ESTCP
Cost and Performance Report

(EW-201135)

Coupling Geothermal Heat Pumps with Underground Seasonal Thermal Energy Storage

March 2017

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The objective of this demonstration was to fully maximize the inherent advantages of the geology and hydrogeology accessed by means of Ground-loop Heat Exchangers (GHX) with closed loop systems or via direct ground water use with open-loop systems, which conventional GHP systems in the U.S. are not designed to achieve. Deliberately engineered UTES systems not only allow for the waste heat of cooling systems and the waste cool of heating systems to be captured, but also allow for the out-of-season capture of the winter's "cold" or summer's "heat" (from the air or via solar thermal collectors), if needed, in cooling-dominated or heating-dominated buildings, respectively.

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ACRONYMS AND ABBREVIATIONS

AGWT	American Ground Water Trust
AHU	Air Handling Unit
ATES	Aquifer Thermal Energy Storage
BTES	Borehole Thermal Energy Storage
COP	Coefficient of Performance
CW	Chilled Water
DC	District of Columbia
DOD	Department of Defense
DOE	U.S. Department of Energy
ESTCP	Environmental Security Technology Certification Program
etc.	Etcetera
GA	Georgia
GHP	Geothermal Heat Pump (also known as GSHP or GSHC System)
GHX	Ground Heat Exchanger
GPM	Gallons Per Minute
HDPE	High-Density Polyethylene
HVAC	Heating, Ventilating and Air-Conditioning
HW	Hot Water
Hz	Hertz
kBtu	Kilo British Thermal Unit
kW	Kilowatt
kWh	Kilowatt-Hour
LCC	Life Cycle Cost
LCCA	Life Cycle Cost Analysis
MCLB	Marine Corps Logistics Base (Albany GA location in this report)
MCLBA	Marine Corps Logistics Base Albany
SIR	Savings-to-Investment Ratio
sq. ft.	Square Feet
SW	Source Water
TAB	Test, Adjust and Balance
TC	Thermal Conductivity
TRNSYS	Transient System Simulation Tool

US	United States
USTES	Underground Seasonal Thermal Energy Storage
UTES	Underground Thermal Energy Storage
VDI	Verein Deutscher Ingenieure (Largest Engineering Association in Western Europe)
VAV	Variable Air Volume

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ACKNOWLEDGEMENTS

This project attempted, and succeeded, in implementing the first known Borehole Thermal Energy Storage (BTES) in the United States (US). It also created the US's only known active "full" (warm and cold) Aquifer Thermal Energy Storage (ATES) system. This Demonstration was a team effort with many contributors and "champions", without whose support and enthusiasm the project would have stalled or even failed. Though too many people and organizations were involved to mention everyone by name, the Principal Investigator (PI) and Co-PI would like to identify the following contributors:

Environmental Security Technology Certification Program (ESTCP): The entire leadership and staff of ESTCP including the head of the Energy and Water (EW) Program Tim Tetreault, and former employees and support personnel Dr. Jim Galvin, Glen DeWille and Scott Clark. Without ESTCP, the US would still not have a BTES or full ATES system.

The Marine Corps Logistics Base (MCLB), Albany, Georgia (GA): BG Terry Williams, Fred Broome, "Ski" Smigelski, Mike Henderson, Eddie Hunt, David Anderson, DJ Riordan, Jeanne Geisel, Chuck Phelps, Patty Morgans LCDR Jason Boatright, personnel with NAVFAC LANT/ NAVFAC Mid-LANT/NAVFAC SE. Also, the General Contractor Artesian Contracting and their sub-contractors.

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AH&P: Without the support of key players at Andrews, Hammock and Powell, Inc. the project would not have succeeded. Those included, but are not limited to Brandon Caves, Ed Powell, Jim Hughes, Mark Andrews, Joey Ringer, Dillon Fowler, and Spencer Penley.

Industry Partners: Several Industry Partners made significant partial or full in-kind contributions to the ATES project at Ft. Benning. Their role, and the high-quality equipment, systems and support they contributed is detailed in Appendix H. Key contributors included: Goulds (submersible pumps), ABB/Borie-Davis (Variable Frequency Drives-VFD & Filters), Climate Master (Geothermal Heat Pumps), and ISCO (High-Density Polyethylene [HDPE] Pipe).

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EXECUTIVE SUMMARY

OBJECTIVES OF THE DEMONSTRATION

EW-201135, *Coupling Geothermal Heat Pumps (GHPs) with Underground Thermal Energy Storage (UTES)* was proposed because, in the United States (US), the fundamental design of GHP systems, with their underground Ground Heat Exchanger (GHX) or water supply wells, has been largely unchanged for decades. In pursuit of reducing energy consumption, the heating, ventilating and air-conditioning (HVAC) industry is typically progressing to develop various types of HVAC technology to help reduce the energy consumption of an associated HVAC system. Historically, conventional GHP HVAC systems are considered one of the most, if not the most efficient active HVAC systems. Most Department of Defense (DoD) (and non-DoD commercial) facilities in many geographic regions are cooling dominated due to the consistent presence of cooling loads associated with people, lights and equipment (computers, copiers, monitors, etc.). Furthermore, most HVAC systems used in the Southeastern (SE) US (the region where both Environmental Security Technology Certification Program [ESTCP] projects were accomplished), are *significantly* cooling dominated. Typically, DoD facilities have imbalanced cooling versus heating loads, which in some applications, can have annual cooling loads that are as much as 5-10 times more than the annual heating loads. For a conventional GHP system, this load imbalance, over time, can lead to higher supply water temperatures and cause the operating efficiencies of the water-cooled equipment to decrease. In extreme cases, the supply water temperatures can increase up to the point where the water-cooled equipment can fail/fault due to high refrigerant pressure safeties. HVAC systems with UTES capability do not necessarily have to reject (or extract when heating dominated) heat during peak conditions. In retrospect, since both the Borehole Thermal Energy Storage System (BTES) installed at the Marine Corps Logistic Base in Albany Georgia (MCLB) and the Aquifer Thermal Energy Storage (ATES) installed at Ft. Benning Georgia (GA) both are capable of diurnal and seasonal storage, this project would more aptly be named simply *Coupling GHPs with **UTES***.

The objective of this demonstration was to fully maximize the inherent advantages of the geology and hydrogeology accessed by means of GHX with closed loop systems or via direct ground water use with open-loop systems, which conventional GHP systems in the U.S. are not designed to achieve. Deliberately engineered UTES systems not only allow for the waste heat of cooling systems and the waste cool of heating systems to be captured, but also allow for the out-of-season capture of the winter's "cold" or summer's "heat" (from the air or via solar thermal collectors), if needed, in cooling-dominated or heating-dominated buildings, respectively.

TECHNOLOGY DESCRIPTION

This demonstration project involved the implementation of high-efficiency GHP systems, coupled with an UTES system, at two locations in the SE U.S. to provide a sustainable infrastructure with higher energy savings than conventional geothermal systems, but with lower installation cost. The demonstration project at the Marine Corps Logistics Base Albany (MCLBA) coupled GHPs with a particular form of UTES commonly known within the international community as BTES. The demonstration project at Fort Benning, GA coupled GHPs with a particular form of UTES known internationally as ATES.

- **BTES**

  GHP's were connected to closed loop system comprised of 306 conventional underground grouted vertical boreholes with high-density polyethylene (HDPE) u-bends, but has an active outdoor adiabatic dry cooler. The dry cooler is optimized, from a construction and control/operational perspective, to capture the cooling energy of winter and store this energy in the underground formation for use in the peak summer months. This style of USTES is commonly referred to as a Seasonal Borehole Thermal Energy Storage system or simply "BTES".

- **ATES**

  The ATES system at Fort Benning includes an outdoor adiabatic dry-cooler, but utilizes an open loop system of four wells to directly extract/inject the native ground water from/to the local aquifer. The Fort Benning open loop is properly known as a seasonal Aquifer Thermal Energy Storage system or simply "ATES".

DEMONSTRATION RESULTS

As part of the demonstration project, several quantitative performance objectives were proposed and evaluated as part of the overall performance. *(See Table 1.1)* All but one of the performance objective were achieved as part of this demonstration project. Overall, the demonstration project illustrated a successful performance evaluation for the implemented technology and it is hoped opens up two new architectures of HVAC system that can create significant energy and water savings for DoD and others.

IMPLEMENTATION ISSUES

The challenges described herein are generally applicable for most ATES/BTES projects throughout the US. With both projects involving either boreholes (BTES) or water wells/injection wells (ATES) they fall under the jurisdiction of the GA Department of Natural Resources' (DNR) Environmental Protection Division (EPD). They have been given the authority to rule on groundwater injection through a legal mechanism called "Primacy". ATES projects are considered a "Class V Injection Wells" and therefore they fall under EPA's jurisdiction and in this case, a UIC permit is required. In some states, this is not a complex affair. In GA it proved to be difficult.

Overall, in the US, BTES system are not generally difficult to permit as they do not physically remove or inject groundwater and therefore no UIC permit is required. BTES projects can be permitted easily in most states and in some locations (like GA), no State permit is required.

Due to the demonstration plan goal of an 80-100% water reduction for the ESTCP project, a rare (in the US) adiabatic dry-cooler (sometimes referred to as a hybrid dry-cooler) was chosen. While common in Europe and elsewhere, these are rare in the US. Nevertheless, there are multiple manufactures of this product and the selected units were made in North America.

In the US, open loop GHP system do not typically have high level ATES well injection valve designs or controls. After US manufacturers were investigated, the search turned to Europe and elsewhere. After extensive investigation, ultimately a firm in Switzerland was selected. Ironically, this company was the European branch of a US firm, but with no demand yet for ATES valves in the US, this product is only manufactured in Europe and in metric dimensions and European electrical characteristics (230 VAC/50 Hertz [Hz]). These seemingly minor inconvenience created several delays, but though the use of US and Swiss piping adapters/fittings, and the ability of the hydraulic unit to be furnished at 120 VAC/60 Hz, the issues were ultimately resolved.

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1.0 INTRODUCTION

This project was proposed because the “conventional architectures” of Geothermal Heat Pumps (GHP) in the United States (US) do not fully maximize the inherent advantages of the geology they access by means of Ground Heat Exchangers (GHX) with closed loop systems or via direct ground water use with open-loop systems. Deliberately engineered Underground Seasonal Thermal Energy Storage (USTES) systems allow not only the waste heat of cooling systems and the waste cool of heating system to be captured, but also allow for the out-of-season capture of the winter’s “cold” or summer’s “heat” if needed in cooling dominated or heating dominated buildings respectively.

1.1 BACKGROUND

Combining GHPs with a USTES in this demonstration allowed the Department of Defense (DoD) to utilize the "inside the fence" (secure) native geology/ground water to store both waste heat and "waste cooling" to reduce electrical and water consumption and eliminate on-site fossil fuel consumption and the associated greenhouse gas emissions.

There are two variations of USTES featured in this demonstration: Borehole Thermal Energy Storage System (BTES) and Aquifer Thermal Energy Storage System (ATES). The BTES technology demonstrated in this project at Marine Corps Logistics Base, Albany Georgia (GA) is a closed loop GHX system that utilizes a bore field configured in a bullseye pattern, an adiabatic dry cooler, and reversing valves to redirect flow into the perimeter or the core of the bore field depending upon the season. The principle of operation for this technology is to utilize the adiabatic dry cooler in the dry mode during periods of cold outside air temperatures to efficiently dump heat from the building and bore field to the outside air and therefore “charge” the core of the bore field with “cold”. In the opposite season, the reversing valves change position to use the stored energy from the core of the bore field to cool the building. Given the geographic location of the BTES, it is not designed to store heat for heating in the building during the heating season. If this particular building were located in a colder climate, the BTES could be designed as a “hot” BTES to store heat during the cooling season.

The ATES technology featured at a different location (Ft. Benning, GA) is similar to the BTES mentioned above, but is an open loop system instead of a closed loop. With the ATES technology, energy is stored in the aquifer in either the cold well or the warm well. These wells are located approximately 500’- 600’ apart. During the cooling season, cold water is pumped from the cold well and used to cool the building. The heat extracted from the building is then injected into the warm well. During the heating season, warm water is extracted from the warm well and used to heat the building. An adiabatic dry cooler is then used to efficiently dump additional heat to the air during times of cold outside air conditions. This helps to balance the load between heating and cooling, and allows for additional cooling to be stored in the cold well. After the water leaves the building or dry cooler, the cold water is injected back into the cold well where it is stored for use again in the cooling season.

1.2 OBJECTIVES OF THE DEMONSTRATION

The objective of this project was to successfully demonstrate that a high-efficiency GHP System, coupled with an USTES system could provide truly sustainable infrastructure with higher energy savings than conventional geothermal systems, but with lower installation cost and thereby address DoD's substantial building energy consumption issues in a widely deployable and more affordable manner. The specific performance objectives for this demonstration are as follows.

Table 1.1. Performance Objective Summary

Performance Objective	Achieved (Yes/No)
(30% Reduction) Facility GHP-USTES Heating, Ventilating and Air-Conditioning (HVAC) Energy Usage vs. Conventional HVAC	Yes
(10% Reduction) Facility GHP-USTES HVAC Energy Usage vs. Conventional GHP HVAC	Yes
(80-100% Reduction) Water Usage by On-Site Conventional Cooling Tower	Yes
(100% Reduction) Direct On-Site Greenhouse Gas (GHG) Emissions for HVAC Space Heating	Yes
(20% Construction Cost Reduction) Installed Cost Of GHP-BTES vs. Conventional GHP Systems	Yes
(40% reduction) Greenhouse Gas Emissions at Source (Power Plant) to power Air-to-Air Heat Pumps vs. GHP-USTES System	No
(Positive Maintenance Experience) Elimination of maintenance of HVAC water treatment system	Yes
Greater Perceived Energy Security of Base Personnel	Yes

1.3 REGULATORY DRIVERS

1.3.1 Executive Orders:

EO 13514, "Federal Leadership in Environmental, Energy and Economic Performance" stresses Sustainable Buildings, greenhouse gas reduction, water efficiency and most of the aspects of EO 13423. EO 13423, "Strengthening Federal Environmental, Energy and Transportation Management" mandates reducing energy intensity and water intensity and increasing renewable energy consumption.

1.3.2 Legislative Mandates

EPAct 2005 mandates an increase in the use of renewables and the procurement of energy efficient products.

1.3.3 Federal Policy

The Federal Leadership in High Performance and Sustainable Buildings MOU 2006 brought together 16 Federal Agencies to commit to design, construct and operate their facilities in an efficient and sustainable manner.

2.0 TECHNOLOGY DESCRIPTION

2.1 TECHNOLOGY/METHODOLOGY OVERVIEW

2.1.1 Description

This project proposed taking the existing technology of GHPs, which is somewhat known/implemented within the DoD community and coupling it with another technology, USTES, which is virtually unknown in the U.S. This project sought to demonstrate that this marriage of GHPs and USTES can truly define “Sustainable Infrastructure” and is innovative in the realm of HVAC systems.

- **BTES**

Building 3700 at Marine Corps Logistics Base-Albany, GA (MCLB) received 6 heat recovery modular chillers capable of simultaneous heating and cooling. The building’s existing ductwork and air distribution system was re-used where possible. The system architecture is a four-pipe chilled water (CW)/hot water (HW) system that is distributed to variable air volume (VAV) air handling units (AHUs) (six each) with CW coils and VAV terminal boxes (105 total) with HW coils. The AHUs were reused whereas the VAV boxes were replaced with new VAV boxes equipped with deeper (four-row) HW coils to accommodate the lower temperature water produced by the six-new modular heat recovery water-to-water Geothermal Heat Pumps. The building’s GHP was connected to closed loop system comprised of 306 conventional underground grouted vertical boreholes with high-density polyethylene (HDPE) u-bends, but has an active outdoor adiabatic dry cooler. The dry cooler is optimized, from a construction and control/operational perspective, to capture the cooling energy of winter and store this energy in the underground formation for use in the peak summer months. This style of USTES is commonly referred to as a Seasonal Borehole Thermal Energy Storage system or simply “BTES”.

- **ATES**

Building 3215 at Ft Benning received conventional, off-the-shelf water source heat pumps suitable for GHP duty, along with the necessary ancillary associated HVAC sub-systems like ductwork, piping, pumps, etc. The ATES system at Fort Benning includes an outdoor adiabatic dry-cooler, but utilizes an open loop system of four wells to directly extract/inject the native ground water from/to the local aquifer. The Fort Benning open loop is properly known as a seasonal Aquifer Thermal Energy Storage system or simply “ATES”.

2.1.2 Overall Schematics

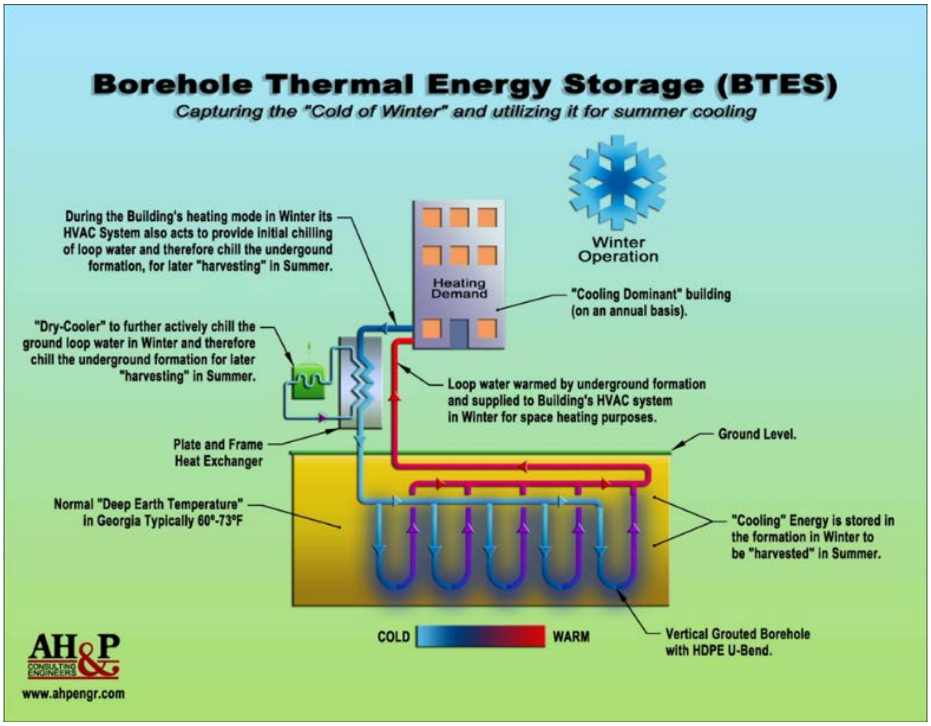

Figure 2.1. BTES Schematic

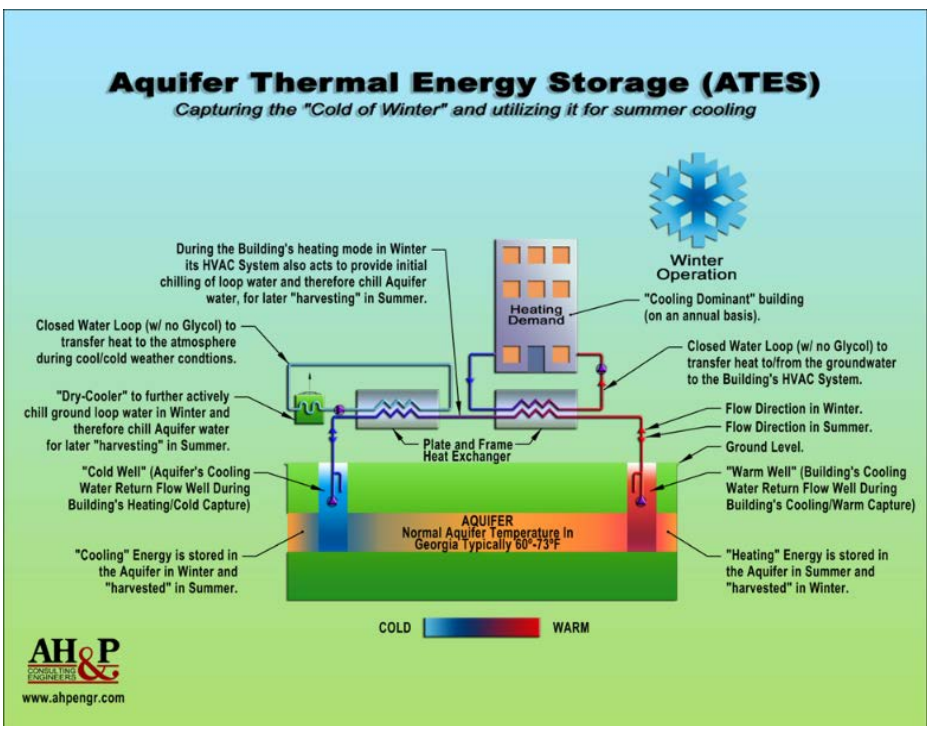

Figure 2.2. ATES Schematic

2.1.3 Chronological Summary

The basic heat pump (reverse Carnot cycle) at the heart of each GHP is approximately 100 years old. GHPs themselves have been in use in this country for over 50 years. USTES has been very successful in the Netherlands, having been implemented in over 1000 projects.

2.1.4 Technology Development Conducted Under The Environmental Security Technology Certification Program (ESTCP) Project

To supplement the in-house knowledge of conventional and hybrid GHP systems, a team was assembled to accomplish this project. It included the Dutch firm "IF Technology", the world's leading Engineering and Consultancy firm on USTES systems.

2.2 ADVANTAGES AND LIMITATIONS OF THE TECHNOLOGY/ METHODOLOGY

GHPs with USTES offer a variety of cost and performance advantages and feature very few performance limitations due to their inherently efficient nature. Advantages and limitations of the technology are discussed in the following sections.

2.2.1 Performance and Cost Advantages

The benefits of this technology are numerous and includes the ability to enhance already highly efficient GHP technology to achieve a lower first cost. Additional benefits of the technology are: higher efficiencies, renewable HVAC, smaller carbon footprint, lower energy consumption, and elimination of on-site fossil fuel consumption. All this is done while still achieving the important goals of maintainability, system longevity and minimized Life Cycle Cost (LCC). The underground GHX utilized in BTES has no moving parts, an indefinite life and when properly viewed as the sustainable infrastructure (and therefore amortized over its life cycle like other infrastructure investments such as power-lines, pipelines, etc.), its true impact on actual building first cost is minimal. In terms of expected aggregate benefit to DoD, it is expected that GHPs with USTES will provide a benefit of an average of at least 30% less energy consumption than conventional HVAC systems.

2.2.2 Performance and Cost Limitations

GHPs, even without the enhancement of USTES are generally viewed as one of the most, if not the most, efficient architectures to use for a HVAC system. Therefore, their limitations are not really performance related but rather first cost related and lack-of-knowledge related. Of the two USTES architectures that are being demonstrated, BTES, with its closed loop design has the least environmental impacts. As long as the borehole is fully grouted from top to bottom, it is environmentally acceptable everywhere and does not depend on the presence of a large aquifer. Generally, as long as the horizontal movement of the groundwater stays below 3–11 centimeters per day (1.2 to 4.3 inches per day or 36.5 to 130 feet per year), BTES can be installed. Economic considerations are primarily related to the local drilling cost and type of formation (rock, sand, etc.), thermal conductivity (TC), economics of scale (tonnage), land availability and thermal balance (heating vs. cooling loads) of the building. Figure 2.16, a color coded "ATES Feasibility Map" that the Dutch consultant, IF Tech, has generated for the entire U.S., is shown to provide just a rough initial guideline as to where ATES might successfully be deployed. However, a local hydrological investigation is needed before any ATES site is ruled “in” or “out”.

- Having an un-desirable aquifer for an ATES project is viewed as a performance limitation. Aquifers can generally be classified as either containing oxygen (oxic or aerobic) or without oxygen (anoxic or anaerobic). Oxygenated aquifers tend to be near the surface of the earth (so-called surficial aquifer) and due to issues like fertilizer run-off, may also contain nitrogen and other undesirable contaminates. While either type of aquifer can potentially be utilized, anoxic aquifers are preferred, as the water remains anoxic and potential biological or mineral precipitate issues are minimized. Intra-aquifer transfers of water are also not preferred due to environmental considerations and other issues. The ATES demonstration project remained in the same aquifer with the extraction and injection wells. Overall, an aquifer that has an upper and lower confining layer (typically made of clay on top and sometimes rock on the bottom), is generally considered the optimum aquifer for an ATES project. This project utilized an aquifer free from surface contaminants with an upper confining layer, generally insuring it will be anoxic.

- ATES injection permits are required for some states by the EPD to inject water into the aquifer, regardless if the injected water was recently removed from the same aquifer. Obtaining the required injection permits can prove to be very time consuming.

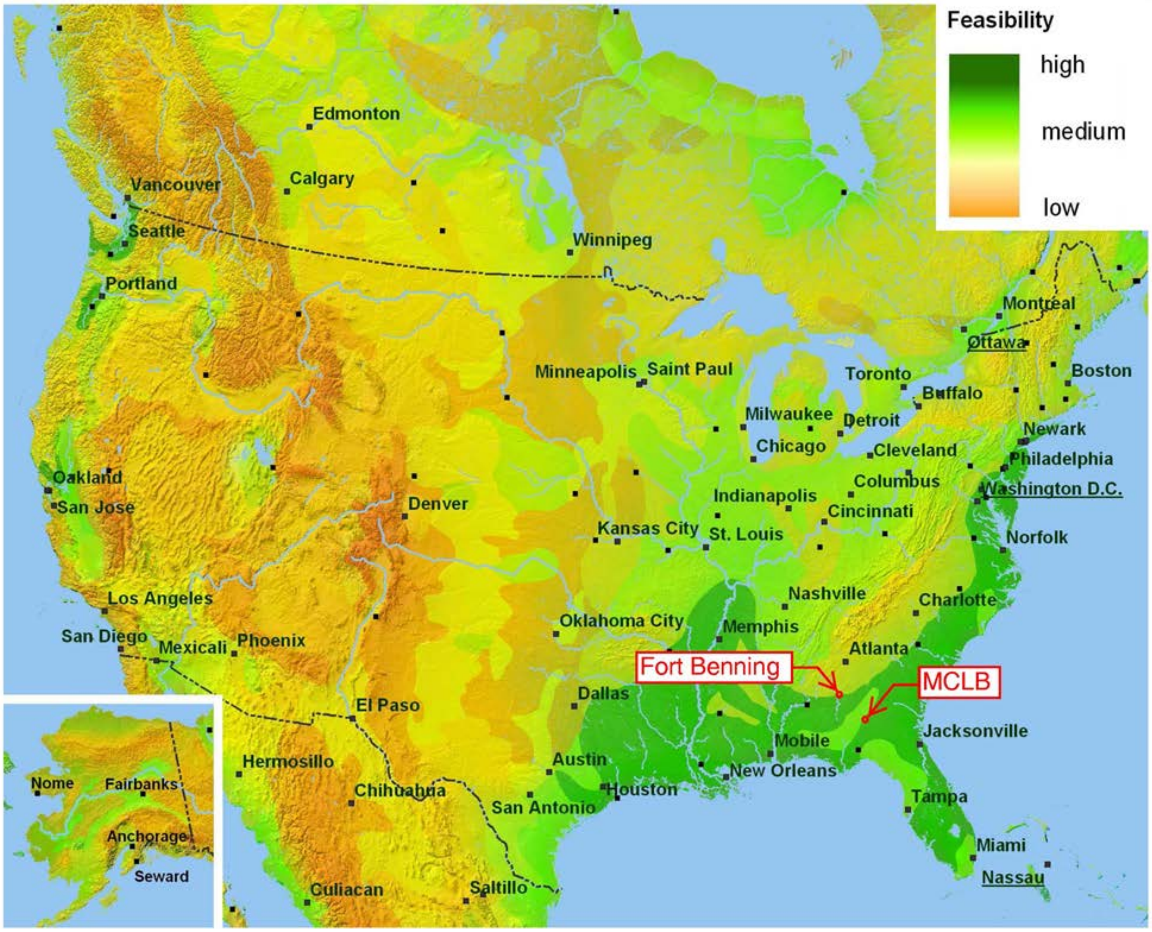

Figure 2.3. North America ATES Feasibility Map (Courtesy of IF Technology)

3.0 PERFORMANCE OBJECTIVES

Performance Objective	Metric	Data Requirements	Success Criteria	Results
Quantitative Performance Objectives				
Facility GHP-USTES HVAC Energy Usage vs. Conventional HVAC	Energy Intensity (MMBtu/sq.ft. or kilowatt-hour kWh/sq.ft.)	Actual metered readings of HVAC energy used by installation (baseline and demonstration); square footage of the buildings using energy	30% Reduction compared to baseline	BTES: 47.5% Reduction ATES: 52.7% Reduction (Modeled)
Facility GHP-USTES HVAC Energy Usage vs. Conventional GHP HVAC	Energy Intensity (MMBtu/ sq.ft. or kWh/ sq.ft.)	Actual metered readings of demonstrated HVAC energy used by installation versus modeled conventional GHP HVAC; square footage of the buildings using energy	10% Reduction compared to Conventional GHP HVAC	BTES: 15.1% Reduction ATES: 13.8% Reduction (Modeled)
Water Usage by On-Site Conventional Cooling Tower	Water (Gallons)	Actual metered readings of water used by installation (baseline and demonstration)	80-100% Reduction compared to baseline	100% Reduction compared to baseline
Direct On-Site Greenhouse Gas (GHG) Emissions for HVAC Space Heating	Direct on-site fossil fuel GHG emissions (metric tons)	Measured/calculated release of GHG based on source of energy (baseline and demonstration)	100% Reduction compared to baseline	100% Reduction compared to baseline
Installed Cost Of GHP-BTES vs. Conventional GHP Systems	HVAC Construction Cost	Construction cost data from construction contractor for both GHP-BTES and alternate conventional GHP design	20% Construction Cost Reduction from conventional GHP systems vs. GHP-BTES systems	33.6% Reduction
Greenhouse Gas Emissions at Source (Power Plant) to power Air-to-Air Heat Pumps vs. GHP-USTES System	Source fossil fuel GHG emissions (metric tons)	Measured/calculated release of GHG at Source (demonstration) versus an Hour-By-Hour model of project building with air-to-air heat pumps (baseline)	40% reduction compared to air-to-air baseline model	BTES: 32.5% Reduction ATES: 26.5% Reduction (Modeled)
Qualitative Performance Objectives				
Elimination of maintenance of HVAC water treatment system	Hours/Cost spent maintaining HVAC water treatment system	Observe presence/removal of HVAC Cooling Tower Water treatment system	Interview/record maint. personnel positive experience with removal of HVAC water treatment system	Maintenance personnel extremely satisfied. Pending formal results.
Energy Security	Survey of Base personnel regarding the perceived Energy Security Aspect of the GHP-USTES system	Conduct formal Surveys of Base personnel to determine if USTES system provides Energy Security	Survey results show the inside-the-fence (underground) USTES system is highly robust and provides additional Energy Security	Pending formal results. MCLB is in the process of implementing BTES for 3 other buildings.

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4.0 SITE DESCRIPTION

The ATES system was demonstrated at the Army Base at Fort Benning, GA and the BTES system was demonstrated at the MCLB. The Fort Benning ATES project was conducted at Building 3215 (B3215). The MCLB BTES project was conducted at Building 3700 (B3700).

4.1 FACILITY/SITE LOCATION AND OPERATIONS

B3700 at MCLB is located just north of the main gate. Below is a Google Earth image of B3700's location illustrating the location of the BTES bore-field.

Figure 4.1. MCLB Albany, Building 3700 Google Earth Image

The Google Earth image above shows the BTES bore-field located North of B3700. The field originally contained standing timber that was cleared for the installation of the BTES field.

B3215 at Fort Benning is located northeast of the main gate on the Sand Hill side. Below is a Google Earth image of the location of B3215 and well locations.

Figure 4.2. Fort Benning, Building 3215 Google Earth Image

The locations of both facilities are not located near any non-administrative military operations (physical training, maneuvering, etc.). Therefore, there were little interactions or disruptions to either of the military operations.

4.2 FACILITY/SITE CONDITIONS

With this demonstration project focusing on seasonal UTES more consideration had to be given concerning the underground geology of the site versus the real-estate above ground. Also, understanding that harvesting cooling energy from the outside air during the winter is very important to balancing the cooling/heating load in most commercial buildings in the Unites States helped to determine that adequate "above ground" real-estate was needed for the installation dry coolers. The site conditions for each system are listed below.

4.2.1 BTES Site Conditions

Bldg. 3700 at the MCLB is below the "Fall Line" and the underground formation consists of karst limestone. This "swiss cheese like" limestone holds a vast amount of ground water, and the movement of the ground water was determined to be minimal.

Bldg. 3700 had a large wooded area directly to the north of the parking lot that was prime real-estate for installing the BTES bore field.

The existing HVAC system for Bldg. 3700 was found to be compatible since it utilized a system of CW air handlers and HW re-heat VAV terminal units. This system could be converted very easily to BTES.

4.2.2 ATES Site Conditions

Bldg 3215 at Ft. Benning located in Columbus, GA was selected for the location of the ATES system. Located in West Georgia, Ft. Benning is approximately 90 miles North West of MCLB. The underground formation at Ft. Benning contains an aquifer located below a confining clay layer.

With an ATES system, adequate water flow for the cooling load can be provided by utilizing two wells each (cold and warm). Bldg. 3215 has enough property located North, North East, and West of the parking lot to accommodate these wells.

5.0 TEST DESIGN

Existing HVAC system performance data at each site was monitored and recorded for a minimum of 12 months, which was compared against performance data of the new USTES systems to determine several of the energy consumption comparison-based performance objective's success or failure. Note that as stated in previous sections the ATES baseline data was metered, but the demonstration data was modeled due to ongoing construction schedule.

5.1 CONCEPTUAL TEST DESIGN

To evaluate the performance objectives, AH&P implemented an extensive data monitoring plan to determine the energy usage, heating and cooling output, and the coefficient of performance (COP) of the original and the demonstration projects. The following strategies used for each system is listed below.

5.1.1 MCLB Bldg. 3700 (Conventional HVAC System):

The monitoring for the original conventional HVAC system focused primarily on electrical usage monitoring, and cooling and heating output monitoring. In addition to this, historical weather data was monitored to compare weather data from the pre-demonstration period to the demonstration period.

5.1.2 MCLB Bldg. 3700 (BTES HVAC System):

To compare the energy usage of the BTES with the energy usage of the conventional system, additional instrumentation was installed for the new pumps, the modular chiller, and the cooling tower. An additional watt hour meter was placed at the new electrical panel to capture the energy usage of all the newly installed HVAC equipment.

AH&P monitored the water temperatures in and out of the BTES bore-field, the water temperatures in and out of the dry cooler, the dry cooler valve position, and the two reversing valve positions. This data was analyzed and used to determine how much energy was being stored in the BTES bore-field by the dry cooler.

5.1.3 Ft. Benning Bldg. 3215 (Conventional HVAC System):

The monitoring for the original conventional HVAC system focused primarily on electrical usage monitoring, and cooling and heating output monitoring. In addition to this, historical weather data was monitored to compare weather data from the pre-demonstration period to the demonstration period.

To determine the pro-rata share of energy consumed by the building at the central plant, the central plant equipment was evaluated and an equivalent central plant kilowatt (kW)/ton was calculated based on equipment literature and capacities.

5.1.4 Ft. Benning Bldg. 3215 (ATES HVAC System):

The monitoring instrumentation for the new ATES system has not been installed yet since the project is still under construction. The ATES system energy consumption was modeled to compare against the metered baseline data.

5.2 BASELINE CHARACTERIZATION

5.2.1 Reference Conditions

Table 5.1. MCLB Albany: List of Baseline Reference Conditions

MCLB ALBANY - MCLB BUILDING 3700		
#	**Reference Condition**	**Units**
1	CW Supply Temperature	°F
2	CW Return Temperature	°F
3	HW Supply Temperature	°F
4	HW Return Temperature	°F
5	Supply Air Temperature	°F
6	Return Air Temperature	°F
7	Mixed Air Temperature	°F
8	Outside Air Temperature	°F
9	Supply Air Humidity	% RH
10	Return Air Humidity	% RH
11	Mixed Air Humidity	% RH
12	Outside Air Humidity	% RH
13	Energy Consumption	KWh
14	CW Flow	Gallons Per Minute (GPM)
15	HW Flow	GPM

Table 5.2. Ft. Benning: List of Baseline Reference Conditions

FT. BENNING - BUILDING 3215		
#	**Reference Condition**	**Units**
1	CW Supply Temperature	°F
2	CW Return Temperature	°F
3	HW Supply Temperature	°F
4	HW Return Temperature	°F
5	Supply Air Temperature (downstream of hot and cold deck)	°F
6	Return Air Temperature	°F
7	Mixed Air Temperature	°F
8	Outside Air Temperature	°F
9	Supply Air Humidity	% RH
10	Return Air Humidity	% RH
11	Mixed Air Humidity	% RH
12	Outside Air Humidity	% RH
13	Energy Consumption	KWh
14	CW Flow	GPM
15	HW Flow	GPM

5.3 DESIGN AND LAYOUT OF TECHNOLOGY COMPONENTS

5.3.1 MCLB Albany (BTES):

In this project, the building's existing six (6) VAV AHUs, which were recently replaced during a renovation project, remained for reuse while the associated VAV terminal units were replaced. The new VAV boxes were equipped with deep-row heating coils to achieve the necessary heating load capacity with 115°F heating HW temperature in lieu of the original 180°F. The existing chillers, boilers, cooling tower and pumps were also replaced with a new central plant capable of providing the necessary chilled and HW supply temperatures. The boilers and chillers were replaced with water-cooled heat recovery modular chillers, which can generate CW, heating HW or both as needed for space heating and space cooling purposes.

The BTES design has four separate water loops; CW, HW, source water (SW) and BTES water. The BTES water loop is responsible for pumping water thru the closed loop piping system that is coupled to two (2) dry coolers and 306 vertical boreholes (GHX) that serve as the heat source (in winter) and heat sink (in summer). The SW, which is responsible for pumping water thru the modular chillers, is connected to the BTES loop by a de-coupler pipe.

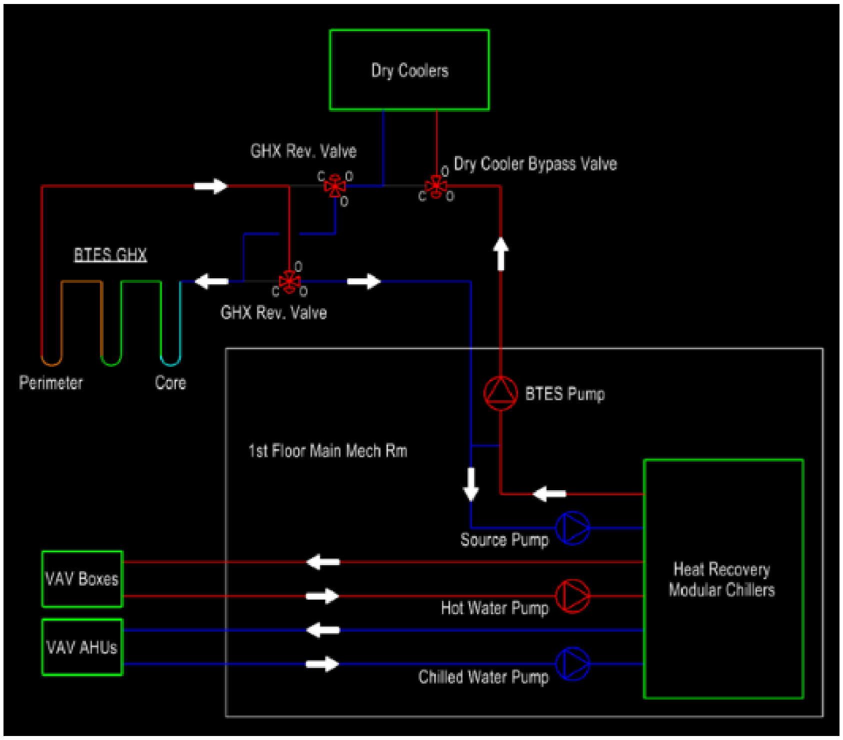

Figure 5.1. BTES Charging Mode

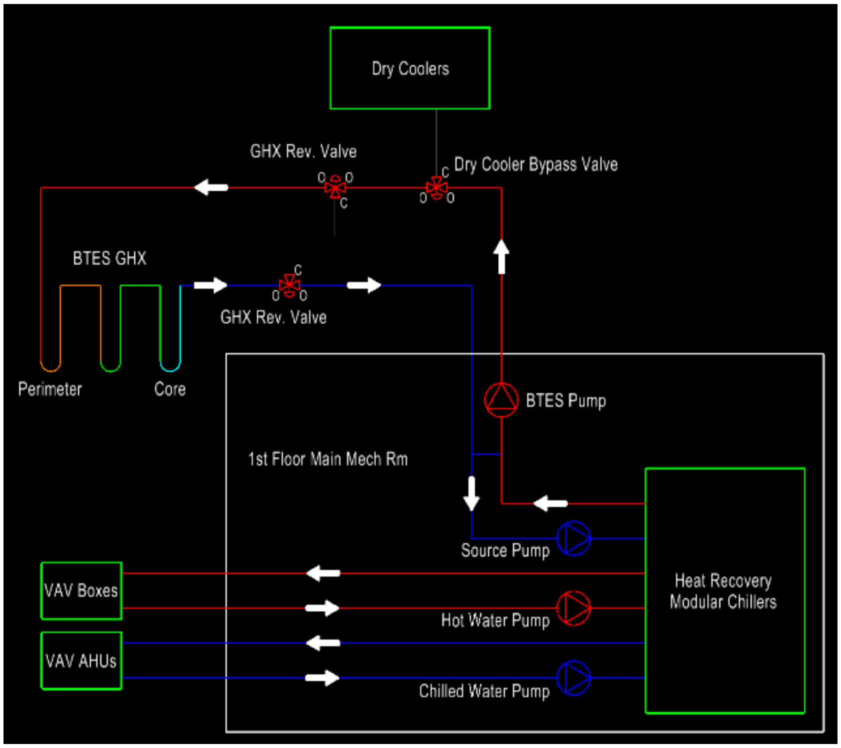

Figure 5.2. BTES Discharging Mode

5.3.2 Fort Benning – Building 3215 (ATES):

For this demonstration project, the HVAC system now consists of individual water source heat pumps (WSHPs) serving each of the seven (7) zones. In lieu of CW and HW, the WSHPs utilize SW supplied by the ATES system. The ATES system has warm and cold wells that operate as injection or extraction wells depending upon building heating/cooling loads and outside air conditions. The water extracted from the aquifer is hydraulically separated from the WSHP SW by a stainless-steel plate-and-frame heat exchanger (HX). This will insure that the water injected back into the underground formation will be free any refrigerant that could possibly leak from the WSHPs.

An adiabatic dry cooler is also being utilized for this project to provide an active means of storing seasonal energy into the underground aquifer. Depending on the time of year and outside air conditions, the dry cooler operates to capture the cold of winter and store its energy for use during the cooling dominant months of the year.

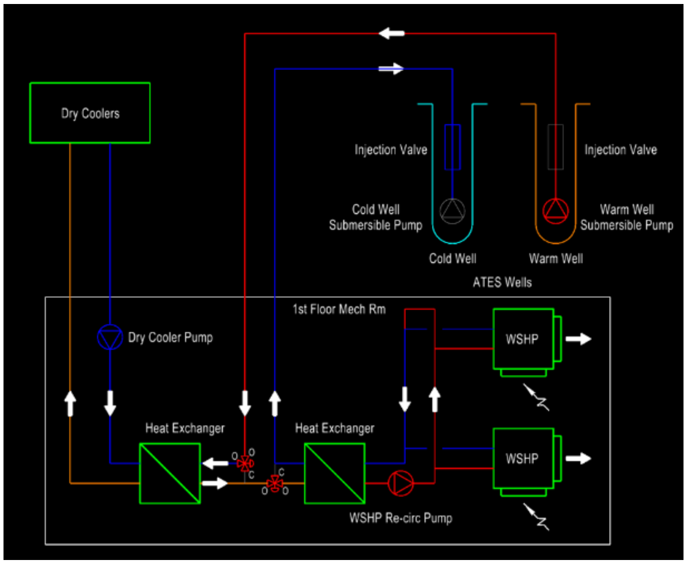

Figure 5.3. ATES Charging Mode

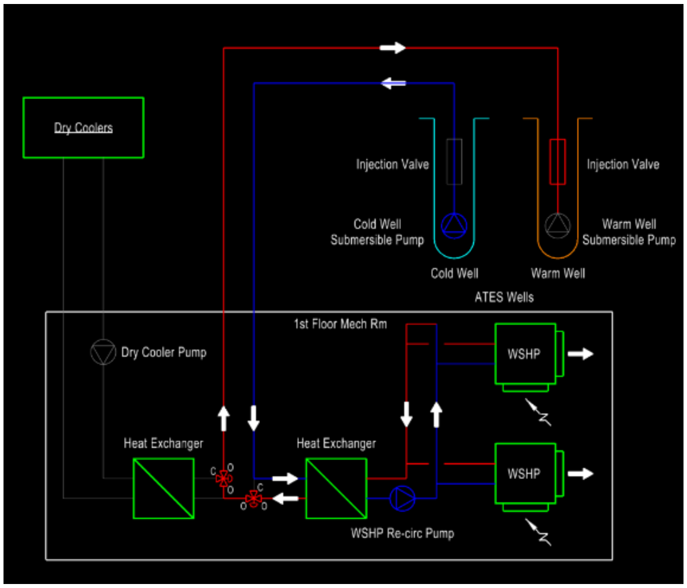

Figure 5.4. ATES Discharging Mode

5.4 OPERATIONAL TESTING

5.4.1 System Start Up

All systems involved with the BTES and ATES systems were fully commissioned. During the Commissioning (Cx) process, the new equipment was installed and started up per the manufacturers recommendations. In addition to this, AH&P performed flushing and purging of the BTES system to ensure that the boreholes were free from all air and debris. AH&P also assisted with well development of the ATES wells.

5.4.2 Operational Testing Under Different Operating Parameters:

All systems involved with the BTES and ATES systems were fully commissioned. During the Commissioning (Cx) and Test, Adjust and Balance (TAB) process, the new equipment operated at various conditions to simulate peak cooling and heating loads as best as possible.

5.4.3 Operational Testing During Warranty Phase

AH&P continued to test and fine tune the BTES system after construction by monitoring and optimizing the operation of the system.

5.5 SAMPLING PROTOCOL

The method used for sampling was to utilize a combination of standalone data loggers, remote access data loggers, and the Building Automation System storing trend data.

5.6 SAMPLING RESULTS

The data recorded in the pre-demonstration and the demonstration period resulted in literally millions of data points that were analyzed using standard computer programs such as Onset Hoboware, Microsoft Excel, and Microsoft Access. The data files were required to be split up monthly to keep the file size down, and the results were compiled into a summary spreadsheet. Below is a sample of the graphs that show the results of each point that was monitored in terms of both spatial and temporal dependence.

5.6.1 MCLB Bldg. 3700 BTES Baseline Period Data Graph Sample

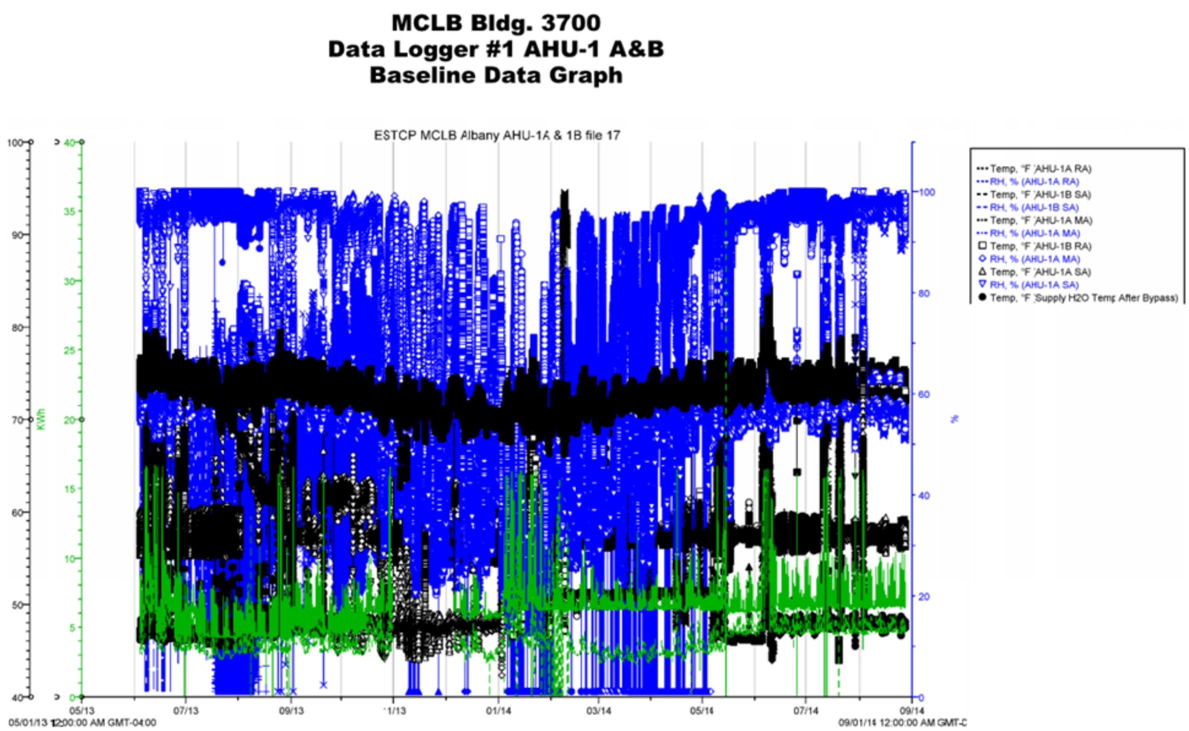

Figure 5.5. MCLB BTES AHU-1 A&B Baseline Data Graph

5.6.2 MCLB Bldg. 3700 BTES Demonstration Period Data Graphs Sample

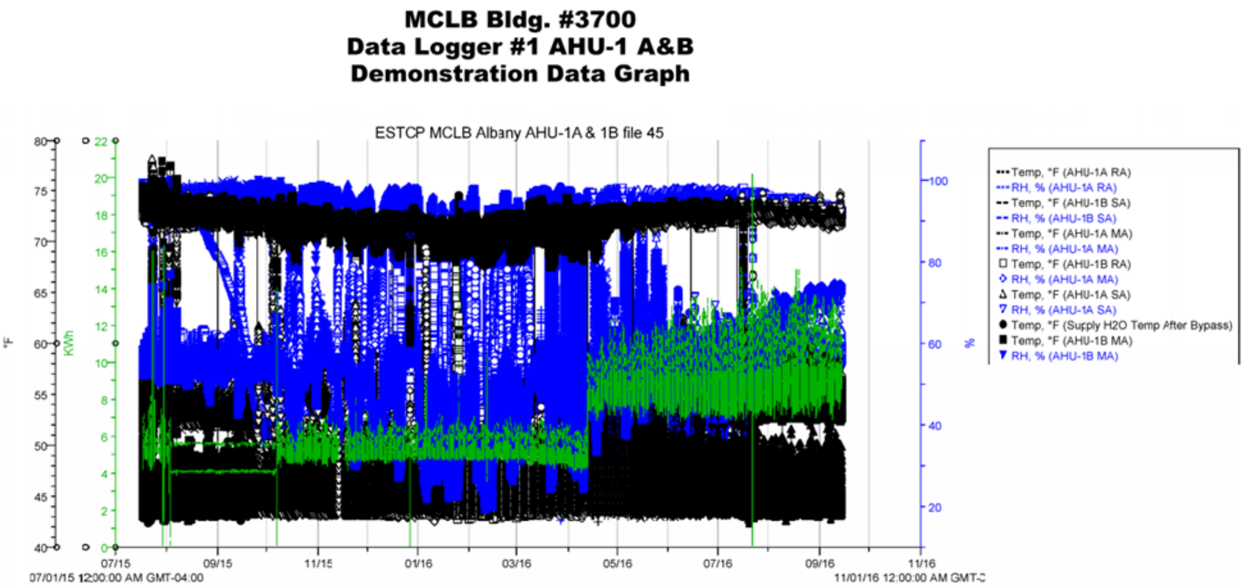

Figure 5.6. MCLB BTES AHU-1 A&B Demonstration Data Graph

5.6.3 Ft. Benning Bldg. 3215 ATES Pre-Demonstration Period Data Graphs Sample

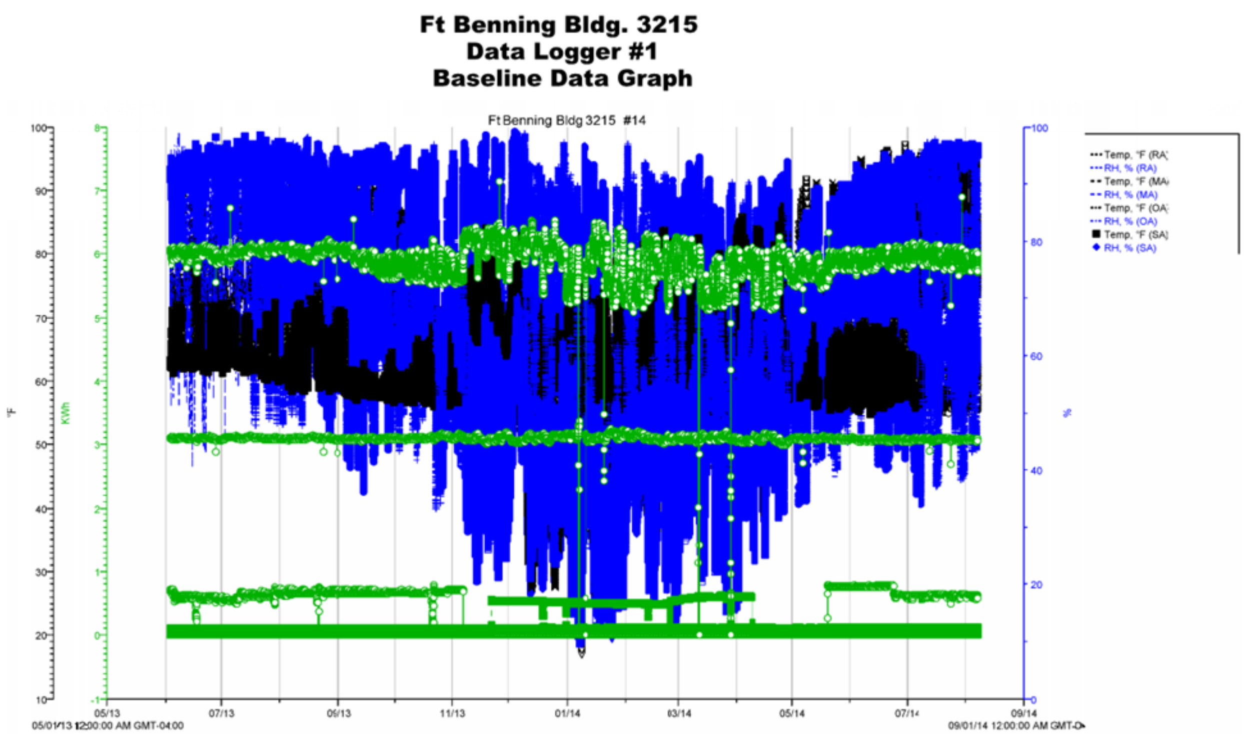

Figure 5.7. Fort Benning ATES Datalogger #1 Baseline Data Graph

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6.0 PERFORMANCE ASSESSMENT

6.1 PERFORMANCE OBJECTIVES:

1. Performance Objective: Reduction in Energy Consumption vs. Conventional HVAC

The first quantitative performance objective is to evaluate the energy consumption of each GHP-USTES system when compared to a conventional HVAC system.

Table 6.1. Baseline vs. BTES HVAC Energy Consumption Summary

MCLB – Albany, GA – B3700 Baseline vs. BTES HVAC Energy Consumption Summary			
08/01/2013 thru 07/31/2014		08/01/2015 thru 07/31/2016	
Centrifugal Chiller/Boiler		BTES	
Electrical Consumption (kWh)	2,065,586	Electrical Consumption (kWh)	1,690,506
Gas Usage (Therms)	39,443	Gas Usage (Therms)	0.00
Total Consumption Kilo British Thermal Unit (kBTU)	10,992,103	Total Consumption (kBTU)	5,768,008
Building Area square feet (sq. ft.)	168,138	Building Area (sq. ft.)	168,138
HVAC kBTU/sq. ft.	65.38	HVAC kBTU/sq. ft.	34.30
		Energy Consumption Savings (kBtu)	**5,224,095**
		Energy Consumption Savings (%)	**47.5%**

Table 6.2. Baseline vs. ATES HVAC Energy Consumption Summary

Fort Benning – B3215 Baseline vs. ATES HVAC Energy Consumption Summary			
08/01 thru 07/31		08/01 thru 07/31	
Multi-Zone AHU w/ CHW & HHW		ATES	
Electrical Consumption (kWh)	127,392	Electrical Consumption (kWh)	79,834
Gas Usage (Therms)	1,413	Gas Usage (Therms)	0.00
Total Consumption (kBTU)	575,964	Total Consumption (kBTU)	272,394
Building Area (sq. ft.)	9,638	Building Area (sq. ft.)	9,638
HVAC kBTU/sq. ft.	59.8	HVAC kBTU/sq. ft.	28.3
		Energy Consumption Savings (kBtu)	**303,570**
		Energy Consumption Savings (%)	**52.7%**

2. Performance Objective: Reduction in Energy Consumption vs. Conventional GHP HVAC

This quantitative performance objective evaluates the energy consumption of a GHP-USTES system compared to a conventional GHP system.

Table 6.3. Conventional GHP vs. BTES HVAC Energy Consumption Summary

MCLB – Albany, GA – B3700 Conventional GHP vs. BTES HVAC Energy Consumption Summary			
08/01 to 07/31		08/01/2015 thru 07/31/2016	
Conventional GHP		BTES	
Electrical Consumption (kWh)	1,990,677	Electrical Consumption (kWh)	1,690,506
Gas Usage (Therms)	0.00	Gas Usage (Therms)	0.00
Total Consumption (kBTU)	6,792,190	Total Consumption (kBTU)	5,768,008
Building Area (sq. ft.)	168,138	Building Area (sq. ft.)	168,138
HVAC kBTU/sq. ft.	40.40	HVAC kBTU/sq. ft.	34.30
		Energy Consumption Savings (kBtu)	**1,024,182**
		Energy Consumption Savings (%)	**15.1%**

Table 6.4. Conventional GHP vs. BTES HVAC Energy Consumption Summary

Fort Benning – B3215 Conventional GHP vs. ATES HVAC Energy Consumption Summary			
08/01 to 07/31		08/01 thru 07/31	
Conventional GHP		ATES	
Electrical Consumption (kWh)	92,664	Electrical Consumption (kWh)	79,834
Gas Usage (Therms)	0.00	Gas Usage (Therms)	0.00
Total Consumption (kBTU)	316,170	Total Consumption (kBTU)	272,394
Building Area (sq. ft.)	9,638	Building Area (sq. ft.)	9,638
HVAC kBTU/sq. ft.	32.8	HVAC kBTU/sq. ft.	28.3
		Energy Consumption Savings (kBtu)	**43,776**
		Energy Consumption Savings (%)	**13.8%**

3. Performance Objective: Reduction in water consumption

This quantitative performance objective evaluates the water consumption of a GHP-USTES system compared to a conventional cooling tower.

Table 6.5. MCLB-B3700-Baseline vs BTES Evaporative Water Consumption

MCLB – B3700 – Evaporative Water Consumption Comparison			
Baseline vs BTES Water Consumption			
Baseline		BTES	
Month-Year	Water Usage (Gallons)	Month-Year	Water Usage (Gallons)
Sept-2013	Start	Aug-2015	Start
Oct-2013	186,400	Thru	↓
Jan-2014	440,100		
Feb-2014	237,800		
Jun-2014	1,121,800		
Jul-2014	254,500		
Sept-2014	450,800	Jul-2016	0.00
Total:	2,691,400	100% Reduction	

Table 6.6. Benning-B3215-Baseline vs. ATES Evaporative Water Consumption

Benning – B3215 – Estimated Baseline vs. Estimated ATES Evaporative Water Consumption			
Baseline vs. ATES Water Consumption			
Baseline		ATES	
Month-Year	Water Usage (Gallons)	Month-Year	Water Usage (Gallons)
Aug-2013	165,593	Aug	0.00
Thru		Thru	
Jul-2014		Jul	
Total:	165,593	100% Reduction	

4. Performance Objective: Reduction in direct on-site Greenhouse Gas Emissions for HVAC Space Heating

This quantitative performance objective evaluates the Greenhouse Gas Emission (GHG) associated with Space Heating of each GHP-USTES system compared to the existing HVAC system.

Table 6.7. MCLB-B3700-Baseline vs. BTES GHG Comparison

MCLB – B3700 – Greenhouse Gas (GHG) Emission Comparison		
Baseline vs. BTES GHG Emission		
	Baseline	BTES
Annual HHW Gas Consumption (therms)	39,443	0.00
GHG Equivalency (0.005302 metric tons CO2 per therm)	209.1	0.00
	100% Reduction	

Table 6.8. Benning-B3215-Baseline vs. ATES GHG Comparison

Benning – B3215 – Greenhouse Gas (GHG) Emission Comparison		
Baseline vs. ATES GHG Emission		
	Baseline	ATES
Annual HHW Gas Consumption (therms)	1,413	0.00
GHG Equivalency (0.005302 metric tons CO2 per therm)	7.5	0.00
	100% Reduction	

5. Performance Objective: Reduction in BTES Construction Cost vs. Conventional GHP HVAC

This quantitative performance objective evaluates the construction cost of the BTES GHX compared to a conventional GHP HVAC GHX.

Table 6.9. MCLB-B3700-BTES GHX Construction Cost

MCLB – B3700 – BTES GHX Construction Cost Summary	
BTES GHX Construction Costs (before GC mark-up)	
	Cost ($)
Site Preparation/Demolition/Utility Modifications	$24,630
Grading	$212,570
Base & Asphalt Paving	$44,775
Storm Drainage Connection	$6,750
Erosion Control	$14,785
Dry Cooler Fencing	$6,449
Construction Temporary Fencing	$15,500
Above Ground Concrete	$4,028
Geothermal Drilling, Materials and Testing	$1,332,514
Dry Coolers	$300,000
Total Cost Associated with ONLY BTES GHX	$1,962,001

Table 6.10. MCLB-B3700-Conventional GHP GHX Construction Cost

MCLB – B3700 – Conventional GHP GHX Construction Cost Summary	
Conventional GHP GHX Construction Costs (before GC mark-up)	
	Cost ($)
Site Preparation/Demolition/Utility Modifications	$24,630
Grading	$212,570
Base & Asphalt Paving	$44,775
Erosion Control	$14,785
Construction Temporary Fencing	$15,500
Geothermal Drilling, Materials and Testing	$2,645,031
Total Cost Associated with BTES GHX	$2,957,291

6. Performance Objective: Reduction in Greenhouse Gas Emissions at Source (Power Plant) vs. Conventional air-to-air heat pump HVAC

This quantitative performance objective evaluates the Source Site Greenhouse Gas Emission (GHG) of the GHP-USTES systems compared to conventional air-to-air heat pump systems.

Table 6.11. MCLB-B3700-Baseline vs. BTES Source GHG Comparison

MCLB – B700 – Source GHG Emission Comparison		
Baseline vs. BTES Source GHG Emission		
	Baseline	**BTES**
Annual HVAC Site Electrical Consumption (kWh)	2,504,246	1,690,506
Electrical Site-to-Source Ratio (Energy Star)	3.14	
Annual HVAC Source Electrical Consumption (kWh)	7,863,332	5,308,189
eGRID SRSO sub-region CO_2 Emission Rate (lb/MWh)	1,144.5	
eGRID SRSO sub-region CH_4 Emission Rate (lb/GWh)	105.4	
eGRID SRSO sub-region N_2O Emission Rate (lb/GWh)	15.6	
Source GHG Equivalent: CO_2 (lbs)	8,999,584	6,075,222
Source GHG Equivalent: CH_4 (lbs)	828.8	559.5
Source GHG Equivalent: N_2O (lbs)	122.7	82.8
	32.5% Reduction	

Table 6.12. Benning-B3215-Baseline vs. ATES Source GHG Comparison

Benning – B3215 – Source GHG Emission Comparison		
Baseline vs. ATES Source GHG Emission		
	Baseline	**ATES**
Annual HVAC Site Electrical Consumption (kWh)	110,389	81,126
Electrical Site-to-Source Ratio (Energy Star)	3.14	
Annual HVAC Source Electrical Consumption (kWh)	346,621	254,736
eGRID SRSO sub-region CO_2 Emission Rate (lb/MWh)	1,144.5	
eGRID SRSO sub-region CH_4 Emission Rate (lb/GWh)	105.4	
eGRID SRSO sub-region N_2O Emission Rate (lb/GWh)	15.6	
Source GHG Equivalent: CO_2 (lbs)	396,708	291,544
Source GHG Equivalent: CH_4 (lbs)	36.5	26.8
Source GHG Equivalent: N_2O (lbs)	5.4	4.0
	26.5% Reduction	

7. Performance Objective: Eliminate maintenance of HVAC water treatment system

This qualitative performance objective evaluates the benefit of eliminating maintenance of the current HVAC water treatment system associated with the cooling tower open loop system.

A brief survey was sent to maintenance personnel at MCLB observe what the benefits were to the maintenance department, such as time savings spent maintaining, repairing and monitoring the water treatment system. Now, survey results from the maintenance department have not be received.

At Fort Benning, the current water treatment system serves the central plant system. The elimination of one building off that system will not make a significant impact or improvement on maintenance.

8. Performance Objective: Energy Security

The other qualitative performance objective is to evaluate the energy security benefit of a GHP-USTES system.

A brief survey was sent to MCLB personnel interested in reducing energy consumption to observe what the benefit of the BTES system are to energy security. Now, survey results from the maintenance department have not be received.

A brief survey will also be sent to Fort Benning personnel interested in reducing energy consumption.

7.0 COST ASSESSMENT

For both demonstration projects, a Life Cycle Cost Analysis (LCCA) was completed. The critical components relevant to the GHP-USTES technology tracked during the implementation of the demonstration project are listed in Table 7.1.

Table 7.1. Cost Model

System	Cost Element	Data Tracked During the Demonstration	Estimated Costs	
BTES	Geothermal Heat Exchanger Vertical Borehole (GHX) System	• Capital Cost: $ per foot of Vertical Borehole • Installation Cost: $ per foot of Vertical Borehole	Total	$1,207,514
			$/ft. Total	$18.79
ATES	ATES Cold & Warm Wells	• Capital Cost: $ per foot of Vertical Well • Installation Cost: $ per foot of Vertical Borehole	Total	$53,742
			$/ft Total	$33.59
	Horizontal Piping for ATES Wells	• Capital Cost: $ per foot of Vertical Well • Installation Cost: $ per foot of Vertical Borehole	Total	$25,980
			$/ft Total	$16.24
BTES & ATES	Dry Coolers	• Capital Cost: $ per Dry Cooler • Install/Shipping Costs: • Maintenance Cost:	BTES Total	$306,449
			$ per Dry Cooler	$153,225
			ATES Total	$16,173
			$ per Dry Cooler	$16,173
BTES	Heat Recovery Modular Chillers	• Capital Cost: $ per Modular Chiller • Install/Shipping Costs: • Maintenance Cost:	Total	$325,000
			$ per Chiller	$65,000
ATES	WSHPs	• Capital Cost: $ per WSHP • Install/Shipping Costs: • Maintenance Cost:	Total	$25,900
			$ per WSHP	$3,700
BTES & ATES	Pumps & Injection Valves	• Capital Cost: • Install/Shipping Costs: • Maintenance Cost:	BTES Total	$53,000
			ATES Total	$31,661
BTES & ATES	Pumping Accessories (Air separators, expansion tanks, suction diffusers, etc.)	• Capital Cost: • Install/Shipping Costs:	BTES Total	Included in Pumps
			ATES Total	Included in Pumps
BTES & ATES	Controls and Control Components	• Capital Cost: • Installation Cost: • Maintenance Cost:	BTES Total	$517,000
			ATES Total	$86,400
BTES & ATES	Maintenance	• Maintenance Cost/Year.:	BTES Total	$10,000
			ATES Total	
BTES & ATES	Training	• Cost of Training	BTES Total	$5,000
			ATES Total	$5,000
BTES & ATES	Operational	• Utility Bills:	BTES HVAC Total kWh	1,690,506
			BTES HVAC Estimated $	$160,598
			ATES Estimated HVAC kWh	79,834
			ATES Estimated HVAC $	$4,950
BTES & ATES	Commissioning & TAB	• Cost of Commissioning • Cost of TAB	BTES Cx Total	$74,000
			BTES TAB Total	$56,700
			ATES Total	$30,000

7.1 COST DRIVERS

As in any project where a reduction in energy consumption is a key point, energy rates must be considered when selecting any technology for future implementation. The locations for these two demonstration sites have some of the lowest electrical energy cost in the US and were still able to achieve a favorable cost analysis.

Another cost driver is installation costs associated with drilling wells or boreholes. Some regions of the US have lower drilling costs than others.

The underground geology and hydrogeology are also important cost drivers. For BTES, some sites will have better underground geology than others, which will lead to less boreholes and a decrease in capital investment costs. For ATES, hydrogeology is important as its operation is directly dependent upon the ability of the system to extract and inject groundwater.

7.2 COST ANALYSIS AND COMPARISON

BTES:

The cost analysis and comparison for the BTES demonstration was performed against a conventional HVAC system. In this particular case, the costs associated with the BTES system was compared against a replacement system for the mechanical room HVAC system similar to HVAC system in place before the demonstration project was installed.

Performing a cost comparison analysis computes the following results:

- Savings-to-Investment Ratio (SIR): 1.42
- Adjusted Internal Rate of Return: 4.84%
- Simply Payback: 11 years
- Discounted Payback: 13 years

Table 7.2. Conventional vs. ATES Cost Comparison Summary

MCLB – B3700 – Cost Comparison Input Summary		
Input	**Conventional HVAC Project**	**Demonstration HVAC Project**
Initial Investment	$3,196,912	$5,100,000
Annual Electrical Consumption (kWh)	2,065,586	1,690,506
Annual Natural Gas Consumption (therms)	39,443	0.0
Annual Evaporative Water Consumption (gallons)	4,300,000	0.0
Initial Annual Electrical Cost ($)	$196,231	$160,598
Initial Annual Natural Gas Cost ($)	$25,638	$0
Initial Annual Evaporative Water Cost ($)	$42,871	$0
General Maintenance ***Savings*** ($)	$50,000	$0
Chemical Treatment ***Savings*** ($)	$15,000	$0

ATES:

The cost analysis and comparison for the ATES demonstration was performed against a conventional HVAC system. In this particular case, the costs associated with the ATES system was compared to a replacement system for the mechanical room HVAC system similar to HVAC system in place before the demonstration project was installed.

Performing a cost comparison analysis computes the following results:

- SIR: 1.61
- Adjusted Internal Rate of Return: 5.49%
- Simply Payback occurs in year: 10
- Discounted Payback occurs in year: 12

Table 7.3. Conventional vs. ATES Cost Comparison Summary

Benning – B3215 – Cost Comparison Input Summary		
Input	**Conventional HVAC Project**	**Demonstration HVAC Project**
Initial Investment ($)	$608,375	$648,304
Annual HVAC Electrical Consumption (kWh)	129,698	79,834
Annual HVAC Natural Gas Consumption (therms)	1,417	0
Annual Evaporative Water Consumption (gallons)	0	0
Initial Annual HVAC Electrical Cost ($)	$8,041	$4,950
Initial Annual HVAC Natural Gas Cost ($)	$723	$0
Initial Annual HVAC Evaporative Water Cost ($)	$0	$0
General Maintenance ***Savings*** ($)	$0	$0
Chemical Treatment ***Savings*** ($)	$0	$0

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8.0 IMPLEMENTATION ISSUES

8.1 REGULATORY/PERMITTING CHALLENGES:

Though the challenges described herein are specifically related to the implementation of ATES (Ft. Benning) and BTES at the Marine Corps Logistics Base Albany (MCLBA) in Georgia (GA), the issues encountered will be generally applicable for most ATES/BTES projects throughout the US. With both projects involving either boreholes (BTES) or water wells/injection wells (ATES) they fall under the jurisdiction of the GA Department of Natural Resources' (DNR) Environmental Protection Division (EPD), hereinafter referred to as GAEPD. In the arena of so called Underground Injection Control (UIC), the GAEPD acts on behalf of the Federal Government's Environmental Protection Agency (EPA). They have been given the authority to rule on groundwater injection though a legal mechanism called "Primacy". Although ATES projects simply withdraw local groundwater, change it a few degrees and transfer it back to the aquifer from whence it came, legally this is considered a "Class V Injection Well" and therefore it falls under EPA's jurisdiction and in this case, a UIC permit is required from GAEPD. In some states, this is not a complex affair. In GA it proved to be difficult.

8.1.1 BTES Regulations/Permitting:

Overall, in the US, BTES system are not generally difficult to permit as they do not physically remove or inject groundwater and therefore no UIC permit is required. In GA, the regulations are deceptively simple, the driller of the boreholes must be a licensed well driller in the state of GA and the boreholes must be fully grouted. Both are good practices, independent of the regulatory necessity. Generally, most states allow simple close loop boreholes to be installed in virtually every geological formation. Many regulations require the borehole to be grouted from top to bottom and some only require the upper (surface) region to be grouted (to prevent surface contamination) or if multiple aquifers are penetrated, grouting between aquifers is required to prevent inter-aquifer transfer of water. Overall, BTES projects can be permitted easily in most states and in some locations (like GA), no State permit is required. Closed loop boreholes do not require an injection permit under the UIC program as no liquid "injection" is occurring.

8.1.2 ATES Regulations/Permitting:

As described previously, the fact that ATES systems inject water into the ground invoke the need for a Class V, UIC permit to inject the water. "Class V" is basically a group of widely diversified type wells that EPA groups together when they don't fall into any other category. It includes everything from "Cesspools" (no longer used), drainage wells for storm water, recharge wells for aquifers, salt water intrusion barrier wells and more.

8.2 END-USER CONCERNS/RESERVATIONS/DECISION MAKING FACTORS:

8.2.1 ATES Concerns

Overall, if the military base has management, engineering, geologist, managerial or administrative personnel that are involved with traditional HVAC systems, they can fairly quickly gain an understanding of the fundamentals of an inject well type system. If they have water wells on base for irrigation or domestic water usage, they will generally have a basic understanding of a water supply well. Their past history of maintaining submersible pumps will generally eliminate concerns about maintenance.

8.2.2 BTES Concerns

If a Base has had good experiences with conventional GHP systems, then the next step of utilizing a BTES is often a small one. Generally, most users can fairly quickly see the superiority of the BTES architecture over normal closed loop geothermal systems.

8.3 PROCUREMENT ISSUES

The clear majority of the entire ATES and BTES systems are considered standard Commercial Off The Shelf (COTS) products. The major equipment and all the basic components have been available for decades. Two equipment exceptions, while COTS internationally, are rare in the US and are highlighted below.

8.3.1 Adiabatic Dry Cooler Issues:

Due to the Demonstration plan goal of an 80-100% water reduction for the ESTCP project, a rare (in the US) adiabatic dry-cooler (sometimes referred to as a hybrid dry-cooler) was chosen. While common in Europe and elsewhere, these are rare in the US. Nevertheless, there are multiple manufactures of this product and the selected units were made in North America.

8.3.2 Injection Control Valves-imported from Europe

In the US, open loop GHP system do not typically have high level injection valve designs or controls. After US manufacturers were investigated, the search turned to Europe and elsewhere. After extensive investigation, ultimately a firm in Switzerland was selected. Ironically, this company was the European branch of a US firm, but with no demand yet for ATES valves in the US, this product is only manufactured in Europe and in metric dimensions and European electrical characteristics (230 VAC/50 Hertz [Hz]). These seemingly minor inconvenience created several delays, but though the use of US and Swiss piping adapters/fittings, and the ability of the hydraulic unit to be furnished at 120 VAC/60 Hz, the issues were ultimately resolved.

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