call conducted as part of this report (results located in appendix A). Note there are a number of data points not reported in the data call.

1. Includes the sum of the reported installed and operating GSHPs as well as Installed GSHP Ton Capacity. Note a number of GSHP projects did not report values for these parameters. Therefore, actual GSHP installations are higher then the #'s in this table. DOD Overall % responded to the data call for GSHP installed units and installed tons was 90% and 93% respectively.

2. The buildings in which GSHP have been installed for all of the projects reported in the datacall have been classified using the DOD Real-Property Classification System (RPCS) two-digit code level. The following two digits correspond to the building types: 71-Family Housing, 72-Unaccompanied Personnel Housing, 61-Administrative Buildings, 17-Training Facilities, 74-Indoor Morale Welfare, and Recreation Facilities, 73-Personnel Support and Services Facilities, 44-Covered Storage, 21-Maintenance Facilities, 53-Medical and Medical Support Facilities, 14-Land Operational Facilities, 22-Production Facilities, 54-Dental Clinics, 69-Administrative Structures Other Than Buildings, 13-Communications, Navigation Aids and Airfield Light.

3. Includes the sum of reported installed GSHP annual energy savings. Note A number of GSHP projects did not report values for these parameters. DOD Overall % responded to the data call for GSHP annual energy savings in kWh was 56%.

4. Reported as the sum of the following categories reported in the data call: App / Other = Appropriated Funds and any other Federally Funded Options, UESC = Utility Energy Savings Contracts, ESPC = Energy Savings Performance Contracts (including Super ESPC's).

Table 3(a). DOD CONUS GSHP Average and Range for Installed Project Technical Data

DOD Branch	Average (Range) Building Area (KSF)	Average (Range) Calendar Year Installed	Average (Range) Cooling Efficiency (EER)	Average (Range) Heating Efficiency (COP)	Average (Range) Land Area Used for GSHP Loop (KSF)	Average (Range) Thermal Conductivity (BTU/hr-foot-^{o}F)	Average (Range) Bore Hole Depth (ft)	Average (Range) Distance to Water Table (ft)	Average (Range) Distance to Bedrock (ft)	Average (Range) Frost Depth (ft)
ARMY	12.2 (0.98 - 6,762)	2002 (1988 - 2006)	13.0 (9.6 - 24)	3.4 (3 - 5)	42 (0.001 - 2,320)	1.53 (0.97 - 1.85)	329 (80 - 520)	57 (5 - 450)	409 (6 - 4,000)	3 (0 - 7)
AIRFORCE	642 (7 - 1,871)	2002 (1998 - 2005)	14 (14 - 14)	4.3 (4 - 4.5)	0.04 (0.04 - 0.04)	1.4 (1.4 - 1.4)	250 (250 - 250)	6 (6 - 6)	n/a	1.3 (0 - 6.1)
NAVY / MARINE CORPS	334 (1.1 - 3,000)	2001 (1995 - 2004)	14.89 (12.1 - 18.9)	3.72 (3 - 5)	102 (1.6 - 994)	1.24 (0.90 - 2)	251 (176 - 500)	357 (3 - 1000)	80 (80 - 80)	1.36 (0.2 - 4)
DOD WIDE	139 (0.98 - 6,762)	2001 (1988 - 2006)	13.2 (9.6 - 24)	3.5 (3 - 5)	52 (0.001 - 2,320)	1.46 (0.90 - 2)	313 (80 -520)	96.5 (3 - 1,000)	404 (6 - 4,000)	2.8 (0 - 7)

Table 3(b). DOD CONUS GSHP Average and Range for Installed Project Economic Data

DOD Branch	Average (Range) Electric Utility Rate ($/kWh)	Average (Range) Natural Gas Rate ($/kcf)	Average (Range) Project Investment Cost / Ton ($)	Average (Range) Reported Annual Energy Savings / Ton (kWh)	Average (Range) Project Estimated Economic Life (yrs)	Average (Range) Project Payback Period (yrs)
ARMY	0.06 (0.01 - 0.10)	12.69 (9.00 - 17.81)	8,175 (712 - 20,265)	8,390 (6 - 34,898)	21.8 (14 - 50)	11.2 (5 - 86)
AIRFORCE	0.06 (0.02 - 0.08)	8.24 (6.81 - 14.95)	3,172 (2,539 - 4,244)	N/A	20 (20 - 20)	11.8 (11.8 - 11.8)
NAVY / MARINE CORPS	0.06 (0.04 - 0.09)	5.48 (1.12 - 8.38)	6,286 (438 - 15,335)	1,409 (2 - 45,000)	20.6 (20 - 22)	11.39 (2 - 19.96)
DOD WIDE	0.06 (0.01 - 0.10)	11.78 (1.12 - 17.81)	7,718 (438 - 20,265)	2,444 (2 - 45,000)	21.6 (14 - 50)	11.3 (2 - 86)

Figure 3(a): DOD GSHP Project Breakdown by RPCS Class

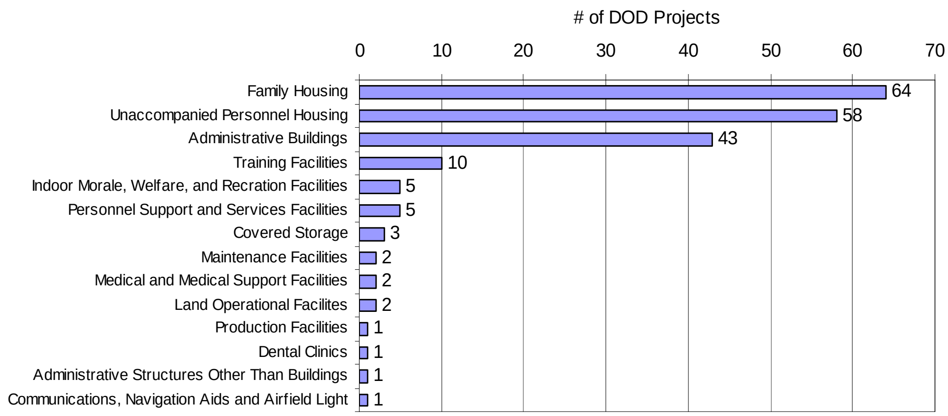


Figure 3(b): DOD Currently Operating GSHP Installed Tons Capacity Broken Down by RPCS (Logarithmic Scale)

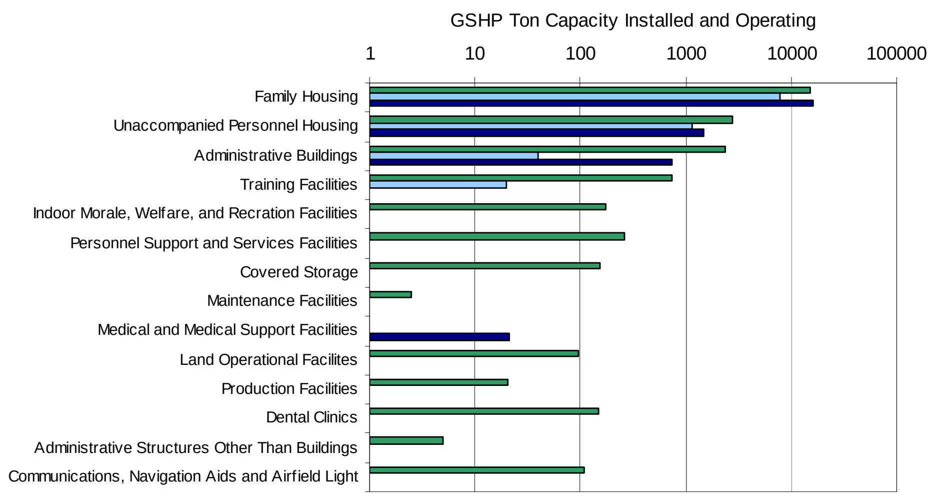


Figure 3(c): DOD % of Each RPCS Class for Currently Operating GSHP Tons Installed

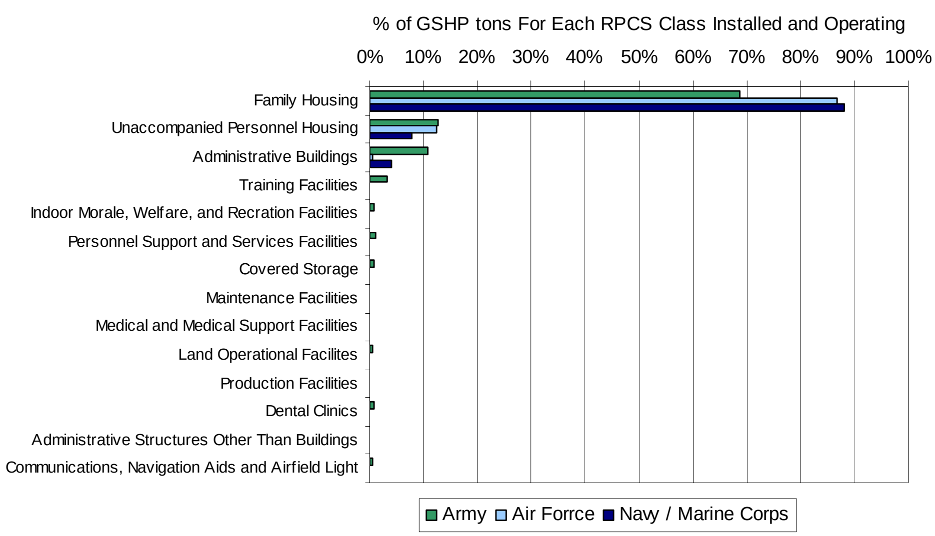


Figure 4: GSHP Historical Tons Installed

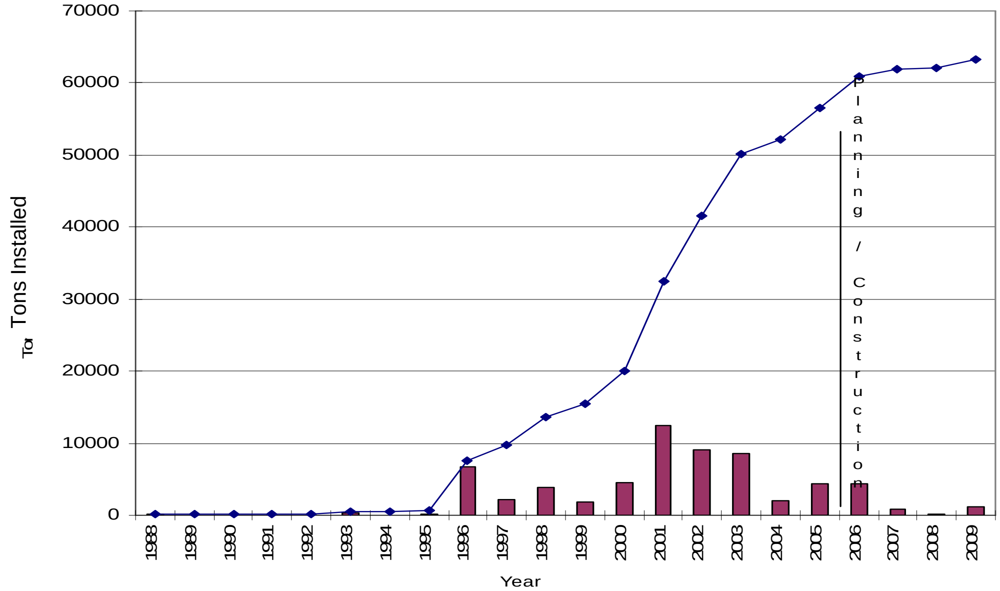


Figure 5(a): Project Cost (Dollars) vs. Installed Capacity (Tons)
(Commercial Projects, Log Scale)

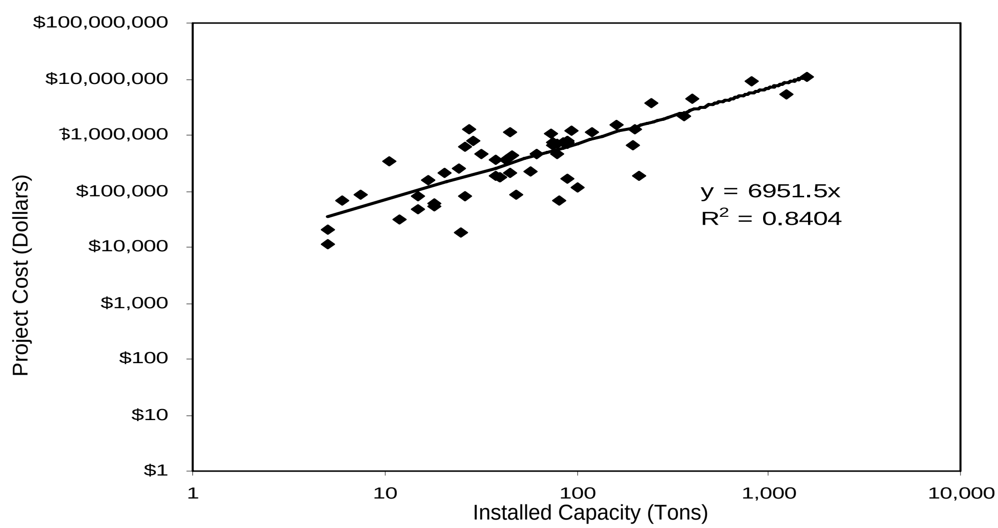
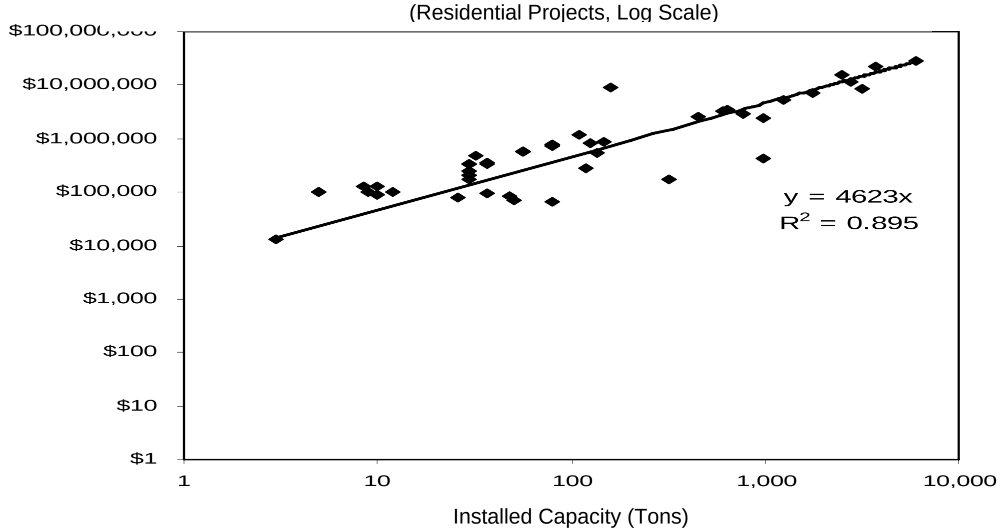


Figure 5(b): Project Cost (Dollars) vs. Installed Capacity (Tons)
(Residential Projects, Log Scale)



3. An Assessment of Applicability and Cost Effectiveness of GSHPs at DoD Facilities for Different Climatic Regions of the CONUS

3.1 Design Considerations that Affect Applicability and Cost Effectiveness

GSHPs can be technically feasible at most CONUS DoD installations. However, state and local regulations, as shown in Appendix B, may restrict the use of an otherwise feasible GSHP application. The restrictions are based on concerns such as ground water contamination introduced from deep drilling bore holes. ASHRAE reports that describe related GSHP design issues are listed in the References section.

In determining project economic viability, life cycle cost analysis compares the capital and operating costs of using conventional HVAC technology versus GSHP technology. Capital cost for a conventional HVAC system is largely determined by its peak load capacity, whereas the capital cost of a GSHP system is highly dependent on other site-specific requirements in addition to peak capacity. One site requirement is to select the type of heat transfer methodology. For example, ground coupling can be a major portion of the total GSHP system cost. An over-sized ground coupling will yield an economically unattractive project. If the ground coupling is discovered to be under-sized after construction is completed, it can be difficult to correct and will often lead to increased operational costs and degraded equipment performance.

HVAC load requirements, specific load demand of conditioned zones within the building, and seasonal heating and cooling cycles must be determined to properly design a ground loop. The ground loop needs to be sized to accommodate the load demand and the peak heat transfer rate. For most CONUS locations (other than the most northern climates), office buildings will require more heat rejection than extraction.

Design of GSHP systems requires consideration of load variations, peak load, building type, building envelope construction, HVAC zone layout, and any non-space heating and cooling requirements such as large domestic hot water loads and pool heating. GSHP design calculations, such as heat transfer interaction between adjacent loops and long-term heat build-up potential, can be performed using GSHP design software. Two commonly used GSHP design software packages are GchpCalc from Energy Information Services Co. and GLHEPRO from IGSHPA. Unified Facilities Guide Specifications (UFGS)-15741 cites both as software to use for GSHP design.

Typically, GSHP design software requires information about the ground loop in addition to building load data. Soil thermal properties, bore hole resistance, type of piping, bore hole arrangement, and type of heat transfer fluid are required as well. Although default values are provided for many of these parameters, the designer should ensure that values chosen are representative of actual site conditions.[6] GSHP design software makes it

[6] One method to ensure data accuracy is to make sample borings, which can be used to determine soil formation type and aquifer location. Several commercially available sources for such testing are listed in Appendix C.

possible to conveniently test the sensitivity of a project to variances in design parameters in assessing the degree of risk these uncertainties present.

Ground coupling capacity is sized according to the greater requirement for either heating or cooling. When GSHP systems become cost prohibitive due to design adjustments required to account for imbalanced loads, a hybrid GSHP system should be considered. A hybrid system combines the ground coupling of any of the three basic GSHP types with a supplemental heat rejecter, such as a closed circuit fluid cooler type-cooling tower, or a supplemental heat source such as a boiler. The precise mix of ground loop size and supplemental heat source or heat rejector is determined by a design analysis.

For medium and large commercial scale buildings, Ground Water Heat Pumps (GWHPs), tend to have lower installation costs than Ground Coupled Heat Pumps (GCHPs). Ground water availability and associated regulatory issues must be considered. Information on ground water resources suitable for preliminary analysis is available from the United States Geological Survey's (USGS's) ground water atlas, at: http://capp.water.usgs.gov/gwa/gwa.html.

Feasibility of GSHPs is highly dependent on the existence of a local GSHP commercial infrastructure, such as, designers, installers, and suppliers. In regions that lack a local infrastructure, acquiring a properly designed and installed GSHP system can be difficult, which may lead to a poorly functioning or overpriced system. Using experienced GSHP professionals from outside the local area is recommended over inexperienced local providers, especially for complex or larger systems.

3.2 General DoD GSHP Geographical Assessment

Generalizations about the applicability of GSHPs on a regional basis are difficult to make without numerous caveats. Each GSHP system requires detailed analysis. With a few exceptions, geographic region is a minor factor in predicting the success of using GSHP technology. However, GSHP project experiences can provide some insight into identifying successful regional applications. The general assessments provided in this section are largely based on experiences from the private sector.

Northeast: The Northeast has seen very limited development of GSHP systems. For residential scale applications such as family housing, the economics are generally less favorable than in other areas of the country mostly due to lower cooling requirements. The economics are also hampered by the relative cost effectiveness of fossil fuels for space heating as opposed to electric based GSHP technology. With high electricity rates, the Northeast is at a comparative disadvantage for electric based technologies. However, there has been some shift in the relative cost of electricity due to the rapid price escalation of fossil fuels in the past few years. Thus, residential applications may be worthy of consideration.

In contrast, due primarily to cooling requirements, commercial scale applications possess more favorable economics. However, site-specific factors determine applicability. Standing column well systems have the widest application of any system type in commercial scale applications in the Northeast. Vertical ground coupled systems are often cost prohibitive due to high costs associated with shallow bedrock drilling. Horizontal ground coupled systems, when land area requirements can be met, are generally hindered by unfavorable soil and topography conditions. As for surface water systems, they are essentially unfeasible due to low water temperatures during the heating season.

Mid-Atlantic States: In the Mid-Atlantic States, commercial scale applications have been successful on a limited basis, but still more widespread than in the Northeast. Residential systems have also been installed, but in smaller numbers then other areas. Most applications in the region are vertical ground coupled, while some commercial applications are hybrid systems. Significant heating requirements and the lower cost of fossil fuels have been significant impediments to GSHP adoption, but that may soon change as fossil fuels prices increase.

Southeast: GSHPs have seen widespread development in the Southeast. Installations have been common in both residential and commercial applications. The majority of installations are vertical ground coupled, but there have been some surface water and ground water systems installed as well. Commercial scale ground coupled hybrid systems tend to be cost effective. GSHPs have found many successes in schools. GSHP systems for schools with dispersed floor plans may be more economical when configured with individual units and ground coupling for each zone/room, rather than a single array of heat exchangers that serves the entire building.

Midwest: Conditions in the Midwest are quite favorable for GSHP systems and resulted in many installations made on both residential and commercial scales. Residential scale systems are both vertical and horizontal ground coupled. Commercial scale systems are often vertical ground coupled, but are found to be ground water based in some instances. Some surface water systems have been applied specifically in commercial scale applications where significant cooling loads exist. GSHPs have been found favorable in schools.

Southwest: Development of GSHPs in the Southwest has lagged behind most of the country. The absence of ground water in most areas not only precludes the use of ground water based systems but also leads to unfavorable soil thermal properties for vertical ground-coupled systems. However, hybrid GSHPs may be viable options in areas with low soil thermal conductivity. The limited number of installed systems spans both residential and commercial applications.

Northwest: The Northwest has a long history of using commercial scale ground water based heat pump systems. Low electricity rates have allowed the technology to compete very successfully even in the absence of significant cooling loads. Ground-coupled systems are now increasing in popularity, but overall market penetration is still relatively low.

3.3 Detailed DoD GSHP Geographical Assessment

Using data from existing DoD GSHP installations, computer models predicted the feasibility of GSHP systems in different climate zones.[7] The feasibility of using GSHP technology was analyzed for those climate zones with GSHPs systems operating at DoD installations. The analysis determined applicability and cost effectiveness of using GSHP technology throughout a zone. For those zones where GSHP technology has not been used at DoD installations, computer based models simulated GSHP performance to predict the feasibility of using the technology throughout those zones.

3.3.1 DoD Existing, Installed GSHP Regional Analysis

The feasibility of using GSHP technology was evaluated for different regional zones of CONUS. Table 4 identifies where GSHP systems have been installed throughout DoD with climate zone 3A having the most installed systems. Estimates of total DoD building square footage for each climate zone was calculated by adding all building[8] square footage for each climate zone as reported in the DoD's Base Structure Report for FY05. The percentage of building area using GSHP technology was calculated for each zone to determine the extent of its use. Climate zone 3A has an estimated 5% of DoD building square footage using GSHP systems while all other climate zones have less than 1% of building area using systems. This low percentage of GSHP use indicates that there is a great potential for DoD buildings to implement GSHP technology.

For purposes of this study, cost effectiveness has been defined as the reported annual energy savings (in kWh) of a project divided by its total installed tons with an assumed unity cost factor. A higher ratio translates into a higher likelihood that the project will be cost effective. Normalizing the cost factors prevents discrepancies that are introduced from misreported and changing utility energy costs. In addition, normalizing the data facilitates GSHP project developers to complete any required site-specific cost analysis to account for actual local cost factors. Although, as discussed previously, analysis of the data quality indicated some of the annual reported cost savings to be inaccurate, the reported annual energy savings values were determined to be accurate. Therefore, this analysis only includes annual energy savings values in kWh. An important note is that these cost effectiveness values do not take into consideration systems that have been designed improperly. The cost effectiveness values can provide a basis for comparing the cost effectiveness of applying GSHP technology in one climate zone to another. Another value that can aid in understanding where GSHP systems have been most cost effective for different climate zones is the project payback period.

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7 DOE's IECC climate classification system defines different climate zones.

8 Per the Base Structure Report, a building is classified as a roofed, floored, and walled enclosed structure (of one or more levels) that is constructed over a plot of land and is suitable for any of a wide variety of activities, such as living, office and/or manufacturing spaces.

Insufficient DoD data[9] is available to draw conclusions regarding cost effectiveness on an empirical basis for climate zones in the Dry (B) category and Marine (C) category shown in Figure 6. However, Figure 7 compares cost effectiveness for the humid zones of CONUS as most DoD GSHP projects have been installed these climate zones 2A – 6A. Figure 7 indicates that in the Humid (A) category, the most cost effective projects have been installed in the 4A climate zone, followed by 3A, 2A, 5A, and 6A. The best average project payback periods have been climate zone 3A, followed by 4A, 2A, 5A, and 6A. One conclusion to draw is that GSHP systems have been most successful in the South, Southeast, Midwest, and Mid-Atlantic regions of the country. Furthermore, from the analyses conducted in this section, climate zones 3A and 4A appear to be the most cost effective climate zones, followed by 2A, 5A, and 6A.

[9] Only 10 projects have been installed at DoD installations in the Dry (B) climate zones. Furthermore, many of these projects have not reported complete data, making it difficult to compare them with climate zones in the Humid (A) category. No GSHP systems have been reported at DoD installations on the west coast, climate zones 3C and 4C in the Marine (C) zones.

Table 4(a): DOD GSHP Geographical Information Broken into different Climate Zones

Climate Zone No.	Number of Projects Reported	Total Building Area GSHPs Service (KSF)	Total Number of GSHP units Installed	Total GSHP Installed Tons	Average GSHP Cooling Efficiency (EER)	Average GSHP Heating Efficiency (COP)	Total Estimated Land Area Used for GSHP Ground Loops (KSF)	Average Thermal Conductivity (BTU / hr-foot-°F)	Average Bore Hole Depth For Vertical Loops (ft)	Total Project Investment Cost ($)	Total Annual Energy Savings(kWh)	Average Project Estimated Economic Life (yrs)
3A	60	17,186	12,962	28,557	12.31	3.86	4,669	1.06	233	92,278,945	92,173,838	20.1
4A	103	3,444	4,152	10,143	13.25	3.24	3,098	1.65	376	83,137,786	63,205,062	23.0
2A	26	374	2,126	8,271	14.70	3.40	306	1.24	253	9,431,799	2,208,287	20.9
3B	4	No Data	791	2,715	13.50	No Data	441,000	No Data	No Data	6,885,000	No Data	20.0
5A	5	276	1,066	2,168	20.83	4.00	17	1.30	430	9,591,351	756,583	21.7
6A	3	104	44	155	14.80	3.53	17	1.05	267	238,088	1,310	20.0
4B	1	No Data	No Data	40	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
2B	1	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
5B	4	25	6	No Data	No Data	No Data	No Data	No Data	No Data	2,509,345	No Data	No Data

Notes:

No Data - Indicates project(s) has been reported in the climate zone, but no data was reported for the specific category.

Table 4(b): DOD GSHP Projects Geographical Information (cont'd) and Cost Effectiveness Estimates

Climate Zone No.[1]	Climate Zone Name / Type[1]	Representative US City	DOD Bldgs Owned[2] (KSF)	DOD Reported GSHP Installed (KSF)	DOD % Building square Footage using GSHP	Average Cost Effectiveness[3] (Annual Savings (kWh) / Ton Installed)	Average Project Payback Period (yrs)
1A	Very Hot - Humid	Miami, FL	78,716	0	0.00%	N/A	N/A
1B	Very Hot - Dry	--		0	0.00%	N/A	N/A
2A	Hot - Humid	Houston, TX	153,252	374	0.24%	1,304.67	12.20
2B	Hot - Dry	Phoenix, AZ	22,967	1 Project	No Data	No Data	No Data
3A	Warm - Humid	Memphis, TN	361,013	17,186	4.76%	4,941.33	8.60
3B	Warm - Dry	El Paso, TX	205,839	4 Projects	No Data	No Data	No Data
3C	Warm - Marine	San Francisco, CA	70,089	0	0.00%	N/A	N/A
4A	Mixed - Humid	Baltimore, MD	377,642	3,444	0.91%	9,682.90	12.00
4B	Mixed - Dry	Albuquerque, NM	14,385	1 Project	No Data	No Data	No Data
4C	Mixed - Marine	Salem, OR	50,039	0	0.00%	N/A	N/A
5A	Cool - Humid	Chicago, IL	184,607	276	0.15%	511.06	15.10
5B	Cool - Dry	Boise, ID	100,140	25	0.02%	No Data	No Data
6A	Cold - Humid	Burlington, VT	55,527	104	0.19%	16.22	27.30
6B	Cold - Dry	Helena, MT	5,488	0	0.00%	N/A	N/A
7	Very Cold	Duluth, MN	15,543	0	0.00%	N/A	N/A
8	Subartic	Fairbanks, AK	-	0	0.00%	N/A	N/A

Notes:

No Data - Indicates project(s) has been reported in the climate zone, but no data was reported for the specific category.

N/A - Indicates no GSHP projects reported in this climate zone, therefore, no calculation can be made.

1. Climate Zone classification system as proposed by the DOE for use when analyzing energy efficiency strategies. More information located at: http://resourcecenter.pnl.gov/html/ResourceCenter/1420.html and http://www.energycodes.gov/implement/pdfs/climate_paper_review_draft_rev.pdf

2. Data In this column calculated by using the DOD building information reported in the DOD Base Structure Report, Fiscal Year 2005 Baseline and totaling the Building Square footage for each climate zone.

3. Calculated for each climatezone by taking the average of all project's individual cost effectiveness (defined as the reported annual energy savings divided by tons installed GSHP system).

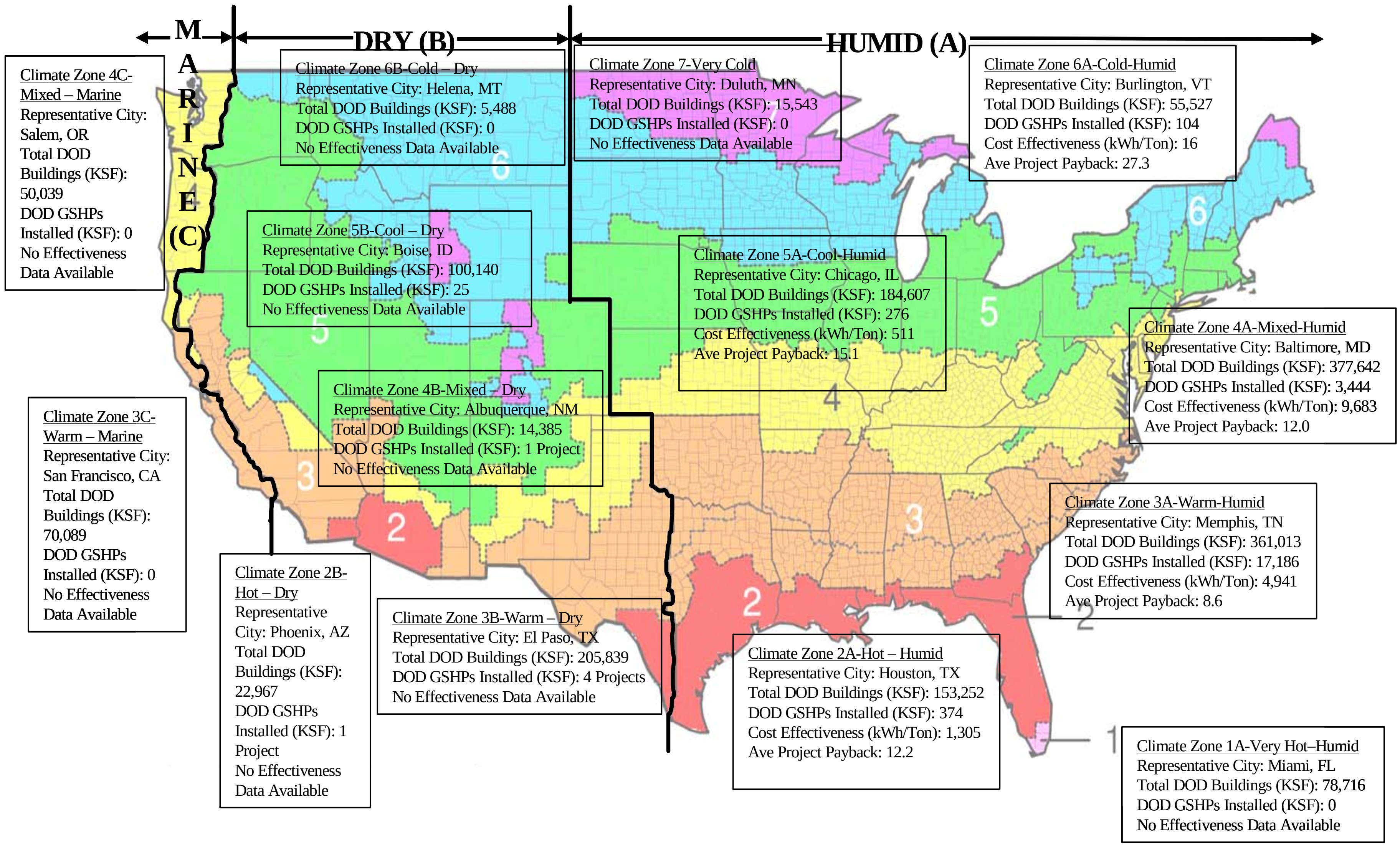


Figure 6: Geographical Summary of Existing GSHPs for each Climate Class

Figure 7(a): DoD GSHP Cost Effectiveness (kWh/TON) vs. Climate Zone

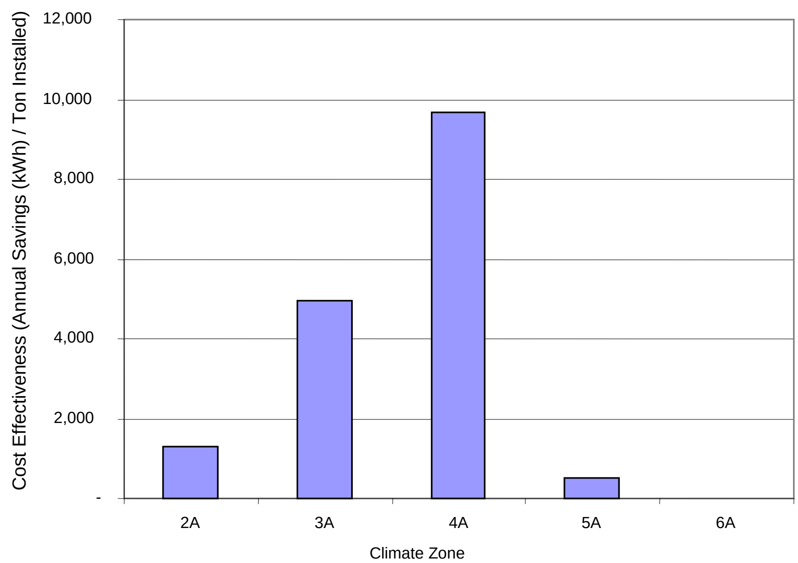
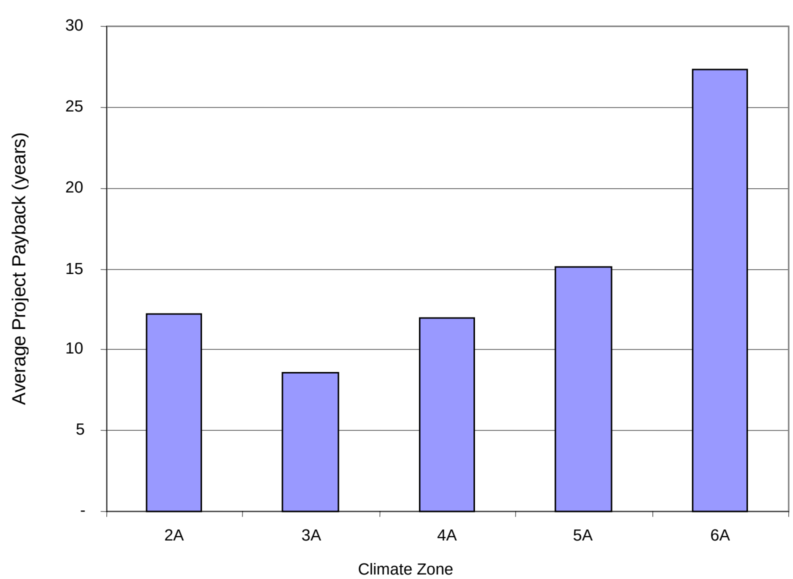


Figure 7(b): DoD GSHP Average Project Payback (years) vs. Climate Zone



3.3.2 Modeling Simulation Analysis

In order to assess the applicability of GSHPs in climate zones where few GSHPs have been installed at DoD installations, ORNL performed computer modeling of several different GSHP applications. Three building types commonly found at DoD installations were chosen for the study: a BOQ, an administrative building, and a training facility. The three were chosen to be representative of type and size that would be most eligible to use GSHP technology.

For each building, as-built drawings, site notes, and blueprints were used to develop a detailed multi-zone building simulation model. Details about the wall construction, window types, shading, occupancy patterns, internal generation, and lighting were taken from the provided drawings or estimated based upon the building type, size, function, and location. The building zones were identified from HVAC drawings, or by building floor plans if the existing HVAC drawings proved incompatible with the goals of the project.

3.3.2.1 The Modeled Buildings

Building 137, located at Naval Air Station Oceana, Virginia Beach, Virginia, consists of office and classroom space along with aircraft hangars. The hangar spaces are not conditioned and were therefore not considered as part of this study. The building is two stories tall and the exterior construction is steel siding over insulation and concrete block. The roof is a built-up roof on steel decking. Interior walls are concrete block. Flooring is vinyl and carpeted. The building has a total area of 42,000 square feet, of which 29,400 square feet is conditioned. The occupancy schedule for the building is 0700 to 1700 hours during weekdays and unoccupied on weekends. The conditioned portion of the building is subdivided into 21 zones.

Building 1150, located at Fort Polk, Louisiana, is a barracks-type building used as a BOQ. The area of the building is 28,200 square feet. The living quarters are arranged in pods of four bedrooms and a living space. There are six pods on each of the three floors. In the newly renovated building, the individual bedrooms and living spaces are each conditioned by individual heat pumps. To simplify the analysis, each pod was modeled as a single zone. This simplification allowed the building to be modeled with 18 zones. The exterior walls are constructed with face brick covering lightweight concrete masonry blocks and the interior walls are gypsum board covering the lightweight concrete masonry blocks. The roof is insulated built-up roofing on a concrete deck. Because the building includes living spaces, the occupancy is considered to be 24 hours a day, 7 days a week. Fresh ventilation air and infiltration for this building are assumed to combine for a constant rate of 0.5 air changes per hour.

Also located at Fort Polk, Louisiana, building 1264 is an administration building consisting of offices and clerical spaces. The building is a single floor, 12,800 square foot building and is occupied from 0700 to 1700 hours on weekdays. The exterior walls are constructed of face brick on insulated concrete masonry units, the interior walls of gypsum board covering concrete masonry units, and the roof is a built up roof on insulated steel decking. Fresh ventilation air and infiltration for this building are assumed to combine for a constant rate of 0.5 air changes per hour.

3.3.2.2 The Climates Selected

Eleven locations were chosen for the modeling study: Boston, MA, Fresno, CA, Great Falls, MT, Guam, Honolulu, HI, Minot, ND, Portland, ME, San Diego, CA, Santa Maria, CA, Seattle, WA, and Tucson, AZ. These places were chosen for two reasons:

- There is a significant presence of DoD installations
- There have been few GSHP systems installed

In each location, a closed-loop, vertical bore GSHP system was designed for each building. A hybrid GSHP system -- which includes either a secondary heat rejecter or a boiler in addition to the ground heat exchanger array – was also designed for each building in each location.

3.3.2.3 The Simulation Modeling Program

Transient Energy System Simulation Tool (TRNSYS) simulation package was used to model and analyze GSHP applications for the common building types and climate zones. The TRNSYS program was designed for this type of analysis and has been used successfully in several previous projects to study geothermal and hybrid geothermal heat pump systems in federal facilities. The TRNSYS program is modular in nature and allows the user to connect components (pumps, ground heat exchangers, pipes, controllers, etc.) together in the simulation tool in much the same way real systems are connected together via pipes and wires. Each of the major components of the HVAC systems studied in this report (ground heat exchanger, water-source heat pump, cooling tower, and chillers) has also been validated against data in previous projects.

In all simulations, the buildings were controlled such that they maintained a heating set-point of 70°F and a cooling set-point of 76°F with a 2°F dead band temperature difference. The heating and cooling was allowed to be on at any time of the year (not scheduled as in typical two-pipe HVAC systems). Auxiliary heat was not utilized in these buildings although it is likely that auxiliary devices would be used in extreme heating locations such as Minot, ND.

3.3.2.4 The Heat Pumps Selected

The heat pumps used in this analysis were Trane model Ground Source High Efficiency Upflow Heat Pumps (GSU). In cooling mode, this heat pump is rated at 19.5 energy efficiency ratio (EER) with 68°F entering water temperature, 80.6°F entering air dry-bulb temperature, and 66.2°F entering air wet-bulb temperature. In heating mode, this heat pump is rated at 3.8 COP with 32°F entering water temperature and 68°F entering air dry-bulb temperature. Manufacturer’s catalog data was used as the basis for the simulation models. The performance from a 2-ton heat pump was normalized such that heat pumps of other sizes could quickly be simulated. Performance of the heat pump model, as specified in the data sets, is affected by entering water temperature, water flow rate, airflow rate, and entering air conditions. TRNSYS uses a multi-variable linear interpolation scheme to estimate the off-design performance based on the normalized catalog data points. The heat pumps were each assumed to operate at a liquid flow rate of 2.88 gallons per minute per ton and an airflow rate of 400 cubic feet per minute per ton.

The heat pumps were individually sized for each zone in each of the buildings such that the temperature of the zone was maintained between set points at design entering water conditions (30°F minimum entering fluid temperature for glycol-based heating, 40°F minimum entering fluid temperature for water-based heating, and 95°F maximum entering fluid temperature) during all hours of the year.

For the standard geothermal heat pump system a rather generic system was assumed, one that is representative of many installed GSHP projects at federal facilities. There is only one piping loop and the ground heat exchanger is not separated from the building loop by a heat exchanger.

3.3.2.5 The Ground Heat Exchangers

The ground heat exchanger system is comprised of a set of vertical, closed-loop borehole ground heat exchangers, connected in parallel. The boreholes contain one u-tube pipe per borehole. The u-tube piping is 1″ Standard Dimension Ratio SDR-11 polyethylene pipe with 3 inches between centers of the u-tube legs. The boreholes are 4.5 inches in diameter, spaced 20 feet apart and are drilled to a depth of 250 feet. The assumption is that bores are grouted using a mixture with a thermal conductivity of 0.85 British Thermal Units per hour-foot-degree-Fahrenheit. For each building in each location, sufficient bores were included to limit the maximum entering fluid temperature to 95°F in cooling dominated systems, and to a minimum of 30°F in heating dominated systems (which use glycol in the loop), over a 20-year design period.

The simulation uses the duct ground storage model (DST), developed by Lund University in Sweden. The DST model has been tested extensively, and has been found to agree well with monitored data from actual ground heat exchanger installations.

3.3.2.6 The Soil Parameters

One of the most important factors in the design of ground heat exchangers is soil thermal conductivity. Soil conductivity depends on the composition of the soil formation, and can vary considerably in a given area. In most projects, in situ tests are performed to measure the soil conductivity at several locations on the site. For this reason, three different soil types were simulated in each location: a heavy saturated soil with thermal conductivity of 1.6 British Thermal Units per hour-foot-degree-Fahrenheit; a heavy damp soil with thermal conductivity of 1.3 British Thermal Units per hour-foot-degree-Fahrenheit; and a damp light soil with thermal conductivity 1.0 British Thermal Units per hour-foot-degree-Fahrenheit.

3.3.2.7 Hybrid GSHP systems

For the hybrid systems, a closed-circuit cooling tower was chosen as the secondary heat rejection device and a gas-fired boiler was chosen for the secondary heat supply device. The cooling tower is assumed to be located upstream of the ground heat exchanger in cooling dominated locations and the boiler is assumed to be located downstream of the ground heat exchanger in heating dominated applications. For cooling dominated locations, the boiler is valved-out of the simulation and for heating dominated locations the cooling tower is valved-out of the simulations.

In the hybrid systems, the ground heat exchanger is designed to meet the peak cooling load in heating dominant applications, and to meet the peak heating load in cooling dominant applications. The fluid is diverted to the ground heat exchanger whenever the heat pumps are in net heating mode or whenever the ground heat exchanger temperature is less than the entering fluid temperature to the ground heat exchanger in cooling mode.

The cooling tower is controlled to act as a peaking device, coming on whenever the heat pump leaving fluid temperature reaches some critical value. The tower fan and spray pump are initiated at a leaving heat pump fluid temperature of 89°F with the tower fan operating at half its rated speed. The tower fan and spray pump remain on until the leaving heat pump fluid temperature falls below 86°F. If the heat pump leaving fluid temperature reaches 94°F, the tower goes to full-speed fan operation until the heat pump leaving fluid temperature falls below 91°F, at which time the fan speed is reduce to half-speed operation.

In heating-dominated systems, a natural gas boiler is used to provide heat to the working fluid during the heating season. The boiler is assumed to have an overall efficiency of 82%. The boiler adds heat to the loop whenever the loop temperature falls below a specified set point. The boiler is assumed to be infinitely adjustable with no degradation due to part-load effects, and maintains the minimum set point temperature at all times of the year.

3.3.2.8 Baseline System

In order to estimate savings associated with a retrofit project, some assumptions must be made about the baseline equipment. Experience has shown that most of the commercial buildings receiving GSHP retrofits at DoD facilities were formerly served by central steam and hot water plants for heating, and either air- or water-cooled chillers for cooling. Installing GSHPs permits the central plants and chillers to be decommissioned, resulting in significant energy and maintenance savings. Given the popularity of this retrofit, the baseline equipment in all buildings was assumed to be four-pipe systems served by a central heat plant and on-site air-cooled chillers.

Representative values were used for the cost of heat pumps, boilers, pumps, and cooling towers as well as drilling and installation of ground heat exchangers. The price of utilities was taken from current defense utilities energy reporting system (DUERS) data for military installations in each city. Average values of maintenance savings were derived from records of retrofit projects. For the hybrid GSHP systems, maintenance savings were reduced by 50% to account for the increased maintenance required for the boiler or cooling tower.

3.3.2.9 Results

Table 5 presents the simple payback of the GSHP and hybrid GSHP systems for each of the three buildings, in each city, and for each of the soil types. The simple payback is calculated as the first cost of the GSHP system divided by the annual energy and maintenance cost savings realized by the GSHP retrofit.

For the most part, the results accord with experience. First, it is clear that many of the cities selected are not ideal for vertical bore GSHPs, and it is for this reason that few vertical bore GSHP systems have been installed in DoD facilities in these locations. Fresno, San Diego, Santa Maria, and Seattle have relatively light space conditioning loads, and the shorter run times of the heat pumps reduce the annual savings, leading to longer paybacks. Since Honolulu and Guam have essentially no heating loads, a large number of ground heat exchangers are required to limit the fluid temperature to 95°F over a 20-year period. This increases the system cost and the payback period. Minot has large heating loads and rather light cooling loads, so a large number of ground heat exchangers are required to keep the minimum fluid temperature above 40°F over a 20-year period. This results in high system costs and long paybacks. In addition, as expected, the higher the thermal conductivity, the shorter the payback, because soil formations with high thermal conductivity require fewer bores, which lowers the first cost.

What these results show most clearly is that hybrid GSHP systems can be economically feasible in locations where vertical bore GSHP systems are not. On the other hand, in locations with more balanced heating and cooling loads, hybrid systems offer smaller advantages and may have even longer paybacks.

Of course, these numbers are representative only, and are meant for comparison. The costs and benefits of actual GSHP systems in all of these climates may be quite different because of the particulars of the application, utility rates, soil parameters, local drilling conditions, and the cost of labor in the local economy. It should also be recognized that these results apply to vertical bore GSHP systems only. Depending on the availability of resources, other GSHP system types — open loop and standing column wells, for example — may be economical in locations where vertical bore GSHP systems are not.

Table 5(a): Bldg 137 (classroom): Simple payback (years) of vertical bore GSHP and hybrid GSHP systems in various cities, and with various soil types

	Vertical bore GSHP			Hybrid GSHP		
	Soil type			Soil type		
City	Heavy sat	Damp heavy	Damp light	Heavy sat	Damp heavy	Damp light
Boston, MA	11	15	19	12	16	19
Fresno, CA	20	> 25	> 25	12	14	16
Great Falls, MT	13	20	> 25	10	11	13
Honolulu, HI	> 25	> 25	> 25	> 25	> 25	> 25
Minot, ND	22	> 25	> 25	11	13	14
Portland, ME	6	9	13	5	7	8
San Diego, CA	> 25	> 25	> 25	> 25	> 25	> 25
Santa Maria, CA	> 25	> 25	> 25	> 25	> 25	> 25
Seattle, WA	17	23	> 25	19	23	21
Tucson, AZ	> 25	> 25	> 25	12	14	16

Table 5(b): Bldg 1264 (admin): Simple payback (years) of vertical bore GSHP and hybrid GSHP systems in various cities, and with various soil types

	Vertical bore GSHP			Hybrid GSHP		
	Soil type			Soil type		
City	Heavy sat	Damp heavy	Damp light	Heavy sat	Damp heavy	Damp light
Boston, MA	12	19	> 25	12	16	19
Fresno, CA	11	15	19	12	15	18
Great Falls, MT	13	22	> 25	6	7	8
Honolulu, HI	> 25	> 25	> 25	17	17	17
Minot, ND	24	> 25	> 25	7	8	9
Portland, ME	7	11	16	4	4	5
San Diego, CA	> 25	> 25	> 25	> 25	> 25	> 25
Santa Maria, CA	12	16	23	13	16	19
Seattle, WA	11	17	> 25	8	10	11
Tucson, AZ	12	18	> 25	8	10	12

Table 5(c): Bldg 1150 (barracks): Simple payback (years) of vertical bore GSHP and hybrid GSHP systems in various cities, and with various soil types

	Vertical bore GSHP			Hybrid GSHP		
	Soil type			Soil type		
City	Heavy sat	Damp heavy	Damp light	Heavy sat	Damp heavy	Damp light
Boston, MA	14	22	> 25	11	14	16
Fresno, CA	11	17	23	9	11	13
Great Falls, MT	16	25	> 25	5	6	6
Honolulu, HI	> 25	> 25	> 25	24	24	24
Minot, ND	> 25	> 25	> 25	6	7	7
Portland, ME	8	13	18	3	4	4
San Diego, CA	> 25	> 25	> 25	> 25	> 25	> 25
Santa Maria, CA	14	22	> 25	14	17	20
Seattle, WA	11	17	> 25	8	10	11
Tucson, AZ	12	18	> 25	8	10	12

3.3.2.10 Additional Cities Modeled for Building 137

Of the three buildings simulated, Building 137 appears economically feasible in the fewest locations, for all three soil types. To show how the economics of GSHP systems change in locations that have already proven to be economically feasible, this building was simulated in three additional cities: Baltimore, Maryland; Louisville, Kentucky; and Oklahoma City, Oklahoma. A significant numbers of GSHP systems have been installed at DoD facilities in the climate regions these cities represent.

The results are presented in Table 5(d). Vertical bore GSHP systems for Building 137 have much shorter paybacks in these three cities than in the eleven cities shown in Tables 5(a)-(c). The balanced annual heating and cooling loads in these locations reduce the required heat exchanger lengths, which lowers the installation cost of the system. Note also that for this building in Baltimore and Louisville, a hybrid GSHP system offers little advantage over a conventional vertical bore GSHP system. Because of the balanced loads, the reduction in drilling cost is less than the additional cost of the cooling tower or boiler and the required maintenance.

Table 5(d): Simple payback (years) for Building 137 of vertical bore GSHP and hybrid GSHP systems with various soil types in three additional cities.

	Vertical bore GSHP			Hybrid GSHP		
	Soil type			Soil type		
City	Heavy sat	Damp heavy	Damp light	Heavy sat	Damp heavy	Damp light
Baltimore, MD	6	8	10	7	8	10
Louisville, KY	8	11	15	9	11	13
Oklahoma City, OK	9	12	16	7	8	10

3.3.2.11 Retrofit vs. New Construction

In Tables 5(a) – (d), the simple payback is calculated by dividing the installation cost of the GSHP or hybrid system by the annual energy and maintenance cost savings. In new construction, or when the existing equipment is near the end of its useful life and the choices are replacement with other conventional equipment or installing ground source heat pumps, only the cost *difference* between the GSHP system and the conventional equipment must be considered. While this difference will always be less than the cost of the GSHP system itself, energy and maintenance cost savings will also be lower when comparing GSHPs with new conventional equipment. The results are highly dependent on the conventional alternative considered.

4. Applicability of GSHPs in New Construction and Retrofitting for DoD Facilities

DoD owns and manages more than fifty percent of all federal buildings in CONUS, with 283,547 buildings currently in operation.[10] This significant number of buildings represents an excellent opportunity for DoD to assume an active leadership role in energy conservation and reduction by incorporating sustainable design practices, including GSHP technology, into existing buildings as well as any new construction.

4.1 Federal and DoD Requirements for New Construction and Retrofit Projects

Section 109 of EPAct 2005 entitled "Federal Building Performance Standards" identifies requirements for all new Federal buildings to be designed at a level 30% below ASHRAE 90.1-2004 energy efficiency standards or International Energy Code if life cycle cost effective, and to apply sustainable design principles in all new federal buildings. The following delineates some of the actions taken by DoD that will affect new construction and retrofit energy projects.

- The Air Force is revising the Air Force Policy Directive on Energy Management that implements requirements of DoD Instruction 4170.11 "Installation Energy Management."

- The Army issued the Army Energy Strategy for Installations in July 2005. In December 2005, the Office of the Assistant Secretary of the Army (OASA) mandated by memorandum the immediate implementation of various no-cost, low-cost energy conservation measures. The Army issued the Army Energy and Water Campaign Plan for Installations in August 2006.

- The Assistant Secretary of the Navy (ASN) issued by memorandum in August 2006 a new policy that includes all new and all replacement buildings to at least meet LEED-silver rating[11] in addition to meeting the requirements of EPAct 2005.

- DoD and several Federal agencies signed a Memorandum of Understanding as part of the Whole Building Design Guide[12] (WBDG) for new building design. WBDG is a building design approach aimed at creating efficient, high-performance buildings through integrated design. One of the main design objectives of the WBDG is to incorporate a sustainable design to include the optimization of energy use.

[10] Reported in the DoD Base Structure Report for FY05, reference shown at end of report. The DOE's Energy Efficiency and Renewable Energy website indicates the Federal Government as a whole oversees about 500,000 buildings: http://www.eere.energy.gov/femp/technologies/sustainable.cfm

[11] The United States Green Building Council's (USGBCs) Leadership in Energy and Efficiency Design (LEED). More information on the USGBC and LEED levels can be found at http://www.leedbuilding.org/.

[12] The WBDG is available for review at www.wbdg.org.

4.2 GSHP Applicability for New Construction and Retrofit Projects

Recent research comparing GSHP systems with conventional systems indicates that well designed GSHP systems can be life cycle cost competitive with traditional systems in certain regions of the country. As shown in Appendix A, 138 out of the 264 existing GSHP projects currently operating at DoD facilities have positive annual energy savings, operations and maintenance savings, and overall reduced energy consumption. For the remaining GSHP projects, data related to savings was not reported. Despite that data verification methodologies indicate that some of the reported savings are inflated, none of the projects evaluated for this study were reported as having costs exceeding savings. GSHP technology has been successful at a variety of DoD buildings, in both new construction and retrofit scenarios, and in many different locations throughout CONUS. Best design guidance for GSHP retrofits is to maximize the reuse of components of the existing system, which can reduce initial cost. GSHP retrofitting can be a cost effective alternative[13] when considering a replacement for an existing traditional HVAC system that is operating near the end of the equipment life cycle. A Hybrid GSHP system[14] offers a unique opportunity for a retrofit project to be sized optimally. GSHP technologies offer a viable life cycle cost effective option for achieving EPAct 2005 requirements while incorporating sustainable design principles. DoD can increase the use of GSHP technology by ensuring DoD offices responsible for construction of new facilities and heating and cooling system retrofit projects take advantage of opportunities to incorporate sustainable design.

4.2.1 Family Housing

Since GSHP technology is a viable heating and cooling option for existing and new construction family housing, DoD has installed as much as 79% of its total installed capacity at family housing. GSHP experts suggest that existing systems are often relatively easy to retrofit, which is consistent with data showing that most DoD systems have been retrofits. Although land area available for ground coupling is a primary factor in considering GSHP technology for new construction of family housing, other site-specific factors affect project economics as discussed previously.[15] In addition to land area, retrofit applications in family housing often must address issues such as:

- Capacity of the electrical system to accommodate increased load
- Access for pipes to be routed from the ground-coupling to the building interior and providing freeze protection to these pipes
- Difficulty related to using desuperheaters[16] for domestic hot water heating where HVAC and domestic hot water heating equipment are not collocated

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[13] Cost effective in this context considers an evaluation based on the GSHP system having marginal cost premium over a traditional system replacement in-kind.

[14] Hybrid GSHP systems are discussed in more detail in Section 4.3.

[15] Section 3.1 identifies factors for consideration for GSHP systems.

[16] A de-superheater is defined as an energy saving device in a heat pump that recycles heat from a building to heat domestic hot water. This is mainly achieved during the cooling season when excess heat is available, but can also be achieved in the heating season to heat some or all of the heat needed for domestic hot water.

- Difficulty related to installing new ductwork as usually required in buildings using electric baseboard heat, hydronic baseboard heat, or no existing HVAC
- Difficulty related to increasing existing ductwork size as usually required in buildings equipped with forced air heating but no cooling system

DoD is awarding contracts, which provide operations, maintenance, and renovation of its family housing, an effort known as housing privatization. Although privatized houses are contractor maintained and operated, DoD has an interest in using energy efficient facilities. A possible solution is for DoD to require the privatized housing contractors to incorporate and implement the best available life cycle cost effective technologies for all renovation and new construction of DoD family housing.

4.2.2 Administration and Office Buildings and Unaccompanied Personnel Housing

GHSP systems, when properly designed for commercial scale buildings, offer equal or superior comfort compared to conventional HVAC systems with reduced operations and maintenance costs. Commercial scale buildings include the following categories: administrative, office, and unaccompanied personnel housing. DoD data shows that 17% of the total installed GSHP capacity is used at commercial scale buildings. When choosing a GSHP system over a conventional HVAC system, the return-on-investment of a commercial scale application is typically more favorable than that of a residential scale application, given the same conditions. Further, the cost savings[17] from using a GSHP system in-lieu of a more complex conventional HVAC system is often much greater than the savings from a residential application. The reduction in operations and maintenance costs contributes to the lower life cycle cost of a GSHP system and helps to offset its higher initial expense.

There are no impediments to installing GSHP systems in new construction of DoD commercial scale buildings as long as adequate land area is available. In general, the economics will be more favorable than for family housing unit installations, but the viability of a project is specific to the site and the usage of the building.

For retrofit applications of commercial scale DoD buildings, available land area and economic issues should be considered. Other potential issues include:

- Adequate sizing of the electrical system where fossil fuel heating equipment is being replaced;
- Potential modification of ventilation air systems due to the inability of the water to air heat pump to heat large quantities of cold outdoor air to acceptable air temperatures;
- Adequate sizing of ductwork where units that have been equipped with fossil fuel fired forced air heating but not air-conditioning since GSHP systems use lower output temperatures requiring higher air flow rates to match the heating of fossil fuel fired furnaces

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[17] Cost savings are from simplified operations and maintenance of a GSHP system.

- Use of water-to-water heat pumps for radiant floor heating systems. They may be used, but they do not produce high enough temperatures for baseboard hot water heating or fan coil units originally sized for the typical 160-180 °F hot water supply;
- Buildings currently supplied heating and/or cooling from a centralized plant may experience many of the same issues as buildings with fossil fuel fired equipment. However, the ability to distribute heating/cooling equipment into the conditioned zones, which results in little or no requirement for mechanical room space, is an advantage of GSHP retrofits that other decentralization options may not possess; and
- The misconception that a single large GSHP system is more efficient than several smaller ones. Considering that smaller GSHP units often have higher efficiencies and that air distribution from a single source results in increased fan power consumption and frictional losses, locating the heat pump units out in the zones may be more favorable. However, this will often require a complete renovation of the ductwork system even where it otherwise may have been adequate.

4.2.3 Shops, Hangars, and Warehouses

Shops, hangers, and warehouses are seldom good candidates for GSHP systems. These industrial buildings rarely have any air-conditioning equipment installed, which results in an uneven heating and cooling load profile. This results in the requirement for very large and expensive GSHP systems for all but ground water heat pump systems assuming that adequate water resources are available. Additionally, the typical means of heat delivery in such buildings - fuel fired overhead infrared or unit air heaters, or steam or hot water unit heaters - do not lend themselves to GSHP retrofits. These types of buildings often require very fast recovery from heavy loads, such as the opening of large doors, and providing such capacity using heat pump based systems is often prohibitively expensive.

The exception where GSHP systems may be feasible is in industrial settings with radiant slab heating. In this case, for either new or retrofit applications, water-to-water heat pumps are worthy of closer evaluation. Radiant slab heating systems offer two advantages over the other types of heating systems mentioned above that make them suitable for use with GSHP: They operate at very low supply water temperatures of typically about 100 °F or lower and the thermal mass of the slab provides for very quick recovery when doors have been opened. In addition, radiant floor heating systems offer ideal heat delivery for shops, hangers, and warehouses, providing superior comfort to occupants while reducing thermal stratification in the building and hence reduce heat losses.

4.3 Utilizing Hybrid System Design in New Construction and Retrofit Projects

Hybrid systems can be another option to consider, especially for retrofit projects where an older existing system can be retrofitted and combined with a GSHP system. Hybrid systems often involve coupling a ground heat exchanger with an auxiliary heat rejecter, such as a cooling tower. Alternatively, the ground heat exchanger can be coupled with a supplemental boiler. “A Capitol Cost Comparison of Commercial Ground-Source Heat

Pump Systems" by Rafferty indicates that reductions in the capital cost of commercial GSHP systems by 20-80% can be achieved by incorporating hybrid or groundwater system designs. Additionally, the results from the computer modeling of DoD buildings indicate that a number of systems that are not economically viable projects when modeled with vertical-bore GSHP systems become economically viable when the systems are hybridized. These results indicate that hybrid GSHP systems may have better applicability for DoD facilities in CONUS regions where non-hybrid GSHP systems are not cost effective. DoD personnel are encouraged to consider hybrid GSHP system in these regions for new-construction and especially for retrofit projects. The Federal Energy Management Program (FEMP) report, "Assessment of Hybrid Geothermal Heat Pump Systems," is a resource for more information on hybrid GSHP systems.

4.4 Additional Resources Available for Considering GSHP Systems for New Construction and Retrofit Projects

DOE's Energy Efficiency and Renewable Energy (EERE) FEMP website provides information on new construction and retrofitting opportunities for federal facilities from

- http://www1.eere.energy.gov/femp/program/newconstruction.html

DoD personnel interested in evaluating GSHP potential for their facility can use the following document provided by FEMP:

- http://www1.eere.energy.gov/femp/pdfs/ghp_screening_21oct03.pdf

Additional technical information on retrofit guidelines for retrofitting GSHP systems in existing facilities is available in "Guide to Geothermal Heat Pump Applications in Federal Facilities" from ORNL. The information includes retrofit guidelines for multiple dwelling units such as barracks, officer/visitor quarters, military hospitals, schools, and offices. This document is still in press. For a copy of this report, the reader is encouraged to contact the author listed in the reference section.

Typically, projects with larger capital costs and longer payback periods are combined with shorter payback energy conservation measures through alternative financing mechanisms like ESPCs or UESCs. The majority of GSHP systems within DoD have been financed through either an ESPC or UESC. DoD personnel interested in evaluating GSHP technology potential through alternative financing mechanisms are encouraged to visit the following sites:

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

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

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

For more information regarding UESC Contracting:
www.eren.doe.gov/femp/utility.html

Additionally, Appendix D.1.1 includes a section on financing as related to lessons learned from past DoD projects and includes a discussion on alternative financing methods.

The following DoD points of contact have been provided for each service for further inquiry of GSHP systems:

- Army: Mr. Don C. Juhasz, Chief Army Utilities and Energy Team, Office of the Assistant Chief of Staff for Installation Management, (703) 601-0374, DSN: 329-0374, email: don.juhasz@us.army.mil
- Air Force: Mr. Gerald Doddington, AFCESA, Gerald.Doddington@tyndall.af.mil
- Navy / Marine Corps: Mr. Bryan Long, Naval Facilities Engineering Service Center, Energy Engineering Branch OP22, (805) 982-5177, DSN: 551-5177, email: Bryan.p.long@navy.mil; or
- Commanding Officer, Marine Corps Air Station Beaufort, Attn. Mr. Neil Tisdale, PO Box 55019, Beaufort, SC 29904-5019, email: belton.tisdale@usmc.mil

5. Conclusions and Recommendations for Facilitating an Increased use of GSHPs at DoD Facilities

This chapter summarizes the findings of this report, including recommendations for further GSHP implementation at DoD facilities. Appendix D includes information from lessons learned associated with DoD GSHP past projects.

5.1 Conclusions

The most common application of GHSP in DoD has been in family housing units in the eastern half of the United States where GSHP technology has been most cost effective. GSHP can be a cost effective alternative in new construction and retrofitting of facilities. However, several site-specific parameters must be considered. In order to increase the usage of GSHP in DoD this report recommends some strategies DoD can undertake.

This report was conducted to fulfill the requirements of Section 2825 of the National Defense Authorization Act for Fiscal Year 2006 (Public Law 109-163) and the Joint Explanatory Statement to accompany H.R. 2863, Department of Defense Appropriations Act, 2006 (Public Law 109-148). As required, this report identifies the most common applications of GSHP in the Department; provides an assessment of applicability and cost effectiveness of the use of GSHP in various geographic regions of the U.S.; provides a description of the relative applicability of GSHP systems as related to new construction or retrofitting of DoD facilities; and provides recommendations to encourage the increased use of GSHP in DoD.

Section 2825 (b)(1) required a description of the types of DoD facilities where GSHPs have been used. A data call conducted to fulfill the requirements of this report indicates that GSHP systems have been installed in the following DoD buildings in percent installed capacity: family housing (79%), unaccompanied personnel housing (11%), administrative / office buildings (6%), training facilities (2%), and various other building types (2%).

Section 2825 (b)(2) of NDAA06 required an assessment of the applicability and cost effectiveness of the use of GSHP systems at DoD facilities in different geographic regions of CONUS. Chapter 3 discussed the applicability and cost effectiveness by climate zones of CONUS. The analyses of DoD data identified that the most cost effective regions are in the South, Southeast, Midwest, and Mid-Atlantic. To date, neither the GSHP industry nor DoD facilities have widely used GSHP systems in the other regions of the country. Computer modeling conducted for three representative DoD buildings indicated that vertical-bore GSHP systems when hybridized[18] with conventional HVAC equipment were cost effective in the Northeast, Southwest, Western Mountain, Northwest, and West Coast regions of the CONUS. However, modeling shows that vertical-bore GSHP systems alone are not cost effective, in general, within these regions with the caveat that other specific site conditions could yield favorable

[18] The term "hybridized" refers to installing a GSHP system coupled with traditional HVAC equipment such as a cooling tower or a boiler.

economics. Some anomalies that may influence favorable economics at sites within these regions may be uniquely high utility charges or economic incentives such as rebates. Further analysis, such as detailed modeling, is needed to identify specific opportunities in those areas of the continental United States.

Section 2825 (b)(3) of NDAA06 required a description of the relative applicability of GSHP systems as related to new-construction and retrofitting of DoD facilities. Chapter 4 discussed this applicability. Chapter 4 discussed the new federal and DoD requirements as per EPAct 2005 and subsequent service policies for new-construction and retrofit projects at Federal facilities. These new requirements include aggressive new standards for incorporating sustainable design practices into all federal new construction and retrofit projects as long as they are life cycle cost effective options. GSHP systems are an option to be considered, as they can be energy efficient systems when designed and installed properly, for federal faculties in achieving these new standards especially in regions of the country where the technology has been proven to be cost effective: the South, Southeast, Midwest, and Mid-Atlantic regions of CONUS. Chapter 4 also discussed site-specific issues related to new construction and retrofit scenarios for major DoD building categories. Some specific parameters that heavily affect the cost effectiveness of using GSHP technology for facilities under new construction or retrofit are:

- Climate and soil thermal properties;
- The GSHP technology type to be used;
- Size of system(s);
- Building characteristics and infrastructure;
- Feasibility of using GSHP hybrid design; and
- The cost and efficiency of the new or existing conventional HVAC equipment compared to a GSHP system

Decisions should be made with these site-specific parameters in mind on a life cycle cost basis to ensure the most life cycle cost effective and energy efficient technology is chosen.

Appendix D contains a summary of the vast number of lessons learned from DoD GSHP projects. GSHP can be a cost effective alternative in new construction and retrofitting of facilities. Lessons learned include:

- Correct GSHP system design and installation is paramount to ensuring system performance and energy savings are achieved;
- Experienced designers and installers are critical to ensuring GSHP systems are designed and installed properly;
- Great care must be shown when planning GSHP system layout to ensure ground heat exchanger bore fields do not interfere with each other or future changes in the mission of the base;
- Education of GSHP system operation for maintenance staff and building tenants is critical to ensure that systems continue to operate properly; and

- Hybridizing GSHP systems can solve system underperformance issues and, in some instances, may be the most cost effective design option.

5.2 Recommendations for Facilitating and Encouraging the Increased Use of Ground-Source Heat Pumps at DoD facilities

1. *Train select personnel who will act as the advocate for GSHP within each service.* Utilize training opportunities provided by IGSHPA or others to train select personnel within each service. These personnel will educate others and advocate GSHP use in cases, which are life cycle cost effective. The Department will encourage the Services to initially choose personnel from the respective engineering centers and provide training as part of the normal professional development process. Training may expand to facility managers in regional areas where GSHP are considered viable.

2. *Design assistance*. DoE's ORNL is considered a federal government center of expertise for GSHP. Service advocates will be familiar with product and services available through ORNL and will serve as a facilitator between the requirements generators and ORNL to obtain any needed services. ORNL will work initially on a reimbursable basis. DoD will work with DoE FEMP to provide specified general services using DoE funding in the future.

3. *Specifications*. The Department will review DoD Unified Facilities Guide Specifications covering GSHP systems will be reviewed for consistency, applicability, etc. and updated as needed.

4. *Design manual*. DoD will encourage the industry and ASHRAE to update the GSHP design manual. While the existing ASHRAE manual (ASHRAE, 1997) is still pertinent, it is nearly 10 years old and in an evolving field such as GSHP an updated design manual is prudent. DoD will ask ORNL to assist as needed.

5. *Soil thermal properties database*. ORNL has begun an effort to collect a database of soil thermal properties. DoD will work with ORNL to populate and publicly deploy this database. The database could store data for future use at the collection location, for extrapolation to similar locations, and for study purposes as.

6. *Continue DoD screening feasibility analyses*. Screening results from this report have identified regions where GSHP technology can potentially be life cycle cost effective. These analyses will be continued for more site-specific DoD installations. DoD advocates will continue this work in collaboration with ORNL, using established computer modeling capability.

7. *Studies of long term performance of existing DoD GSHP installations*. The Services will be encouraged to budget for and execute long-term performance studies at select existing GSHP installations. Although many GSHP projects have been constructed, aside from a project at Fort Polk, no detailed studies have been conducted. GSHP system degradation due to potential heat build-up will be a central theme of focus, since some of the earlier DoD GSHP installations are nearing or past their design life.

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APPENDIX A: DoD Ground Source Heat Pump Database for Continental United States as Reported Summer 2006

APPENDIX A1 – US Army Operational Projects
APPENDIX A2 – US Army Planned Projects
APPENDIX A3 – US Air Force Operational Projects
APPENDIX A4 – US Air Force Planned Projects
APPENDIX A5 – US Navy/Marine Corps Operational Projects
APPENDIX A6 – US Navy/Marine Corps Planned Projects

	A	B	C	D	E	F	G	H	I	J	K	L
1	General Information											
2	**Federal Agency**	**Facility Name**	**City**	**State**	**Building Area (Sq. Ft.)**	**DOD RPCS Facility Class (2-digit Group)**	**DOD RPCS 2-digit Code**	**Building Additional Information**	**Project Point of Contact (Name, Phone, e-mail)**	**Calender Year Installed**	**Project Status**	**New Construction / Retrofit**
3	Army	Fort Irwin	Barstow	CA	No Data	Family Housing	71	New FHU	Mr. Frank Talampas, (760) 380-3429, francisco.talampas@irwin.army.mil	1997	No Data	No Data
4	Army	Fort McNair	Washington	DC	41,795	Family Housing	71	Bldgs. 16-20,29,31	Mark Zangara, Fort Myer DPW, (703) 696-3804, mark.zangara@us.army.mil	2001	No Data	No Data
5	Army	Mobile District - U.S. Army Corps of Engineers, Panama City Site Office	Panama City	FL	No Data	Administrative	61	No Data	Terrence D. Jangula, Panama City Site Manager, (850) 784-9780, terrence.d.jangula@sam.usace.army.mil	1995	Operational	No Data
6	Army	National Guard Armory	Estherville	IA	31,205	Covered Storage	44	New construction 31,205 Sq Ft	Earl Harper, Energy Manager, (515) 252-4513, earl.harper@ia.ngb.army.mil	2003	Operational	No Data
7	Army	National Guard Armory	Warterloo	IA	35,305	Covered Storage	44	Addition/Alteration 35,305 Sq Ft	Earl Harper, Energy Manager, (515) 252-4513, earl.harper@ia.ngb.army.mil	2005	Operational	No Data
8	Army	National Guard Armory	Ft Dodge	IA	37,307	Covered Storage	44	Addition/Alteration 37,307 Sq Ft	Earl Harper, Energy Manager, (515) 252-4513, earl.harper@ia.ngb.army.mil	2006	Operational	No Data
9	Army	St. Louis District - U.S. Army Corps of Engineers, 1 Bldg	Carlyle	IL	No Data	Administrative	61	No Data	(618) 594-2484	2000	Operational	No Data
10	Army	St. Louis District - U.S. Army Corps of Engineers, 1 Bldg	Carlyle	IL	No Data	Administrative	61	No Data	(618) 594-2484	1993	Operational	No Data
11	Army	Rock Island Arsenal	Rock Island	IL	59,280	Family Housing	71	Retro Bldgs. 92-100	David Osborn, RIA DPW, (309) 782-2393, david.l.osborn@us.army.mil	2003	Operational	No Data
12	Army	Fort Riley	Manhattan	KS	38,146	Unaccompanied Personnel Housing	72	Retro BOQ	Russ Goering, Fort Riley DPW, (785) 239-2371, russ.goering@riley.army.mil	1995	Operational	Retrofit
13	Army	Fort Riley	Manhattan	KS	No Data	No Data	No Data	No Data	Russ Goering, Fort Riley DPW, (785) 239-2371, russ.goering@riley.army.mil	1999	Operational	New Construction
14	Army	Fort Knox	Fort Knox	KY	127,096	Administrative	61	# 1467	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2003	Operational	No Data
15	Army	Fort Knox	Fort Knox	KY	72,016	Administrative	61	# 1468	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2004	Operational	No Data
16	Army	Fort Knox	Fort Knox	KY	23,605	Administrative	61	# 1476	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2006	Operational	No Data
17	Army	Fort Knox	Fort Knox	KY	8,485	Administrative	61	# 1477	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2006	Operational	No Data
18	Army	Fort Knox	Fort Knox	KY	8,485	Administrative	61	# 1478	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2006	Operational	No Data
19	Army	Fort Knox	Fort Knox	KY	3,707	Administrative	61	# 1489	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2006	Operational	No Data
20	Army	Fort Knox	Fort Knox	KY	8,485	Administrative	61	# 2372	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2005	Operational	No Data
21	Army	Fort Knox	Fort Knox	KY	9,088	Training Facilities	17	# 5217	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2001	Operational	No Data
22	Army	Fort Knox	Fort Knox	KY	12,652	Unaccompanied Personnel Housing	72	# 855	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2002	Operational	No Data
23	Army	Fort Knox	Fort Knox	KY	12,991	Unaccompanied Personnel Housing	72	# 856	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2002	Operational	No Data
24	Army	Fort Knox	Fort Knox	KY	12,500	Unaccompanied Personnel Housing	72	# 857	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2002	Operational	No Data
25	Army	Fort Knox	Fort Knox	KY	39,218	Unaccompanied Personnel Housing	72	# 1474	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2006	Operational	No Data
26	Army	Fort Knox	Fort Knox	KY	41,631	Unaccompanied Personnel Housing	72	# 1475	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2006	Operational	No Data

	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
1	**GHP Technical Information**																	
2	**GHP Type**	**# of GHP units Installed**	**Project Total Installed Tons**	**GHP Cooling Efficiency (EER)**	**GHP Cooling Capacity (TON)**	**GHP Heating Efficiency (COP)**	**GHP Heating Capacity (BTUH)**	**Fluid Type used in GHP**	**GHP Piping Material Used**	**Estimated Land Area Used for Project (sq ft)**	**Thermal Conductivity (BTU / hr-foot-°F)**	**Average Bore Hole Depth For Vertical Loops (ft)**	**Predominant Soil Type**	**Predominant Rock Formations**	**Average Distance to Water Table (ft)**	**Average Distance to Bedrock (ft)**	**Average Frost Depth (ft)**	**IECC Climate Zone Class**
3	Water Util	200	600	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	3B
4	V	7	40	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	4A
5	H,O	16	16	No Data	16	No Data	192,000	Water	Copper	300	No Data	No Data	SS	Limestone	30	120	0	2A
6	V,C	16	81	16.20	43	3.6	453,400	30% Glycol	HDPE	1,200	No Data	300	Sand/Clay	Limestone	35	No Data	4.5	6A
7	V,C	11	26	12.00	15	3.0	134,100	30% Glycol	HDPE	9,800	1.05	200	Sand	Limestone	15	No Data	4.5	6A
8	V,C	17	48	16.20	26	4.0	262,500	30% Glycol	HDPE	6,400	No Data	300	Clay/Silt	Limestone	6	No Data	4.5	6A
9	V,C	4	18	15.40	35	3.77	50,000	Glycol	Polyethylene	1	No Data	200	Silt/clay	No Data	25	250	2	4A
10	V,C	2	12	15.40	35	3.77	50,000	Glycol	Polyethylene	1	No Data	200	Silt/clay	No Data	25	250	2	4A
11	V	40	120	14.50	3	No Data	34,700	28% methanol	PVC	10,000	No Data	250	Silt	Dolomite	50	6	3	5A
12	V	32	51	No Data	51	No Data	712,000	25% propylene glycol	PE	8,000	769,000 BTUH heat rejection in 60 holes 200' deep.	200	Silty clay	Limestone, shale	None	10	3	4A
13	V	88	245	No Data	245	No Data	2,472,700	No Data	PE or PB	8,800	3,698,000 BTUH heat rejection in 74 holes 250' deep + 102 holes 300' deep.	275	Silty clay	Limestone, shale	None	10	3	4A
14	H,C	69	195	13.00	195	3.1	2,690,000	Water	HDPE	8,800	1.85	400	Clay/Dirt	Limestone	70	35	2.5	4A
15	H,C	52	160	13.00	160	3.1	2,208,000	Water	HDPE	7,200	1.85	400	Clay/Dirt	Limestone	70	35	2.5	4A
16	H,C,Hy	15	46	13.00	46	3.1	634,800	Water	HDPE	2,800	1.85	500	Clay/Dirt	Limestone	70	35	2.5	4A
17	H,C,Hy	6	17	13.00	17	3.1	234,600	Water	HDPE	1,120	1.85	500	Clay/Dirt	Limestone	70	35	2.5	4A
18	H,C,Hy	6	17	13.00	17	3.1	234,600	Water	HDPE	1,120	1.85	500	Clay/Dirt	Limestone	70	35	2.5	4A
19	H,C,Hy	3	6	13.00	6	3.1	82,800	Water	HDPE	500	1.85	500	Clay/Dirt	Limestone	70	35	2.5	4A
20	H,C,Hy	29	90	13.00	90	3.1	1,242,000	Water	HDPE	5,200	1.85	500	Clay/Dirt	Limestone	70	35	2.5	4A
21	H,C	3	15	13.00	15	3.1	207,000	Water	HDPE	2,000	1.85	427	Clay/Dirt	Limestone	70	35	2.5	4A
22	H,C	20	30	13.00	30	3.1	414,000	Water	HDPE	3,000	1.85	400	Clay/Dirt	Limestone	70	35	2.5	4A
23	H,C	20	30	13.00	30	3.1	414,000	Water	HDPE	3,000	1.85	400	Clay/Dirt	Limestone	70	35	2.5	4A
24	H,C	21	30	13.00	30	3.1	414,000	Water	HDPE	3,000	1.85	400	Clay/Dirt	Limestone	70	35	2.5	4A
25	H,C,Hy	25	80	13.00	80	3.1	1,104,000	Water	HDPE	4,480	1.85	500	Clay/Dirt	Limestone	70	35	2.5	4A
26	H,C,Hy	25	80	13.00	80	3.1	1,104,000	Water	HDPE	4,480	1.85	500	Clay/Dirt	Limestone	70	35	2.5	4A

	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN
1	GHP Economic Information									
2	**Average Utility Rate at Project onset ($/kWh)**	**Current Average Natural Gas Rate ($/kcf)**	**Current Average Electric Rate ($/kWh)**	**Project Finance Mechanism**	**Project Investment Cost ($)**	**GHP annual Operation and Maintenance Savings ($)**	**Annual Energy Savings from GHP Installation ($)**	**Annual Energy Savings from GHP Installation (kWh)**	**GHP Project Estimated Economic Life (yrs)**	**Project Payback Period (yrs)**
3	No Data	No Data	UESC	No Data	No Data	No Data	No Data	No Data	No Data	No Data
4	No Data	$ 17.39	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
5	No Data	No Data	$ 0.09600	A	No Data	No Data	No Data	No Data	No Data	No Data
6	$ 0.07123	$ 10.52	$ 0.08921	A	$ 61,100	No Data	$ 2,236	1,310	20	27.3
7	$ 0.07553	$ 9.60	$ 0.06333	A.	$ 78,500	No Data	No Data	No Data	20	No Data
8	$ 0.08035	$ 10.22	$ 0.07194	A	$ 98,488	No Data	No Data	No Data	20	No Data
9	$ 0.06000	No Data	$ 0.09000	A	$ 50,000	$ 1,436	$ 2,872	48,000	50	17.4
10	$ 0.06000	No Data	$ 0.09000	A	$ 24,000	$ 1,933	$ 3,866	64,000	50	6.2
11	$ 0.03100	$ 12.10	$ 0.03100	Super ESPC TS	$ 291,351	$ 13,269	$ 4,138	17,407	25	13.3
12	$ 0.04000	$ 11.10	$ 0.05000	A	No Data	No Data	No Data	No Data	No Data	No Data
13	$ 0.04000	$ 11.10	$ 0.05000	A	No Data	No Data	No Data	No Data	No Data	No Data
14	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 635,000	$ 9,530	$ 46,379	654,162	23	9.0
15	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 1,440,000	$ 21,600	$ 105,120	1,482,708	23	9.0
16	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 495,000	$ 7,000	$ 34,067	480,657	23	9.0
17	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 180,000	$ 2,500	$ 12,167	171,747	23	9.0
18	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 180,000	$ 2,500	$ 12,167	171,747	23	9.0
19	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 78,000	$ 1,100	$ 5,353	75,615	23	9.0
20	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 178,150	$ 2,545	$ 12,386	174,678	23	9.0
21	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 75,000	$ 2,725	$ 13,262	186,987	23	9.0
22	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 196,000	$ 3,800	$ 18,493	260,844	23	9.0
23	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 196,000	$ 3,800	$ 18,493	260,844	23	9.0
24	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 196,000	$ 3,800	$ 18,493	260,844	23	9.0
25	$ 0.03911	$ 11.78	$ 0.03911	ECIP	$ 825,000	$ 11,800	$ 57,427	810,082	23	9.0
26	$ 0.03911	$ 11.78	$ 0.03911	ECIP	$ 875,000	$ 12,500	$ 60,833	858,148	23	9.0

	A	B	C	D	E	F	G	H	I	J	K	L
1	General Information											
2	**Federal Agency**	**Facility Name**	**City**	**State**	**Building Area (Sq. Ft.)**	**DOD RPCS Facility Class (2-digit Group)**	**DOD RPCS 2-digit Code**	**Building Additional Information**	**Project Point of Contact (Name, Phone, e-mail)**	**Calender Year Installed**	**Project Status**	**New Construction / Retrofit**
27	Army	Fort Knox	Fort Knox	KY	41,631	Unaccompanied Personnel Housing	72	# 1479	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2006	Operational	No Data
28	Army	Fort Knox	Fort Knox	KY	39,218	Unaccompanied Personnel Housing	72	# 1480	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2006	Operational	No Data
29	Army	Fort Knox	Fort Knox	KY	40,650	Unaccompanied Personnel Housing	72	# 5916	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2005	Operational	No Data
30	Army	Fort Knox	Fort Knox	KY	40,650	Unaccompanied Personnel Housing	72	# 5919	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2005	Operational	No Data
31	Army	Fort Knox	Fort Knox	KY	40,650	Unaccompanied Personnel Housing	72	# 5920	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2005	Operational	No Data
32	Army	Fort Knox	Fort Knox	KY	40,650	Unaccompanied Personnel Housing	72	# 5921	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2005	Operational	No Data
33	Army	Fort Knox	Fort Knox	KY	40,650	Unaccompanied Personnel Housing	72	# 5922	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2005	Operational	No Data
34	Army	Fort Knox	Fort Knox	KY	41,905	Unaccompanied Personnel Housing	72	# 5936	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2005	Operational	No Data
35	Army	Fort Knox	Fort Knox	KY	41,905	Unaccompanied Personnel Housing	72	# 5937	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2005	Operational	No Data
36	Army	Fort Knox	Fort Knox	KY	41,905	Unaccompanied Personnel Housing	72	# 5938	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2005	Operational	No Data
37	Army	Fort Knox	Fort Knox	KY	41,905	Unaccompanied Personnel Housing	72	# 5939	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2005	Operational	No Data
38	Army	Fort Knox	Fort Knox	KY	41,905	Unaccompanied Personnel Housing	72	# 5941	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2005	Operational	No Data
39	Army	Fort Knox	Fort Knox	KY	40,650	Unaccompanied Personnel Housing	72	# 6010	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2005	Operational	No Data
40	Army	Fort Knox	Fort Knox	KY	40,650	Unaccompanied Personnel Housing	72	# 6011	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2005	Operational	No Data
41	Army	Fort Knox	Fort Knox	KY	40,650	Unaccompanied Personnel Housing	72	# 6015	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2005	Operational	No Data
42	Army	Fort Knox	Fort Knox	KY	40,650	Unaccompanied Personnel Housing	72	# 6017	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2005	Operational	No Data

	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
1	GHP Technical Information																	
2	**GHP Type**	**# of GHP units Installed**	**Project Total Installed Tons**	**GHP Cooling Efficiency (EER)**	**GHP Cooling Capacity (TON)**	**GHP Heating Efficiency (COP)**	**GHP Heating Capacity (BTUH)**	**Fluid Type used in GHP**	**GHP Piping Material Used**	**Estimated Land Area Used for Project (sq ft)**	**Thermal Conductivity (BTU / hr-foot-°F)**	**Average Bore Hole Depth For Vertical Loops (ft)**	**Predominant Soil Type**	**Predominant Rock Formations**	**Average Distance to Water Table (ft)**	**Average Distance to Bedrock (ft)**	**Average Frost Depth (ft)**	**IECC Climate Zone Class**
27	H,C,Hy	25	80	13.00	80	3.1	1,104,000	Water	HDPE	4,480	1.85	500	Clay/Dirt	Limestone	70	35	2.5	4A
28	H,C,Hy	25	80	13.00	80	3.1	1,104,000	Water	HDPE	4,480	1.85	500	Clay/Dirt	Limestone	70	35	2.5	4A
29	H,C	20	57	13.00	57	3.1	787,000	Water	HDPE	3,400	1.85	400	Clay/Dirt	Limestone	70	35	2.5	4A
30	H,C	20	57	13.00	57	3.1	787,000	Water	HDPE	3,400	1.85	400	Clay/Dirt	Limestone	70	35	2.5	4A
31	H,C	20	57	13.00	57	3.1	787,000	Water	HDPE	3,400	1.85	400	Clay/Dirt	Limestone	70	35	2.5	4A
32	H,C	20	57	13.00	57	3.1	787,000	Water	HDPE	3,400	1.85	400	Clay/Dirt	Limestone	70	35	2.5	4A
33	H,C	20	57	13.00	57	3.1	787,000	Water	HDPE	3,400	1.85	400	Clay/Dirt	Limestone	70	35	2.5	4A
34	H,C	20	57	13.00	57	3.1	787,000	Water	HDPE	3,400	1.85	400	Clay/Dirt	Limestone	70	35	2.5	4A
35	H,C	20	57	13.00	57	3.1	787,000	Water	HDPE	3,400	1.85	400	Clay/Dirt	Limestone	70	35	2.5	4A
36	H,C	20	57	13.00	57	3.1	787,000	Water	HDPE	3,400	1.85	400	Clay/Dirt	Limestone	70	35	2.5	4A
37	H,C	20	57	13.00	57	3.1	787,000	Water	HDPE	3,400	1.85	400	Clay/Dirt	Limestone	70	35	2.5	4A
38	H,C	20	57	13.00	57	3.1	787,000	Water	HDPE	3,400	1.85	400	Clay/Dirt	Limestone	70	35	2.5	4A
39	H,C	20	57	13.00	57	3.1	787,000	Water	HDPE	3,400	1.85	400	Clay/Dirt	Limestone	70	35	2.5	4A
40	H,C	20	57	13.00	57	3.1	787,000	Water	HDPE	3,400	1.85	400	Clay/Dirt	Limestone	70	35	2.5	4A
41	H,C	20	57	13.00	57	3.1	787,000	Water	HDPE	3,400	1.85	400	Clay/Dirt	Limestone	70	35	2.5	4A
42	H,C	20	57	13.00	57	3.1	787,000	Water	HDPE	3,400	1.85	400	Clay/Dirt	Limestone	70	35	2.5	4A

	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN
1	**GHP Economic Information**									
2	**Average Utility Rate at Project onset ($/kWh)**	**Current Average Natural Gas Rate ($/kcf)**	**Current Average Electric Rate ($/kWh)**	**Project Finance Mechanism**	**Project Investment Cost ($)**	**GHP annual Operation and Maintenance Savings ($)**	**Annual Energy Savings from GHP Installation ($)**	**Annual Energy Savings from GHP Installation (kWh)**	**GHP Project Estimated Economic Life (yrs)**	**Project Payback Period (yrs)**
27	$ 0.03911	$ 11.78	$ 0.03911	ECIP	$ 875,000	$ 12,500	$ 60,833	858,148	23	9.0
28	$ 0.03911	$ 11.78	$ 0.03911	ECIP	$ 825,000	$ 11,800	$ 57,427	810,082	23	9.0
29	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 615,000	$ 12,300	$ 59,860	844,373	23	9.0
30	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 615,000	$ 12,300	$ 59,860	844,373	23	9.0
31	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 615,000	$ 12,300	$ 59,860	844,373	23	9.0
32	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 615,000	$ 12,300	$ 59,860	844,373	23	9.0
33	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 615,000	$ 12,300	$ 59,860	844,373	23	9.0
34	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 615,000	$ 12,300	$ 59,860	844,373	23	9.0
35	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 615,000	$ 12,300	$ 59,860	844,373	23	9.0
36	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 615,000	$ 12,300	$ 59,860	844,373	23	9.0
37	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 615,000	$ 12,300	$ 59,860	844,373	23	9.0
38	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 615,000	$ 12,300	$ 59,860	844,373	23	9.0
39	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 615,000	$ 12,300	$ 59,860	844,373	23	9.0
40	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 615,000	$ 12,300	$ 59,860	844,373	23	9.0
41	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 615,000	$ 12,300	$ 59,860	844,373	23	9.0
42	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 615,000	$ 12,300	$ 59,860	844,373	23	9.0

	A	B	C	D	E	F	G	H	I	J	K	L
1	General Information											
2	Federal Agency	Facility Name	City	State	Building Area (Sq. Ft.)	DOD RPCS Facility Class (2-digit Group)	DOD RPCS 2-digit Code	Building Additional Information	Project Point of Contact (Name, Phone, e-mail)	Calender Year Installed	Project Status	New Construction / Retrofit
43	Army	Fort Knox	Fort Knox	KY	23,605	Training Facilities	17	# 2371	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2005	Operational	No Data
44	Army	Fort Knox	Fort Knox	KY	41,631	Training Facilities	17	# 2373	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2005	Operational	No Data
45	Army	Fort Knox	Fort Knox	KY	39,218	Administrative	61	# 2374	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2005	Operational	No Data
46	Army	Fort Knox	Fort Knox	KY	39,218	Training Facilities	17	# 2375	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2005	Operational	No Data
47	Army	Fort Knox	Fort Knox	KY	35,760	Unaccompanied Personnel Housing	72	# 2376	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2005	Operational	No Data
48	Army	Fort Knox	Fort Knox	KY	35,760	Unaccompanied Personnel Housing	72	# 2377	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2005	Operational	No Data
49	Army	Fort Knox	Fort Knox	KY	39,218	Unaccompanied Personnel Housing	72	# 2378	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2005	Operational	No Data
50	Army	Fort Knox	Fort Knox	KY	39,218	Unaccompanied Personnel Housing	72	# 2379	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2005	Operational	No Data
51	Army	Fort Knox	Fort Knox	KY	41,647	Unaccompanied Personnel Housing	72	# 2380	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2005	Operational	No Data
52	Army	Fort Knox	Fort Knox	KY	23,605	Unaccompanied Personnel Housing	72	# 2381	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2005	Operational	No Data
53	Army	Fort Knox	Fort Knox	KY	9,752	Administrative	61	# 2002	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2002	Operational	No Data
54	Army	Fort Knox	Fort Knox	KY	31,602	Indoor Morale, Welfare, and Recreation Facilities	74	# 1174	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2001	Operational	No Data
55	Army	Fort Knox	Fort Knox	KY	22,363	Indoor Morale, Welfare, and Recreation Facilities	74	# 4249	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2002	Operational	No Data
56	Army	Fort Knox	Fort Knox	KY	22,956	Indoor Morale, Welfare, and Recreation Facilities	74	# 4250	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2002	Operational	No Data
57	Army	Fort Knox	Fort Knox	KY	11,699	Unaccompanied Personnel Housing	72	# 5915	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2004	Operational	No Data
58	Army	Fort Knox	Fort Knox	KY	11,699	Unaccompanied Personnel Housing	72	# 5917	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2004	Operational	No Data
59	Army	Fort Knox	Fort Knox	KY	11,796	Unaccompanied Personnel Housing	72	# 5940	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2004	Operational	No Data
60	Army	Fort Knox	Fort Knox	KY	No Data	Unaccompanied Personnel Housing	72	# 5942	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2004	Operational	No Data

	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
1	GHP Technical Information																	
2	GHP Type	# of GHP units Installed	Project Total Installed Tons	GHP Cooling Efficiency (EER)	GHP Cooling Capacity (TON)	GHP Heating Efficiency (COP)	GHP Heating Capacity (BTUH)	Fluid Type used in GHP	GHP Piping Material Used	Estimated Land Area Used for Project (sq ft)	Thermal Conductivity (BTU / hr-foot-^oF)	Average Bore Hole Depth For Vertical Loops (ft)	Predominant Soil Type	Predominant Rock Formations	Average Distance to Water Table (ft)	Average Distance to Bedrock (ft)	Average Frost Depth (ft)	IECC Climate Zone Class
43	H,C,Hy	27	62	13.00	62	3.1	856,000	Water	HDPE	3,600	1.85	500	Clay/Dirt	Limestone	70	35	2.5	4A
44	H,C,Hy	29	90	13.00	90	3.1	1,242,000	Water	HDPE	5,200	1.85	500	Clay/Dirt	Limestone	70	35	2.5	4A
45	H,C,Hy	29	90	13.00	90	3.1	1,242,000	Water	HDPE	5,200	1.85	500	Clay/Dirt	Limestone	70	35	2.5	4A
46	H,C,Hy	29	90	13.00	90	3.1	1,242,000	Water	HDPE	5,200	1.85	500	Clay/Dirt	Limestone	70	35	2.5	4A
47	H,C,Hy	29	90	13.00	90	3.1	1,242,000	Water	HDPE	5,200	1.85	500	Clay/Dirt	Limestone	70	35	2.5	4A
48	H,C,Hy	29	90	13.00	90	3.1	1,242,000	Water	HDPE	5,200	1.85	500	Clay/Dirt	Limestone	70	35	2.5	4A
49	H,C,Hy	29	90	13.00	90	3.1	1,242,000	Water	HDPE	5,200	1.85	500	Clay/Dirt	Limestone	70	35	2.5	4A
50	H,C,Hy	29	90	13.00	90	3.1	1,242,000	Water	HDPE	5,200	1.85	500	Clay/Dirt	Limestone	70	35	2.5	4A
51	H,C,Hy	29	90	13.00	90	3.1	1,242,000	Water	HDPE	5,200	1.85	500	Clay/Dirt	Limestone	70	35	2.5	4A
52	H,C,Hy	27	62	13.00	62	3.1	856,000	Water	HDPE	3,600	1.85	500	Clay/Dirt	Limestone	70	35	2.5	4A
53	H,C,Hy	11	38	13.00	38	3.1	530,000	Water	HDPE	2,200	1.85	400	Clay/Dirt	Limestone	70	35	2.5	4A
54	H,C	16	80	13.00	80	3.1	1,104,000	Water	HDPE	8,000	1.85	300	Clay/Dirt	Limestone	70	35	2.5	4A
55	H,C	13	43	13.00	43	3.1	590,000	Water	HDPE	3,750	1.85	400	Clay/Dirt	Limestone	70	35	2.5	4A
56	H,C	13	38	13.00	38	3.1	530,000	Water	HDPE	3,750	1.85	400	Clay/Dirt	Limestone	70	35	2.5	4A
57	V,C	2	40	13.00	40	3.1	552,000	Water	HDPE	2,400	1.85	400	Clay/Dirt	Limestone	70	35	2.5	4A
58	V,C	2	40	13.00	40	3.1	552,000	Water	HDPE	2,400	1.85	400	Clay/Dirt	Limestone	70	35	2.5	4A
59	V,C	2	40	13.00	40	3.1	552,000	Water	HDPE	2,400	1.85	400	Clay/Dirt	Limestone	70	35	2.5	4A
60	V,C	2	40	13.00	40	3.1	552,000	Water	HDPE	2,400	1.85	400	Clay/Dirt	Limestone	70	35	2.5	4A

	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN
1	GHP Economic Information									
2	Average Utility Rate at Project onset ($/kWh)	Current Average Natural Gas Rate ($/kcf)	Current Average Electric Rate ($/kWh)	Project Finance Mechanism	Project Investment Cost ($)	GHP annual Operation and Maintenance Savings ($)	Annual Energy Savings from GHP Installation ($)	Annual Energy Savings from GHP Installation (kWh)	GHP Project Estimated Economic Life (yrs)	Project Payback Period (yrs)
43	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 495,600	$ 7,080	$ 34,456	485,932	23	9.0
44	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 875,000	$ 12,500	$ 60,833	858,148	23	9.0
45	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 822,500	$ 11,750	$ 57,183	806,565	23	9.0
46	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 822,500	$ 11,750	$ 57,183	806,565	23	9.0
47	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 750,750	$ 10,725	$ 52,195	736,225	23	9.0
48	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 750,750	$ 10,725	$ 52,195	736,225	23	9.0
49	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 822,500	$ 11,750	$ 57,183	806,565	23	9.0
50	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 822,500	$ 11,750	$ 57,183	806,565	23	9.0
51	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 875,000	$ 12,500	$ 60,833	858,148	23	9.0
52	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 495,600	$ 7,080	$ 34,456	485,932	23	9.0
53	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 175,000	$ 2,925	$ 14,235	200,762	23	9.0
54	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 632,000	$ 9,480	$ 46,136	650,645	23	9.0
55	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 339,000	$ 6,600	$ 32,120	453,107	23	9.0
56	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 339,000	$ 6,600	$ 32,120	453,107	23	9.0
57	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 175,000	$ 3,500	$ 17,033	240,328	23	9.0
58	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 175,000	$ 3,500	$ 17,033	240,328	23	9.0
59	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 175,000	$ 3,500	$ 17,033	240,328	23	9.0
60	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 175,000	$ 3,500	$ 17,033	240,328	23	9.0

	A	B	C	D	E	F	G	H	I	J	K	L
1	General Information											
2	Federal Agency	Facility Name	City	State	Building Area (Sq. Ft.)	DOD RPCS Facility Class (2-digit Group)	DOD RPCS 2-digit Code	Building Additional Information	Project Point of Contact (Name, Phone, e-mail)	Calender Year Installed	Project Status	New Construction / Retrofit
61	Army	Fort Knox	Fort Knox	KY	11,699	Unaccompanied Personnel Housing	72	# 6012	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2004	Operational	No Data
62	Army	Fort Knox	Fort Knox	KY	11,699	Unaccompanied Personnel Housing	72	# 6018	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2004	Operational	No Data
63	Army	Fort Knox	Fort Knox	KY	No Data	Unaccompanied Personnel Housing	72	# 6424	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2005	Operational	No Data
64	Army	Fort Knox	Fort Knox	KY	4,292	Personnel Support and Services Facilities	73	# 5223	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2001	Operational	No Data
65	Army	Fort Knox	Fort Knox	KY	63,927	Personnel Support and Services Facilities	73	# 7729	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2001	Operational	No Data
66	Army	Fort Knox	Fort Knox	KY	36,758	Administrative	61	# 5101	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2003	Operational	No Data
67	Army	Fort Knox	Fort Knox	KY	135,840	Training Facilities	17	# 1720	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2003	Operational	No Data
68	Army	Fort Knox	Fort Knox	KY	50,816	Training Facilities	17	# 1726	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2004	Operational	No Data
69	Army	Fort Polk	Leesville	LA	29,029	Communications, Navigation Aids and Airfield Light	13	Bldg. 1560	David Hopper, Fort Polk DPW, (337) 531-6877, david.l.hopper@us.army.mil	1993	Operational	No Data
70	Army	Fort Polk	Leesville	LA	25,168	Dental Clinics	54	Bldg. 1562	David Hopper, Fort Polk DPW, (337) 531-6877, david.l.hopper@us.army.mil	1993	Operational	No Data
71	Army	Fort Polk	Leesville	LA	25,168	Administrative	61	Bldg. 1563	David Hopper, Fort Polk DPW, (337) 531-6877, david.l.hopper@us.army.mil	1993	Operational	No Data
72	Army	Fort Polk	Leesville	LA	25,168	Administrative	61	Bldg. 1830	David Hopper, Fort Polk DPW, (337) 531-6877, david.l.hopper@us.army.mil	1996	Operational	No Data
73	Army	Fort Polk	Leesville	LA	17,175	Training Facilities	17	Bldg. 1456	David Hopper, Fort Polk DPW, (337) 531-6877, david.l.hopper@us.army.mil	1996	Operational	No Data
74	Army	Fort Polk	Leesville	LA	39,020	Unaccompanied Personnel Housing	72	Bldg. 522	David Hopper, Fort Polk DPW, (337) 531-6877, david.l.hopper@us.army.mil	1988	Operational	No Data
75	Army	Fort Polk	Leesville	LA	6,762,608	Family Housing	71	Retro FHU	David Hopper, Fort Polk DPW, (337) 531-6877, david.l.hopper@us.army.mil	1996	Operational	No Data
76	Army	Fort Polk	Leesville	LA	1,472	Family Housing	71	Bldg. 15009A	David Hopper, Fort Polk DPW, (337) 531-6877, david.l.hopper@us.army.mil	1989	Operational	No Data
77	Army	Fort Polk	Leesville	LA	1,472	Family Housing	71	Bldg. 15009D	David Hopper, Fort Polk DPW, (337) 531-6877, david.l.hopper@us.army.mil	1989	Operational	No Data
78	Army	Fort Polk	Leesville	LA	1,472	Family Housing	71	Bldg. 15010A	David Hopper, Fort Polk DPW, (337) 531-6877, david.l.hopper@us.army.mil	1989	Operational	No Data
79	Army	Fort Polk	Leesville	LA	1,472	Family Housing	71	Bldg. 15010D	David Hopper, Fort Polk DPW, (337) 531-6877, david.l.hopper@us.army.mil	1989	Operational	No Data
80	Army	Fort Polk	Leesville	LA	1,434	Family Housing	71	Bldg. 15008B	David Hopper, Fort Polk DPW, (337) 531-6877, david.l.hopper@us.army.mil	1989	Operational	No Data
81	Army	Fort Polk	Leesville	LA	1,434	Family Housing	71	Bldg. 15008C	David Hopper, Fort Polk DPW, (337) 531-6877, david.l.hopper@us.army.mil	1989	Operational	No Data
82	Army	Fort Polk	Leesville	LA	2,406	Family Housing	71	Bldg. 15509A	David Hopper, Fort Polk DPW, (337) 531-6877, david.l.hopper@us.army.mil	1989	Operational	No Data
83	Army	Fort Polk	Leesville	LA	2,406	Family Housing	71	Bldg. 15509B	David Hopper, Fort Polk DPW, (337) 531-6877, david.l.hopper@us.army.mil	1989	Operational	No Data
84	Army	Fort Polk	Leesville	LA	2,406	Family Housing	71	Bldg. 15509C	David Hopper, Fort Polk DPW, (337) 531-6877, david.l.hopper@us.army.mil	1989	Operational	No Data
85	Army	Fort Polk	Leesville	LA	2,406	Family Housing	71	Bldg. 15509D	David Hopper, Fort Polk DPW, (337) 531-6877, david.l.hopper@us.army.mil	1989	Operational	No Data

	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
1	GHP Technical Information																	
2	GHP Type	# of GHP units Installed	Project Total Installed Tons	GHP Cooling Efficiency (EER)	GHP Cooling Capacity (TON)	GHP Heating Efficiency (COP)	GHP Heating Capacity (BTUH)	Fluid Type used in GHP	GHP Piping Material Used	Estimated Land Area Used for Project (sq ft)	Thermal Conductivity (BTU / hr-foot-°F)	Average Bore Hole Depth For Vertical Loops (ft)	Predominant Soil Type	Predominant Rock Formations	Average Distance to Water Table (ft)	Average Distance to Bedrock (ft)	Average Frost Depth (ft)	IECC Climate Zone Class
61	V,C	2	40	13.00	40	3.1	552,000	Water	HDPE	2,400	1.85	400	Clay/Dirt	Limestone	70	35	2.5	4A
62	V,C	2	40	13.00	40	3.1	552,000	Water	HDPE	2,400	1.85	400	Clay/Dirt	Limestone	70	35	2.5	4A
63	V,H,C, Hy	16	86	13.00	86	3.1	1,033,000	Water	HDPE	2,400	1.85	500	Clay/Dirt	Limestone	70	35	2.5	4A
64	H,C	1	5	13.00	5	3.1	69,000	Water	HDPE	500	1.85	427	Clay/Dirt	Limestone	70	35	2.5	4A
65	H,C	68	200	13.00	200	3.1	2,760,000	Water	HDPE	28,000	1.85	300	Clay/Dirt	Limestone	70	35	2.5	4A
66	V,C	25	75	13.00	75	3.1	1,035,000	Water	HDPE	6,800	1.85	427	Clay/Dirt	Limestone	70	35	2.5	4A
67	H,O,Hy	26	75	13.00	75	3.1	1,035,000	Water	HDPE	600	1.85	1000	Clay/Dirt	Limestone	70	35	2.5	4A
68	H,C	16	73	13.00	73	3.1	1,007,000	Water	HDPE	6,500	1.85	400	Clay/Dirt	Limestone	70	35	2.5	4A
69	V, H,C	no data	110	13.0	110.0	3.8	1,320,000	R-22	Polyethylene	22,792	No Data	250	Clay	No Data	35	Unknown	No Data	3A
70	V, H, hybrid,C	no data	150	13.0	150.0	3.8	1,800,000	R-22	Polyethylene	31,080	No Data	250	Clay	No Data	35	Unknown	No Data	3A
71	hybrid,C	no data	85	13.0	85.0	3.8	1,020,000	R-22	Polyethylene	17,612	No Data	250	Clay	No Data	35	Unknown	No Data	3A
72	V,C	no data	99	13.0	99.0	3.8	1,188,000	R-22	Polyethylene	20,512.8	No Data	250	Clay	No Data	35	Unknown	No Data	3A
73	V,C	no data	82	13.0	82.0	3.8	984,000	R-22	Polyethylene	16,990.4	No Data	250	Clay	No Data	35	Unknown	No Data	3A
74	V,C	70	105	12.0	105.0	3.5	1,260,000	R-22	Polyethylene	21,757	No Data	250	Clay	No Data	35	Unknown	No Data	3A
75	V,C	3,641	6,000	13.0	6,000.0	3.8	72,000,000	R-22	Polyethylene	1,131,695.6	No Data	225	Clay	No Data	35	Unknown	No Data	3A
76	V,C	1	2	12.0	2.0	3.5	24,000	R-22	Polyethylene	414.4	No Data	250	Clay	No Data	35	Unknown	No Data	3A
77	V,C	1	2	12.0	2.0	3.5	24,000	R-22	Polyethylene	414.4	No Data	250	Clay	No Data	35	Unknown	No Data	3A
78	V,C	1	2	12.0	2.0	3.5	24,000	R-22	Polyethylene	414.4	No Data	250	Clay	No Data	35	Unknown	No Data	3A
79	V,C	1	2.13	12.0	2.1	3.5	25,560	R-22	Polyethylene	441.3	No Data	250	Clay	No Data	35	Unknown	No Data	3A
80	V,C	1	2.13	12.0	2.1	3.5	25,560	R-22	Polyethylene	441.3	No Data	250	Clay	No Data	35	Unknown	No Data	3A
81	V,C	1	2.13	12.0	2.1	3.5	25,560	R-22	Polyethylene	441.3	No Data	250	Clay	No Data	35	Unknown	No Data	3A
82	V,C	1	2.13	12.0	2.1	3.5	25,560	R-22	Polyethylene	441.3	No Data	250	Clay	No Data	35	Unknown	No Data	3A
83	V,C	1	2.13	12.0	2.1	3.5	25,560	R-22	Polyethylene	441.3	No Data	250	Clay	No Data	35	Unknown	No Data	3A
84	V,C	1	1.86	12.0	1.9	3.5	22,320	R-22	Polyethylene	385.4	No Data	250	Clay	No Data	35	Unknown	No Data	3A
85	V,C	1	1.86	12.0	1.9	3.5	22,320	R-22	Polyethylene	385.4	No Data	250	Clay	No Data	35	Unknown	No Data	3A

	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN
1	**GHP Economic Information**									
2	**Average Utility Rate at Project onset ($/kWh)**	**Current Average Natural Gas Rate ($/kcf)**	**Current Average Electric Rate ($/kWh)**	**Project Finance Mechanism**	**Project Investment Cost ($)**	**GHP annual Operation and Maintenance Savings ($)**	**Annual Energy Savings from GHP Installation ($)**	**Annual Energy Savings from GHP Installation (kWh)**	**GHP Project Estimated Economic Life (yrs)**	**Project Payback Period (yrs)**
61	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 175,000	$ 3,500	$ 17,033	240,328	23	9.0
62	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 175,000	$ 3,500	$ 17,033	240,328	23	9.0
63	$ 0.03911	$ 11.78	$ 0.03911	A	$ 800,000	$ 12,000	$ 58,400	823,857	23	9.0
64	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 10,000	$ 1,300	$ 6,327	89,097	23	9.0
65	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 1,150,000	$ 19,000	$ 92,467	1,304,220	23	9.0
66	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 698,000	$ 11,025	$ 53,655	756,741	23	9.0
67	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 614,000	$ 12,000	$ 58,400	823,857	23	9.0
68	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 1,016,000	$ 15,250	$ 74,217	1,046,893	23	9.0
69	$ 0.06500	$ 12.00	$ 0.07800	A	No Data	No Data	$ 38,115	495,000	20	8.0
70	$ 0.06500	$ 12.00	$ 0.07800	A	No Data	No Data	$ 51,975	675,000	20	8.0
71	$ 0.06500	$ 12.00	$ 0.07800	A	No Data	No Data	$ 29,453	382,500	20	8.0
72	$ 0.06500	$ 12.00	$ 0.07800	A	No Data	No Data	$ 34,304	445,500	20	8.0
73	$ 0.06500	$ 12.00	$ 0.07800	A	No Data	No Data	$ 28,413	369,000	20	8.0
74	$ 0.05000	$ 12.00	$ 0.07800	A	No Data	No Data	$ 36,383	472,500	20	8.0
75	$ 0.06500	$ 12.00	$ 0.07800	ESPC-Army	$ 20,000,000	No Data	$ 2,079,000	27,000,000	20	10.0
76	$ 0.05000	$ 12.00	$ 0.07800	A	No Data	No Data	$ 693	9,000	20	8.0
77	$ 0.05000	$ 12.00	$ 0.07800	A	No Data	No Data	$ 693	9,000	20	8.0
78	$ 0.05000	$ 12.00	$ 0.07800	A	No Data	No Data	$ 693	9,000	20	8.0
79	$ 0.05000	$ 12.00	$ 0.07800	A	No Data	No Data	$ 738	9,585	20	8.0
80	$ 0.05000	$ 12.00	$ 0.07800	A	No Data	No Data	$ 738	9,585	20	8.0
81	$ 0.05000	$ 12.00	$ 0.07800	A	No Data	No Data	$ 738	9,585	20	8.0
82	$ 0.05000	$ 12.00	$ 0.07800	A	No Data	No Data	$ 738	9,585	20	8.0
83	$ 0.05000	$ 12.00	$ 0.07800	A	No Data	No Data	$ 738	9,585	20	8.0
84	$ 0.05000	$ 12.00	$ 0.07800	A	No Data	No Data	$ 644	8,370	20	8.0
85	$ 0.05000	$ 12.00	$ 0.07800	A	No Data	No Data	$ 644	8,370	20	8.0

	A	B	C	D	E	F	G	H	I	J	K	L
1	General Information											
2	Federal Agency	Facility Name	City	State	Building Area (Sq. Ft.)	DOD RPCS Facility Class (2-digit Group)	DOD RPCS 2-digit Code	Building Additional Information	Project Point of Contact (Name, Phone, e-mail)	Calender Year Installed	Project Status	New Construction / Retrofit
86	Army	Fort Polk	Leesville	LA	2,406	Family Housing	71	Bldg. 15510A	David Hopper, Fort Polk DPW, (337) 531-6877, david.l.hopper@us.army.mil	1989	Operational	No Data
87	Army	Fort Polk	Leesville	LA	2,406	Family Housing	71	Bldg. 15510B	David Hopper, Fort Polk DPW, (337) 531-6877, david.l.hopper@us.army.mil	1989	Operational	No Data
88	Army	Fort Polk	Leesville	LA	2,406	Family Housing	71	Bldg. 15510C	David Hopper, Fort Polk DPW, (337) 531-6877, david.l.hopper@us.army.mil	1989	Operational	No Data
89	Army	Fort Polk	Leesville	LA	2,406	Family Housing	71	Bldg. 15510D	David Hopper, Fort Polk DPW, (337) 531-6877, david.l.hopper@us.army.mil	1989	Operational	No Data
90	Army	Aberdeen Proving Grounds	Aberdeen	MD	No Data	Family Housing	71	642 Units - Slab on Grade with 17 year old Failing Air to Air Heat Pump's	Brandon Davis, Site Energy Manager, (410) 306-1151, brandon.davis16@us.army.mil	2002	Operational	No Data
91	Army	Fort Meade	Fort Meade	MD	347,291	Family Housing	71	FH Areas 2500, 4200, 4300, & 4500	Joseph Moyer, Site Energy Manager, (301) 677-9276, joseph.v.moyer@us.army.mil	2000	Operational	No Data
92	Army	Selfridge Air National Guard	Detroit	MI	No Data	Family Housing	71	Single & Duplex Dwelling Units	Ron Wesley, (586) 307-4189, ronald.p.wesley@us.army.mil	1995	No Data	No Data
93	Army	Lake City Army Ammunition Plant	Independence	MO	No Data	Administrative	61	GHPs part of a larger bldg. retrofit project	Brian Yeager, (816) 796-7347 (operating contractor engineering rep.)	2005	Operational	No Data
94	Army	Kansas City District - U.S. Army Corps of Engineers	Stockton Lake, Stockton	MO	No Data	Administrative	61	Ten to 15 staff members, plus general public	Thomas P. Long, Operations Project Manager, (417) 276-3196, Thomas.P.Long@nwk02.usace.army.mil	2005	Operational	No Data
95	Army	St. Louis District - U.S. Army Corps of Engineers, 2 Bldgs	Wappapello Lake	MO	No Data	Administrative	61	No Data	James Gracey, (573) 222-8562, James.W.Gracey@usace.army.mil	1995	Operational	No Data
96	Army	Fort Monmouth	Monmouth County	NJ	7,200	Administrative	61	Bldg. 2525, Bay 6 - 7.2KSF	Kevin Dooney, Fort Monmouth DPW, (732) 532-6360, Kevin.Dooney@mail1.monmouth.army.mil	2004	Operational	Retrofit
97	Army	Fort Monmouth	Monmouth County	NJ	7,200	Administrative	61	Bldg. 2525, Bay 2, 2ND Floor - 7.2KSF	Kevin Dooney, Fort Monmouth DPW, (732) 532-6360, Kevin.Dooney@mail1.monmouth.army.mil	1999	Operational	Retrofit
98	Army	Fort Monmouth	Monmouth County	NJ	14,400	Administrative	61	Bldg. 2525, Bays 1&2, 1st Floor - 14.4 KSF	Kevin Dooney, Fort Monmouth DPW, (732) 532-6360, Kevin.Dooney@mail1.monmouth.army.mil	2005	Operational	Retrofit
99	Army	Fort Monmouth	Monmouth County	NJ	7,200	Administrative	61	Bldg. 2525, Bay 1, 2nd Floor - 7.2 KSF	Kevin Dooney, Fort Monmouth DPW, (732) 532-6360, Kevin.Dooney@mail1.monmouth.army.mil	2002	Operational	Retrofit
100	Army	Fort Monmouth	Monmouth County	NJ	28,800	Administrative	61	Bldg. 2525, Bays 3, 5 - 28.8 KSF	Kevin Dooney, Fort Monmouth DPW, (732) 532-6360, Kevin.Dooney@mail1.monmouth.army.mil	2001	Operational	Retrofit
101	Army	Fort Monmouth	Monmouth County	NJ	3,000	Administrative	61	Bldg. 2539 - 3 KSF	Kevin Dooney, Fort Monmouth DPW, (732) 532-6360, Kevin.Dooney@mail1.monmouth.army.mil	2004	Operational	New Construction
102	Army	Fort Monmouth	Monmouth County	NJ	3,300	Indoor Morale, Welfare, and Recreation Facilities	74	Bldg. 700 - 3.3 KSF	Kevin Dooney, Fort Monmouth DPW, (732) 532-6360, Kevin.Dooney@mail1.monmouth.army.mil	2005	Operational	Retrofit
103	Army	Fort Monmouth	Monmouth County	NJ	14,400	Administrative	61	Bldg. 2525, Bay 4 - 14.4 KSF	Kevin Dooney, Fort Monmouth DPW, (732) 532-6360, Kevin.Dooney@mail1.monmouth.army.mil	2002	Operational	Retrofit
104	Army	Fort Monmouth	Monmouth County	NJ	68,300	Unaccompanied Personnel Housing	72	Bldgs. 1077, 1078, 2705, 2715 - 68.3 KSF	Kevin Dooney, Fort Monmouth DPW, (732) 532-6360, Kevin.Dooney@mail1.monmouth.army.mil	1999	Operational	Retrofit
105	Army	Fort Monmouth	Monmouth County	NJ	5,500	Unaccompanied Personnel Housing	72	Bldg. 360, DVQ - 5.5KSF	Kevin Dooney, Fort Monmouth DPW, (732) 532-6360, Kevin.Dooney@mail1.monmouth.army.mil	2001	Operational	Retrofit
106	Army	Fort Monmouth	Monmouth County	NJ	16,700	Training Facilities	17	Bldgs. 1204/1205 - 167 KSF	Kevin Dooney, Fort Monmouth DPW, (732) 532-6360, Kevin.Dooney@mail1.monmouth.army.mil	2005	Operational	Retrofit
107	Army	Fort Monmouth	Monmouth County	NJ	7,200	Administrative	61	Bldg. 2719 - 7.2 KSF	Kevin Dooney, Fort Monmouth DPW, (732) 532-6360, Kevin.Dooney@mail1.monmouth.army.mil	2005	Operational	New Construction
108	Army	Fort Sill	Lawton	OK	19,878	Unaccompanied Personnel Housing	72	Bldg. 635	Andrew Bennett, Chief - OMD / All Projects, (580) 442-3608, andrew.f.bennett@us.army.mil	2001	Operational	No Data
109	Army	Fort Sill	Lawton	OK	22,883	Administrative	61	Bldg. 652	Jerry Schmidt, Engineering / All Projects, (580) 442-4219, jerry.schmidt1@us.army.mil	2001	Operational	No Data

	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
1	GHP Technical Information																	
2	**GHP Type**	**# of GHP units Installed**	**Project Total Installed Tons**	**GHP Cooling Efficiency (EER)**	**GHP Cooling Capacity (TON)**	**GHP Heating Efficiency (COP)**	**GHP Heating Capacity (BTUH)**	**Fluid Type used in GHP**	**GHP Piping Material Used**	**Estimated Land Area Used for Project (sq ft)**	**Thermal Conductivity (BTU / hr-foot-°F)**	**Average Bore Hole Depth For Vertical Loops (ft)**	**Predominant Soil Type**	**Predominant Rock Formations**	**Average Distance to Water Table (ft)**	**Average Distance to Bedrock (ft)**	**Average Frost Depth (ft)**	**IECC Climate Zone Class**
86	V,C	1	2.13	12.0	2.1	3.5	25,560	R-22	Polyethylene	441.3	No Data	250	Clay	No Data	35	Unknown	No Data	3A
87	V,C	1	2.13	12.0	2.1	3.5	25,560	R-22	Polyethylene	441.3	No Data	250	Clay	No Data	35	Unknown	No Data	3A
88	V,C	1	1.86	12.0	1.9	3.5	22,320	R-22	Polyethylene	385.4	No Data	250	Clay	No Data	35	Unknown	No Data	3A
89	V,C	1	1.86	12.0	1.9	3.5	22,320	R-22	Polyethylene	385.4	No Data	250	Clay	No Data	35	Unknown	No Data	3A
90	642 Individual V, C	642	1,242	12.40	1.5 - 1.8 - 3.0	5.3 - 5.0 - 4.8	16,300 - 20,900 - 35,000	Water + Methanol	Polyethylene	Total FH Units - 900,000	No Data	140	Sandy Soil	No Data	No Data	No Data	3	4A
91	V,H	166	452	16.0 - 16.9	452	3.40 - 3.70	20,000 - 40,000	Water	HDPE	2,320,000	0.04	300	Earth	No Data	450	520	3	4A
92	H,C	3	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	CH/CL Clays	No Data	No Data	100	3 to 6	5A
93	H, C	3	24	14.4	12	3.4	141,000	Ethylene glycol	PVC	13,000	No Data	not applicable	Silty clay loam	Limestone	14	100	3	4A
94	V,C	3	16	ISO-A27-30/B25, 19 KW	16, three units, 104 oz. Refrigerant per unit	A20/W20/B0 23/16Kw heating	132 BTUH at 12 BTU per ton. 16 Ton total capacity 1 – 6 Ton, and 2 – 5 Ton units	Ethylene glycol	Polyethylene	2,500	No Data	200 feet per each well	Various clays	Limestone	Less than 125 feet	25	3	4A
95	V,C	2	15	14.6,15.1,16.6	15	4.79-4.88	173,200	Methanol	PE	19,000	No Data	225	Clays	Limestone	300	N/A	2	4A
96	V,C	9	45	14.00	38	3.2	401,000	Ethanol	HDPE	3,600	1.03	398 X 20	Sand and Clay	None	50	None	3	4A
97	V,C	8	26	12.00	22	3.3	202,000	Ethanol	HDPE	943	1.03	375 X 8	Sand and Clay	None	50	None	3	4A
98	V,C	31	57	16.00	52	4	610,000	Ethanol	HDPE	6,800	1.03	405 X 27	Sand and Clay	None	50	None	3	4A
99	V,C	10	29	13.50	23	3.4	253,000	Ethanol	HDPE	950	1.03	375 X 8	Sand and Clay	None	50	None	3	4A
100	V,C	24	100	11.00	72	3.4	840,600	Ethanol	HDPE	5,600	1.03	400 X 27	Sand and Clay	None	50	None	3	4A
101	V,C	7	8	14.00	7	3.9	70,700	Ethanol	HDPE	400	1.03	300 X 4	Sand and Clay	None	50	None	3	4A
102	V,C	7	11	13.50	10	3.8	93,100	Ethanol	HDPE	400	1.03	420 X 4	Sand and Clay	None	50	None	3	4A
103	V,C	14	45	13.50	35	3.4	329,200	Ethanol	HDPE	2,800	1.03	400 X 14	Sand and Clay	None	50	None	3	4A
104	V, C, Hy	102	211	14.00	187	3.1	1,487,440	Ethanol	HDPE	22,000	1.02	320 x 79	Sand and Clay	None	50	None	3	4A
105	V,C	23	17	15.50	15	3.2	169,000	Ethanol	HDPE	2,400	1.03	300 X 12	Sand and Clay	None	50	None	3	4A
106	V,C	280	243	13.50	432	3.7	4,622,000	Water	HDPE	58,600	1.03	305 X 264	Sand and Clay	None	50	None	3	4A
107	V,C	6	18	12.70	16	3.2	132,630	Ethanol	HDPE	800	1.03	400 X 6	Sand and Clay	None	50	None	3	4A
108	V-C	42	32	9.6	38,780	3.8	11,000	Water	SDR-11	12,800	0.97	200	Silt/clay	Sandstone	No Data	No Data	7	3A
109	V-C	42	32	9.6	38,780	3.8	11,000	Water	SDR-11	12,800	0.97	200	Silt/clay	Sandstone	No Data	No Data	7	3A

	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN
1	**GHP Economic Information**									
2	**Average Utility Rate at Project onset ($/kWh)**	**Current Average Natural Gas Rate ($/kcf)**	**Current Average Electric Rate ($/kWh)**	**Project Finance Mechanism**	**Project Investment Cost ($)**	**GHP annual Operation and Maintenance Savings ($)**	**Annual Energy Savings from GHP Installation ($)**	**Annual Energy Savings from GHP Installation (kWh)**	**GHP Project Estimated Economic Life (yrs)**	**Project Payback Period (yrs)**
86	$ 0.05000	$ 12.00	$ 0.07800	A	No Data	No Data	$ 738	9,585	20	8.0
87	$ 0.05000	$ 12.00	$ 0.07800	A	No Data	No Data	$ 738	9,585	20	8.0
88	$ 0.05000	$ 12.00	$ 0.07800	A	No Data	No Data	$ 644	8,370	20	8.0
89	$ 0.05000	$ 12.00	$ 0.07800	A	No Data	No Data	$ 644	8,370	20	8.0
90	$ 0.04550	$ 13.77	$ 0.10000	Super ESPC TS	$ 4,964,428	$ 170,000	$ 392,597	8,637,858	21	10.0
91	$ 0.04890	$ 14.82	$ 0.06880	ESPC	$ 2,237,933	$ 310,000	$ 52,200	10,129 MBtu (electric and gas)	18	18.0
92	$ 0.07000	No Data	No Data	Utility Co Paid	No Data	No Data	No Data	No Data	No Data	No Data
93	$ 0.04200	No Data	$ 0.04200	ARMS	$ 300,000	not determined	not determined	not determined	20	not determined
94	$ 0.05600	No Data	$ 0.05600	Congressional Add after original facility was destroyed by a tornado in May of 2003	Unknown - Can find with additional time for research - Approximately $50K	$ 2,688	$ 5,000	85,000 - 90,000	No Data	Less than 10 years
95	No Data	No Data	$ 0.01090	A	No Data	No Data	Unknown (no metering)	Unknown (no metering)	No Data	No Data
96	$ 0.08940	$ 15.43	$ 0.07180	SRM	$ 400,000	$ 5,000	No Data	No Data	20	No Data
97	$ 0.08940	$ 15.43	$ 0.07180	SRM	$ 250,000	$ 5,000	No Data	No Data	20	No Data
98	$ 0.08940	$ 15.43	$ 0.07180	SRM	$ 650,000	$ 10,000	No Data	No Data	20	No Data
99	$ 0.08940	$ 15.43	$ 0.07180	SRM	$ 300,000	$ 5,000	No Data	No Data	20	No Data
100	$ 0.08940	$ 15.43	$ 0.07180	SRM	$ 900,000	$ 30,000	No Data	No Data	20	No Data
101	$ 0.08940	$ 15.43	$ 0.07180	SRM	$ 125,000	$ 5,000	No Data	No Data	20	No Data
102	$ 0.08940	$ 15.43	$ 0.07180	SRM	$ 100,000	$ 5,000	No Data	No Data	20	No Data
103	$ 0.08940	$ 15.43	$ 0.07180	SRM	$ 450,000	$ 10,000	No Data	No Data	20	No Data
104	$ 0.07750	$ 15.43	$ 0.07180	UESC	$ 1,235,930	$ 50,000	$ 18,000	250,700	20	8.0
105	$ 0.08940	$ 15.43	$ 0.07180	SRM	$ 200,000	$ 5,000	No Data	No Data	20	No Data
106	$ 0.08940	$ 15.43	$ 0.07180	MCA	$ 5,000,000	$ 100,000	No Data	No Data	20	No Data
107	$ 0.08940	$ 15.43	$ 0.07180	SRM	$ 79,000	$ 5,000	No Data	No Data	20	No Data
108	No Data	$ 13.77	$ 0.07540	IDIQ	$ 387,358	No Data	No Data	No Data	20	No Data
109	No Data	$ 13.77	$ 0.07540	IDIQ	$ 387,358	No Data	No Data	No Data	20	No Data

	A	B	C	D	E	F	G	H	I	J	K	L
1	General Information											
2	Federal Agency	Facility Name	City	State	Building Area (Sq. Ft.)	DOD RPCS Facility Class (2-digit Group)	DOD RPCS 2-digit Code	Building Additional Information	Project Point of Contact (Name, Phone, e-mail)	Calender Year Installed	Project Status	New Construction / Retrofit
110	Army	Fort Sill	Lawton	OK	22,465	Unaccompanied Personnel Housing	72	Bldg. 850	Michael Baird, REM / All Projects, (580) 442-3577, michael.baird1@us.army.mil	2001	Operational	No Data
111	Army	Fort Sill	Lawton	OK	14,710	Unaccompanied Personnel Housing	72	Bldg. 851	Michael Baird, REM / All Projects, (580) 442-3577, michael.baird1@us.army.mil	2001	Operational	No Data
112	Army	Fort Sill	Lawton	OK	11,117	Unaccompanied Personnel Housing	72	Bldg. 852	Michael Baird, REM / All Projects, (580) 442-3577, michael.baird1@us.army.mil	2001	Operational	No Data
113	Army	Fort Sill	Lawton	OK	11,117	Unaccompanied Personnel Housing	72	Bldg. 853	Michael Baird, REM / All Projects, (580) 442-3577, michael.baird1@us.army.mil	2001	Operational	No Data
114	Army	Fort Sill	Lawton	OK	11,117	Unaccompanied Personnel Housing	72	Bldg. 854	Michael Baird, REM / All Projects, (580) 442-3577, michael.baird1@us.army.mil	2001	Operational	No Data
115	Army	Fort Sill	Lawton	OK	9,330	Personnel Support and Services Facilities	73	Bldg. 1005	Michael Baird, REM / All Projects, (580) 442-3577, michael.baird1@us.army.mil	2006	Operational	No Data
116	Army	Fort Sill	Lawton	OK	No Data	No Data	No Data	No Data	Michael Baird, REM / All Projects, (580) 442-3577, michael.baird1@us.army.mil	N/A	No Data	No Data
117	Army	Fort Sill	Lawton	OK	No Data	No Data	No Data	Bldg. 1602-1603	Michael Baird, REM / All Projects, (580) 442-3577, michael.baird1@us.army.mil	Open	Planning	No Data
118	Army	Fort Sill	Lawton	OK	25,715	Land Operational Facilities	14	Bldg. 1607	Michael Baird, REM / All Projects, (580) 442-3577, michael.baird1@us.army.mil	2006	Operational	No Data
119	Army	Fort Sill	Lawton	OK	9,287	Administrative	61	Bldg. 1803	Michael Baird, REM / All Projects, (580) 442-3577, michael.baird1@us.army.mil	2002	Operational	No Data
120	Army	Fort Sill	Lawton	OK	34,452	Family Housing	71	Bldgs. 300 Area	Michael Baird, REM / All Projects, (580) 442-3577, michael.baird1@us.army.mil	2005	Operational	No Data
121	Army	Fort Sill	Lawton	OK	8,256	Family Housing	71	Bldgs. 1800 Area	Michael Baird, REM / All Projects, (580) 442-3577, michael.baird1@us.army.mil	2005	Operational	No Data
122	Army	Fort Sill	Lawton	OK	21,819	Family Housing	71	Bldgs. 1900 Area	Michael Baird, REM / All Projects, (580) 442-3577, michael.baird1@us.army.mil	2005	Operational	No Data
123	Army	Fort Sill	Lawton	OK	117,882	Family Housing	71	Bldgs. 2000 Area	Michael Baird, REM / All Projects, (580) 442-3577, michael.baird1@us.army.mil	1998	Operational	No Data
124	Army	Fort Sill	Lawton	OK	2,048	Maintenance Facilities	21	Bldg. 2285	Michael Baird, REM / All Projects, (580) 442-3577, michael.baird1@us.army.mil	2001	Operational	No Data
125	Army	Fort Sill	Lawton	OK	14,710	Unaccompanied Personnel Housing	72	Bldg. 5670	Michael Baird, REM / All Projects, (580) 442-3577, michael.baird1@us.army.mil	2001	Operational	No Data
126	Army	Fort Sill	Lawton	OK	14,710	Unaccompanied Personnel Housing	72	Bldg. 5671	Michael Baird, REM / All Projects, (580) 442-3577, michael.baird1@us.army.mil	2003	Operational	No Data
127	Army	Fort Sill	Lawton	OK	14,710	Unaccompanied Personnel Housing	72	Bldg. 5674	Michael Baird, REM / All Projects, (580) 442-3577, michael.baird1@us.army.mil	2001	Operational	No Data
128	Army	Fort Sill	Lawton	OK	14,710	Unaccompanied Personnel Housing	72	Bldg. 5675	Michael Baird, REM / All Projects, (580) 442-3577, michael.baird1@us.army.mil	2001	Operational	No Data
129	Army	McAlester Army Ammunition Plant	McAlester	OK	17,604	Production Facilities	22	Bldg. 164	Kevin Henderson, MCAAP Energy Coordinator, (918) 420-7455, DSN:956 7455, kevin.d.henderson@us.army.mil	2005	Operational	No Data
130	Army	Tulsa District - U.S. Army Corps of Engineers - Navigation Project Office	Sallisaw	OK	No Data	Administrative	61	Office complex	Todd Carr, (918) 775-4474 ext. 739, Todd.Carr@SWT03.usace.army.mil	1992	Operational	No Data
131	Army	AWC Carlisle Barracks	Carlisle	PA	109,570	Family Housing	71	104 residences	Gary Sweppenhiser, Carlisle Barracks DPW, (717) 245-3746, Gary.Sweppenhiser@us.army.mil	2003	Complete	New Construction

	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
1	**GHP Technical Information**																	
2	**GHP Type**	**# of GHP units Installed**	**Project Total Installed Tons**	**GHP Cooling Efficiency (EER)**	**GHP Cooling Capacity (TON)**	**GHP Heating Efficiency (COP)**	**GHP Heating Capacity (BTUH)**	**Fluid Type used in GHP**	**GHP Piping Material Used**	**Estimated Land Area Used for Project (sq ft)**	**Thermal Conductivity (BTU / hr-foot-^{o}F)**	**Average Bore Hole Depth For Vertical Loops (ft)**	**Predominant Soil Type**	**Predominant Rock Formations**	**Average Distance to Water Table (ft)**	**Average Distance to Bedrock (ft)**	**Average Frost Depth (ft)**	**IECC Climate Zone Class**
110	V-C	40	30	9.6	38,780	3.8	11,000	Water	SDR-11	12,000	0.97	200	Silt/clay	Sandstone	No Data	No Data	7	3A
111	V-C	40	30	9.6	38,780	3.8	11,000	Water	SDR-11	12,000	0.97	200	Silt/clay	Sandstone	No Data	No Data	7	3A
112	V-C	40	30	9.6	38,780	3.8	11,000	Water	SDR-11	12,000	0.97	200	Silt/clay	Sandstone	No Data	No Data	7	3A
113	V-C	40	30	9.6	38,780	3.8	11,000	Water	SDR-11	12,000	0.97	200	Silt/clay	Sandstone	No Data	No Data	7	3A
114	V-C	40	30	9.6	38,780	3.8	11,000	Water	SDR-11	12,000	0.97	200	Silt/clay	Sandstone	No Data	No Data	7	3A
115	V-C	9	54	13.9	7	4.6	76,000	Water	SDR-11	5,400	0.97	200	Silt/clay	Sandstone	No Data	No Data	7	3A
116	No Data	No Data	No Data	14.3	10	5.0	145,000	Water	SDR-11	8,200	0.97	200	Silt/clay	Sandstone	No Data	No Data	No Data	3A
117	V-C	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	No Data	No Data	7	3A
118	V-C	4	80	13.3	20	3.1	334,500	Water	SDR-11	28,512	No Data	No Data	No Data	No Data	No Data	No Data	7	3A
119	V-C	No Data	No Data	No Data	No Data	No Data	No Data	Water	SDR-11	No Data	0.97	200	Silt/clay	Sandstone	No Data	No Data	7	3A
120	V-C	10	30	13.9	3	4.4	42,000	Water	SDR-11	1,125/ea.	1.08	200	Silt/clay	Sandstone	No Data	No Data	7	3A
121	V-C	4	12	13.9	3	4.4	42,000	Water	SDR-11	1,125/ea.	1.08	200	Silt/clay	Sandstone	No Data	No Data	7	3A
122	V-C	10	30	13.9	3	4.4	42,000	Water	SDR-11	1,125/ea.	1.08	200	Silt/clay	Sandstone	No Data	No Data	7	3A
123	V-C	37	111	11.0	3	3.9	42,500	Water	SDR-11	1,125/ea.	1.08	300	Silt/clay	Sandstone	No Data	No Data	7	3A
124	V-C	2	No Data	No Data	No Data	No Data	No Data	Water	SDR-11	No Data	No Data	No Data	No Data	No Data	No Data	No Data	7	3A
125	V-C	17	37	12.2	2	4.5	30,000	Water	SDR-11	13,600	0.97	200	Silt/clay	Limestone	No Data	No Data	7	3A
126	V-C	17	37	N/A	N/A	N/A	N/A	Water	SDR-11	N/A	0.97	N/A	Silt/clay	Limestone	No Data	No Data	7	3A
127	V-C	17	37	12.2	2	4.5	30,000	Water	SDR-11	13,600	0.97	200	Silt/clay	Limestone	No Data	No Data	7	3A
128	V-C	17	37	12.2	2	4.5	30,000	Water	SDR-11	13,600	0.97	200	Silt/clay	Limestone	No Data	No Data	7	3A
129	Vertical and Horizontal	6	21	13.6	20	3.3	178,400	N/A	HDPESDR11	7,500	N/A	300	Clay	Shale w/ sandstone	20	20	1.5	3A
130	C	5	25	N/A	N/A	N/A	N/A	Chevron G54	Polybutylene	2,500	N/A	180	Sandy	N/A	75	12	2	3A
131	Standing column well	171	639	24.00	639.0	4.0	7,675,200	Water	PVC Sch 80	4,200	1.3	520	Clay	Limestone	28	18	2.3	5A

	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN
1	GHP Economic Information									
2	**Average Utility Rate at Project onset ($/kWh)**	**Current Average Natural Gas Rate ($/kcf)**	**Current Average Electric Rate ($/kWh)**	**Project Finance Mechanism**	**Project Investment Cost ($)**	**GHP annual Operation and Maintenance Savings ($)**	**Annual Energy Savings from GHP Installation ($)**	**Annual Energy Savings from GHP Installation (kWh)**	**GHP Project Estimated Economic Life (yrs)**	**Project Payback Period (yrs)**
110	No Data	$ 13.77	$ 0.07540	IDIQ	$ 276,255	No Data	No Data	No Data	20	No Data
111	No Data	$ 13.77	$ 0.07540	IDIQ	$ 276,255	No Data	No Data	No Data	20	No Data
112	No Data	$ 13.77	$ 0.07540	IDIQ	$ 276,255	No Data	No Data	No Data	20	No Data
113	No Data	$ 13.77	$ 0.07540	IDIQ	$ 276,255	No Data	No Data	No Data	20	No Data
114	No Data	$ 13.77	$ 0.07540	IDIQ	$ 276,255	No Data	No Data	No Data	20	No Data
115	$ 0.07000	$ 13.77	$ 0.07540	ECIP	No Data	No Data	No Data	No Data	20	No Data
116	No Data	$ 13.77	$ 0.07540	No Data	No Data	No Data	No Data	No Data	No Data	No Data
117	No Data	$ 13.77	$ 0.07540	ECIP	$ 2,329,600	No Data	$ 154,309	263,114	20	9.6
118	$ 0.07000	$ 13.77	$ 0.07540	JOC	$ 490,792	No Data	No Data	No Data	20	No Data
119	No Data	$ 13.77	$ 0.07540	IDIQ	$ 211,254	No Data	No Data	No Data	20	No Data
120	$ 0.07000	$ 13.77	$ 0.07540	JOC	$ 24,733.21/ea.	No Data	No Data	No Data	20	No Data
121	$ 0.07000	$ 13.77	$ 0.07540	JOC	$ 24,733.21/ea.	No Data	No Data	No Data	20	No Data
122	No Data	$ 13.77	$ 0.07540	JOC	$ 24,733.21/ea.	No Data	No Data	No Data	20	No Data
123	No Data	$ 13.77	$ 0.07540	8A Set-Aside	$ 24,733.21/ea.	No Data	No Data	No Data	20	No Data
124	No Data	$ 13.77	$ 0.07540	IDIQ	$ 79,138	No Data	No Data	No Data	20	No Data
125	No Data	$ 13.77	$ 0.07540	Demand-Side	$ 298,780	No Data	No Data	No Data	20	No Data
126	$ 0.06700	$ 13.77	$ 0.07540	COE	No Data	No Data	No Data	No Data	20	No Data
127	No Data	$ 13.77	$ 0.07540	Demand-Side	$ 298,780	No Data	No Data	No Data	20	No Data
128	No Data	$ 13.77	$ 0.07540	Demand-Side	$ 298,780	No Data	No Data	No Data	20	No Data
129	$ 0.04700	$ 9.13	$ 0.07100	A	$ 200,000	$ 500	$ 11,500	Eliminated steam	25	14.0
130	No Data	No Data	No Data	No Data	$ 11,983	No Data	No Data	No Data	25	10.0
131	$ 0.06490	$ 17.81	$ 0.06990	Super ESPC TS	$ 2,500,000	51,187	152,632	443,506	20	16.0

	A	B	C	D	E	F	G	H	I	J	K	L
1	General Information											
2	**Federal Agency**	**Facility Name**	**City**	**State**	**Building Area (Sq. Ft.)**	**DOD RPCS Facility Class (2-digit Group)**	**DOD RPCS 2-digit Code**	**Building Additional Information**	**Project Point of Contact (Name, Phone, e-mail)**	**Calender Year Installed**	**Project Status**	**New Construction / Retrofit**
132	Army	AWC Carlisle Barracks	Carlisle	PA	107,613	Administrative	61	18 Bldgs, mixed use	Gary Sweppenhiser, Carlisle Barracks DPW, (717) 245-3746, Gary.Sweppenhiser@us.army.mil	2003	Complete	New Construction
133	Army	Fort Jackson	Fort Jackson	SC	1,787,000	Family Housing	71	1295 units at Family Housing, 74 units at Palmato, 174 units at Kennedy Hall	Georges Dib, Fort Jackson DPW, (803) 751-3823, georges.dib@us.army.mil	2002	Operational	No Data
134	Army	Fort Bliss	Fort Bliss	TX	No Data	No Data	No Data	Multiple	Juan Morales, (915) 568-2823, moralesj@bliss.army.mil	2000	Operational	No Data
135	Army	Fort Bliss	Fort Bliss	TX	No Data	Family Housing	71	Multiple	Juan Morales, (915) 568-2823, moralesj@bliss.army.mil	2000	Operational	No Data
136	Army	Fort Hood	Fort Hood	TX	No Data	Family Housing	71	Bldgs. 83008-1 and 82006-1	Bobby Lynn, (254) 287-8716, bobby.lynn@us.army.mil	1994	Operational	No Data
137	Army	Fort Hood	Fort Hood	TX	40,782	Administrative	61	Bldg. 4612	Kenneth.R.Allison, (254) 287-7194, kenneth.r.allison@us.army.mil	1999	Operational	No Data
138	Army	Tooele Army Depot	Tooele	UT	25,091	Personnel Support and Services Facilities	73	Fire Station (Bldg 8) - (Ammo handling (Bldg 1254)	Jay Weyland, (435) 833-3702, DSN:790-3702, weylandj@emh3.tooele.army.mil	2003	Operational	No Data
139	Army	Fort Myer	Arlington	VA	31,698	Family Housing	71	Bldgs. 19 - 22	Mark Zangara, Fort Myer DPW, (703) 696-3804, mark.zangara@us.army.mil	2001	No Data	No Data
140	Army	Fort A.P. Hill	Bowling Green	VA	No Data	No Data	No Data	No Data	Frederick Hwee, DPW/EPS, (804) 633-8426, frederick.hwee@us.army.mil	2001	No Data	No Data
141	Army	Fort Belvoir	Fort Belvoir	VA	2,948	Land Operational Facilities	14	Bldg. 3137	Randy Smidt, Site Energy Engineer, (703) 806-0023, randall.smidt@belvoir.army.mil	2001	Operational	Retrofit
142	Army	Fort Belvoir	Fort Belvoir	VA	5,728	Medical and Medical Support Facilities	53	Bldg. 610	Randy Smidt, Site Energy Engineer, (703) 806-0023, randall.smidt@belvoir.army.mil	2001	Operational	Retrofit
143	Army	Fort Belvoir	Fort Belvoir	VA	984	Administrative Structures Other Than Buildings	69	Bldg. 1472	Randy Smidt, Site Energy Engineer, (703) 806-0023, randall.smidt@belvoir.army.mil	2001	Operational	Retrofit
144	Army	Fort Eustis	Fort Eustis	VA	No Data	Administrative	61	Bldg. 2715	Loop contractor - Cliff Bunn, VA Energy Services, (804) 749-1962, 200 bores at 300 ft depth? Tried Wayne Spitzner, Evantage, (804) 819-2926	1998	No Data	No Data
145	Army	Fort Eustis	Fort Eustis	VA	No Data	Administrative	61	Bldg. 2716	Loop contractor - Cliff Bunn, VA Energy Services, (804) 749-1962, 200 bores at 300 ft depth? Tried Wayne Spitzner, Evantage, (804) 819-2926	1999	No Data	No Data
146	Army	Fort Monroe	Fort Monroe	VA	25,911	Administrative	61	Bldg. 100	Select Energy, R Rauf	2002	Operational	No Data
147	Army	Fort Monroe	Fort Monroe	VA	5,958	Family Housing	71	Qtrs. 93	Rob McRacken, Fort Monroe DPW, (757) 788-5366, robert.mcracken@us.army.mil	2003	Operational	No Data
148	Army	Fort Monroe	Fort Monroe	VA	3,204	Family Housing	71	Qtrs. 19	Rob McRacken, Fort Monroe DPW, (757) 788-5366, robert.mcracken@us.army.mil	2003	Operational	No Data
149	Army	Fort Monroe	Fort Monroe	VA	7,021	Family Housing	71	Qtrs. 157	Rob McRacken, Fort Monroe DPW, (757) 788-5366, robert.mcracken@us.army.mil	2003	Operational	No Data
150	Army	Fort Monroe	Fort Monroe	VA	7,021	Family Housing	71	Qtrs. 158	Rob McRacken, Fort Monroe DPW, (757) 788-5366, robert.mcracken@us.army.mil	2003	Operational	No Data
151	Army	Fort Monroe	Fort Monroe	VA	No Data	Family Housing	71	Qtrs. 15A	Rob McRacken, Fort Monroe DPW, (757) 788-5366, robert.mcracken@us.army.mil	2003	Operational	No Data
152	Army	Fort Monroe	Fort Monroe	VA	No Data	Family Housing	71	Qtrs. 15B	Rob McRacken, Fort Monroe DPW, (757) 788-5366, robert.mcracken@us.army.mil	2003	Operational	No Data
153	Army	Huntington District - U.S. Army Corps of Engineers - Beach Fork Lake	Lavalette	WV	1,065	Maintenance Facilities	21		Gary Trautwein, Beach Fork Lake, (304) 525-4831, gary.p.trautwein@lrh01.usace.army.mil	1996	Operational	No Data

	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
1	GHP Technical Information																	
2	GHP Type	# of GHP units Installed	Project Total Installed Tons	GHP Cooling Efficiency (EER)	GHP Cooling Capacity (TON)	GHP Heating Efficiency (COP)	GHP Heating Capacity (BTUH)	Fluid Type used in GHP	GHP Piping Material Used	Estimated Land Area Used for Project (sq ft)	Thermal Conductivity (BTU / hr-foot-°F)	Average Bore Hole Depth For Vertical Loops (ft)	Predominant Soil Type	Predominant Rock Formations	Average Distance to Water Table (ft)	Average Distance to Bedrock (ft)	Average Frost Depth (ft)	IECC Climate Zone Class
132	Standing column well	62	426	24.00	426	4.0	5,116,800	Water	PVC Sch 80	2,800	1.3	520	Clay	Limestone	28	18	2.3	5A
133	Vertical	1,543	3,801	10.45	3,801	3.3	30,000	Water	HDPE	978,375	1.4	350	Sand/Clay	Sandstone	75-100	75	1	3A
134	V, H	6	360	13.50	360	80	8.6 MBTU	Water	HDP	435,000	No Data	No Data	No Data	No Data	No Data	No Data	No Data	3B
135	V	585	1,755	85.00	1755	80	21 MBTU	Water	HDP	6,000	No Data	No Data	No Data	No Data	No Data	No Data	No Data	3B
136	V	2	3	16.0-16.0	2.5	3.3-3.5	21,000 - 25,000	Water	1" Polyethelene	800	1.2	250	Brown Clay	Shale	Appx 200	Appx 350	0	3A
137	V	27	166.9	13.0-16.2	93.6	3.0-3.3	312,200	Water	Phillips Driscopipe 5300 Climate Guard Pipe (Black Polyethelene) 3/4"-4"	45,544	1.2	300	Brown Clay	Shale	Appx 200	Appx 350	0	3A
138	Water Util	2	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	5B
139	V	4	75	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	4A
140	V,C	38	119	No Data	No Data	No Data	No Data	Water, glycol	Polyethylene	N/A	No Data	172	No Data	No Data	No Data	No Data	No Data	4A
141	V	1	15	10.80	10	3.5	No Data	Water	SDR 11	6,000	No Data	290	No Data	No Data	No Data	No Data	No Data	4A
142	V	4	No Data	No Data	No Data	No Data	No Data	Water	SDR 11	6,000	No Data	N/A	No Data	No Data	No Data	No Data	No Data	4A
143	V	1	5	15.60	3	3.2	No Data	Water	SDR 11	1,200	No Data	210	No Data	No Data	No Data	No Data	No Data	4A
144	V	No Data	305	No Data	305	No Data	No Data	Water	1" HDPE	68,400	No Data	275	Sandy/Clay	None	25	No Data	2	4A
145	V	No Data	No Data	No Data	No Data	No Data	No Data	Water	1" HDPE	44,800	No Data	280	Sandy/Clay	None	25	No Data	2	4A
146	V,C	11	81	4.30 (SI)	43.6	3.4	No Data	Glycol	PVC	9000	No Data	280	Loam	None	5	4000	1	4A
147	V,C	2	10	No Data	10	No Data	No Data	Glycol	Polyethylene	900	No Data	200	Loam	None	5	4000	1	4A
148	V,C	2	10	No Data	10	No Data	No Data	Glycol	Polyethylene	900	No Data	200	Loam	None	5	4000	1	4A
149	V,C	2	10	No Data	10	No Data	No Data	Glycol	Polyethylene	900	No Data	200	Loam	None	5	4000	1	4A
150	V,C	2	10	No Data	10	No Data	No Data	Glycol	Polyethylene	900	No Data	200	Loam	None	5	4000	1	4A
151	V,C	2	5	No Data	5	No Data	No Data	Glycol	Polyethylene	450	No Data	200	Loam	None	5	4000	1	4A
152	V,C	2	5	No Data	5	No Data	No Data	Glycol	Polyethylene	450	No Data	200	Loam	None	5	4000	1	4A
153	V, C	1	3	13.0	24	4.4	38.0	Water-Glyco	polyethylene	360	No Data	80	No Data	No Data	No Data	No Data	2	No Data

	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN
1	GHP Economic Information									
2	**Average Utility Rate at Project onset ($/kWh)**	**Current Average Natural Gas Rate ($/kcf)**	**Current Average Electric Rate ($/kWh)**	**Project Finance Mechanism**	**Project Investment Cost ($)**	**GHP annual Operation and Maintenance Savings ($)**	**Annual Energy Savings from GHP Installation ($)**	**Annual Energy Savings from GHP Installation (kWh)**	**GHP Project Estimated Economic Life (yrs)**	**Project Payback Period (yrs)**
132	$ 0.06490	$ 17.81	$ 0.06990	Super ESPC TS	$ 4,300,000	34,124	101,755	295,670	20	16.0
133	$ 0.04230	$ 12.03	$ 0.04920	Super ESPC R	$ 10,763,588	$ 222,475	$ 470,325	1,761,937	22	15.5
134	$ 0.05810	$ 10.86	$ 0.06860	OMA	$ 1,620,000	Unknown	Unknown	Unknown	20	Unknown
135	$ 0.05810	$ 10.86	$ 0.06860	MCA	$ 5,265,000	Unknown	Unknown	Unknown	20	Unknown
136	$ 0.06100	$ 12.03	$ 0.08000	A	No Cost Demo Units	$ 1,200	$ 5,000	65,000	14	5.0
137	$ 0.07000	$ 12.03	$ 0.08300	A	$ 354,603	$ 6,488	$ 55,627	695,342	19	5.0
138	$ 0.03390	$ 9.00	$ 0.03880	P2 Funding	$ 160,345	No Data	No Data	No Data	No Data	No Data
139	No Data	$ 13.59	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
140	No Data	No Data	No Data	ESPC-Army	$ 931,000	$ 146,000	$ 57,000	479,000	18	5.0
141	$ 0.04400	$ 14.53	$ 0.04800	ESPC	$ 38,430	No Data	$ 557	12,780	No Data	69.0
142	$ 0.04400	$ 14.53	$ 0.04800	ESPC	$ 74,394	No Data	$ 1,438	23,393	No Data	52.0
143	$ 0.04400	$ 14.53	$ 0.04800	ESPC	$ 17,010	No Data	$ 198	2,695	No Data	86.0
144	No Data	$ 9.76	No Data	A	No Data	No Data	No Data	No Data	No Data	No Data
145	No Data	$ 9.76	No Data	A	No Data	No Data	No Data	No Data	No Data	No Data
146	$ 0.05500	$ 14.74	$ 0.05900	ESPC-Army	No Data	$ 1,850	Unknown (no metering)	Unknown (no metering)	No Data	No Data
147	$ 0.05500	$ 14.74	$ 0.05900	A	$ 78,096	$ 350	Unknown (no metering)	Unknown (no metering)	No Data	No Data
148	$ 0.05500	$ 14.74	$ 0.05900	A	$ 110,816	$ 350	Unknown (no metering)	Unknown (no metering)	No Data	No Data
149	$ 0.05500	$ 14.74	$ 0.05900	A	$ 74,580	$ 350	Unknown (no metering)	Unknown (no metering)	No Data	No Data
150	$ 0.05500	$ 14.74	$ 0.05900	A	$ 74,580	$ 350	Unknown (no metering)	Unknown (no metering)	No Data	No Data
151	$ 0.05500	$ 14.74	$ 0.05900	A	$ 86,852	$ 350	Unknown (no metering)	Unknown (no metering)	No Data	No Data
152	$ 0.05500	$ 14.74	$ 0.05900	A	$ 86,852	$ 350	Unknown (no metering)	Unknown (no metering)	No Data	No Data
153	No Data	No Data	No Data	$ 8,684	No Data	No Data	No Data	30-40	No Data	No Data

	A	B	C	D	E	F	G	H
1								
2	**Federal Agency**	**Facility Name**	**City**	**State**	**Building Area (Sq. Ft.)**	**DOD RPCS Facility Class (2-digit Group)**	**RPCS 2-digit Code**	**Building Additional Information**
3	Army	Fort Irwin	Barstow	CA	No Data	Family Housing	71	New FHU
4	Army	Fort McNair	Washington	DC	41,795	Family Housing	71	Bldgs. 16-20,29,31
5	Army	Fort Campbell	Fort Campbell	KY	No Data	No Data	No Data	Bldg. 7112
6	Army	Fort Knox	Fort Knox	KY	13,752	Administrative	61	# 488
7	Army	Fort Knox	Fort Knox	KY	8,573	Administrative	61	# 1001
8	Army	Fort Knox	Fort Knox	KY	41,783	Administrative	61	# 1002
9	Army	Fort Knox	Fort Knox	KY	28,884	Communications, Navigation Aids and Airfield Light	13	# 1227
10	Army	Fort Knox	Fort Knox	KY	15,438	Administrative	61	# 1101
11	Army	Fort Knox	Fort Knox	KY	No Data	No Data	No Data	# 4249A
12	Army	Fort Knox	Fort Knox	KY	18,912	Dental Clinics	54	# 2724
13	Army	Fort Knox	Fort Knox	KY	66,577	Administrative	61	# 1110
14	Army	Fort Knox	Fort Knox	KY	10,052	Personnel Support and Services Facilities	73	# 469
15	Army	Fort Knox	Fort Knox	KY	55,934	Administrative	61	# 203
16	Army	Fort Knox	Fort Knox	KY	No Data	No Data	No Data	# 1327
17	Army	Fort Knox	Fort Knox	KY	16,692	Medical and Medical Support Facilities	53	# 1003
18	Army	Fort Knox	Fort Knox	KY	29,800	Personnel Support and Services Facilities	73	# 204
19	Army	Fort Knox	Fort Knox	KY	9,600	Administrative	61	# 614
20	Army	Fort Knox	Fort Knox	KY		Indoor Morale, Welfare, and Recreation Facilities	74	# 1102
21	Army	Fort Knox	Fort Knox	KY	16,753	Unaccompanied Personnel Housing	72	# 1117
22	Army	Selfridge Air National Guard	Detroit	MI	No Data	Family Housing	71	Single & Duplex Dwelling Units
23	Army	Fort Monmouth	Monmouth County	NJ	726,986	Administrative	61	Bldgs. 800, 1150, 1152, 1200, 1201, 1202, 1206, 1207, 1208, 1209, 1210, 1212
24	Army	Fort Monmouth	Monmouth County	NJ	2,500	Administrative	61	Bldg. 603 - 2.5 KSF
25	Army	Fort Drum	Fort Drum	NY	86,900	Unaccompanied Personnel Housing	72	MCA project
26	Army	Fort Sill	Lawton	OK	No Data	No Data	No Data	No Data
27	Army	Fort Sill	Lawton	OK	279,050	Unaccompanied Personnel Housing	72	Bldg. 1602-1603
28	Army	Fort Sill	Lawton	OK	70,995	Unaccompanied Personnel Housing	72	Bldg. 2025

	I	J	K	L
1	**General Information**			
2	**Project Point of Contact (Name, Phone, e-mail)**	**Calender Year Installed**	**Project Status**	**New Construction / Retrofit**
3	Mr. Frank Talampas, (760) 380-3429, francisco.talampas@irwin.army.mil	1997	No Data	No Data
4	Mark Zangara, Fort Myer DPW, (703) 696-3804, mark.zangara@us.army.mil	2001	No Data	No Data
5	Dewayne Smith, (270) 798-5652, neal.d.smith@us.army.mil	2006	Under Construction	No Data
6	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2006	Design	No Data
7	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2006	Construction	No Data
8	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2006	Planning	No Data
9	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2006	Design	No Data
10	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2006	Design	No Data
11	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2006	Planning	No Data
12	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2006	Construction	No Data
13	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2006	Design	No Data
14	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2006	Planning	No Data
15	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2006	Design	No Data
16	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2006	Construction	No Data
17	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2006	Planning	No Data
18	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2006	Planning	No Data
19	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2006	Construction	No Data
20	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2006	Design	No Data
21	Gary Meredith, Fort Knox Energy Manager, (502) 624-8358, gary.meredith@knox.army.mil	2006	Design	No Data
22	Ron Wesley, (586) 307-4189, ronald.p.wesley@us.army.mil	1995	No Data	No Data
23	Kevin Dooney, Fort Monmouth DPW, (732) 532-6360, Kevin.Dooney@mail1.monmouth.army.mil; Terry Matthews, Fort Monmouth DPW (732) 532-5662, Terry.Matthews@mail1.monmouth.army.mil	2004 / 06	Operational / Under Construction	Retrofit
24	Kevin Dooney, Fort Monmouth DPW, (732) 532-6360, Kevin.Dooney@mail1.monmouth.army.mil	2006	Under Construction	New Construction
25	Clark/ Zandler LLC	2006	50% complete	New Construction
26	Michael Baird, REM / All Projects, (580) 442-3577, michael.baird1@us.army.mil	No Data	No Data	No Data
27	Michael Baird, REM / All Projects, (580) 442-3577, michael.baird1@us.army.mil	Open	Planning	No Data
28	Michael Baird, REM / All Projects, (580) 442-3577, michael.baird1@us.army.mil	2007	Planning	No Data

	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
1	**GHP Technical Information**																	
2	**GHP Type**	**# of GHP units Installed**	**Project Total Installed Tons**	**GHP Cooling Efficiency (EER)**	**GHP Cooling Capacity (TON)**	**GHP Heating Efficiency (COP)**	**GHP Heating Capacity (BTUH)**	**Fluid Type used in GHP**	**GHP Piping Material Used**	**Estimated Land Area Used for Project (sq ft)**	**Thermal Conductivity (BTU / hr-foot-^{o}F)**	**Average Bore Hole Depth For Vertical Loops (ft)**	**Predominant Soil Type**	**Predominant Rock Formations**	**Average Distance to Water Table (ft)**	**Average Distance to Bedrock (ft)**	**Average Frost Depth (ft)**	**IECC Climate Zone Class**
3	Water Util	200	600	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	3B
4	V	7	40	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	4A
5	Vertical	89	64	16.00	64	3.5	764,500	Water	HDPE	32,000	1.68	290	Clay/Chert	Ft Payne Chert	214	58	2	4A
6	H,C,Hy	No Data	No Data	13.00	No Data	3.1	No Data	Water	HDPE	No Data	1.85	500	Clay/Dirt	Limestone	70	35	2.5	4A
7	V,H,C,Hy	13	24	13.00	24	3.1	330,000	Water	HDPE	8,000	1.85	500	Clay/Dirt	Limestone	70	35	2.5	4A
8	H,C,Hy	No Data	No Data	13.00	No Data	3.1	No Data	Water	HDPE	No Data	1.85	500	Clay/Dirt	Limestone	70	35	2.5	4A
9	H,C,Hy	No Data	No Data	13.00	No Data	3.1	No Data	Water	HDPE	No Data	1.85	No Data	Clay/Dirt	Limestone	70	35	2.5	4A
10	H,C,Hy	No Data	No Data	13.00	No Data	3.1	No Data	Water	HDPE	No Data	1.85	500	Clay/Dirt	Limestone	70	35	2.5	4A
11	H,C	No Data	No Data	13.00	No Data	3.1	No Data	Water	HDPE	No Data	1.85	400	Clay/Dirt	Limestone	70	35	2.5	4A
12	V,C	8	89	13.00	89	3.1	1,228,000	Water	HDPE	6,000	1.85	500	Clay/Dirt	Limestone	70	35	2.5	4A
13	H,C,Hy	No Data	No Data	13.00	No Data	3.1	No Data	Water	HDPE	No Data	1.85	500	Clay/Dirt	Limestone	70	35	2.5	4A
14	H,C	No Data	No Data	13.00	No Data	3.1	No Data	Water	HDPE	No Data	1.85	500	Clay/Dirt	Limestone	70	35	2.5	4A
15	H,C,Hy	30	97	13.00	97	3.1	1,339,000	Water	HDPE	12,000	1.85	500	Clay/Dirt	Limestone	70	35	2.5	4A
16	H,C	No Data	No Data	13.00	No Data	3.1	No Data	Water	HDPE	No Data	1.85	400	Clay/Dirt	Limestone	70	35	2.5	4A
17	H,C,Hy	No Data	No Data	13.00	No Data	3.1	No Data	Water	HDPE	No Data	1.85	500	Clay/Dirt	Limestone	70	35	2.5	4A
18	H,C,Hy	No Data	No Data	13.00	No Data	3.1	No Data	Water	HDPE	No Data	1.85	500	Clay/Dirt	Limestone	70	35	2.5	4A
19	H,C	1	5	13.00	5	3.1	69,000	Water	HDPE	200	1.85	500	Clay/Dirt	Limestone	70	35	2.5	4A
20	H,C,Hy	No Data	No Data	13.00	No Data	3.1	No Data	Water	HDPE	No Data	1.85	500	Clay/Dirt	Limestone	70	35	2.5	4A
21	H,C,Hy	No Data	No Data	13.00	No Data	3.1	No Data	Water	HDPE	No Data	1.85	500	Clay/Dirt	Limestone	70	35	2.5	4A
22	H,C	3	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	CH/CL Clays	No Data	No Data	100	3 to 6	5A
23	V,C	1670	2,777	15.50	2,777	3.1	24,993,000	Water	HDPE	8 Acres	1.08	420 X 832	Sand and Clay	None	50	None	3	4A
24	V,C	5	10	14.00	9	3.8	92,500	Ethanol	HDPE	5,000	1.03	340 X 6	Sand and Clay	None	50	None	3	4A
25	V,C	5	160	11.00	160	3.0	900	23% glycol	Polyethylene	12,600	1.3	250	Sand (moist)	No Data	No Data	200	5	6A
26	No Data	No Data	No Data	14.3	10	5.0	145,000	Water	SDR-11	8,200	0.97	200	Silt/clay	Sandstone	No Data	No Data	No Data	3A
27	V-C	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	7	3A
28	V-C	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	7	3A

	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN
1	GHP Economic Information									
2	**Average Utility Rate at Project onset ($/kWh)**	**Current Average Natural Gas Rate ($/kcf)**	**Current Average Electric Rate ($/kWh)**	**Project Finance Mechanism**	**Project Investment Cost ($)**	**GHP annual Operation and Maintenance Savings ($)**	**Annual Energy Savings from GHP Installation ($)**	**Annual Energy Savings from GHP Installation (kWh)**	**GHP Project Estimated Economic Life (yrs)**	**Project Payback Period (yrs)**
3	No Data	No Data	UESC	No Data	No Data	No Data	No Data	No Data	No Data	No Data
4	No Data	$ 17.39	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
5	$ 0.05620	$ 12.57	$ 0.05620	UESC	$ 509,450	$ 15,440	$ 9,767	531,241	22	20.2
6	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 275,040	$ 4,125	$ 20,075	283,118	23	9.0
7	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 171,000	$ 2,575	$ 12,532	176,729	23	9.0
8	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 901,660	$ 13,525	$ 65,822	928,488	23	9.0
9	$ 0.03911	$ 11.78	$ 0.03911	UESC	No Data	No Data	$ 3,000	No Data	23	9.0
10	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 308,667	$ 4,630	$ 22,533	317,702	23	9.0
11	$ 0.03911	$ 11.78	$ 0.03911	UESC	No Data	No Data	No Data	No Data	23	9.0
12	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 378,000	$ 5,675	$ 27,618	389,508	23	9.0
13	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 1,331,667	$ 19,975	$ 97,212	1,371,336	23	9.0
14	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 201,000	$ 3,015	$ 14,673	206,917	23	9.0
15	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 1,119,000	$ 16,780	$ 81,663	1,151,817	23	9.0
16	$ 0.03911	$ 11.78	$ 0.03911	A	No Data	No Data	No Data	No Data	23	9.0
17	$ 0.03911	$ 11.78	$ 0.03911	UESC	No Data	No Data	No Data	No Data	23	9.0
18	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 596,000	$ 8,940	$ 43,508	613,716	23	9.0
19	$ 0.03911	$ 11.78	$ 0.03911	Private Funds	$ -	$ -	$ 750	43,083	23	0.0
20	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 252,000	$ 3,780	$ 18,396	259,379	23	9.0
21	$ 0.03911	$ 11.78	$ 0.03911	UESC	$ 335,000	$ 5,025	$ 24,455	327,374	23	9.0
22	$ 0.07000	No Data	No Data	Utility Co Paid	No Data	No Data	No Data	No Data	No Data	No Data
23	$ 0.08940	$ 15.43	$ 0.07175	Super ESPC TS	$ 21,500,000	$ 841,296	$ 271,764	-8,655	30	22.0
24	$ 0.08940	$ 15.43	$ 0.07180	SRM	$ 75,000	$ 5,000	No Data	No Data	20	No Data
25	$ 0.07020	$ 11.89	$ 0.07020	A (MCA)	$ 734,079	No Data	No Data	No Data	No Data	No Data
26	No Data	$ 13.77	$ 0.07540	No Data	No Data	No Data	No Data	No Data	No Data	No Data
27	No Data	$ 13.77	$ 0.07540	ECIP	$ 2,329,600	No Data	$ 154,309	263,114	20	9.6
28	No Data	$ 13.77	$ 0.07540	ECIP	$ 995,800	No Data	$ 66,693	231,763	20	9.6

	A	B	C	D	E	F	G	H
1								
2	**Federal Agency**	**Facility Name**	**City**	**State**	**Building Area (Sq. Ft.)**	**DOD RPCS Facility Class (2-digit Group)**	**RPCS 2-digit Code**	**Building Additional Information**
29	Army	Fort Sill	Lawton	OK	27,491	Indoor Morale, Welfare, and Recreation Facilities	74	Bldg. 3281
30	Army	Fort Sill	Lawton	OK	197,252	Administrative	61	Bldg. 4700
31	Army	Fort Sill	Lawton	OK	58,765	Indoor Morale, Welfare, and Recreation Facilities	74	Bldg. 5485
32	Army	Fort Sill	Lawton	OK	46,034	Unaccompanied Personnel Housing	72	Bldgs. 5600 Area
33	Army	Fort Sill	Lawton	OK	13,288	Unaccompanied Personnel Housing	72	Bldg. 5684
34	Army	Fort Sill	Lawton	OK	No Data	Family Housing	71	No Data
35	Army	Fort Sill	Lawton	OK	No Data	Family Housing	71	No Data
36	Army	Fort Sill	Lawton	OK	No Data	Family Housing	71	No Data
37	Army	McAlester Army Ammunition Plant	McAlester	OK	12,915	Land Operational Facilities	14	Bldg. 228
38	Army	McAlester Army Ammunition Plant	McAlester	OK	1,686	Training Facilities	17	Armed Forces Reserve Center
39	Army	McAlester Army Ammunition Plant	McAlester	OK	No Data	Production Facilities	22	BCT Building
40	Army	McAlester Army Ammunition Plant	McAlester	OK	21,438	Production Facilities	22	Bldg. 103
41	Army	Fort Myer	Arlington	VA	31,698	Family Housing	71	Bldgs. 19 - 22
42	Army	Fort A.P. Hill	Bowling Green	VA	No Data	No Data	No Data	No Data
43	Army	Fort Eustis	Fort Eustis	VA	No Data	Administrative	61	Bldg. 2715
44	Army	Fort Eustis	Fort Eustis	VA	No Data	Administrative	61	Bldg. 2716

	I	J	K	L
1	**General Information**			
2	**Project Point of Contact (Name, Phone, e-mail)**	**Calender Year Installed**	**Project Status**	**New Construction / Retrofit**
29	Michael Baird, REM / All Projects, (580) 442-3577, michael.baird1@us.army.mil	Open	Planning	No Data
30	Michael Baird, REM / All Projects, (580) 442-3577, michael.baird1@us.army.mil	2006	Under Construction - 95%	No Data
31	Michael Baird, REM / All Projects, (580) 442-3577, michael.baird1@us.army.mil	2006	Under Construction - 95%	No Data
32	Michael Baird, REM / All Projects, (580) 442-3577, michael.baird1@us.army.mil	Open	Planning	No Data
33	Michael Baird, REM / All Projects, (580) 442-3577, michael.baird1@us.army.mil	Open	Planning	No Data
34	Michael Baird, REM / All Projects, (580) 442-3577, michael.baird1@us.army.mil	2006	Under Construction - 80%	No Data
35	Michael Baird, REM / All Projects, (580) 442-3577, michael.baird1@us.army.mil	2006-07	Under Construction - 42%	No Data
36	Michael Baird, REM / All Projects, (580) 442-3577, michael.baird1@us.army.mil	Open	Design	No Data
37	Kevin Henderson, MCAAP Energy Coordinator, (918) 420-7455, DSN:956-7455, kevin.d.henderson@us.army.mil	2007	Planning	No Data
38	Kevin Henderson, MCAAP Energy Coordinator, (918) 420-7455, DSN:956-7455, kevin.d.henderson@us.army.mil	2008	Planning	No Data
39	Kevin Henderson, MCAAP Energy Coordinator, (918) 420-7455, DSN:956-7455, kevin.d.henderson@us.army.mil	2007	Planning	No Data
40	Kevin Henderson, MCAAP Energy Coordinator, (918) 420-7455, DSN:956-7455, kevin.d.henderson@us.army.mil	2007	Planning	No Data
41	Mark Zangara, Fort Myer DPW, (703) 696-3804, mark.zangara@us.army.mil	2001	No Data	No Data
42	Frederick Hwee, DPW/EPS, (804) 633-8426, frederick.hwee@us.army.mil	2001	No Data	No Data
43	Loop contractor - Cliff Bunn, VA Energy Services, (804) 749-1962, 200 bores at 300 ft depth? Tried Wayne Spitzner, Evantage, (804) 819-2926	1998	No Data	No Data
44	Loop contractor - Cliff Bunn, VA Energy Services, (804) 749-1962, 200 bores at 300 ft depth? Tried Wayne Spitzner, Evantage, (804) 819-2926	1999	No Data	No Data

	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
1	**GHP Technical Information**																	
2	**GHP Type**	**# of GHP units Installed**	**Project Total Installed Tons**	**GHP Cooling Efficiency (EER)**	**GHP Cooling Capacity (TON)**	**GHP Heating Efficiency (COP)**	**GHP Heating Capacity (BTUH)**	**Fluid Type used in GHP**	**GHP Piping Material Used**	**Estimated Land Area Used for Project (sq ft)**	**Thermal Conductivity (BTU / hr-foot-^{o}F)**	**Average Bore Hole Depth For Vertical Loops (ft)**	**Predominant Soil Type**	**Predominant Rock Formations**	**Average Distance to Water Table (ft)**	**Average Distance to Bedrock (ft)**	**Average Frost Depth (ft)**	**IECC Climate Zone Class**
29	V-C	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	7	3A
30	V-C-Hy	10	261	No Data	No Data	No Data	No Data	Water	SDR-11	No Data	No Data	No Data	No Data	No Data	No Data	No Data	7	3A
31	V-C-Hy	No Data	No Data	No Data	No Data	No Data	No Data	Water	SDR-11	No Data	No Data	No Data	No Data	No Data	No Data	No Data	7	3A
32	V-C	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	7	3A
33	V-C	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	7	3A
34	V-C	110	330	3.0	14	4.5	42,000	Water	SDR-11	1,125	0.97	200	Silt/clay	Sandstone	No Data	No Data	7	3A
35	V-C	200	600	3.0	14	4.5	42,000	Water	SDR-11	1,125	0.97	200	Silt/clay	Sandstone	No Data	No Data	7	3A
36	V-C	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	7	3A
37	Vertical	No Data	11	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	3A
38	Vertical	No Data	250	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	3A
39	Vertical	No Data	5	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	3A
40	Vertical	No Data	75	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	3A
41	V	4	75	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	4A
42	V,C	38	119	No Data	No Data	No Data	No Data	Water, glycol	Polyethylene	No Data	No Data	172	No Data	No Data	No Data	No Data	No Data	4A
43	V	No Data	305	No Data	305	No Data	No Data	Water	1" HDPE	68,400	No Data	275	Sandy/Clay	None	25	No Data	2	4A
44	V	No Data	No Data	No Data	No Data	No Data	No Data	Water	1" HDPE	44,800	No Data	280	Sandy/Clay	None	25	No Data	2	4A

	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN
1	GHP Economic Information									
2	**Average Utility Rate at Project onset ($/kWh)**	**Current Average Natural Gas Rate ($/kcf)**	**Current Average Electric Rate ($/kWh)**	**Project Finance Mechanism**	**Project Investment Cost ($)**	**GHP annual Operation and Maintenance Savings ($)**	**Annual Energy Savings from GHP Installation ($)**	**Annual Energy Savings from GHP Installation (kWh)**	**GHP Project Estimated Economic Life (yrs)**	**Project Payback Period (yrs)**
29	No Data	$ 13.77	$ 0.07540	ECIP	$ 710,410	No Data	$ 8,935	96,983	20	11.6
30	$ 0.07000	$ 13.77	$ 0.07540	ECIP	No Data	No Data	No Data	No Data	20	No Data
31	$ 0.07000	$ 13.77	$ 0.07540	ECIP	No Data	No Data	No Data	No Data	20	No Data
32	No Data	$ 13.77	$ 0.07540	ECIP	$ 1,356,000	No Data	$ 33,555	345,154	20	11.7
33	No Data	$ 13.77	$ 0.07540	No Data	No Data	No Data	No Data	No Data	20	No Data
34	No Data	$ 13.77	$ 0.07540	COE	No Data	No Data	No Data	No Data	20	No Data
35	No Data	$ 13.77	$ 0.07540	COE	No Data	No Data	No Data	No Data	20	No Data
36	No Data	$ 13.77	$ 0.07540	COE	No Data	No Data	No Data	No Data	20	No Data
37	No Data	$ 9.13	No Data	ECIP	$ 55,000	No Data	No Data	No Data	No Data	No Data
38	No Data	$ 9.13	No Data	A	$ 1,500,000	No Data	No Data	No Data	No Data	No Data
39	No Data	$ 9.13	No Data	A	No Data	No Data	No Data	No Data	No Data	No Data
40	No Data	$ 9.13	No Data	ECIP	$ 375,000	No Data	No Data	No Data	No Data	No Data
41	No Data	$ 13.59	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
42	No Data	No Data	No Data	ESPC-Army	$ 931,000	$ 146,000	$ 57,000	479,000	18	5.0
43	No Data	$ 9.76	No Data	A	No Data	No Data	No Data	No Data	No Data	No Data
44	No Data	$ 9.76	No Data	A	No Data	No Data	No Data	No Data	No Data	No Data

	A	B	C	D	E	F	G	H	I	J	K	L
1	General Information											
2	Federal Agency	Facility Name	City	State	Building Area (Sq. Ft.)	DOD RPCS Facility Class (2-digit Group)	DOD RPCS 2-digit Code	Building Additional Information	Project Point of Contact (Name, Phone, e-mail)	Calender Year Installed	Project Status	New Construction / Retrofit
3	Air Force	Little Rock Air Force Base	Little Rock	AR	1,871,448	Family Housing	71	Retro FHU	Larry Whitt, DSN 574-3087	1998	hsg priv	Retrofit
4	Air Force	Little Rock AFB	Little Rock	AR	7,018	Personnel Support Facility	73	No Data	Craig Jendrusch, PJM, Capstone Building Corp., 501.983.8040	2005	No Data	No Data
5	Air Force	Luke Air Force Base	Glendale	AZ	No Data	Unaccompanied	72	espc? Hybrid?	No Data	No Data	No Data	No Data
6	Air Force	USAF Academy	Colo. Springs	CO	No Data	Administrative	61	Office Bldg 8486	USAFA Energy Manager	2003	Operational	No Data
7	Air Force	USAF Academy	Colo. Springs	CO	No Data	Administrative	61	South Gate	USAFA Energy Manager	2003	Operational	No Data
8	Air Force	USAF Academy	Colo. Springs	CO	No Data	Indoor MWR fac	74	Batters Cages	USAFA Energy Manager	2005	Operational	No Data
9	Air Force	Bolling AFB	Washington	DC	No Data	Family Housing	71	Base Housing	Kavanaugh's list	2000	Operational	No Data
10	Air Force	Hurlburt Air Base	Ft. Walton Beach	FL	No Data	Family Housing	71	Retro FHU	No Data	1999	Operational	Retrofit
11	Air Force	Eglin Air Force Base	Ft. Walton Beach	FL	No Data	Family Housing	71	One pilot project in housing (106 Palm Cir.)	James Mardis, 850-883-4810	2002	Operational	No Data
12	Air Force	Tyndall Air Force Base	Panama City	FL	No Data	No Data	No Data	No Data	Gilbert Walker, DSN 523-4715	2003	Operational	Retrofit
13	Air Force	Tyndall Air Force Base	Panama City	FL	No Data	Training Facilitie	17	No Data	Gilbert Walker, DSN 523-4715	2003	Operational	Retrofit
14	Air Force	Tyndall Air Force Base	Panama City	FL	No Data	Training Facilitie	17	No Data	Gilbert Walker, DSN 523-4715	1999	Operational	No Data
15	Air Force	Tyndall Air Force Base	Panama City	FL	No Data	Family Housing	71	Base Housing	Gilbert Walker, DSN 523-4715	2000	Operational	New Construction
16	Air Force	MacDill	Tampa	FL	48,000	Unaccompanied	72	BQ	Bill Gregg, 813-828-8681	2003	No Data	No Data
17	Air Force	Offutt AFB	Offutt	NE	No Data	Unaccompanied	72	commercial	No Data	2002-5	Operational	No Data
18	Air Force	Cannon	Clovis	NM	No Data	Administrative	61	No Data	No Data	2005	Operational	No Data
19	Air Force	Charleston Air Force Base	Charleston	SC	No Data	Family Housing	71	residential	Chris Gain, 843-963-5019	2001	Operational	No Data
20	Air Force	Dyess AFB	Abilene	TX	No Data	No Data	No Data	No Data	Kavanaugh's list	2000	Operational	No Data

	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
1	**GHP Technical Information**																	
2	**GHP Type**	**# of GHP units Installed**	**Project Total Installed Tons**	**GHP Cooling Efficiency (EER)**	**GHP Cooling Capacity (TON)**	**GHP Heating Efficiency (COP)**	**GHP Heating Capacity (BTUH)**	**Fluid Type used in GHP**	**GHP Piping Material Used**	**Estimated Land Area Used for Project (sq ft)**	**Thermal Conductivity (BTU / hr-foot-°F)**	**Average Bore Hole Depth For Vertical Loops (ft)**	**Predominant Soil Type**	**Predominant Rock Formations**	**Average Distance to Water Table (ft)**	**Average Distance to Bedrock (ft)**	**Average Frost Depth (ft)**	**IECC Climate Zone Class**
3	Vertical	1535	3070	14	2	4.5	23000	Water	HDPE	No Data	0.82, 1.65, 2.47	No Data	varies	No Data	No Data	No Data	1.16	3A
4	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	3A
5	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	2B
6	H & V, C	3	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	3.16	5B
7	H, C	1	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	3.16	5B
8	C	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	3.16	5B
9	Vertical	318	795	No Data	2.5	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	n/a	4A
10	Vertical	100	250	No Data	2.5				HDPE				No Data	No Data	No Data	No Data	0	2A
11	Vertical	1	3	14.5 SEER	3	4	40	WATER	HDPE	40	1.4	250	Medium to fine sa	None	6	No Data	0.25	2A
12	Vertical	10	40	No Data	4	No Data	No Data	No Data	HDPE	No Data	No Data	No Data	No Data	No Data	No Data	No Data	0	2A
13	Vertical	1	20	No Data	20	No Data	No Data	No Data	HDPE	No Data	No Data	No Data	No Data	No Data	No Data	No Data	0	2A
14	Vertical	No Data		No Data		No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	0	2A
15	Vertical	160	540	No Data	3.4	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	0	2A
16	Vertical	50	150	No Data	3	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	0	2A
17	vertical	790	983	No Data	1.2	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	6.08	5A
18	No Data	No Data	40	No Data		No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	1.5	4B
19	Vertical	965	3200	No Data	3.3	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	0	3A
20	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	0.58	3B

	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN
1	GHP Economic Information									
2	**Average Utility Rate at Project onset ($/kWh)**	**Current Average Natural Gas Rate ($/kcf)**	**Current Average Electric Rate ($/kWh)**	**Project Finance Mechanism**	**Project Investment Cost ($)**	**GHP annual Operation and Maintenance Savings ($)**	**Annual Energy Savings from GHP Installation ($)**	**Annual Energy Savings from GHP Installation (kWh)**	**GHP Project Estimated Economic Life (yrs)**	**Project Payback Period (yrs)**
3	0.0416	7.41	0.0484	UESC	No Data	No Data	No Data	No Data	No Data	No Data
4	No Data	7.41	0.0484	No Data	$ 43,277	No Data	No Data	No Data	No Data	No Data
5	No Data	7.98	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
6	0.0438	6.81	0.0542	O&M/SRM/EEIC 52	$ 1,057,000	No Data	No Data	No Data	No Data	No Data
7	0.0438	6.81	0.0542	O&M/SRM/EEIC 52	$ 682,000	No Data	No Data	No Data	No Data	No Data
8	0.0542	6.81	0.0542	O&M/SRM/EEIC 52	$ 610,000	No Data	No Data	No Data	No Data	No Data
9	0.0647	14.95	0.0767	A	No Data	No Data	No Data	No Data	No Data	No Data
10	0.0406	9.03	0.0573	UESC & ECIP	No Data	No Data	No Data	No Data	No Data	No Data
11	0.0433	9.03	0.0607	UESC/PILOT	10000	70	780	TBD	20	11.8
12	0.027	8.53	0.0719	UESC	No Data	No Data	No Data	No Data	No Data	No Data
13	0.027	8.53	0.0719	UESC	No Data	No Data	No Data	No Data	No Data	No Data
14	0.032	8.53	0.0719	AF	No Data	No Data	No Data	No Data	No Data	No Data
15	0.0382	8.53	0.0513	AF	No Data	No Data	No Data	No Data	No Data	No Data
16	0.0651	9.02	0.0692		No Data	No Data	No Data	No Data	No Data	No Data
17	0.0178	7.62	0.019	UESC	2500000	No Data	No Data	No Data	No Data	No Data
18	0.0513	6.94	0.0513		No Data	No Data	No Data	No Data	No Data	No Data
19	0.0454	7.41	0.0585	ESPC-Army	6500000	No Data	No Data	No Data	No Data	No Data
20	0.0476	6.93	0.079	A	No Data	No Data	No Data	No Data	No Data	No Data

	A	B	C	D	E	F	G	H	I	J	K	L
1	General Information											
2	**Federal Agency**	**Facility Name**	**City**	**State**	**Building Area (Sq. Ft.)**	**DOD RPCS Facility Class (2-digit Group)**	**RPCS 2-digit Code**	**Building Additional Information**	**Project Point of Contact (Name, Phone, e-mail)**	**Calender Year Installed**	**Project Status**	**New Construction / Retrofit**
3	Air Force	Little Rock AFB	Little Rock	AR	7,018	Personnel Supp	73	No Data	Craig Jendrusch, PJM, Capstone Building Corp., 501.983.8040	2005	No Data	No Data
4	Air Force	Luke Air Force Base-added	Glendale	AZ	No Data	Unaccompanied	72	espc? Hybrid?	No Data	No Data	No Data	No Data
5	Air Force	USAF Academy	Colo. Springs	CO	No Data	Administrative	61	Stadium Blvd.	USAFA Energy Manager	Est 2006	Design	No Data
6	Air Force	USAF Academy	Colo. Springs	CO	No Data	Administrative	61	Visitor Center	USAFA Energy Manager	Est 06/07	Design	No Data
7	Air Force	USAF Academy	Colo. Springs	CO	No Data	Administrative	61	North Gate	USAFA Energy Manager	Est 06/07	Design	No Data
8	Air Force	MacDill	Tampa	FL	48,000	Unaccompanied	72	BQ	Bill Gregg, 813-828-8681	2003	No Data	No Data
9	Air Force	Charleston Air Force Base	Charleston	SC	No Data	No Data	No Data	None	Chris Gain, 843-963-5019	2005	under cntr	No Data
10	Air Force	Laughlin Air Force Base-added	Del Rio	TX	No Data	Unaccompanied	72	new constr	Ben Graf, DSN 732-4917	2006	in constr	No Data
11	Air Force	Whiteman	Knob Noster	MO	205,908	Maintenance; Unaccompanied Personnel Housing	21, 72	10 buildings	Whiteman CE Energy Manager	2007	constr to start Oct - Dec '06	Retrofit

	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
1	**GHP Technical Information**																	
2	**GHP Type**	**# of GHP units Installed**	**Project Total Installed Tons**	**GHP Cooling Efficiency (EER)**	**GHP Cooling Capacity (TON)**	**GHP Heating Efficiency (COP)**	**GHP Heating Capacity (BTUH)**	**Fluid Type used in GHP**	**GHP Piping Material Used**	**Estimated Land Area Used for Project (sq ft)**	**Thermal Conductivity (BTU / hr-foot-^oF)**	**Average Bore Hole Depth For Vertical Loops (ft)**	**Predominant Soil Type**	**Predominant Rock Formations**	**Average Distance to Water Table (ft)**	**Average Distance to Bedrock (ft)**	**Average Frost Depth (ft)**	**IECC Climate Zone Class**
3	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	3A
4	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	2B
5	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	3.16	5B
6	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	3.16	5B
7	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	3.16	5B
8	Vertical	50	150	No Data	3	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	0	2A
9	Vertical	46	1055	No Data	22.9	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	0	3A
10	Vertical	58	No Data	16.1 to 18.3	080 to 12,14	3.4 to 3.7	1,120 to 5,592	water	HDPE	42000	1.17	350	limestone	No Data	No Data	No Data	0	2B
11	H & V, C	13	200	16	54 to 10	No Data	No Data	water	HDPE	No Data	No Data	No Data	No Data	No Data	No Data	No Data	3.83	No Data

	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN
1	**GHP Economic Information**									
2	**Average Utility Rate at Project onset ($/kWh)**	**Current Average Natural Gas Rate ($/kcf)**	**Current Average Electric Rate ($/kWh)**	**Project Finance Mechanism**	**Project Investment Cost ($)**	**GHP annual Operation and Maintenance Savings ($)**	**Annual Energy Savings from GHP Installation ($)**	**Annual Energy Savings from GHP Installation (kWh)**	**GHP Project Estimated Economic Life (yrs)**	**Project Payback Period (yrs)**
3	No Data	7.41	0.0484	No Data	$ 43,277	No Data	No Data	No Data	No Data	No Data
4	No Data	7.98	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
5	No Data	6.81	0.0542	No Data	No Data	No Data	No Data	No Data	No Data	No Data
6	No Data	6.81	0.0542	No Data	No Data	No Data	No Data	No Data	No Data	No Data
7	No Data	6.81	0.0542	No Data	No Data	No Data	No Data	No Data	No Data	No Data
8	0.0651	9.02	0.0692		No Data	No Data	No Data	No Data	No Data	No Data
9	0.0484	7.41	0.0484	ESPC-Army	6500000	No Data	No Data	No Data	No Data	No Data
10	$0.07	6.77	0.0703	MILCON	7300000	No Data	No Data	No Data	No Data	No Data
11	0.04	7.15	0.038	ESPC-DOE	$2,135,834	$23,124	$41,942	35268	20	32.8

	A	B	C	D	E	F	G	H	I	J	K	L
1	General Information											
2	**Federal Agency**	**Facility Name**	**City**	**State**	**Building Area (Sq. Ft.)**	**DOD RPCS Facility Class (2-digit Group)**	**DOD RPCS 2-digit Code**	**Building Additional Information**	**Project Point of Contact (Name, Phone, e-mail)**	**Calender Year Installed**	**Project Status**	**New Construction / Retrofit**
3	Navy	Washington Naval Yard	Anacostia	DC	No Data	Unaccompanied Personnel Housing	72	Bldg A-93	Doug Henderson, BFA (703-466-7400); David Ames, VA Energy Svcs, 804	1998	No Data	No Data
4	Navy	US Naval Observatory	Washington	DC	10,519	Administrative E	61	Bldg 78	Pete Collat, Summer Consultants, Inc., 703-556-8820	2001	Operational	No Data
5	Navy	US Naval Observatory	Washington	DC	No Data	Administrative E	61	Bldg 1	Douglas Henderson, BFA (757-466-7400);	1998	Operational	No Data
6	Navy	Pensacola Naval Air Station	Pensacola	FL	No Data	Family Housing	71	LHT	Gladies Wooten, 850-452-4412 / Patricia Melton, SCES PGMELTON@sou	1996	Operational	Retrofit
7	Navy	Pensacola Naval Air Station	Pensacola	FL	No Data	Family Housing	71	Corry Housing	Gladies Wooten, 850-452-4412 / Patricia Melton, SCES PGMELTON@sou	1997	Operational	Retrofit
8	Navy	Pensacola Naval Air Station	Pensacola	FL	No Data	Family Housing	71	Quarters 2	Gladies Wooten, 850-452-4412 / Patricia Melton, SCES PGMELTON@sou	2000	Operational	Retrofit
9	Navy	Pensacola Naval Air Station	Pensacola	FL	No Data	Family Housing	71	Quarters 4	Gladies Wooten, 850-452-4412 / Patricia Melton, SCES PGMELTON@sou	2000	Operational	Retrofit
10	Navy	Pensacola Naval Air Station	Pensacola	FL	No Data	Family Housing	71	Barrancas/Cabanis	Gladies Wooten, 850-452-4412 / Patricia Melton, SCES PGMELTON@sou	2001	Operational	Retrofit
11	Navy	Pensacola Naval Air Station	Pensacola	FL	No Data	Family Housing	71	Cabaniss / Barrancas	Gladies Wooten, 850-452-4412 / Patricia Melton, SCES PGMELTON@sou	2001	Operational	Retrofit
12	Navy	Pensacola Naval Air Station	Pensacola	FL	No Data	Family Housing	71	Barrancas	Gladies Wooten, 850-452-4412 / Patricia Melton, SCES PGMELTON@sou	2001	Operational	Retrofit
13	Navy	Pensacola Naval Air Station	Pensacola	FL	No Data	Family Housing	71	Cabaniss Crescent 2	Gladies Wooten, 850-452-4412 / Patricia Melton, SCES PGMELTON@sou	2002	Operational	Retrofit
14	Navy	Naval Air Station Whiting Field	Milton	FL	No Data	Family Housing	71	Whiting Pines	Gladies Wooten, 850-452-4412 / Patricia Melton, SCES PGMELTON@sou	1999	Operational	Retrofit
15	Navy	Naval Air Station Whiting Field	Milton	FL	No Data	Family Housing	71	Whiting Pines	Gladies Wooten, 850-452-4412 / Patricia Melton, SCES PGMELTON@sou	2001	Operational	Retrofit
16	Navy	NA Corry Station	Pensacola	FL	No Data	Family Housing	71	No Data	Gladies Wooten, 850-452-4412 / Patricia Melton, SCES PGMELTON@sou	2002	Operational	Retrofit
17	Navy	NA Corry Station	Pensacola	FL	No Data	Family Housing	71	No Data	Gladies Wooten, 850-452-4412 / Patricia Melton, SCES PGMELTON@sou	2003	Operational	Retrofit
18	Navy	Naval Supply Corps School	Athens	GA	No Data	Family Housing	71	No Data	Patricia Melton, SCES PGMELTON@southernco.com	2002	Operational	Retrofit
19	Navy	Patuxent River Naval Air Station	Patuxent R. NAS	MD	27,247	Administrative E	61	Bldg. 2189	Mel Green, NAVFAC PAXRIV, 301-757-4721, Melvin.green@navy.mil	1995	Operational	
20	Navy	Patuxent River Naval Air Station	Patuxent R. NAS	MD	137,440	Administrative E	61	9 bldgs total	Mel Green, NAVFAC PAXRIV, 301-757-4721, Melvin.green@navy.mil	2000	Operational	Retrofit
21	Navy	Naval Air Station Oceana	Virginia Beach	VA	470,000	Unaccompanied Personnel Housing	72	No Data	Robert P. Harvey, NAVFAC MIDLANT, 757-492-8533	2004	Operational	No Data
22	Navy	Naval Air Station Oceana	Virginia Beach	VA	164,000	Unaccompanied Personnel Housing	72	MILCON Project # P712; 4	Brian Cooper, USN Facilities Engineering, 757-322-4242	2001	Operational	No Data
23	Navy	Naval Air Station Oceana	Virginia Beach	VA	93,000	Unaccompanied Personnel Housing	72	No Data	Miles Lumbard, NAVFAC MIDLANT, 757-433-2844	2000	Operational	No Data
24	Navy	Naval Air Station Oceana	Virginia Beach	VA	8,000	Medical and Medical Support Facilities	53	No Data	Miles Lumbard, NAVFAC MIDLANT, 757-433-2844	1999	Operational	No Data
25	Navy	NWS Charleston	Goose Creek	SC	1,000,000	Unaccompanied Personnel Housing	72	1,000,000 sq. ft	No Data	2002	Operational	No Data
26	Marines	Albany MCLB	Albany	GA	1,100	family housing	71	46 residences	Eddie Hunt, (229) 639-5979	2004	operational	Retrofit
27	Marines	Albany MCLB	Albany	GA	1,300	family housing	71	139 residences	Eddie Hunt, (229) 639-5979	2004	operational	Retrofit
28	Marines	Albany MCLB	Albany	GA	1,500	family housing	71	54 residences	Eddie Hunt, (229) 639-5979	2004	operational	Retrofit
29	Marines	Albany MCLB	Albany	GA	1,400	family housing	71	5 residences	Eddie Hunt, (229) 639-5979	2004	operational	Retrofit
30	Marines	Albany MCLB	Albany	GA	1,800	family housing	71	5 residences	Eddie Hunt, (229) 639-5979	2004	operational	Retrofit
31	Marines	Albany MCLB	Albany	GA	2,500	family housing	71	1 residences	Eddie Hunt, (229) 639-5979	2004	operational	Retrofit
32	Marines	MCAS Cherry Point	Havelock	NC	No Data	family housing	72	No Data	Joseph Jackson, (252) 466-4703, JacksonJG@cherrypoint.usmc.mil	2002	operational	No Data
33	Marines	New River MCAS	Jacksonville	NC	145,854	Unaccompanied Personnel Housing	72	AS4211, AS4212 2@3story	Jim Sides, Utilities Director, 910-451-5024	1997	operational	Retrofit
34	Marines	Camp Lejeune	Jacksonville	NC	8,400	Admin Building	61	SH50 - Ammo Supply	Jim Sides, Utilities Director, 910-451-5024	2001	operational	Retrofit
35	Marines	Camp Lejeune	Jacksonville	NC	3,000,000	Family Housing	71	2,049 Residences	Jim Sides, Utilities Director, 910-451-5024	2001	operational	Retrofit
36	Marines	Camp Lejeune	Jacksonville	NC	22,088	Admin Building	61	Marston Pavillion, PP730	Jim Sides, Utilities Director, 910-451-5030	2001	operational	Retrofit
37	Marines	Beaufort Marine Corps Air Station	Beaufort	SC	1,482,000	Family Housing	71	1,236 residences, 1482000 sq ft.	Bill Eisele, South Carolin Electric and Gas, (803) 217-9220, beisele@scana.com	2001	operational	RETROFIT
38	Marines	Beaufort Marine Corps Air Station (I&II)	Beaufort	SC	424,451	ies, Administrativ	17, 21, 22, 53,	38 Bldgs, mixed use	David Hayden, Trane GCC Account Executive, (361) 883-5561, dhayden@trane.com	2003	operational	RETROFIT
39	Marines	Marine Corps Recruit Depot	Parris Island	SC	27,170	Unaccompanied Personnel Housing	72	2 story	Ronnie Myers, ronnie.myers@usmc.mil	2001	operational	No Data
40	Marines	Quantico Marine Corps Base	Quantico	VA	No Data	No Data	No Data	No Data	No Data	1997	No Data	No Data
41					No Data	No Data	No Data	No Data	No Data	2000	No Data	No Data

	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
1	GHP Technical Information																	
2	GHP Type	# of GHP units Installed	Project Total Installed Tons	GHP Cooling Efficiency (EER)	GHP Cooling Capacity (TON)	GHP Heating Efficiency (COP)	GHP Heating Capacity (BTUH)	Fluid Type used in GHP	GHP Piping Material Used	Estimated Land Area Used for Project (sq ft)	Thermal Conductivity (BTU / hr-foot-°F)	Average Bore Hole Depth For Vertical Loops (ft)	Predominant Soil Type	Predominant Rock Formations	Average Distance to Water Table (ft)	Average Distance to Bedrock (ft)	Average Frost Depth (ft)	IECC Climate Zone Class
3	V	29	36	No Data	36	No Data	320500	water	PE	5625	No Data	280	No Data	No Data	11.4	No Data	4	4A
4	H, V	38	46	4.5 *	46	2.8 *	419500	water	PE	9600	2	400 (all 24)	0' of rock, 50' of cl	lots	No Data	70'	2.5	4A
5	H, V	47	75.7	No Data	75.7	No Data	904300	water	PE	16000	2	400	70-80 ft clay & roc	No Data	No Data	80	2.5	4A
6	V,O	250	625	12.23	2.5	3	Unknown	Water	Polyethelene	Unknown	1.4	225	Spodosols	No Data	No Data	No Data	No Data	2A
7	V	200	500	12.23	2.5	3	Unknown	Water	Polyethelene	Unknown	1.4	225	Spodosols	No Data	No Data	No Data	No Data	2A
8	V	1	9	No Data	9	No Data	No Data	water	Polyethelene	1600	1.4	260	sand	No Data	No Data	No Data	No Data	2A
9	V	2	8.5	No Data	8.5	No Data	No Data	water	Polyethelene	1600	1.4	260	sand	No Data	No Data	No Data	No Data	2A
10	V	152	320	12.23	2.5	3	Unknown	Water	Polyethelene	Unknown	1.4	225	Spodosols	No Data	No Data	No Data	No Data	2A
11	V	30	126.5	No Data	126.5	No Data	No Data	water	Polyethelene	12000	1.4	260	sand	No Data	No Data	No Data	No Data	2A
12	V	10	30	No Data	30	No Data	No Data	water	Polyethelene	4000	1.4	270	sand	No Data	No Data	No Data	No Data	2A
13	V	36	135	No Data	135	No Data	No Data	water	Polyethelene	14400	1.4	240	sand	No Data	No Data	No Data	No Data	2A
14	V	328	984	12.23	2.5	3	Unknown	Water	Polyethelene	Unknown	1.4	225	Spodosols	No Data	No Data	No Data	No Data	2A
15	V	329	770	No Data	770	No Data	No Data	water	Polyethelene	131600	1.4	225	sand	No Data	No Data	No Data	No Data	2A
16	V	200	600	No Data	600	No Data	No Data	water	Polyethelene	80000	1.4	260	sand	No Data	No Data	No Data	No Data	2A
17	No Data	No Data	2500	No Data		No Data	No Data		Polyethelene		1.4			No Data	No Data	No Data	No Data	2A
18	V	55	148	No Data	148	No Data	No Data	21% methanc	Polyethelene	22000	No Data	245	rock	No Data	No Data	No Data	No Data	3A
19	V	18	114	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	4A
20	V,H	137	399	18.9	399	4.3	4,367,000	water	Polyethelene	90400	No Data	225	sand, gravel, clay	No Data	No Data	No Data	2.5	4A
21	vertical	499	814	No Data	No Data	4.376	No Data	water/glyc	HDPE	130,680	1.007	500	Grey Clay	none	10	N/A	1	4A
22	vertical	273	330	13.4-16.1	330	3.2-3.4	3,670,000	Water	HDPE	60,000 (15 ft OC)	1.007	200	Sand/Silt	none	10	N/A	1	4A
23	vertical	124	160	No Data	No Data	No Data	No Data	water/glyc	HDPE	parking lot	1.007	200	Sand/Silt	none	10	N/A	1	4A
24	vertical	No Data	21	No Data	No Data	No Data	No Data	water/glyc	HDPE	No Data	1.007	200	Sand/Silt	none	10	N/A	1	4A
25	No Data	8	27.5	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	3A
26	T024-1VTC-F	46	92	16.2	2	3.5	18200	H2O	HDPE	10,000	0.9	231	Sand, Sandy	Fract Limestone	1000	unknown	N/A	2A
27	T030-1VTC-F	139	347.5	18.5	2.5	4.0	19000	H2O	HDPE	10,000	0.9	305	Sand, Sandy	Fract Limestone	1000	unknown	N/A	2A
28	T036-1VTC-F	54	162	17.0	3	3.5	24500	H2O	HDPE	10,000	0.9	221	Sand, Sandy	Fract Limestone	1000	unknown	N/A	2A
29	T042-1VTC-F	5	17.5	16.6	3.5	3.7	30000	H2O	HDPE	10,000	0.9	268	Sand, Sandy	Fract Limestone	1000	unknown	N/A	2A
30	T048-1VTC-F	5	20	15.8	4	3.5	36500	H2O	HDPE	10,000	0.9	292	Sand, Sandy	Fract Limestone	1000	unknown	N/A	2A
31	T060-1VTC-F	1	5	14	5	3.2	48000	H2O	HDPE	10,000	0.9	305	Sand, Sandy	Fract Limestone	1000	unknown	N/A	2A
32	Closed Vertica	1128	2773	16	2773		20,866,000	H2O	HDPE	45,120	1.21	250	Sand	No Data	7	No Data	N/A	3A
33	V-C	118	40	13.5 - 14.1	35	4.6 - 5.1	258,000	R-410A	Polyethylene	38,400	1.12	239	Baymeade, Fine Sand	None	3	N/A	0.20	3A
34	V-C	10	20.5	13 - 14.1	1.0 - 7.5	3.0 - 3.3	100,450	Water	Polyethylene	6,300	No Data	205	Baymeade-Urban	None	3	N/A	0.20	3A
35	V-C	2,099	3,700	14.8 - 15.1	3,700	4.6 - 5.0	55,459M	Water	Polyethylene	389,100	1.12 - 1.54	176	Goldsboro, Baymeade	None	3.50	N/A	0.20	3A
36	V-C	8	95	12.1	95	3.25	888,400	Propylene Glycol	Polyethylene	42,000	1.54	200	Baymeade-Urban, Muckalee Loam	None	3	N/A	0.20	3A
37	V	1236	2484	16	2484	5	2649	water	HDPE	993,600	1	180	sand, clay, shell	limestone	Srface water 10-12 ft, Ocala	N/A	N/A	3A
38	various	172 WTA, 34 WTW	1595	16	1595	5	1701	water	HDPE	638,000	1	300	sand, clay, shell	limestone	Srface water 10-12 ft, Ocala	N/A	N/A	3A
39	V, C, 70 boreholes	64	50	12.2	50	4.2	12000	water	HDPE	23,000	No Data	210	Sand	No Data	5	No Data	No Data	3A
40	V	No Data	225	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	4A
41	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	4A

	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN
1	**GHP Economic Information**									
2	**Average Utility Rate at Project onset ($/kWh)**	**Current Average Natural Gas Rate ($/kcf)**	**Current Average Electric Rate ($/kWh)**	**Project Finance Mechanism**	**Project Investment Cost ($)**	**GHP annual Operation and Maintenance Savings ($)**	**Annual Energy Savings from GHP Installation ($)**	**Annual Energy Savings from GHP Installation (kWh)**	**GHP Project Estimated Economic Life (yrs)**	**Project Payback Period (yrs)**
3	No Data	No Data	No Data	A	No Data	No Data	No Data	No Data	No Data	No Data
4	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
5	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
6	No Data	No Data	59	UESC	No Data	No Data	No Data	No Data	No Data	5
7	No Data	No Data	59	A	No Data	No Data	No Data	No Data	No Data	5
8	No Data	No Data	No Data	UESC	76271	No Data	No Data	No Data	20	No Data
9	No Data	No Data	No Data	UESC	98468	No Data	1154	No Data	20	2
10	No Data	No Data	59	A	130000	No Data	No Data	No Data	No Data	5
11	0.059	No Data	No Data	UESC	619170	No Data	19900	337240	20	10
12	No Data	No Data	No Data	UESC	129562	1250	4117	No Data	20	No Data
13	0.06347	No Data	No Data	UESC	435938	7200	27108	56445	20	10
14	No Data	No Data	59	UESC	322000	No Data	No Data	No Data	No Data	5
15	No Data	No Data	No Data	UESC	2180472	7500	20713	No Data	20	10
16	0.07826	No Data	No Data	UESC	2533916	0	122422	907347	20	No Data
17	No Data	No Data	No Data	UESC	No Data	No Data	No Data	No Data		No Data
18	0.0354	No Data	No Data	UESC	787286	24429	29343	No Data	20	10
19	No Data	No Data	No Data	A	No Data	No Data	No Data	No Data	No Data	No Data
20	0.0692	No Data	0.092	Super ESPC TS	$ 3,784,035	$ 43,924	$ 200,369	916999	20	15
21	.033 + $5.20/kW	No Data	.059 + $12.00/kW/Month	ESPC	$8,300,000	$500,000	$530,000	18,000,000	13yr financed term	8.4yr simple payback
22	.035 + $5.20/kW	No Data	.059 + $12.00/kW/Month	A	$15,000,000	No Data	No Data	No Data	No Data	No Data
23	.035 + $5.20/kW	No Data	.059 + $12.00/kW/Month	A	$7,000,000	No Data	No Data	No Data	No Data	No Data
24	.035 + $5.20/kW	No Data	.059 + $12.00/kW/Month	A	No Data	No Data	No Data	No Data	No Data	No Data
25	No Data	No Data	No Data	UESC	$ 1,000,000.00	No Data	No Data	No Data	No Data	10
26	$0.046	$8.38	$0.061	Super ESPC TS	$ 532,864	$ 2,447	$ 26,697	166,935	22	19.96
27	$0.046	$8.38	$0.061	Super ESPC TS	$ 1,610,177	$ 7,395	$ 80,672	504,434	22	19.96
28	$0.046	$8.38	$0.061	Super ESPC TS	$ 625,536	$ 2,873	$ 31,340	195,967	22	19.96
29	$0.046	$8.38	$0.061	Super ESPC TS	$ 57,920	$ 266	$ 2,902	18,145	22	19.96
30	$0.046	$8.38	$0.061	Super ESPC TS	$ 57,920	$ 266	$ 2,902	18,145	22	19.96
31	$0.046	$8.38	$0.061	Super ESPC TS	$ 11,584	$ 53	$ 580	3,629	22	19.96
32	$0.033	No Data	$0.043	UESC	$ 9,164,250	$ 99,470	$ 1,120,175	18,279,000	20	7.00
33	0.0541	1.11843	0.0537	A	No Data	No Data	No Data	No Data	No Data	No Data
34	0.0562	1.11843	0.0537	A	No Data	No Data	No Data	No Data	No Data	No Data
35	0.0562	1.11843	0.0537	UESC	16,117,326	-	1,457,625	20,939,000	20	7.37
36	0.0562	1.11843	0.0537	UESC	878,141	No Data	No Data	No Data	No Data	No Data
37	$0.05494/KWH $7.26/Dekatherm	No Data	$0.063/KWH $15.7421/Dekatherm	UESC	$ 11,501,557	$ 453,600	$ 983,167	12,405,781	20	9.33
38	$0.044/KWH $5.69/Dekatherm	No Data	$0.05469/KWH $10.61/Dekatherm	Super ESPC TS	$ 8,741,219	$ 450,000	$ 259,302	7,778,589	20	15
39	$0.040	No Data	$0.050	A	$ 52,600	$ 36,164	$ 8,085	19,000	20	5.08
40	No Data	No Data	No Data	A	No Data	No Data	No Data	No Data	No Data	No Data
41	No Data	No Data	No Data	A	No Data	No Data	No Data	No Data	No Data	No Data

	A	B	C	D	E	F	G	H	I	J	K	L
1	**General Information**											
2	**Federal Agency**	**Facility Name**	**City**	**State**	**Building Area (Sq. Ft.)**	**DOD RPCS Facility Class (2-digit Group)**	**RPCS 2-digit Code**	**Building Additional Information**	**Project Point of Contact (Name, Phone, e-mail)**	**Calender Year Installed**	**Project Status**	**New Construction / Retrofit**
3	Navy	Washington Naval Yard	Anacostia	DC	No Data	No Data	No Data	Bldg A-93	Doug Henderson, BFA (703-466-7400); David Ames, VA Energy Svcs, 804-358-200x doesn't work tried all 10 digits	1998	No Data	No Data
4	Navy	NA Corry Station	Pensacola	FL	No Data	No Data	No Data	No Data	Gladies Wooten, 850-452-4412 / Patricia Melton, SCES PGMELTON@southernco.com	2003	No Data	No Data
5	Navy	Naval Air Station Oceana	Virginia Beach	VA	No Data	No Data	No Data	No Data	Lutz, Daniel E LTJG NAVFAC MIDLANT, 757-433-2618	2006	Under Contruction	No Data
6	Navy	Kings Point Merchant Marine Academy	Kings Point	NY	No Data	No Data	No Data	Retro	Greg Tinkler, 281-450-3399, greg@tinkler.us	2005-2009	in constr	No Data
7	Marines	Quantico Marine Corps Base	Quantico	VA	No Data	No Data	No Data	No Data	No Data	1997	No Data	No Data
8					No Data	No Data	No Data	No Data	No Data	2000	No Data	No Data

	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
1	**GHP Technical Information**																	
2	**GHP Type**	**# of GHP units Installed**	**Project Total Installed Tons**	**GHP Cooling Efficiency (EER)**	**GHP Cooling Capacity (TON)**	**GHP Heating Efficiency (COP)**	**GHP Heating Capacity (BTUH)**	**Fluid Type used in GHP**	**GHP Piping Material Used**	**Estimated Land Area Used for Project (sq ft)**	**Thermal Conductivity (BTU / hr-foot-^{o}F)**	**Average Bore Hole Depth For Vertical Loops (ft)**	**Predominant Soil Type**	**Predominant Rock Formations**	**Average Distance to Water Table (ft)**	**Average Distance to Bedrock (ft)**	**Average Frost Depth (ft)**	**IECC Climate Zone Class**
3	V	29	36	No Data	36	No Data	320500	water	PE	5625	No Data	280	No Data	No Data	11.4	No Data	4	4A
4	No Data	No Data	2500	No Data		No Data	No Data		Polyethelene		No Data			No Data	No Data	No Data	No Data	2A
5	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	Sand/Silt	none	10		1	No Data
6	Vertical	600	1200	14	No Data	No Data	No Data	water	polyethylene	360,000	1.3	375	sand, gravel, clay	GARNET SCHIST	30	290	2	4A
7	V	No Data	225	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	4A
8	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	4A

	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN
1	**GHP Economic Information**									
2	**Average Utility Rate at Project onset ($/kWh)**	**Current Average Natural Gas Rate ($/kcf)**	**Current Average Electric Rate ($/kWh)**	**Project Finance Mechanism**	**Project Investment Cost ($)**	**GHP annual Operation and Maintenance Savings ($)**	**Annual Energy Savings from GHP Installation ($)**	**Annual Energy Savings from GHP Installation (kWh)**	**GHP Project Estimated Economic Life (yrs)**	**Project Payback Period (yrs)**
3	No Data	No Data	No Data	A	No Data	No Data	No Data	No Data	No Data	No Data
4	No Data	No Data	No Data	UESC	No Data	No Data	No Data	No Data		No Data
5	No Data	No Data	.059 + $12.00/kW/Month	A	No Data	No Data	No Data	No Data	No Data	No Data
6	$0.13	No Data	No Data	No Data	$ 6,000,000.00	$ 30,000.00	$ 300,000.00	650,000	20	1
7	No Data	No Data	No Data	A	No Data	No Data	No Data	No Data	No Data	No Data
8	No Data	No Data	No Data	A	No Data	No Data	No Data	No Data	No Data	No Data

APPENDIX B

STATE REGULATIONS FOR CLOSED LOOP GSHP SYSTEMS AS REPORTED IN (SHONDER, *ET. AL.*, IN PRESS), REPRINTED WITH PERMISSION

NOTE: INFORMATION IN THIS TABLE MAYBE DATED. FOR MORE UP TO DATE INFORMATION, CHECK THE GHPC WEBSITE (www.geoexchange.org) OR CHECK WITH THE STATE

Table B.1. State Regulations for Closed Loop Systems

State	Regulation Type	Regulation Details
Alaska	Vertical Borehole: Grouting:	Section 80.015 of the Drinking Water Rules 18 AAC 80
Arkansas	Horizontal Trench: Vertical Borehole: Grouting: Heat Transfer Fluids: Heat Exchanger:	Arkansas Water Well Construction Code Rules and Regulations
Arizona	Vertical Borehole: Grouting:	Well Construction and Licensing of Well Drillers Regulation
	Heat Exchanger:	Constructed in Accordance with Current Industry Standards
Colorado	Horizontal Trench:	Geothermal Well Rules - Office of the State Engineer, Water Resources
	Vertical Borehole: Grouting:	Geothermal Well Rules AND Water Well Construction Rule 2 CCR
	Heat Transfer Fluids:	Non Toxic, Regulated by Office of the State Engineer
	Heat Exchanger:	Closed-Loop Ground Source Heat Pump Systems: Installation Guide
Connecticut	Vertical Borehole: Grouting:	Connecticut Well Drilling Code
	Heat Transfer Fluids:	Department of Consumer Protection, Department of Environmental Protection
	Heat Exchanger: Direct Expansion System:	Department of Consumer Protection, Division of Plumbing and Piping
Delaware	Vertical Borehole: Grouting:	Regulations Governing the Construction of Water Wells
Florida	Vertical Borehole:	Water Well Construction Regulations
Georgia	Vertical Borehole:	The Water Well Standards Act
Idaho	Vertical Borehole: Grouting: Heat Transfer Fluids:	Well Construction Standards Rules IDAPA 37.03.09
	Heat Exchanger:	Constructed in Accordance with Current Industry Standards
Illinois	Applicable Regulations:	Illinois Water Well Construction Code
Indiana	Vertical Borehole: Grouting:	The Final Rules Concerning the Regulation of Water Well Drillers 312 IAC 16
Kansas	Vertical Borehole: Grouting:	Water Well Contractor's License; Water Well Construction and Abandonment Regulations
Kentucky	Horizontal Trench: Vertical Borehole:	The Groundwater Protection Plans (401 KAR Chapter 5:037) Regulations
Louisiana	Vertical Borehole: Grouting: Heat Transfer Fluids: Heat Exchanger:	Water Well Rules, Regulations and Standards, State of Louisiana
Maryland	Vertical Borehole:	Environment Article 9-1305, Annotated Code of Maryland
	Grouting: Heat Transfer Fluids:	Well Construction (COMAR 26.04.04) rules
Massachusetts	Vertical Borehole:	The Water Well Diggers and Drillers Registration (313 CMR 3.00)
Michigan	Vertical Borehole:	R 325.1606 of the Michigan Water Well Construction and Pump Installation Code Rules
	Grouting:	Dept. of Health, Bureau of Environmental and Occupational Health, Div. of Water Supply
Minnesota	Vertical Borehole:	Permit to Install Vertical Exchanger / Wells, Borings, and Underground Minnesota Uses
	Grouting: Heat Exchanger:	Wells, Borings, and Underground Uses Minnesota Rules
Mississippi	Vertical Borehole: Grouting:	Surface Water and Groundwater Use and Protection Regulations
Nebraska	Horizontal Trench: Vertical Borehole: Heat Transfer Fluids: Grouting: Heat Exchanger: Direct Expansion System:	Title 178, NAC 12: Regulations Governing Water Well Construction, Pump Installation and Water Well Abandonment Standards

Table B.1. State Regulations for Closed Loop Systems (Cont'd)

State	Regulation Type	Regulation Details
Nevada	Vertical Borehole: Grouting:	Underground Water and Well regulations - Department of Conservation and Natural Resources
New Hampshire	Vertical Borehole:	The New Hampshire Water Well Board Rules - Chapters We 100 through We 1000
New Jersey	Vertical Borehole: Direct Expansion System:	Section 58:4A-23 of the Subsurface and Percolating Waters Act
	Heat Transfer Fluids: Heat Exchanger:	Well Permit - Department of Environmental Protection, Well Permitting and Regulations Section
	Grouting:	New Jersey Grouting Infomation Sheet - Department of Environmental Protection
New York	Horizontal Trench: Vertical Borehole: Heat Transfer Fluids: Direct Expansion System:	Position Paper - New York State Department of Environmental Conservation
	Grouting:	Grouting Procedures for Ground Source Heat Pump Systems - IGSHPA
	Heat Exchanger:	IGSHPA Guidelines - New York State Department of Environmental Conservation
North Carolina	Vertical Borehole: Grouting: Heat Exchanger:	Regulations Pending
North Dakota	Horizontal Trench:	Chapters 33-19 and 43-02-07 of the North Dakota Century and Administrative Codes
	Vertical Borehole:	Chapters 38-19 and 43-02-07 of the North Dakota Century and Administrative Codes
	Grouting:	Grout Regulations - North Dakota Geological Survey
	Heat Transfer Fluids: Heat Exchanger: Direct Expansion System:	Must be Approved by the State Geologist
Oklahoma	Horizontal Trench: Vertical Borehole: Grouting: Direct Expansion System:	Water Resources Board Rules and Regulations, Oklahoma Administrative Code (OAC) Title 785
Oregon	Vertical Borehole: Grouting: Heat Exchanger:	Administrative Rules Chapter 690, Division 240-Construction and Maintenance of Monitoring Wells, Geotechnical Holes, and Other Holes
Rhode Island	Vertical Borehole:	Dept. of Environmental Management, Division of Groundwater and Freshwater Wetlands
	Grouting:	Rules Governing The Enforcement Of Chp. 46-13.2 - Drilling of Drinking Water Wells
South Carolina	Vertical Borehole:	Section R.61-71.2 of the South Carolina Well Standards and Regulations
Tennessee	Vertical Borehole: Grouting:	Underground Injection Control Chapter 1200-4- 6
Vermont	Vertical Borehole: Grouting: Heat Transfer Fluids: Direct Expansion System:	The Water Supply Rule Chapter 21, Part 12 of the Environmental Protection Rules
Virginia	Vertical Borehole: Direct Expansion System:	Section 1.1 of the Private Well Regulations VR 355-34- 100
	Grouting:	Section 3.7 (C) (3) of the Private Well Regulations
	Heat Exchanger:	The Virginia Board for Contractors, Rules and Regulations Title 54.1, Chapter 11
Washington	Vertical Borehole:	Minimum Standards for Construction and Maintenance of Wells
West Virginia	Vertical Borehole:	The Water Well Regulations 64CSR19
Wisconsin	Vertical Borehole:	Section NR 812.02 - Well Construction And Pump Installation Regulations
	Grouting:	Section NR 812.05 Disposal of Pollutants; Injection Prohibition
	Heat Exchanger:	Section NR 812.09 Department Approvals
	Direct Expansion System	Approval by the Bureau of Drinking Water and Groundwater, Dept.of Natural Resource
Wyoming	Horizontal Trench:	Chapter IX of the Wyoming Water Quality Rules And Regulations
	Vertical Borehole:	Chapter IX and Chapter XI Part G, of the Wyoming Water Quality Rules And Regulations
	Grouting:	Section 65 of the Department of Environmental Quality regulations
	Heat Transfer Fluids:	Non-toxic Fluids - The Department of Environmental Quality

APPENDIX C

List of Useful Websites related to GSHPs (SHONDER, *ET. AL.*, IN PRESS), Reprinted with Permission

List of Useful Websites

http://www.eren.doe.gov/femp/financing/ghpresources.html

The website of the **U.S. Department of Energy's Federal Energy Management Program (FEMP)** contains a wealth of information pertaining to GHPs in Federal facilities, including brochures, case studies, a generic GHP guide specification, software tools, and detailed guidance on how Federal facilties can access private financing through the regional, technology specific, and utility energy savings performance contracts (ESPCs) developed by FEMP.

http://www.eren.doe.gov/geothermal/geoheatpumps.html

The Geothermal Energy Program of the **U.S. Department of Energy (DOE)** presents a series articles on GHPs for homes, schools, and commercial buildings. Another article contains a through description of the energy and environmental benefits of GHPs.

http://www.ghpc.org

The **Geothermal Heat Pump Consortium** is an organization of electric utilities and their institutions, equipment manufacturers and their allies, the U.S. Department of Energy, the U.S. Environmental Protection Agency, and the Consortium for Energy Efficiency with the objective of reducing the barriers to wide-scale customer acceptance of GHP technology. In addition to basic information about the technology, the consortium's website contains detailed case studies of more than 100 residential and commercial GHP applications from across North America. There are also links to the websites of heat pump manufacturers, utilities, ESCOs and other organizations active in the GHP industry.

http://www.igshpa.okstate.edu

Another organization promoting the use of GHP technology is the **International Ground Source Heat Pump Association (IGSHPA)** , located on the campus of Oklahoma State University. IGSHPA provides a forum for information exchange and discussion, offers continuing education and training for industry professionals, and promotes the development of industry-related standards. Its website contains basic information on the operation of GHPs, their cost, and their use in various applications. Of particular value is the state-by-state directory of GHP contractors. IGSHPA's semi-annual conferences provide an excellent introduction to the technology, including hands-on demonstrations of how the equipment is installed and operated.

http://www.ornl.gov/femp/

The **Oak Ridge National Laboratory (ORNL)** is the home of FEMP's GHP Core Team, which provides technical expertise and assistance on GHP projects and technologies to the Federal government. The website includes brochures on GHP technology and alternative finance mechanisms, case studies of GHP projects in the Federal sector, and software developed by Core Team members. There is also a link to ORNL's HVAC Construction and Maintenance Cost Database, which was used to develop the cost information contained in this guide.

http://geoheat.oit.edu/

Located at the Oregon Institute of Technology in Klamath, OR, the **Geo-Heat Center** is a small organization promoting the use of GHP technology in the U.S. Northwest. In addition to descriptive brochures and links to other organizations, the website contains information on groundwater source heat pumps that is generally unavailable elsewhere. Of particular interest is the Geo-Heat Center Quarterly Bulletin, which contains case studies and design information for various GHP system types in a wide variety of applications. The website also contains the "Outside the Loop Newsletter", an informative publication produced at the University of Alabama. At present the newsletter is no longer being produced, but the back issues contain valuable information on costs, cost containment and other design issues associated with GHPs.

http://bama.ua.edu/~geocool/

The University of Alabama maintains this website. This site has a lot of different information relating GSHPs.

http://www.alliantgeo.com/

The **Geothermal Information Office** is a collaborative effort bewteen Alliant Utilities and the Electric Power Research Institute. The website provides basic information on geothermal heat pumps, including case studies of applications in Alliant's service territory (Illinois, Iowa, Minnesota and Wisconsin) and links to installers and manufacturers.

http://www.epa.gov/globalwarming/publications/outreach/technology/geothermalheatpumps.pdf

The **U.S. Environmental Protection Agency (EPA)** offers a small brochure describing the benefits of GHPs for energy conservation and reduced emissions of greenhouse gases and other pollutants.

APPENDIX D

DOD GSHP LESSONS LEARNED

D.1 Lessons Learned

This Appendix on lessons learned is broken down into four general categories: Financing, Design, Installation, and Performance and Energy Savings. Additionally, Chapter D.2 includes specific feedback from DOD field personnel with intimate knowledge of DOD GSHP projects.

D.1.1 Financing

A number of methods have been used to finance GSHP projects on DOD facilities. In addition to the more traditional military construction funding, other funding sources exist such as DOD's Energy Conservation Investment Program (ECIP), or alternative financing via Energy Savings Performance Contracts (ESPC) and Utility Energy Savings Contracts (UESC).

In an ESPC, an energy services company (ESCO) conducts a comprehensive energy audit and identifies improvements that will save energy at the facility. In consultation with the agency customer, the ESCO designs and constructs a project that meets the agency's needs and arranges financing to pay for it. The ESCO guarantees that the improvements will generate energy and energy-related operations and maintenance savings sufficient to pay for the project over the term of the contract. After the contract ends, all additional cost savings accrue to the agency. Contract terms up to 25 years are allowed.

UESCs are similar to ESPCs, with the utility company or a subsidiary playing the role of the ESCO. In UESC it is the utility that finances and installs the energy conservation measures, and repayment is made through the utility bill. An example is Fort Knox, Kentucky, which has used UESC contracts to install nearly $90 million in GSHP and associated equipment.

A notable early example of an ESPC was the Fort Polk residential project, which installed 6,600 tons of GSHP equipment in 4,000 family residences with a total cost of $19 million, financed over 20 years. Since 2001, about $49 million in commercial, and $17 million in residential GSHPs have been installed at DOD sites using DOE's Super ESPCs. GSHP projects have also been installed at DOD sites using the ESPC contracts administered by the U.S. Army Corps of Engineers and the Air Force. Site-specific ESPC contracts have been used as well.

In general an ESPC is a comprehensive, facility-wide energy conservation project that may include several conservation measures. GSHP projects and other ECMs with longer paybacks can be included in ESPC projects because they are bundled with shorter-payback ECMs like high efficiency lighting retrofits.

A major advantage of federal ESPC projects is that ESCOs provide annual measurement and verification (M&V) reports to the facility. These reports document the measurements and calculations used by the ESCO to verify that the guaranteed savings were actually delivered during the previous year, and provide assurance to the facility that the projects are performing as advertised. M&V is not a requirement in UESC contracts, but DOD sites can and should include M&V in UESC contracts. Without annual verification of savings, sites will have little or no evidence that the project is performing as expected as discussed in Chapter 2.2 as related to inaccurate reported annual cost savings.

D.1.2 Design

The design of a GSHP system begins like any other HVAC project with the calculation of building loads. However, unlike equipment that rejects heat to air or extracts heat from air, GSHP equipment can have a substantial impact on its heat source/sink, the ground. Thus, rather than being based solely on the maximum amount of energy rejected to/extracted from the ground, the amount of heat rejection/heat extraction must be known along with its history. Thus, when calculating the building loads, it is important to pay attention to the level of detail that will be required by the software to be used in designing the ground loop, as will be discussed in the next section, although, equipment will still be sized based on maximum zone loads.

A number of different types of water-source heat pumps are available for use in GSHP systems. Both up-flow and down-flow units are available as well as horizontal and console units. Water-to-water units are also available for radiant floor heating applications, hot water heating, or ventilation air preconditioning. Typical commercial scale application use units mounted in the ceiling space or small utility closets. These units are quiet enough such that noise is not generally a problem.

One of the principal advantages of GSHP is the flexibility of zoning. In general it is best to treat each zone with its own individual heat pump. In addition, there is little, if any, advantage to using a larger unit to serve several areas even if they are reasonably served as a single zone. There are two reasons why the "bigger is better" mentality may not be best with GSHP systems:

- In general the smaller heat pump units themselves have higher efficiencies than larger units.
- The cost advantage of a single larger unit over multiple smaller units is modest and will be easily offset by the extra ducting costs of larger units. Total fan energy will also be lower with less ducting.

In concert with the decision on how to serve the zones with heat pumps, a decision needs to be made regarding the best way to configure the ground coupling loops that will serve the heat pumps. The principal options are:

- Connect all heat pumps to a common circulating loop and a common set of ground-coupling wells. This works best for compact floor plans and allows the maximum benefit to be derived from diversity of the zone loads.
- Provide a separate ground-coupling loop field for each heat pump unit. This works well where the floor plan is spread out, like school buildings, and in retrofit situations where it would be difficult to run piping for the central circulating loop. It thwarts any attempt to take advantage of diversity, but provides redundancy such that any system failures will only affect single zones.
- Some combination of the two solutions above. This solution offers exceptional flexibility for buildings that don't fall clearly into one of the categories above.

Consult GSHP design manuals (ASHRAE, 1997) for more detailed discussion and examples of possible arrangements of heat pump units and zones, methods of pumping for the circulating loop, and control of the pumps.

Water source heat pumps are now rated in accordance with ISO 13256-1. Three sets of rating conditions have been established depending on application, ground coupled, ground water, or water loop (a boiler/tower system that is not ground coupled). Recommendations for heat pump units are:

- For cooling the recommended minimum EER when rated is accordance with ISO 13256-1 is 16.2 for ground water systems and 14.1 for ground coupled systems. In heating the recommended minimum COP when rated is accordance with ISO 13256-1 is 3.6 for ground water systems and 3.3 for ground coupled systems.
- Do not allow multi-speed or variable speed units to be rated at any condition other than high speed on compressor and fan. Rating under lower compressor speeds with high fan speed results in impressive EER, but little or no latent heat removal will be possible under this condition.
- The head loss in the water coil of the heat pump should not exceed 45 kPa (15 feet of water) when the flow rate is at 0.19 L/s (3 gpm) per nominal ton of cooling capacity.
- Avoid the use of heat pumps that require proprietary thermostats and controls. These can be difficult to maintain without special skills and equipment and simply are not necessary for most systems.

Aside from the energy efficiency motive for specifying high efficiency equipment the designer should be aware of two other major advantages of high efficiency heat pumps:

- High efficiency equipment will discard less heat to the ground loop in the cooling mode and will require smaller ground loops helping to avoid costs on this expensive part of the project.
- High efficiency units will perform much better at conditions other than the design point. Thus, if for example in the cooling mode the EWT ends up being higher than planned, high efficiency units will loose much less capacity and sacrifice much less efficiency than will lower efficiency units.

D.1.2.1 Design of Vertical Ground-Coupling Heat Exchangers

Sizing of the ground-coupling for a heat pump is different than sizing conventional equipment. The capacity of the ground to absorb or provide heat is a transient heat transfer problem. The thermal state of the ground is determined by prior heat addition/extractions rates and durations. While significant imbalance of heat extraction/heat rejection can be tolerated, the long term impacts must be considered. The ground can not be assumed infinite and the interaction of adjacent borehole heat exchangers is very important for commercial scale systems. In summary, the designer needs to know the load duration information as well as peak load and needs a design tool that appropriately considers all these factors as well as accurately models the heat transfer in the ground.

Because of the diversity in loads in multizone building, the design of the ground coupling heat exchanger must be based on peak block load rather the installed capacity. This is of paramount importance as ground coupling is usually a major portion of the total GCHP system cost and oversizing will render a project economically unattractive.

Early in the development of GCHP systems many systems were sized using rules-of-thumb and local experience, this is particularly true for residential scale systems. This practice is not prudent for commercial scale systems or for military family housing where the bore-fields from adjacent housing units may be in close proximity. This is particularly true for systems where there will be a large imbalance between heating and cooling loads. For all but the most northern climates, commercial scale buildings will have significantly more heat rejection than extraction. This imbalance in heat rejection/extraction can cause heat buildup in the ground to the point where heat pump performance will be adversely affected and hence system efficiency and possibly occupant comfort will suffer. Proper design for commercial scale systems requires the use of computer design software. Design software for commercial scale GSHP systems should consider the interaction of adjacent loops and predict the potential for long term heat buildup in the soil. Some sources of PC based GSHP design software packages that address this need are:

- GchpCalc, Energy Information Services, http://www.geokiss.com/, 205-799-4591, $300. This program includes built in tables for heat pump equipment from most manufacturers. Input is in the form of daily heat loss and gains at design conditions, approximate annual full load hours, and desired operating temperatures.
- GLHEPRO, International Ground Source Heat Pump Association (IGSHPA), http://www.mae.okstate.edu/Faculty/spitler/glhewin/glhepro.html, 800-626-4747, $525. Input required is monthly heating/cooling loads on heat pumps and monthly peak loads either entered directly by user or read from BLAST or Trane System Analyzer and Trane Trace output files.

Each of these programs will require input about the soil thermal properties, borehole resistance, type of piping and borehole arrangement, fluid to be used, and other design parameters. Many of the required inputs will be available from tables of default values. The designer must be careful to ensure that the values chosen are representative of the actual conditions to be encountered in order to ensure efficient and cost effective designs. More details on design methods can be found in (Sanner, 1999). It is highly recommended that designers be trained in the use of the software by the software vendor before using it for actual design.

Test borings to determine the type soil formations and aquifer locations will substantially improve design accuracy and may help reduce costs by eliminating overly conservative designs that result from uncertainties. Even with the information from test borings some uncertainty will remain with respect to the soil thermal properties. Design software programs make it possible to easily vary design parameters within the range of anticipated values and determine the sensitivity of the design to a particular parameter. In many instances, particularly commercial scale projects or projects with many family housing units, it is advisable to obtain specific information on ground loop performance by doing thermal testing of a sample borehole. A specification for this testing is available in (ASHRAE, 2003) and there are several commercially available sources for such testing.

In heating dominated climates a mixture of antifreeze and water will need to be used in the ground coupling loops if loop temperatures are expected to fall below about 5ºC (41ºF). (Heinonen, 1997) establishes the important considerations for antifreeze solutions for GCHP systems and provides guidance on selection.

The regulatory requirements for vertical boreholes used for ground-coupled heat exchangers varies widely by state and thus the local governing authorities should be consulted. One note of caution to the designer: some regulations, installation manuals, and/or local practices call for partial or full grouting of the borehole. The thermal conductivity of materials normally used for grouting are very low when compared to the thermal conductivity of most native soil formations. Thus, grouting will tend to act as insulation and hinder heat transfer to the ground. Experimental work by (Spilker, 1998) has confirmed the negative impact of grout on bore hole heat transfer. Under heat rejection loading average water temperature was nearly 6ºC (11ºF) higher for a 16.5 cm (6.5 in.) diameter borehole backfilled with standard bentonite grout when compared to a 12.1 cm (4.75 in.) diameter borehole backfilled with thermally enhanced bentonite grout. Using fine sand as backfill in a 16.5 cm (6.5 in.) diameter borehole lowered the average water temperature over 8ºC (14ºF) when compared to the same diameter bore backfilled with standard bentonite grout. For a typical system (Spilker, 1998) with a 16.5 cm (6.5 in.) diameter borehole the use of standard bentonite grout would increase the bore length required by 49% over fine sand backfill in the same borehole. By using thermally enhanced grout in a smaller 12.1 cm (4.75 in.) borehole the bore length is only increased by only 10% over fine sand backfill in the larger 16.5 cm (6.5 in.) diameter borehole. The results of (Spilker, 1998) suggests three steps that may be taken to reduce the impact of grout on system performance:

- Reduce the amount of grout used to the bare minimum. Sand or cuttings may be used where allowed but care must be used to ensure that the entire interstitial space between the piping and the borehole diameter is filled.
- Use thermally enhanced grout wherever possible. For information on thermally enhanced grout consult (ASHRAE, 1997) or (Spilker, 1998).
- Reduce the borehole diameter as much as possible to mitigate the effects of whatever grout or backfill is used.

D.1.2.2 Piping and Pumps for GCHP Systems

Failures in early GCHP systems have led to standard practice and materials for the buried piping used in these systems that will result in long reliable lifetimes. The only piping material that is now used for the buried portion of the systems is high density polyethylene (HDPE) of very specific grades. All joints are thermally fused, either butt or socket type. Specifications for the piping material and joining process may be found in (ASHRAE, 1997). Installers of these systems are certified by International Ground Source Heat Pump Association (IGSHPA) after being trained and demonstrating competency with the materials and methods. For piping within the building any of the normally acceptable materials may be used that are in accordance with local codes.

Many possible header arrangements exist for connecting the multiple ground-coupling wells that exist in a typical commercial scale project. The conflicting objectives that must be considered in designing the headers and sizing the piping are the desire to reduce pumping power consumption and the need to avoid laminar flow which inhibits fluid side heat transfer. (ASHRAE, 1997) contains recommendations for layout and sizing of multiple ground loop systems. An additional consideration for ground-loop piping is the placement of purge valves at strategic locations in the supply and return headers.

Pumping energy consumption in GCHP can be excessive if proper care is not taken in the design. Pumping energy consumption will be acceptable if the following guidelines are observed:

- Size piping and headers properly based on the recommendations of (ASHRAE, 1997).
- Avoid the use of antifreeze unless necessary and if so keep concentrations to a minimum.
- Use variable speed pumping and two-way valves at the heat pumps for all centrally pumped systems.
- Use pumps with high efficiency motors and design them to operate near their point of maximum efficiency.
- Select heat pumps and control valves with low pressure drops.
- Do not pump more fluid to the heat pumps than necessary. High efficiency units will operate with little performance degradation at lower flow rates.

(ASHRAE, 1997) suggests the following benchmarks for pumping energy consumption:

Pump Input Power/Cooling Capacity		Relative Ranking
(W/Ton)	(Hp/100 Tons)	
≤50	≤5	Excellent
50-75	5-7½	Good
75-100	7½-10	Mediocre
100-150	10-15	Poor
>150	>15	Bad

D.1.2.3 Dealing with Ventilation Air Requirements

Emphasis on improved indoor air quality requires much more careful treatment of ventilation air requirements than in the past. Heating and cooling this ventilation air can become a major load for the HVAC system. GCHP's are able to deal with these ventilation loads as long as they are addressed at the outset. The various types of GCHP system arrangements lend themselves to differing solutions. For example, for a classroom or hotel type application in a moderate climate it may be acceptable to use console type heat pump units and provide ventilation air through the wall directly to the unit. For larger systems that will have ducted ventilation air to the units, in heating dominated climates a sensible heat recovery unit may provide the best solution to preconditioning the ventilation air. Another solution for ducted systems in heating dominated climates would be to use a coil for preconditioning the ventilation air. The water/antifreeze solution circulated to the coil could be either heated by fossil fuel, electricity, or a water-to-water heat pump.

Providing ventilation air can be very problematic in humid air conditioning climates as well because of all the excess humidity that it brings into the conditioned space. The water-to-air heat pumps used in GCHP systems have a real advantage here as they have very high latent capacity. For this reason it may not be necessary to consider total heat recovery units in GCHP systems. The use of coils to precondition air is also an option in the air-conditioning mode as well. The chilled water for the coils can be provided by a water-to-water heat pump. When this is done it is possible to downsize the individual zone heat pumps. Under part load conditions this arrangement will provide better humidity control by dehumidifying the incoming air stream effectively. Several detailed examples of methods for handling ventilation air in GCHP systems are contained in (ASHRAE, 1997).

D.1.2.4 Hybrid Systems and Other Cost Control Measures

As noted above, even in northern climates HVAC requirements of commercial scale buildings are often dominated by air conditioning. For ground coupled systems that use the ground as a heat source/sink large imbalances between heat rejection and addition can present a problem. The computer software programs for ground loop design discussed above allow the designer to ensure that heat buildup in the ground will not cause problems over the system's lifetime. However, where large imbalances exist adding a cooling tower is an option that will help reduce the imbalance and also reduce the amount of ground loop required. Closed circuit fluid coolers are often used for this purpose with this type of system often referred to as a "Hybrid GCHP". Some discussion of supplemental heat rejection with cooling towers is contained in (ASHRAE, 1997) but a more comprehensive source of information on design methods is in (Kavanaugh, 1997).

A hybrid design is one of many cost control measures available to designers of GCHP systems. GCHP are inherently simple systems and controlling costs in GCHP system design is easily done as long as the designer does not try to use methods and equipment more appropriate to conventional systems design. An excellent example of this is found in system control. Because the GCHP system achieves zone control via individual heat pump units serving each zone, elaborate controls (i.e. DDC) are neither necessary, nor desirable. The designer new to GCHP systems would be wise to consult a separate chapter in (ASHRAE, 1997) devoted to cost control measures in GCHP systems.

D.1.2.5 Choice of Designer

The basic concept of a GSHP is not new, yet only in the past few years have they become popular. While the design and installation infrastructure is fully in place in some parts of the United States, in many areas the necessary infrastructure is underdeveloped. Thus, it may be difficult to find qualified designers and installers in a particular area. For larger projects involving many individual GSHP systems such as a major project in a family housing area, or for larger commercial-scale applications on DoD facilities, it's quite feasible and often advisable to seek experienced designers and installers from outside the local area when necessary. Many installers of GSHP have shown themselves to be competitive even at locations significantly distant from their normal operating area. Design guidance has also been evolving very rapidly in this field and it's prudent to seek out designers who are familiar with and use the most recent guidance. The most recent comprehensive design guidance can be found in (ASHRAE, 1997) and (ASHRAE, 2003). Training of designers is essential, but experience is also a major factor. In summary, for a successful installation the selection of competent designers and installers cannot be overemphasized.

D.1.3 Installation Lessons Learned

While GSHP systems are not difficult to install, they are significantly different, particularly the ground-coupling portion of the system, from other more conventional types of heating and cooling equipment. Water well drillers, for example, may be able to install a vertical ground-coupling loop field, but unless they are experienced expect them to take much longer than an experienced ground loop installer, with attendance cost increases. The integrity of the installation may also be compromised. Many GSHP projects have been dismissed in the early economic analysis due to the high cost of ground-coupling and in some of these instances a quote from an experienced and competitive installer could have turned the economics of the project around. The International Ground Source Heat Pump Association (IGSHPA) has a certification program for installers and it is recommended that only IGSHPA certified installers be used on DOD projects.

In some situations unexpected problems will be encountered when installing the ground-coupling, especially vertical loops. The contractor and government must be flexible to work around these problems. For example, if the design calls for two 300 foot boreholes for a family housing unit and drilling difficulties are encountered at a depth of 200 feet, then the design must be modified in the field, to three 200 foot boreholes. Assurance of installed vertical heat exchanger lengths is simplified by prefabricated u-tubes that have depth markings printed on the pipes; this is a highly recommended feature that should be specified.

Careful quality control is required on installation of the ground-coupling because of the critical nature of that portion of the systems and the inability to make corrective actions after installation is complete. For example, if the design has been made based on a 4 ½ inch borehole backfilled with thermally enhanced grout, a field change to a larger borehole and/or conventional grout could leave the ground-coupling grossly undersized. Failure to completely grout and/or backfill the bore holes can also be a serious deficiency. Thus, close quality control must be maintained to ensure that seemingly trivial field changes are not made to the design which might render the installation inadequate.

D.1.4 Performance and Energy Savings

Several demonstration projects have monitored the design, installation, and performance of GSHP at DOD installations, many of the lessons learned reported in this section above have come directly or indirectly from these projects. With respect to the performance of the heat pumps themselves results were not substantially different than expected based on manufacturer's data once the additional parasitic losses were accounted for, see (Phetteplace, 1992) and (Phetteplace, 1996) for examples.

Energy saving from GSHP projects have been impressive where comparisons could be made. For example, from early demonstration projects in family housing units at Ft. Polk, LA (Phetteplace, 1999) reported saving of 29% when GSHP were compared to air-to-air heat pumps. The result of these demonstration projects were used as justification to retrofit all 4003 family housing units at Ft. Polk to GSHP using a shared energy saving project. The results of this massive retrofit projects confirmed the earlier findings with energy saving of 32% accompanied by demand reductions of 40% (Shonder and Hughes, 1997). Similar energy saving were found at other DoD demonstration project sites, for example (Sullivan, 1997), reported average annual energy savings of 38% at Ft. Hood Texas, and 29% at Selfridge Air National Guard Base in Michigan.

Despite the impressive energy saving, in small scale retrofit projects the economics were not always attractive. (Sullivan, 1997) for example, estimates simple payback periods 15-20 years based on his results at Ft. Hood (TX) and Selfridge Air National Guard Base (MI). Clearly, economics are more favorable on larger scale installations as well as new construction as evidenced by the many projects that have been implemented as shared saving performance contracts.

D.2 Lessons Learned as Reported by DOD Field Personnel

In addition to the data call that was conducted as part of this report, DOD personnel intimately involved with DOD GSHP projects were asked to volunteer any lessons they have learned in dealing with GSHP systems at their installations. The following are the responses given by DOD personnel.

DOD Branch: ARMY
Project Location: AWC Carlisle Barracks, Carlisle, PA. Residential and Commercial GSHPs installed.
Point of Contact: Gary Sweppenhiser, P.E., General Engineer, 309 Engineer Ave, ATZE-DPW-E, Carlisle, PA 17013, 717-245-3746
Lesson(s) Learned:

1. Well depth is critical on standing column well design. Due to unique geologic conditions in this area, such as limestone caverns, mud pockets, some of the wells were not as deep as design requirements. This requires the well to bleed off excess water more frequently. Since a high quality native trout stream runs through the Post we had to discharge most of the excess bleed water to the local municipal sewer system resulting in high sewer fees.
2. Some of the commercial buildings that have cooking facilities complain about humidity control issues. The geothermal systems do not have reheats to allow for humidity control. Additionally ASHRAE requires a certain amount of outside air, which at certain times will draw in a lot of unconditioned moist air.
3. The first winter, we had numerous problems with units freezing up since the bleed water temperature was set too low. This has been corrected.

4. Make sure you and your well driller have a good plan for controlling runoff during well drilling operations. This can be messy, especially when you hit clay pockets.

DOD Branch: ARMY
Project Location: Fort Belvoir, VA GSHPs installed at Pilot Lounge, Visitors Center, and Veterinary Clinic.
Point of Contact: Randy Smidt, Energy Engineer, SpecPro Inc., Contractor to Fort Belvoir Environmental and Natural Resource Division, Randall.smidt@belvoir.army.mil 703-806-0023
Lesson(s) Learned:
If these 3 projects were not included in a VERY large ESPC, we most likely would not have done these projects. In the case of bldg 610, the location of the well field in close proximity to the building has complicated siting of an addition to the building structure. 610 has issues with needing to be reset after almost every power outage. Not quite so critical for a/c, but has caused problems with keeping the military working dogs warm during heating season if power outage occurs at night or over the weekend.

DOD Branch: ARMY
Project Location: Fort Riley, Manhattan, KS BOQ and Family Housing GSHPs installed, one Hybrid system.
Point of Contact: Russ Goering P.E., Chief, Energy Office, ESD PW
Bldg 408 Pershing Court, Fort Riley, KS 66442-6016, 785-239-2371
russ.goering@riley.army.mil
Lesson(s) Learned:

1.) The only installation problem I can remember was that the well driller encountered many underground voids.
2.) In 2001-2003, new Family Housing units using conventional high-efficiency gas furnace and electric air conditioner were constructed adjacent to the GSHP units. They were built using similar construction, i.e., wood-framed, vinyl-sided, composition shingle roof, and comparable levels of fiberglass insulation. The Ft Riley Energy Office was able to get meters installed and monitored on a few of the units for a short time. This provided a side-by-side comparison of GSHP vs. conventional gas furnace/electric A/C units on similar buildings. Unfortunately only 7 months of side-by-side data was collected. The results showed the GSHP units had metered annual energy intensity at approximately 27 KBtu/SF, and the conventional units had an estimated annual energy intensity at approximately 54 KBtu/SF. (This is total energy usage including HVAC, hot water, power, and lighting. Data was extrapolated for annual estimate for the conventional units.)
3.) Interviews with occupants of the GSHP units revealed they were pleased with the GSHP's. Positive comments included the absence of the noise/unsightly appearance of the exterior condensing unit and good thermal comfort. The only problem reported was difficulty in figuring out the operation of digital thermostats. No reliability or discomfort problems were reported with the GSHP's.

DOD Branch: ARMY
Project Location: YongSan Garrison, Seoul, S. Korea, Various Administration / Family Housing Units.
Point of Contact: Ghim, John D., GS-13, Area II SA DPW , john.d.ghim@us.army.mil
Lesson(s) Learned:
1. The Yongsan ESPC contract was written by Department of Energy for 15 years monitoring service, the contract requires annual verification and testing by contractor for government review and approval. The conditions and requirement of building changes, a savings outlook of 15 years is too long, the dynamics of mission forces installation to be flexible in savings initially calculated, it is very difficult to maintain the same parameters for 15 years.
2. The maintenance and service portion of ESPC contract needs to be clarified; there are gray areas on who is responsible for replacement and repair. The responsibility of replacement and repair work needs to be clearly identified and separated. According to the contract, the equipment is owned by the contractor; however operations and maintenance is responsibility of installation, the repair and replacement related to operations is vague. This is not a problem with new equipment; however as the equipment age, life cycle replacement becomes gray on who is responsible for repair and replacement.

DOD Branch: NAVY
Project Location: NAS PATUXENT RIVER
Point of Contact: Mel Green 301-757-4721
Lesson(s) Learned:

- Filters need to be replaced more often than twice a year.
- Drain plugs need to be cleaned several times a year.
- Ability to remotely monitor each unit greatly improves the support to the customer.
- Have a POC that is familiar with system. Problem was not repaired for three years as personnel unfamiliar with system did took band-aid approach instead of permanent fix.

DOD Branch: Navy / Marine Corps
DOD Installation Project Located and any other Pertinent Project Information:
Marine Corps Cherry Point and Camp Lejeune Bases
POC wishes to remain nameless
Lesson(s) Learned:
The lessons learned can be extensive from a project that does not provide the preconstruction estimated savings.

1. **System Design:** The design of the GSHP systems is highly dependant on tests of the ability of the ground to store excess energy for use from the cooling season for recovery in the heating season. Testing procedures based strictly on acceptable industry practices may result in not considering a critical factor: the flow of underground water in the geological formation in which the ground heat exchangers were installed. Where there is substantial underground water movement, the waste energy is not stored but is “washed” away. The result is that the soil conductivity

test, crucial to the correct sizing of the ground heat exchanger, gives a soil conductivity reading that can be as much as 40% higher than when there is little or no groundwater movement. This may be satisfactory for cooling operation but is a very serious problem when heating is required as the waste energy is not being saved for future use.

2. **System Installation:** The GSHP system is not the same as "split" heat pump systems. It is critical that installation, operation and maintenance personnel understand the differences to ensure the proper service and maintenance of the equipment. There are two installation components: the interior heat pump and the exterior header and ground heat exchanger piping. When connecting to existing residential duct systems, some additional care must be taken. Supply ducts must be properly sealed. Ducts in crawl spaces should not lie on the ground. Openings in walls and ceilings of the room where the GSHPs are located should be closed. In certain circumstances supplemental strip heating may be justified for use in the heating season but this should be looked at closely. The lesson learned is that all units must be carefully inspected for contract compliance and for correct installation of the GSHP systems. These are a system, not merely individual components. The supply and return ducts are also a part of the system. The weakest component will determine the success or failure of the project. Site supervision is crucial to have a satisfactory installation.

3. **Tenants:** Tenant control of temperature settings presents significant challenges to controlling energy use in family housing. A recent survey of GSHP complaints revealed that almost all tenants surveyed had thermostats set at significantly lower temperatures than the GSHP systems were designed to maintain during the cooling season. When set at too high of a temperature during the heating season, GSHP systems will use excessive amounts of energy particularly those systems that have been retrofitted with electric resistance heating coils. The lesson learned is that education alone is not a solution for properly operating the GSHP systems by the tenants. A suggested way to help enforce proper use of the GSHP systems is for the tenant to be metered and excessive energy use billed to the tenant. A program providing individual electric metering at each housing unit is being implemented by the privatization contractor at Camp Lejeune and Cherry Point.

4. **Maintenance Staff**: Equipping and training maintenance staff and implementation of correct maintenance procedures are critical to ensure properly operating systems. In addition, a database used to track the operating history of equipment components at individual buildings provides a method to see and act on trends that develop over time with the equipment. The lesson learned is that the maintenance program, when large quantities of GSHP's are involved, requires technically competent service personnel as well as a database for tracking the performance of the HVAC systems in all of the residences.

There is a very positive lesson that has been learned: the GSHP system has a substantially greater capability to perform under adverse conditions that does a high-efficiency split system while providing significant energy savings. Many observations were made of the GSHP's operating at level in excess of the design criteria in the cooling mode. While this may be attributed to the ground conditions surrounding the ground heat exchangers, it also illustrates that GSHP's are superior to high-efficiency split systems even when the installation leaves much to be desired.

One final lesson learned included in this section isn't from a DOD site at all, rather a Pennsylvania elementary school constructed in 2003 in Hanover, PA that achieved LEED Gold certification and learned a valuable lesson for GSHP systems (Turpin, 2006). The lesson learned involved the original design of a ground heat exchanger for the school having to be reduced in size and depth of boreholes during installation because of the site geology. This caused the system to be undersized and was evident during the first major cold event when returning water temperatures from the ground heat exchanger were 33 degrees F and building temperatures hovered in the mid-60's. The solution was to *hybridize* the system and add an in-line supplemental boiler to contribute during cold spells. It turns out this hybrid system solution cost less then the original design of the ground heat exchanger would've been and the energy and associated savings were still realized. This lesson learned indicates that hybrid systems can make a lot of sense in terms of both cost and system performance.

All of the above lessons learned are excellent information for DOD personnel unfamiliar with GSHP systems to get a feel for potential areas of concern with GSHP systems. The main themes that are evident in these lessons learned include:

- Correct GSHP system design and installation is critical to ensuring the system performs as designed;
- Education of GSHP system operation for maintenance staff and building tenants is critical to ensure the systems continue to operate properly;
- Great care must be shown when planning GSHP system layout to ensure ground heat exchanger bore fields don't interfere with future changes in the mission of the base; and
- Hybridizing GSHP systems can solve system underperformance and may be the most cost effective design option.

APPENDIX E: List of Acronyms

AFCESA	Air Force Civil Engineering Support Activity
ASHRAE	American Society of Heating Refrigeration and Air-conditioning Engineers
BEQ	Bachelor Enlisted Quarters
BOQ	Bachelor Officer Quarters
COP	Coefficient of Performance
CERL	Construction Engineering Research Laboratory
CONUS	Continental United States
CRREL	Cold Regions Research and Engineering Laboratory
DoD	Department of Defense
DoE	Department of Energy
DST	Duct Ground Storage Model
DUERS	Defense Utilities Energy Reporting System
EERE	Energy Efficiency and Renewable Energy
EPAct 2005	Energy Policy Act of 2005
ERDC	Engineer Research and Development Center
ESPC	Energy Savings Performance Contract
ESCO	Energy Services Company
FEMP	Federal Energy Management Program
GCHP	Ground Coupled Heat Pump
GHC	Geo-Heat Center
GHPC	Geothermal Heat Pump Consortium
GSHP	Ground Source Heat Pump
GSU	Ground Source, High Efficiency Upflow Heat Pumps
GWHP	Ground Water Heat Pump
HDPE	High Density Polyethylene
HVAC	Heating, Ventilation, Air Conditioning
IECC	International Energy Conservation Code
IGSHPA	International Ground Source Heat Pump Association
LEED	Leadership in Energy and Environmental Design
NDAA FY06	National Defense Authorization Act of Fiscal Year 2006
NFESC	Naval Facilities Engineering Service Center
OIT	Oregon Institute of Technology
ORNL	Oak Ridge National Laboratory
QC	Quality Control
RPCS	Real Property Classification System
SDR	Standard Dimension Ratio
SME	Subject Matter Expert
SWHP	Surface Water Heat Pumps
TRNSYS	Transient Energy System Simulation Tool
UESC	Utility Energy Services Contract
UFGS	Unified Facilities Guide Specifications
USGBC	United States Green Building Council
USGS	United States Geological Survey
WBDG	Whole Building Design Guide

APPENDIX E: List of Acronyms

AFCESA	Air Force Civil Engineering Support Activity
ASHRAE	American Society of Heating Refrigeration and Air-conditioning Engineers
BEQ	Bachelor Enlisted Quarters
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COP	Coefficient of Performance
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