



**FINAL REPORT**

# Underground Thermal Energy Storage (UTES) Technology Transfer

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**July 2021**

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## ACRONYMS AND ABBREVIATIONS

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AGWT	American Ground Water Trust
AHU	Air Handling Unit
ATES	Aquifer Thermal Energy Storage
ASHRAE	American Society of Heating, Refrigeration and Air-Conditioning Engineers
	AVG Average
BTES	Borehole Thermal Energy Storage
BTU(H)	British Thermal Unit (per Hour)
CGD	Certified GeoExchange Designer (by IGSHPA)
CHP	Combined Heat and Power
CIBL	Capital Improvements Business Line
COP	Coefficient of Performance
COC	Cycles of Concentration
CW	Chilled Water
CxA	Commissioning Agent
DC	District of Columbia
DDC	Direct Digital Control
DoD	Department of Defense
DOE	U.S. Department of Energy
ERCIP	Energy Resiliency Conservation Investment Program (formally ECIP)
ESTCP	Environmental Security Technology Certification Program etc. Etcetera
FEMP	Facility Energy Management Program
FICA	Federal Insurance Contributions Act
ft <sup>2</sup> /person	Square Feet Per Person
FY	Fiscal Year
GHP	Geothermal Heat Pump (also known as GSHP or GSHC System) GHX Groundloop Heat Exchanger
GPM	Gallons Per Minute
GSHP(C)	Ground Source Heat Pump (or sometime “& Cooling System” is substituted for the word Pump-GSHC). Alternately called a GHP
Hr	Hour
HDPE	High-Density Polyethylene
HVAC	Heating, Ventilating and Air-Conditioning
HW	Hot Water
IGSHPA	International Ground Source Heat Pump Association kW Kilo-Watt
kWh	Kilo-Watt Hour

LCCA	Life Cycle Cost Analysis
m	Meter
m <sup>2</sup> /sec	Square Meters Per Second
m <sup>3</sup> /hr	Cubic Meters Per Hour
MAX	Maximum
MCLBA	Marine Corps Logistics Base Albany MILCON Military Construction
MIN	Minimum
NAVFAC SE	Naval Facilities Engineering Command Southeast NEBB National Environmental Balancing Bureau
NIST	National Institute of Standards and Technology
PE	Professional Engineer
PV	Photo-Voltaic
PWD	Public Works Department
SIR	Savings-to-Investment Ratio
SW	Source Water
TAB	Test and Balance
TC	Thermal Conductivity
TCT	Thermal Conductivity Testing
TRNSYS	Transient System Simulation Tool (Software) UESC Utility Energy Service Contract
US	United States
USA	United States of America
UTES	Underground Thermal Energy Storage
UV	Ultraviolet
VA	Veterans Administration
VDI	Verein Deutscher Ingenieure (Largest Engineering Association in Western Europe)
VAV	Variable Air Volume
YR	Year

# EXECUTIVE SUMMARY

## INTRODUCTION

To increase awareness and implementation of the ESTCP-demonstrated Underground Thermal Energy (UTES) technology, Andrews, Hammock & Powell, Inc., Consulting Engineers, developed an educational series of tools including seminars, webinars, websites, videos, guidelines, and software under this Technology Transfer Project, EW18-53. The topic-specific, on-demand, webinars are hosted on the National Institute of Building Sciences' (NIBS) Whole Building Design Guide website. Originally NIBS indicated they would host these webinars for at least two years, but the latest indications are that these webinars will remain active indefinitely. These webinars allow participants to be tested at the end of each Learning Module and receive Professional Development Hour (PDH'S) certificates and AIA's Learning Units. These webinars can be viewed at <https://www.wbdg.org/continuing-education>.

At the time of the publication of this Final Report, the six ESTCP UTES webinars hosted there represent over 50% of the available DoD on-demand webinars at [www.wbdg.org](http://www.wbdg.org) and the only webinars offering AIA Learning Unit (LU) credits.

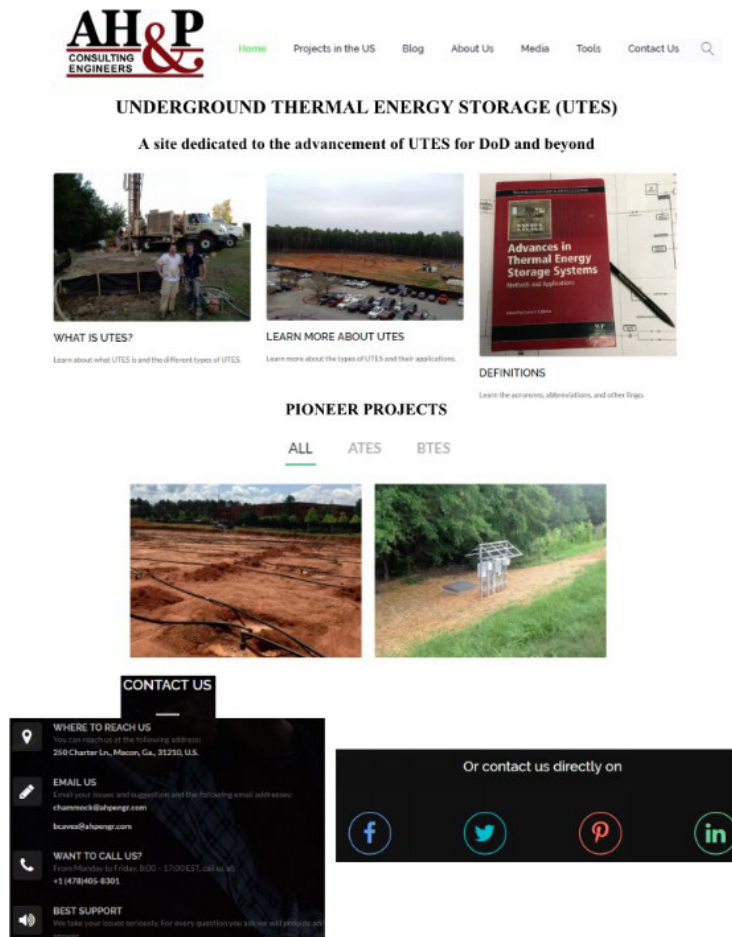


Figure ES-1. Sample UTEShub.com Webpage

The Department of Defense (DoD) has expressed interest in reducing its \$4B energy utility bill, decreasing its water consumption and increasing its inside-the-fence energy security/resiliency. All three of these objectives were achieved under the initial UTES project EW-201135 through the use of a rare (in the US) state-of-the-art form of energy storage known as UTES. Often associated with the better-known Geothermal Heat Pumps (GHP) form of Heating/Ventilating/Air-Conditioning (HVAC) systems, UTES was critical to achieving all three of these objectives. This project aims to deliver accurate, fact-based user-relevant UTES information, disseminated through multiple channels by enthusiastic presenters and relevant media, to DoD personnel and potentially to markets beyond the Federal sector. As excitement builds, and understanding of the benefits UTES brings to organizations through increased energy/water efficiency, cost savings and inherent energy security/resiliency, it is expected that UTES will increasingly become the HVAC system of choice for thoughtful DoD decision makers.

## **OBJECTIVES**

The objective of this project is to transfer the technology of Underground Thermal Energy Storage (UTES) to ESTCP and non-ESTCP projects throughout DoD and other market sectors. The approach involved in the technology transfer focused on creating a website promoting UTES, implementing live and on-demand webinars for viewing across the country. Videos that focused on the key aspects of UTES, fact sheets, and amending the Whole Building Design Guide specifications to include aspects for UTES were also included. It is hoped the original demonstrations and these technology transfer efforts for UTES, have/will spark interest, and overcome the fear of the unknown in implementation of UTES throughout the US.

- Validate: To validate the technology transfer success, surveys were given to attendees of the live webinars (that served as the substitute for the regional workshops). Completing the surveys was a pre-requisite of the attendees that wanted to receive PDH or AIA credits for the course. An average 3.5-star rating with a 1-5 star rating scale was considered a success per the demonstration plan. The actual weighted average of the six live webinars was 4.25.
- Findings and Guidelines: Findings from the demonstration may influence DoD and civilian project managers/owners to request UTES in the design of their systems.
- Technology Transfer: The technology transfer efforts were designed to facilitate the transfer of the underlying UTES demonstration (and serve as a model for other DoD technology demonstrations) by creating knowledge transfer, interest and discussions among DoD and the private sector participants concerning UTES technology. By training Engineers, Architects, Owners, Facility Managers, and Maintenance Personnel, the transfer of the technology would occur more comfortably since much of the mystery of the underlying technology will be revealed during the on-demand webinars and more.
- Acceptance: Once key players in the building design are educated on how UTES works, along with the energy/water savings and resilience benefits of UTES, it is believed that UTES will be more accepted as a practical way to store energy for use during times of need and thereby reduce facility HVAC energy consumption in a resilient manner.

## **TECHNOLOGY DESCRIPTION**

As this project was not utilized for the development of the underlying technology (UTES) per se, the development of the various technologies associated with deploying UTES was developed with the original UTES project.

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 is a closed loop Ground Heat Exchanger (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. The BTES contains sufficient heat to accomplish this if needed, but the main source of heat for the building comes from the modular heat recovery chillers. These chillers use the waste heat from the chilled water loop and the heat of compression to produce heating hot water. 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.

## **PERFORMANCE ASSESSMENT**

The proposed Technology Transfer process to transfer UTES is believed to have been effective based on several factors listed below.

- The live webinars, on-demand webinars, and the [www.uteshub.com](http://www.uteshub.com) website increased the awareness of UTES to Engineers, Architects, Owners, Maintenance Personnel, and others that may be interested in alternative heating and cooling methods, at levels well beyond those anticipated in the Demonstration Plan.
- The quarterly newsletters and fact sheets assisted in informing procurement officials in the idea, and implementation of UTES. The newsletters and fact sheets also kept Engineers updated on current and future projects as they progress.

- AH&P’s proposed edits to the Whole Building Design Guide Unified Facility Guide Specifications, as it relates to UTES-specific technologies, are anticipated to be helpful and increase the adoption of this “new” (to the USA) technology and is hoped to lead to an expanded adoption of UTES inside DoD and beyond.

Under this project, AH&P also expanded and enhanced the existing Environmental Guidelines and UTES Screening Software Tool to assist Engineers, Architects, Owners, Maintenance Personnel, and others that may be interested in implementing UTES.

**Table ES-1. Performance Assessment (July 2018 thru June 2021)**

<b>Performance Objective</b>	<b>Metric</b>	<b>Data Requirements</b>	<b>Success Criteria</b>	<b>Results</b>
<b>Quantitative Performance Objectives</b>				
Deploy <b>Live Webinars</b>	Number of People Attending the Live Webinars	Attendance Sign in Sheet	An average of 10 people attending each workshop	<b>118 attendees</b>
Create UTES website	Website Traffic	Website Statistics	A total of 2,000 website views	<b>9,278 total views</b>
Issue topic related <b>On-Demand Webinars</b>	Number of webinars attended	Webinar attendance	An average of 10 attendees per webinar.	<b>69 average attendees per webinar</b>
Creation of UTES design & construction videos	Number of views of construction videos available on YouTube or Vimeo	Statistics of Video Views	An average of 25 views per video	<b>682 average views per video</b>
Creation and distribution of Quarterly Newsletters and Fact Sheets	Email list for newsletters and fact sheets	Newsletters and Fact Sheets	Email list of a minimum of 100 participants	<b>145 recipients per newsletter</b>
<b>Qualitative Performance Objectives</b>				
Personnel satisfaction with regional workshops	Comments from users	Survey	Average 3.5 Star Rating from a 1 – 5 Star Scale	<b>4.71 of 5 stars</b>
Personnel satisfaction with profession related on- demand webinars	Comments from users	Survey	Average 3.5 Star Rating from a 1 – 5 Star Scale	<b>4.3 of 5 stars</b>

## **COST ASSESSMENT**

This section is not applicable to a Technology Transfer Project. However estimated costs for implementation of ATES and BTES systems are included herein from Energy and Water Project EW-201135. Under project EW-201135, a Life Cycle Cost Analysis (LCCA) was completed. Costs of various critical components were either tracked or obtained from Contractors so the analysis could be applied to other military installations. Since each demonstration site involved construction funding from the military installation, all costs that could not be tracked directly were obtained from installing contractors.

The critical components relevant to the GHP-UTES technology tracked during the implementation of the demonstration project are listed in Table ES-2.

**Table ES-2. UTES Cost Model**

Cost Element		Data Tracked During the Demonstration	Estimated Costs	
BTES	Geothermal Heat Exchanger Vertical Borehole (GHX) System	<ul style="list-style-type: none"> <li>Capital Cost: \$ per foot of Vertical Borehole</li> <li>Installation Cost: \$ per linear foot of Vertical Borehole</li> </ul>	Total	\$1,207,514
			\$/ft. Total	\$18.79
ATES	ATES Cold & Warm Wells	<ul style="list-style-type: none"> <li>Capital Cost: \$ per foot of Vertical Well</li> <li>Installation Cost: \$ per foot of Vertical Borehole</li> </ul>	Total	\$53,742
			\$/ft Total	\$33.59
	Horizontal Piping for ATES Wells	<ul style="list-style-type: none"> <li>Capital Cost: \$ per foot of Vertical Well</li> <li>Installation Cost: \$ per foot of Vertical Borehole</li> </ul>	Total	\$25,980
			\$/ft Total	\$16.24
BTES & ATES	Dry Coolers	<ul style="list-style-type: none"> <li>Capital Cost: \$ per Dry Cooler</li> <li>Install/Shipping Costs:</li> <li>Maintenance Cost:</li> </ul>	BTES Total	\$306,449
			\$ per Dry Cooler	\$153,225
			ATES Total	\$16,173
			\$ per Dry Cooler	\$16,173
BTES	Heat Recovery Modular Chillers	<ul style="list-style-type: none"> <li>Capital Cost: \$ per Modular Chiller</li> <li>Install/Shipping Costs:</li> <li>Maintenance Cost:</li> </ul>	Total	\$325,000
ATES	WSHPs	<ul style="list-style-type: none"> <li>Capital Cost: \$ per WSHP</li> <li>Install/Shipping Costs:</li> <li>Maintenance Cost:</li> </ul>	Total	\$25,900
			\$ per WSHP	\$3,700
BTES & ATES	Pumps & Injection Valves	<ul style="list-style-type: none"> <li>Capital Cost:</li> <li>Install/Shipping Costs:</li> <li>Maintenance Cost:</li> </ul>	BTES Total	\$53,000
			ATES Total	\$31,661
BTES & ATES	Pumping Accessories (Air separators, expansion tanks, suction diffusers, etc.)	<ul style="list-style-type: none"> <li>Capital Cost:</li> <li>Install/Shipping Costs:</li> </ul>	BTES Total	Included in Pumps
			ATES Total	Included in Pumps
BTES & ATES	Controls and Control Components	<ul style="list-style-type: none"> <li>Capital Cost:</li> <li>Installation Cost:</li> <li>Maintenance Cost:</li> </ul>	BTES Total	\$517,000
			ATES Total	\$86,400
BTES & ATES	Maintenance	<ul style="list-style-type: none"> <li>Maintenance Cost/Yr.:</li> </ul>	BTES Total	\$10,000
			ATES Total	
BTES & ATES	Training	<ul style="list-style-type: none"> <li>Cost of Training</li> </ul>	BTES Total	\$5,000
			ATES Total	\$5,000
BTES & ATES	Operational	<ul style="list-style-type: none"> <li>Utility Bills:</li> </ul>	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	<ul style="list-style-type: none"> <li>Cost of Commissioning</li> <li>Cost of TAB</li> </ul>	BTES Cx Total	\$74,000
			BTES TAB Total	\$56,700
			ATES Total	\$30,000

## **IMPLEMENTATION ISSUES**

For implementation issues related to the original demonstration, see the Final Report for EW201135. Implementation issues related to the Technology Transfer were primarily limited to the impossibility of holding live seminars/workshops during the global pandemic. This turned out to be a blessing in disguise as the Live Webinars that were substituted allowed us to reach a larger audience and paved the way for the six On-Demand Webinars that are now hosted on the [www.wbdg.org](http://www.wbdg.org) in perpetuity.

## 1.0 INTRODUCTION

To increase awareness and implementation of the ESTCP-demonstrated Underground Thermal Energy (UTES) technology, Andrews, Hammock & Powell, Inc., Consulting Engineers, developed an educational series of tools including seminars, webinars, websites, videos, guidelines, and software under this Technology Transfer Project, EW18-53. The topic-specific, on-demand, webinars are hosted on the National Institute of Building Sciences' (NIBS) Whole Building Design Guide website. Originally NIBS indicated they would host these webinars for at least two years, but the latest indications are that these webinars will remain active indefinitely. These webinars allow participants to be tested at the end of each Learning Module and receive Professional Development Hour (PDH'S) certificates and AIA's Learning Units. These webinars can be viewed at <https://www.wbdg.org/continuing-education>.

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## 1.1 BACKGROUND

With the billions of dollars DoD spends on energy and millions on water, this Technology Transfer project attempts to transfer the technology of UTES across the US to neatly intersect the energy-water nexus by significantly reducing both energy and water consumption at DoD facilities. Transferring the UTES technology will allow 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 fossil fuel consumption and the associated emissions "on Base".

- Current Technology Transfer State of the Art: Currently one approach to transfer a new technology in DoD is to collaborate with the private sector through Cooperative Research and Development Agreements. In addition to this DoD provides presentations, articles, and website info to transfer a new technology.
- Current State of Technology Transfer in DoD: An alternative tech transfer approach used by DoD is to utilize webinars, and conferences such as the Energy Exchange.

- Technology Opportunity: To expand the outreach targeting the technology transfer, a multitude of measures was taken. A website was created, originally planned “on site” seminars, with the blessing of ESTCP during the pandemic were converted to live webinars that were also recorded and then converted to on-demand webinars that are permanently hosted at [www.wbdg.org](http://www.wbdg.org) and allow for perpetual viewing by interested parties. During the duration of this Contract, newsletters, websites and videos were created to also enhance transfer of the technology. This approach will transfer the technology more efficiently than previous methodologies as witnessed by the hundreds of views logged by WBDG after the live presentations. With this website already serving as the Federal host site to a myriad of building design tools (Federal specifications, design guidelines, webinars, etc.), it is the perfect location to host these ESTCP generated webinars. Though this projects primary interest is disseminating the information to DoD affiliated parties, because NIBS allows registered users full access to the website’s tools, knowledge of the technology can also be spread far and wide to other Federal/State agencies and the private sector which will benefit DoD as design professionals and others often practice across multiple market sectors.

## 1.2 OBJECTIVE OF THE DEMONSTRATION

The objective of this project is to transfer the technology of Underground Thermal Energy Storage (UTES) to ESTCP and non-ESTCP projects throughout DoD and other market sectors. The approach involved in the technology transfer focused on creating a website promoting UTES, implementing live and on-demand webinars for viewing across the country. Videos that focused on the key aspects of UTES, fact sheets, and amending the Whole Building Design Guide specifications to include aspects for UTES were also included. It is hoped the original demonstrations and these technology transfer efforts for UTES, have/will spark interest, and overcome the fear of the unknown in implementation of UTES throughout the US.

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- Findings and Guidelines: Findings from the demonstration may influence DoD and civilian project managers/owners to request UTES in the design of their systems.
- Technology Transfer: The technology transfer efforts were designed to facilitate the transfer of the underlying UTES demonstration (and serve as a model for other DoD technology demonstrations) by creating knowledge transfer, interest and discussions among DoD and the private sector participants concerning UTES technology. By training Engineers, Architects, Owners, Facility Managers, and Maintenance Personnel, the transfer of the technology would occur more comfortably since much of the mystery of the underlying technology will be revealed during the on-demand webinars and more.
- Acceptance: Once key players in the building design are educated on how UTES works, along with the energy/water savings and resilience benefits of UTES, it is believed that UTES will be more accepted as a practical way to store energy for use during times of need and thereby reduce facility HVAC energy consumption in a resilient manner.

## **1.3 REGULATORY DRIVERS**

Many Executive Orders, Policies, Industry Standards, Mandates and Regulations are pushing all DoD entities to lower energy and/or water consumption. Some examples of these drivers and their relationship to this project are as follows:

### **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. UTES in both its forms (Borehole Thermal Energy Storage-BTES and Aquifer based ATES) provide a means for accessing not only the renewable energy of the earth itself, but also allows the renewable (annually recurring) waste heat and waste cooling of the building to be captured and seasonally stored for use in the off season. Due to their inherently efficient nature (due to lower/higher heat sink/source temperatures) energy intensity reduction is always achieved with these systems. Evaporative cooling needs are greatly reduced by a UTES system’s capability of releasing its heat in winter when the heat can easily flow from the loop into the ambient air. This means that the significant metered water consumption of the original cooling tower (approximately 4.3 million gallons/year at the original demonstration’s BTES site at LOGCOM at MCLB, and approximately 166 thousand gallons at the ATES Brigade HQ site at Ft Benning) can be drastically reduced or even eliminated as was done during the original ESTCP demonstration.

### **1.3.2 Legislative Mandates**

EPAct 2005 mandates an increase in the use of renewables and the procurement of energy efficient products and the underlying UTES project provided both of these objectives. The decision to utilize a modular chiller with heat recovery capabilities (the BTES system at MCLB) meant that when operating in the heat recovery mode, the effective COP of the unit increases dramatically as a single compressor does the work of two, creating chilled and hot water simultaneously. The Energy Independence and Security Act of 2007 proposes energy reduction goals for all Federal buildings and the UTES system in the original demonstration made a substantial difference in both buildings where it was installed by reducing HVAC energy consumption by approximately 50%.

### **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 which is exactly what the replacement of the existing HVAC systems at both the BTES site at MCLB and the ATES site at Fort Benning achieved.

### **1.3.4 DoD Policy**

Strategic Sustainability Performance Plan, Energy Security MOU with DOE, the Army Energy Security Implementation Strategy, the Navy’s Task Force Energy and the Air Force Energy Plan all seek the energy efficiency and renewable energy benefits that can be provided by a system such as those provided by coupling GHPs with UTES, the technology behind the original ESTCP project that is the source of this project’s technology that is being transferred.

## 2.0 TECHNOLOGY DESCRIPTION

### 2.1 TECHNOLOGY OVERVIEW

The approach to this technology transfer project was to develop an educational series of tools including seminars, webinars, a website, videos, guidelines, and UTES software. The project team promoted the use of these tools via live and on-demand webinars hosted in-house and ultimately at [www.wbdg.org](http://www.wbdg.org) and also via newsletters and through the [www.uteshub.com](http://www.uteshub.com) website.

- **Description:** The approach to this Technology Transfer effort was multi-pronged to help ensure its success. The challenges of a global pandemic actually benefited this project by forcing what was originally proposed as regional live seminars around the country to become live webinars that ended up serving a larger audience than was anticipated could be served by the regional live seminars. It is believed that interest across the United States will steadily increase after the completion of this Project by means of the permanent hosting of the six on-demand webinars at the popular [www.wbdg.org](http://www.wbdg.org) website/portal. Deliverables furnished under this Project include:
  - The first step in this project involved the creation of the [www.UTEShub.com](http://www.UTEShub.com) website. This website is dedicated to the advancement of UTES for DoD and beyond. Traffic to this website was increased through the use of a Blog Page, software tools, newsletter and links to the live webinars as well as the on-demand webinars and links to multiple social media sites. The website contains UTES system links to videos, webinars, and other tools such as UTES feasibility software. An example homepage of the [www.UTEShub.com](http://www.UTEShub.com) website is shown in Figure 1.
  - What was originally Regional live workshops to be performed at various military installations across the U.S. to educate Engineers, Architects, Owners, and Maintenance Personnel in the area of UTES morphed successfully into live webinars that served hundreds of participants.
  - Six topical on-demand webinars were created from the live webinars and are now permanently hosted on the NIBS WBDG website. The webinars are topic-focused (UTES-Overview, BTES, ATES, Commissioning/Testing-Adjusting Balancing (CxA/TAB), and UTES for electrical power generation/UTES<sub>e</sub> and UTES as an Energy Conservation Measure-ECM for a Utility Energy Service Contract-UESC) and are suitable for multiple professions such as Engineering/Architecture, Operators, Installers/Drillers, Contracting Officers, Energy Managers/Master Planners, and Regulators. After participating in the on-demand webinar, interested participants can, at the end of the webinar, complete a simple online test, have their test instantly graded and if they have a successful score, the website will issue a PDH or AIA-LU certificate.
  - Six videos of key aspects of the UTES design and construction process including technical videos and construction videos were created. The videos are accessible through the [www.UTEShub.com](http://www.UTEShub.com) website and also through video platforms such as YouTube.
  - Quarterly newsletters and fact sheets starting in year two were issued to the list of interested parties that had signed up to receive them. The newsletters/fact sheets highlighted present and upcoming UTES design and construction projects at DoD and/or other Federal/Government entities as well as the private sector.

- The existing Environmental Guidelines established under EW-201135 were expanded and edited into a guideline tool that can help the practitioner and decision makers assess the requirements and suitability of proposed buildings and project sites.
  - The existing UTES Screening Software Tool established under EW-201135 was expanded and converted to an on-line tool to help the practitioner and decision makers promptly assess the requirements and suitability of proposed buildings and project sites. This also eliminated the need to download an executable file on an individual's computer. An example homepage of the UTES Screening Software is shown in Figure 2.
  - Fact sheets were incorporated in the newsletters that provided an “at a glance” of some key aspects of UTES system designs, implementations, cost data, etc.
  - A proposed edit of the relevant Whole Building Design Guide (WBDG) Unified Facility Guide Specifications (UFGS) was performed so that the relevant DoD committees could consider adding the unique UTES components that are not presently included in the UFGS documents.
- **Future Potential for DoD:** It is believed that the perpetual presence of the on-demand webinars at [www.wbdg.org](http://www.wbdg.org) and the information at [www.UTEShub.com](http://www.UTEShub.com) will contribute significantly to the Technology Transfer for DoD and private sector personnel alike to apply UTES technology to future new and retrofit HVAC systems for building.

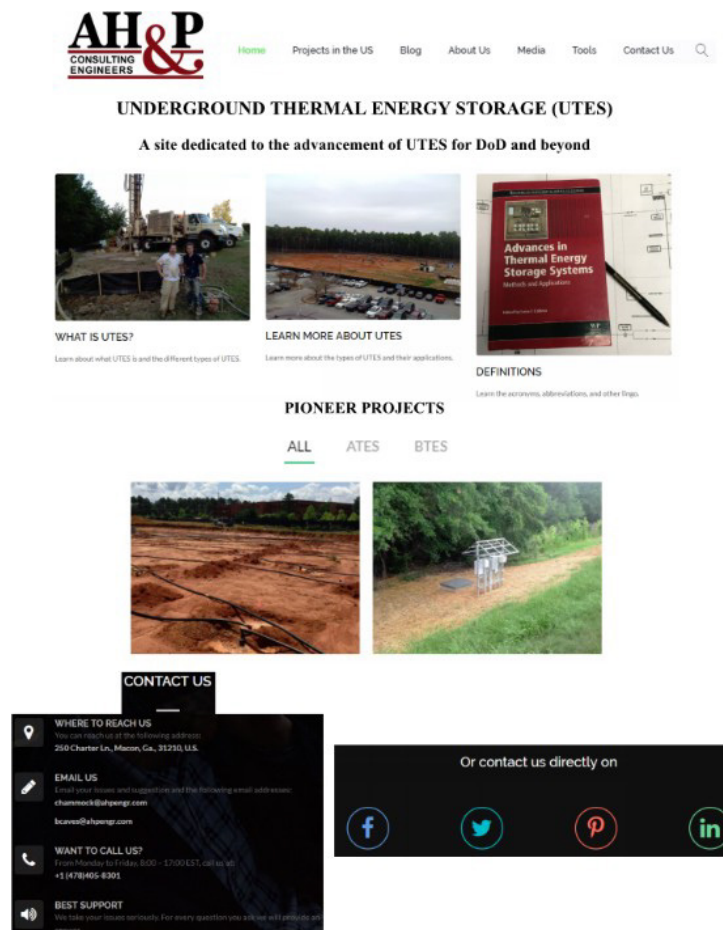


Figure 1. Sample [www.UTEShub.com](http://www.UTEShub.com) Webpage

### Environmental

What state is your project in?

Georgia

ATES systems are open loops systems that extract water from one well, heats/cool the building, and then injects the water back into the opposite well. Injecting water into an aquifer is regulated by the EPA which often delegates their authority to a state organization. BTES systems are closed loop systems that require drilling multiple geothermal wells, which are also regulated. The information listed in the report at the end of this may provide additional information on the regulations for each state concerning the injection of water into the aquifer, and construction of geothermal wells. This information serves as a general guideline only. You should contact your local agency to for more information.

### Available Land Area

Does your project have at least 1 acre of available land for geothermal use?  Yes  No

### Ground Water Velocity

Do you know the ground water velocity (Feet per Day) at your project?  Yes  No

For underground energy storage, groundwater velocity higher than 1 Ft/Day is not recommended. Groundwater velocities in excess of 1 Ft/Day are somewhat rare, therefore it is recommended that the ground water velocity be verified. Groundwater velocity can be determined by monitoring the ground water level in three different monitoring wells, and determining the slope of the groundwater between the three wells. This parameter along with the conduction of an 'aquifer pumping test' allows for estimation of the groundwater velocity. Contact a Professional Engineer and/or Geologist experienced in ATES and BTES design for more information on Groundwater Velocity, and it impact of the ability to store heat or cold at a project site. Sites with high ground-water velocities are favorable for traditional open or closed loop GHP systems.

### System Configuration

Are you interested in ATES or BTES?  ATES  BTES

### Unconsolidated Aquifer

Do you have an unconsolidated aquifer at your project?  Yes  No  Not Sure

### Water Chemistry

#### Oxic/Anoxic

Is the aquifer at your site Oxic or Anoxic?  Oxic  Anoxic  Not Sure

Typically, groundwater from deep formations contains Anoxic water. Anoxic water is typically preferred for ATES to reduce the possibility of clogging the injection well(s). If the water is Oxic, then deeper formations if available should be considered for ATES applications. Please contact a Professional Engineer and/or Geologist experienced in ATES design for more information on determining the amount of dissolved oxygen in groundwater.

#### Iron/No Iron

Does the aquifer at your site contain dissolved iron (Fe2+)?  Iron  No Iron  Not Sure

Figure 2. UTES Screening Tool Screenshot

## 2.2 TECHNOLOGY DEVELOPMENT

As this project was not utilized for the development of the underlying technology (UTES) per se, the development of the various technologies associated with deploying UTES was developed with the original UTES project. Please see the Final Report from EW-201135 for information regarding this topic.

## 2.3 ADVANTAGES AND LIMITATIONS OF THE TECHNOLOGY

- **Performance Advantages:** The approach of utilizing UTES, has a great potential to increase efficiency of new and existing HVAC systems by utilizing storage of hot or “cold” energy out-of-season for use during times of need. Energy security/resiliency can also be achieved using UTES, an “inside the fence” and underground system, that is impervious to most disasters.
- **Cost Advantages:** The major cost considerations for UTES is the required construction of the boreholes (BTES) or water wells (ATES). In some areas of the country, drilling is more feasible due to the quantity of drilling companies and their level of experience.

Accordingly, the local drilling market must be considered when estimating the cost to implement UTES. The cost advantages of BTES combined with geothermal heat pumps vs. conventional geothermal heat exchangers is often significant due to the reduced borehole lengths or reduced over-all number of boreholes and the need for less land due to a more compact (typically closer intra-borehole spacing) footprint. In prolific aquifers, ATES system in particular have great potential for reduced installation cost vs traditional closed-loop geothermal due to the need for far fewer boreholes/wells, its lower consumption of energy vs. conventional open-loop systems and its ability to produce/store/recover colder or warmer source water as needed by the load profile of the building.

- Performance Limitations: Application of UTES can be limited due to geology restraints. ATES system can typically only be executed where there are prolific (typically unconsolidated) aquifers; however, BTES can be considered a “50 State” technology and can typically be executed anywhere DoD has facilities.
- Cost Limitations: UTES systems are typically more expensive than conventional water or air-cooled systems or fossil fuel burning systems due to the cost of the underground work which is essentially an infrastructure investment that some entities are not willing to make. GHP systems with UTES can however be life cycle cost effective, especially when drilling cost are competitive and energy/water cost are considered above average or high. Generally, traditional air or water-cooled systems will have lower initial cost, but UTES systems can have a much lower operating cost. Under the original UTES project that led to this Technology Transfer effort, the HVAC energy cost were reduced approximately 50%.
- Potential Barriers to Acceptance: Barriers to acceptance may include:
  1. A reluctance to implementing UTES by building managers/operators can be traced sometimes to a fear of a more complicated system. Some may feel that they are unable to maintain the system. It is imperative for any technology transfer approach to target these types of personnel to educate them and give them a confidence in the new technology. When view objectively, the underground BTES system has, unlike every other HVAC system, no moving parts and an indefinite life due to its non-corrosive (typically HDPE) construction and underground placement. ATES system, while containing moving parts like all other HVAC system, are simply modified drinking water wells (which DoD personnel often have experience with) and their underground and water-cooled pump motors generally enjoy a long life in their lower temperature and sheltered fresh-water underwater environment. Interviewing DoD personnel involved in past UTES projects can also increase acceptance by personnel considering UTES..
  2. In regard to the technology transfer itself, personnel may be reluctant to attend on- site seminars and webinars due to time constrains, current work-load and presently, the global pandemic situation. The development of six on-demand webinars via this project, that are indefinitely hosted on the Federal website [www.wbdg.org](http://www.wbdg.org), are believed to be critical to helping deploy this technology widely over the coming years/decades. Furthermore, it is important that PDH and AIA certificates be issued after attending the webinars/seminars to encourage participation by engineers, architects and other requiring continuing education, and accordingly, this project also included both for certificates with the on-demand webinars and PDH certificates for the live webinars.

### 3.0 PERFORMANCE OBJECTIVES

The technology being transferred is Underground Thermal Energy Storage, or more commonly known as UTES. There are two types of UTES that were previously demonstrated under ESTCP's Energy and Water EW-201135, namely Aquifer Thermal Energy Storage (ATES) and Borehole Thermal Energy Storage (BTES). The two technologies are described below.

- 1 **ATES:** An ATES system utilizes ground water contained in underground aquifers to store energy in the underground formation for use in the opposite season. In the cooling mode, ground water is extracted from the cooling well(s) and used to cool the building. The resulting warm water is then injected into the warm well(s). In the heating mode, the system reverses to extract warm water from the warm well(s) to heat the building. The resulting cooled water is then injected back into the cold well(s). During times when outdoor air conditions are favorable, a dry cooler is used to further cool the water before injecting into the cold well(s).
- 2 **BTES:** A BTES system stores energy for use in the opposite season in the underground formations similar to an ATES system; however, a BTES system utilizes closed loop vertical boreholes arranged in a way that allows of either cold or warm water circulated first through the center, and then the cold or warm water is circuited through the perimeter of the borefield (depending on whether the building is cooling or heating dominated). BTES systems will almost always feature a “hybrid” component to allow active charging of the BTES in the off season. Two aspects of a BTES system differentiate it from “conventional” closed-loop systems:
  - a. Concentric thermal zones, piped in series. This allows more efficient storage of the desired thermal energy at the “core” boreholes and dissipation of the undesired thermal energy at the “perimeter” boreholes.
  - b. Reversing valves that allow the water to flow first to the core (charging) or perimeter (discharging).

The Performance Objectives for the Technology Transfer are listed in the table and descriptive paragraphs herein. There original traditional performance metrics used in the original technology demonstration are contained in the Final Report of EW-201135. This project's objectives were:

1. **Deploy Regional Workshops** – AH&P planned to perform regional workshops at military installations across the U.S. to educate Engineers, Architects, Owners, and Maintenance Personnel in the area of UTES. These workshops were to be held at locations just outside the fence of the military installation such as an adjacent museum to eliminate any issues with credentialing. The Performance Objective was to deploy the regional workshops, and the Success Criteria is to have an average of 10 people attending each workshop. This objective, with permission of ESTCP, was converted to six very successful live webinars to accommodate the realities of the global pandemic.
2. **Create UTES Website** – AH&P built a UTES website ([www.UTEShub.com](http://www.UTEShub.com)) which promotes the technology of UTES. The website features current and past UTES projects design and construction information. The website also includes a Blog where frequent news and updates were shared. An on-line software assessment tool also resides there. The Performance Objective was to create the UTES website, and the Success Criteria is to have a total of 2,000 website views at the end of the technology transfer period.

**3. Produce On-Demand Webinars** – AH&P produced six various UTES sub-topic related webinars. The webinars are indefinitely hosted on the federal National Institute of Building Science’s (NIBS) Whole Building Design Guideline (WBDG) website [www.wbdg.org](http://www.wbdg.org). The webinars are related to specific UTES sub-topics as follows:

- Underground Thermal Energy Storage (UTES) for Geothermal Heat Pumps (GHP) Overview
- Borehole Thermal Energy Storage (BTES) for Geothermal Heat Pumps (GHP)
- Aquifer Thermal Energy Storage (ATES) for Geothermal Heat Pumps (GHP)
- Underground Thermal Energy Storage for Electrical Generation (UTES<sub>e</sub>)
- Commissioning (CxA) and Testing/Adjusting/Balancing (TAB) for Underground Thermal Energy Storage (UTES)
- Underground Thermal Energy Storage (UTES) as Utility Energy Service Contract (UESC) Energy Conservation Measure (ECM)

After participating in the webinar, the participant may complete an online test, and the test is automatically graded by computer. If successful, a PDH or AIA LU Certificate is issued to the participant. The Performance Objective is to develop these On-Demand Webinars, and the Success Criteria is to have an average of 10 attendees per on-demand webinars. The webinars are available at no charge to the user.

**4. Creation of UTES Design & Construction Videos** – AH&P created videos of key aspects of the UTES design and construction process including technical videos, and construction videos. The videos are hosted either on YouTube and are accessible through the [www.uteshub.com](http://www.uteshub.com) website and AH&P YouTube channel <https://www.youtube.com/channel/UCRCGyvRqS7lrGzbMIUuzG4g>. The Performance Objective is to create UTES Design & Construction Videos, and the Success Criteria is an average of 25 views per video.

**5. Creation and Distribution of Quarterly Newsletters and Fact Sheets** – Starting in Project Year Two, AH&P created quarterly newsletters with updates concerning new and existing UTES projects in DoD, other Federal/Government entities, and private sector jobs. The Performance Objective is to create and distribute the Quarterly Newsletters and Fact Sheets, and the Success Criteria is to have an email mailing list of a minimum of 100 participants.

**6. Personnel Satisfaction with Regional Workshops (live webinars)** – AH&P issued survey forms at the conclusion of each Live Webinar to determine the satisfaction level of the personnel in attendance. The comment sheets/survey forms had an area for comments and a 1-to-5-star rating for the workshop. The Performance Objective is Personnel Satisfaction with the Regional Workshops, and the Success Criteria is an Average 3.5 Star Rating from a 1 – 5 Star Scale.

**7. Personnel Satisfaction with the On-Demand Webinars** – AH&P utilized an online survey at the conclusion of each On-Demand Webinar to determine the satisfaction level of the personnel in attendance. The survey form asked for comments and a 1-to-5-star rating for the webinar. The survey was required to be completed before the participant received a PDH. The Performance Objective is Personnel Satisfaction with the on-demand webinar, and the Success Criteria is an Average 3.5 Star Rating from a 1 – 5 Star Scale.

The traditional performance metrics, used in the original technology demonstration, are not a part of this Technology Transfer project as this is not a traditional ESTCP Demonstration. As an *exclusively* technology transfer effort, traditional metrics for energy and water savings, direct or source fossil fuel emissions reduction, or construction cost reduction are not applicable and instead the above metrics, associated with the Technology Transfer methods are measured and presented herein.

The proposed Technology Transfer process to transfer UTES is believed to have been effective based on several factors listed below.

- The live webinars, on-demand webinars, and the [www.uteshub.com](http://www.uteshub.com) website increased the awareness of UTES to Engineers, Architects, Owners, Maintenance Personnel, and others that may be interested in alternative heating and cooling methods, at levels well beyond those anticipated in the Demonstration Plan.
- The quarterly newsletters and fact sheets assisted in informing procurement officials in the idea, and implementation of UTES. The newsletters and fact sheets also kept Engineers updated on current and future projects as they progress.
- AH&P’s proposed edits to the Whole Building Design Guide Unified Facility Guide Specifications, as it relates to UTES-specific technologies, are anticipated to be helpful and increase the adoption of this “new” (to the USA) technology and is hoped to lead to an expanded adoption of UTES inside DoD and beyond.

Under this project, AH&P also expanded and enhanced the existing Environmental Guidelines and UTES Screening Software Tool to assist Engineers, Architects, Owners, Maintenance Personnel, and others that may be interested in implementing UTES.

**Table 1. Performance Objectives – July 2018 thru June 2021**

Performance Objective	Metric	Data Requirements	Success Criteria	Results
<b>Quantitative Performance Objectives</b>				
Deploy <b>Live Webinars</b>	Number of People Attending the Live Webinars	Attendance Sign in Sheet	An average of 10 people attending each workshop.	<b>118 attendees</b>
Create UTES website	Website Traffic	Website Statistics	A total of 2,000 website views	<b>9,278 Total Views</b>
Issue topic related <b>On-Demand Webinars</b>	Number of webinars attended	Webinar attendance	An average of 10 attendees per webinar.	<b>69 average attendees per webinar</b>
Creation of UTES design & construction videos	Number of views of construction videos available on YouTube or Vimeo.	Statistics of Video Views.	An average of 25 views per video.	<b>682 average views per video</b>
Creation and distribution of Quarterly Newsletters and Fact Sheets	Email list for newsletters and fact sheets	Newsletters and Fact Sheets	Email list of a minimum of 100 participants	<b>145 recipients per newsletter</b>
<b>Qualitative Performance Objectives</b>				
Personnel satisfaction with regional workshops	Comments from users	Survey	Average 3.5 Star Rating from a 1 – 5 Star Scale	<b>4.71 of 5 stars</b>
Personnel satisfaction with profession related on- demand webinars	Comments from users	Survey	Average 3.5 Star Rating from a 1 – 5 Star Scale	<b>4.3 of 5 stars</b>

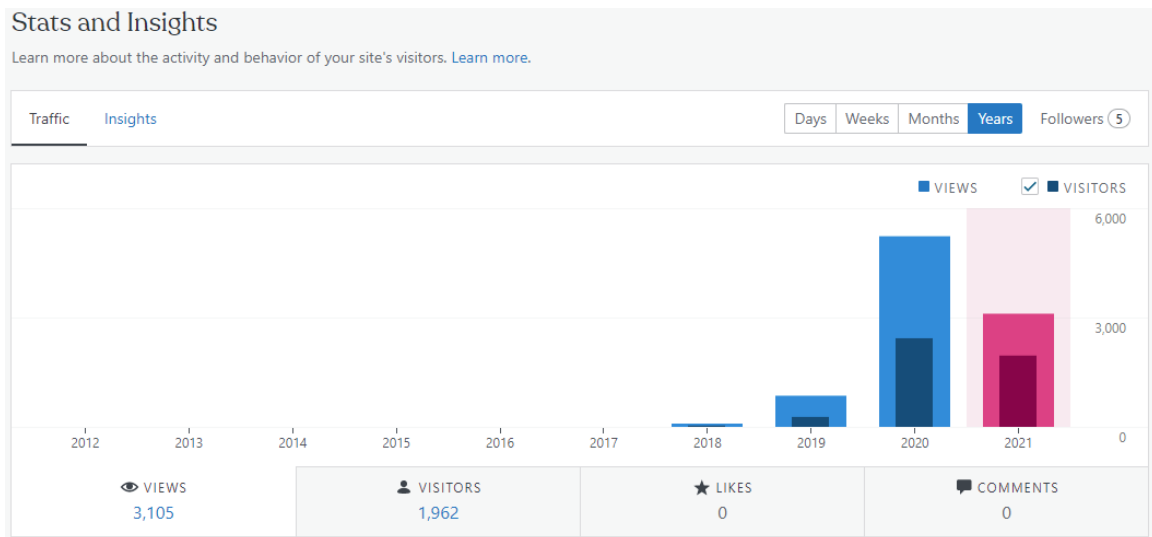
### 3.1 LIVE WEBINARS

- **Name and Definition** – **Live Webinars:** Originally AH&P was to perform “regional workshops” at military installations across the U.S. to educate Engineers, Architects, Owners, and Maintenance Personnel in the area of UTES. These workshops were to be held at locations outside the fence of the military installation such as a nearby museum to eliminate any issue with credentialing. The *regional* workshops were to be used to inform and educate Engineers, Architects, Owners, and Maintenance Personnel across the United States in the area of UTES. The workshops were to be designed to create interest and discussion among peers in the industry to encourage the implementation of UTES. However, due to the Covid-19 pandemic, the regional workshops were not able to be held in person. An alternative plan was proposed and approved by ESTCP to substitute a series of Live Webinars via YouTube Live. Data on that effort is listed herein
- **Metric** – To measure performance, the investigator recorded the number of people attending the workshops deployed. The range of the number of attendees ranged from 51 to 179 people attending each workshop.
- **Data** – The data required to evaluate the metric was the number of views from each video. The recorded video from the live broadcast will serve as a record of the number of attendees and the date, time, and place of each workshop.
- **Success Criteria** – The metric threshold value for this PO was an average of 10 people attending each workshop. The threshold was easily met for all six of the live webinars as shown below. **On average, there were 118 attendees at each live webinar.**
  - Webinar #1 of 6 ESTCP/AH&P Underground Thermal Energy System (UTES) for Geothermal Heat Pumps Webinar – 117 Views
  - Webinar #2 of 6 /ESTCP/AH&P Aquifer Thermal Energy System (ATES) for Geothermal Heat Pumps Webinar – 150 Views
  - Webinar 3 of 6 / ESTCP/AH&P Borehole Thermal Energy Storage (BTES) for Geothermal Heat Pumps Webinar – 116 Views
  - Webinar #4 of 6 ESTCP/AH&P Underground Thermal Energy Storage for Electricity Generation(UTESe) Webinar – 179 Views
  - Webinar #5 of 6 ESTCP/AH&P Commissioning and TAB of Geothermal Heat Pump Systems Webinar – 97 Views
  - Webinar #6 of 6 AH&P Live Webinar on UTES as a UESC and Energy Conservation Measure – 51 Views

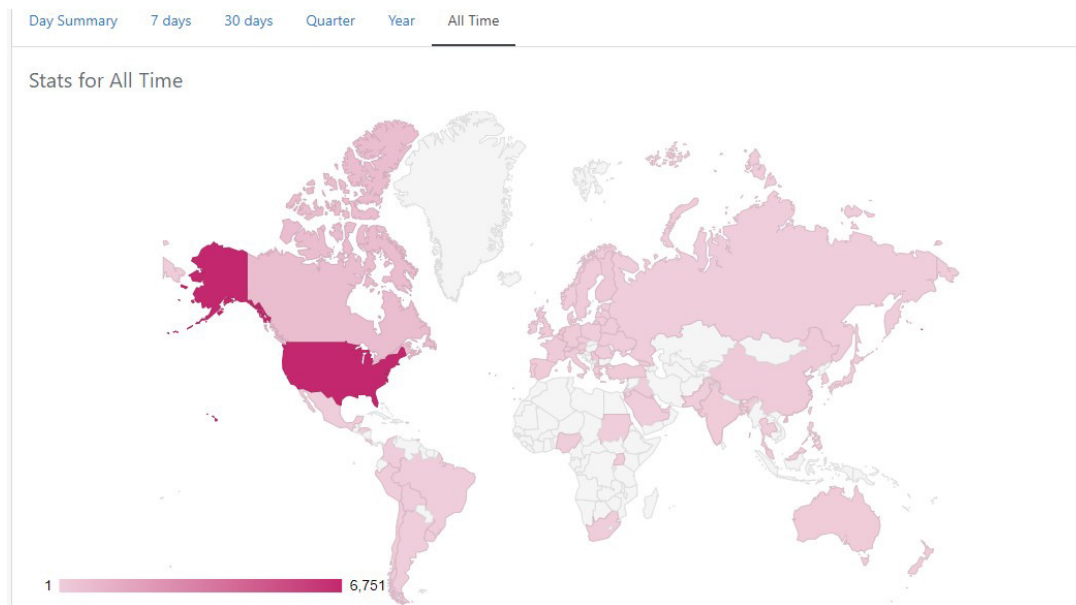
### 3.2 CREATE UTES WEBSITE

- **Name and Definition** – **Create UTES Website,** AH&P built a UTES website (uteshub.com) to promote the technology of UTES. The website features current and past UTES projects design and construction techniques. The website also features a Blog where frequent news and updates can be shared. The purpose of the UTES website is to provide an online community to encourage the use of UTES throughout the United States. The website also contains information to assist in the design and construction of UTES.
- **Metric** – To measure performance of the objective AH&P recorded the website views. AH&P estimated the range of the number of website views could be 1,000- 5,000 views during the Technology Transfer period.

- **Data** – The data required to evaluate the metric will be website statistics. Website statistics can be viewed on the admin page of the website.
- **Success Criteria** – The metric threshold value for this PO is website views of a minimum of 2,000 views. This threshold was met as the total views during the Technology Transfer period exceeded the minimum of 2,000 views as shown below. The UTEShub.com views originated from 56 different countries. **Total views through 2021 is 9278**
  - 2018 – 90 Views & 30 Visitors
  - 2019 – 854 Views & 273 Visitors
  - 2020 – 5,229 Views & 2,419 Visitors
  - 2021 – 3,105 Views & 1,962 Visitors



**Figure 3. UTEShub.com Website Statistics**



**Figure 4. UTEShub.com Statistics by Region**

### 3.3 CREATE ON-DEMAND WEBINARS

- **Name and Definition** – **Create On-Demand Webinars**, AH&P produced six profession related webinars. The webinars are hosted on The National Institute of Building Science’s (NIBS) Whole Building Design Guideline (WBDG) website [www.wbdg.org](http://www.wbdg.org). The on-demand webinars were created from each of the six live webinars (originally regional workshops). After participating in the webinar, the interested participant completes an online test, and the test is graded before receiving a PDH/AIA certificate. The purpose of the on-demand profession related webinars is to allow interested parties to receive information on design, construction, and maintenance of UTES systems. Participation of the on-demand webinars can be completed at the convenience of the individual since the webinars are not live and are hosted 24/7/365 on the WBDG website.
- **Metric** – To measure performance of the objective AH&P received records of the number of attendees of the webinars.
- **Data** – The data required to evaluate the metric is the number of attendees per webinar located on the WBDG website.
- **Success Criteria** – The metric threshold value for this PO is to record a minimum of 10 attendees per webinar. **The average attendees per On-Demand Webinar is 69.**

### 3.4 CREATION OF UTES DESIGN AND CONSTRUCTION VIDEOS

- **Name and Definition** – AH&P created videos of key aspects of the UTES design and construction process including technical videos, and construction videos. The videos are hosted on YouTube, and are accessible through the uteshub.com website.

The purpose of creating the UTES Design and Construction videos is to inform interested parties of UTES design and construction processes.

- **Metric** – To measure performance of the objective AH&P recorded the views per video.
- **Data** – The data required to evaluate the metric is the views of videos available on the UTES website.
- **Success Criteria** – The metric threshold value for this PO is an average of 25 views per video or greater. The criteria was easily met as shown in the statistics below. **The average viewership of the five videos is 682.**
  - Thermal Conductivity Test Instructional Video – 70 Views
  - How Borehole Thermal Energy Storage Works – 2027 Views
  - How Aquifer Thermal Energy Storage Works – 905 Views
  - Borehole Thermal Energy Storage for Electrical Generation – 313 Views
  - Aquifer Thermal Energy Storage Overview – 94 Views

### 3.5 CREATION AND DISTRIBUTION OF QUARTERLY NEWSLETTERS AND FACT SHEETS

- **Name and Definition** – **Creation and Distribution of Quarterly Newsletters and Fact Sheets**, AH&P created quarterly newsletters and fact sheets with updates concerning new and existing UTES projects in DoD, other Federal/Government entities, and private sector jobs.

The purpose of creating the quarterly newsletters and fact sheets was to inform interested parties of progress and new technologies concerning UTES on current and future jobs. The fact sheets and quarterly newsletters will be emailed to a list of people who subscribe to the email list through the uteshub.com website.

- **Metric** – To measure performance of the objective AH&P uploaded the quarterly newsletters and fact sheets to SEMS. The quarterly newsletters began in the 3<sup>rd</sup> quarter of 2020 and ran through the 2<sup>nd</sup> quarter of 2021.
- **Data** – The data required to evaluate the metric is the emails that contain the quarterly newsletters and fact sheets. The newsletters and fact sheets were uploaded to SEMS.
- **Success Criteria** – The metric threshold value for this PO is the distribution of the quarterly newsletters/fact sheets starting in third quarter of 2020 and ending in the second quarter of 2021. **The success criteria was met based on the quarterly newsletters listed below, averaging 145 recipients per newsletter.**
  - 3<sup>rd</sup> Quarter 2020 Newsletter #1 – 104 Recipients
  - 4<sup>th</sup> Quarter 2020 Newsletter #2 – 159 Recipients
  - 1<sup>st</sup> Quarter 2021 Newsletter #3 – 159 Recipients
  - 2<sup>nd</sup> Quarter 2021 Newsletter #4 – 159 Recipients

### 3.6 PERSONNEL SATISFACTION WITH LIVE WEBINARS

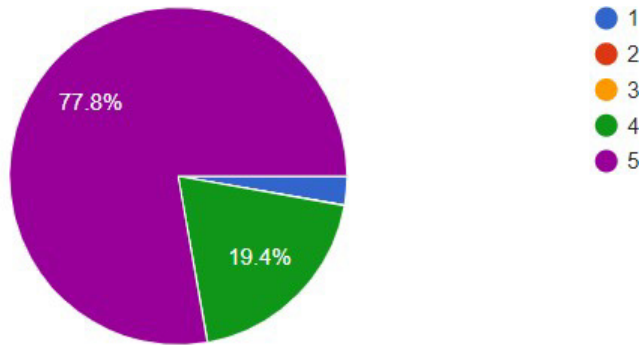
- **Name and Definition** – **Personnel Satisfaction with Live Webinars:** Originally AH&P was to issue comment sheets at the conclusion of each Regional Workshop to determine the satisfaction level of the personnel in attendance; however, since the Regional Workshops were changed to live webinars AH&P used the approach of requiring attendees to complete an online survey before receiving their PDH credits for each of the six Live Webinars. The surveys were used to determine the satisfaction level of the personnel in attendance. The surveys had an area for comments and a 1- to 5-star rating for the live webinar. The purpose of issuing the survey was to determine the satisfaction level of the personnel in attendance at the live webinars. The survey forms were also used to help determine the amount of interest in UTES.
- **Metric** – To measure performance of the objective AH&P reviewed the online survey sheets. The comments and the ratings were added to a spreadsheet and analyzed. The analyzed spreadsheets were uploaded to SEMS. A 1-star rating means very dissatisfied with the workshop, and 5-stars means very satisfied with the workshop.
- **Data** – The data required to evaluate the metric will be the survey sheets recorded from each live webinar.
- **Success Criteria** – The metric threshold value for this PO was an average 3.5-star rating from the comment sheets. This threshold was easily met as shown below. **On average, the weighted “star rating” from the total 157 responses received from the attendees that participated in rating one or more of the six live webinars was 4.71.**

- Webinar #1 of 6 ESTCP/AH&P Underground Thermal Energy System (UTES) for Geothermal Heat Pumps Webinar

*Average Rating 4.75 out of 5 stars*

Please rate our webinar 1 to 5

36 responses



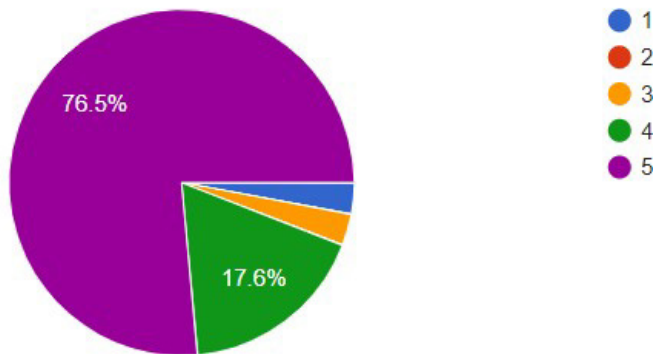
**Figure 5. Live Webinar #1 Ratings**

- Webinar #2 of 6 /ESTCP/AH&P Aquifer Thermal Energy System (ATES) for Geothermal Heat Pumps Webinar

*Average Rating 4.65 out of 5 stars*

Please rate our webinar 1 to 5

34 responses



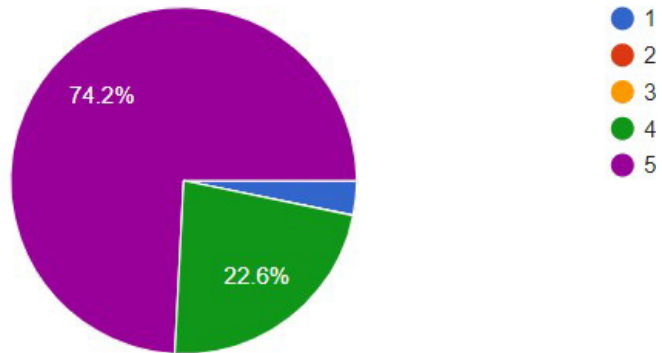
**Figure 6. Live Webinar #2 Ratings**

- Webinar 3 of 6 / ESTCP/AH&P Borehole Thermal Energy Storage (BTES) for Geothermal Heat Pumps Webinar

*Average Rating 4.65 out of 5 stars*

Please rate our webinar 1 to 5

31 responses



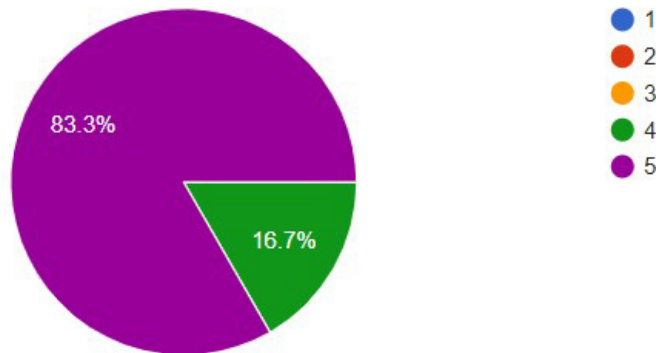
**Figure 7. Live Webinar #3 Ratings**

- Webinar #4 of 6 ESTCP/AH&P Underground Thermal Energy Storage for Electricity Generation (UTESe)

*Average Rating 4.83 out of 5 stars*

Please rate our webinar 1 to 5

30 responses



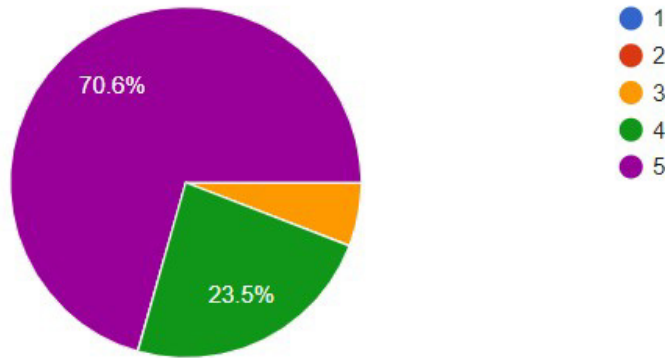
**Figure 8. Live Webinar # 4 Ratings**

- Webinar #5 of 6 ESTCP/AH&P Commissioning and TAB of Geothermal Heat Pump Systems Webinar

*Average Rating 4.65 out of 5 stars*

Please rate our webinar 1 to 5

17 responses



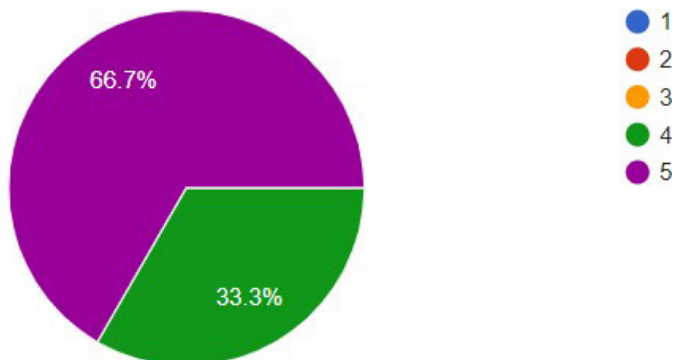
**Figure 9. Live Webinar #5 Ratings**

- Webinar #6 of 6 AH&P Live Webinar on UTES as a UESC and Energy Conservation Measure

*Average Rating 4.67 out of 5 stars*

Please rate our webinar 1 to 5

9 responses



**Figure 10. Live Webinar #6 Ratings**

### 3.7 PERSONNEL SATISFACTION WITH PROFESSION RELATED ON-DEMAND WEBINARS

- **Name and Definition** – Personnel Satisfaction with Profession Related On- Demand Webinars, AH&P utilized an online survey (hosted by WBDG) at the conclusion of each On-Demand Webinar to determine the satisfaction level of the personnel in attendance. The survey asked for comments and a 1- to 5-star rating for the webinar. The surveys were completed before the participant received a PDH/AIA certificate. The purpose of utilizing the online surveys at the conclusion of the webinars was to determine the overall satisfaction with the information received as part of the webinars.
- **Metric** – To measure performance of the objective AH&P collected and reviewed the online surveys. The comments and ratings from the online surveys were added to a spreadsheet and analyzed. The analyzed spreadsheets were uploaded to SEMS. The range of ratings that is to be expected is 1 to 5 stars out of a total of five stars. 1-star meaning very dissatisfied with the webinar, and 5-stars meaning very satisfied with the webinar.
- **Data** – The data required to evaluate the metric is the record of the online surveys.
- **Success Criteria** – The metric threshold value for this PO is an average 3.5-stars of 5 rating from the online surveys. **The average rating of the six on-demand webinars were 4.3 Stars.**

## **4.0 PERFORMANCE ASSESSMENT**

### **4.1 DEPLOY REGIONAL WORKSHOPS (LIVE WEBINARS)**

The Regional Workshops initially were to be held in person at 4 different locations across the US. The Workshops were scheduled to begin in the spring of 2020. However, as the COVID-19 pandemic began in the US in early 2020 and as public gatherings and travel being canceled, a decision was made and approved by ESTCP to host all of the webinars virtually. Hosting the webinars virtually allowed the webinars to have unlimited attendance and a global impact instead of being limited to attendance from one small area of the US. Instead of hosting only four webinars, the decision was made to host six live webinars and utilize enhanced/expanded recordings of the live webinars for use as the On-Demand Webinars to be perpetually hosted on the WBDG website.

The platform for the webinars was YouTube Live, which allowed DoD personnel to view the webinars. Virtual meeting platforms such as Microsoft Teams, or Zoom was not desirable due to issues with high number of attendees. YouTube Live allowed the attendees to simply click on a link after registration which opened YouTube in a standard web browser.

An announcement for each of the six webinars was sent out to a mailing list which was generated from a number of sources. Initially the mailing list was primarily generated from an email request to opt-in to the mailing list. However, after the first webinar was complete each attendee who received a PDH certificate was required to answer a questionnaire which included the opportunity to sign up for the mailing list. Each webinar was also announced in the ASHRAE newsletter (Primarily in the national newsletter), and on the UTEShub.com website. The announcement included a link for the attendee to click which directed the attendee to the UTEShub.com website for registration. After registration the attendee was able to click on a link for the webinar to be added to his/her calendar.

During each webinar the attendees were allowed to ask questions via the Live Chat feature in YouTube Live. There was good participation and question during each of the six webinars. The format for each webinar was as follows.

- a. Each webinar began at 1330 EST, and reminders were sent out to all registered attendees a day in advance.
- b. A virtual waiting room was created by starting the YouTube Live video 30 minutes before the start of each webinar where attendees could view a countdown timer.
- c. Each webinar began with an introduction from the presenters complete with webcams for video of the presenters.
- d. After the introduction of the webinar, the webcams were turned off and the attention was exclusively on the Power Point presentation. The presenter began the presentation and questions were encouraged from the attendees. The presentation was completed before any questions were answered.
- e. After the presentation, all questions were answered and discussion began among the presenters.

- f. At the conclusion of each webinar, the participants were encouraged to complete a survey. The survey was required before a PDH was issued to the participant. The PDH certificates were generated automatically using Google docs. One section of the survey requires the participant to rate the webinar 1-5 stars, with 1 star being the lowest, and 5 stars being the highest. **The average rating for all six seminars is 4.7 stars out of 5, well above the demonstration plans minimum 3.5 rating.**

A total of six webinars were held. Attendance averaged 118 participants, easily exceeding the minimum 10 participants listed in the demonstration plan. The webinar dates and topics are listed below.

- a. Webinar #1 of 6 ESTCP/AH&P Underground Thermal Energy System (UTES) for Geothermal Heat Pumps Webinar – 5/28/2020
- b. Webinar #2 of 6 /ESTCP/AH&P Aquifer Thermal Energy System (ATES) for Geothermal Heat Pumps Webinar – 9/16/2020
- c. Webinar 3 of 6 / ESTCP/AH&P Borehole Thermal Energy Storage (BTES) for Geothermal Heat Pumps Webinar – 12/16/2020
- d. Webinar #4 of 6 ESTCP/AH&P Underground Thermal Energy Storage for Electricity Generation (UTES<sub>e</sub>) Webinar – 1/20/2021
- e. Webinar #5 of 6 ESTCP/AH&P Commissioning (CxA) and Testing/Adjusting/Balancing (TAB) of Geothermal Heat Pump Systems Webinar – 3/10/2021
- f. Webinar #6 of 6 ESTCP/AH&P Live Webinar on Underground Thermal Energy Storage (UTES) as a Utility Energy Service Contract's (UESC) Energy Conservation Measure (ECM) – 5/12/2021

## 4.2 CREATE UTES WEBSITE

During the demonstration period, a website was created dedicated to the advancement of UTES for DoD and beyond. The website is a hub for all things related to UTES and is a place where an individual can easily learn about the fundamentals, design, construction, and operation/maintenance of UTES systems. The website contains numerous photos, videos, and custom selection software to aid individuals in understanding, designing, and implementing UTES systems.

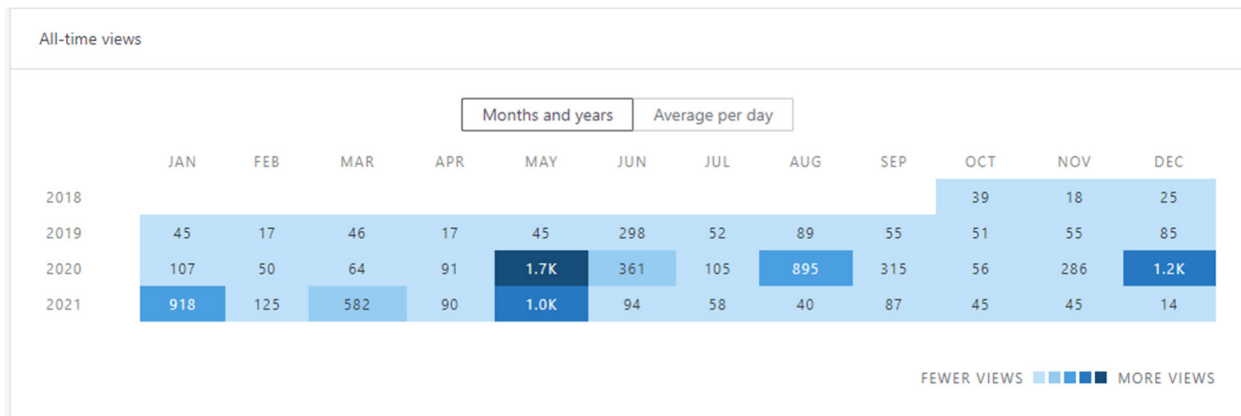
Creation of the website began by securing the website domain [www.uteshub.com](http://www.uteshub.com). The domain utes.com was not available and an attempt was made to purchase the domain from the owner. The owner of utes.com was not willing to sell the domain, therefore the decision was made to continue the website building process with the [www.uteshub.com](http://www.uteshub.com) domain.

The process of building the website began by creating eight different main pages. The eight pages are listed below with a description of their contents.

- a. **Home Page** – The home page has an overview of UTES, and a section to learn more about UTES, it also contains definitions and a section where an individual can learn about Distributed Temperature Sensing (DTS).

- b. **Projects in the U.S.** – This section of the website details all of the UTES HVAC projects completed in the U.S.
- c. **Community** – The community page is where blog posts can be made to keep individuals updated on developments with UTES.
- d. **About Us** – The About Us section of the website describes our company and the history of the company.
- e. **Media** – The Media section of the website contains all pictures related to UTES projects.
- f. **Tools** – The Tools section of the website is a section where an individual can run a Feasibility Software Tool to determine if UTES is feasible for their project.
- g. **Contact Us** – This page allows interested individuals to contact us for more info on UTES.
- h. **Events** – The Events page is where future events are announced. All of the webinars were listed on the Events page of the website.

Traffic was routed through the website as much as possible by requiring registration for the webinars through the uteshub.com website. To gauge the success of the website, the website analytics were observed. The some of the analytics of the website are shown below. **Overall, as of 2021, the website had received 9,278 views.**



**Figure 11. UTEShub.com Website Traffic by Months and Years**

### 4.3 CREATE ON-DEMAND WEBINARS

After each of the six webinars, the recorded video from the webinar was edited and subtitles written and other enhancements made before issuing the files to NIBS personnel for inclusion into the Whole Building Design Guide Website as an On-Demand Webinar. Exam questions were written for each of the On-Demand Webinars for the participants to take before receiving their AIA/PDH credits for the course. The number of On-Demand Webinar attendees was recorded from analytics from the WBDG website. The data for each On-Demand Webinar is listed below. **On average, there have been 69 participants per On-Demand Webinar**

- a. **Underground Thermal Energy Storage (UTES) for Geothermal Heat Pumps On-Demand Webinar – 73 Attendees**

- b. Aquifer Thermal Energy Storage (ATES) for Geothermal Heat Pumps On-Demand Webinar – **47 Attendees**
- c. Borehole Thermal Energy Storage (BTES) for Geothermal Heat Pumps On-Demand Webinar – **98 Attendees**
- d. Underground Thermal Energy Storage for Electricity Generation (UTESe) On-Demand Webinar – **126 Attendees**
- e. Commissioning and TAB of Geothermal Heat Pump Systems On-Demand Webinar – **4 Attendees**
- f. UTES as a UESC and Energy Conservation Measure On-Demand Webinar – **7 Attendees**

#### 4.4 CREATION OF UTES DESIGN AND CONSTRUCTION VIDEOS

UTES Design and Construction Videos were created and uploaded to YouTube. The instructional videos cover the following topics as they relate to UTES Systems. Each video is described below and links to each video is provided. The demonstration plans specified that a minimum of 25 view were required per video. **The average viewership of each video was 682 views.** Individual videos/statistics are as follows:

- Thermal Conductivity Test Instructional Video - <https://youtu.be/fMxdugtfOMM> This video explains what a thermal conductivity test or TCT is as well as how to conduct a TCT. **Number of Views during the Project – 70**
- How Borehole Thermal Energy Storage Works - <https://youtu.be/-hSLP4JpPvU> Borehole Thermal Energy Storage(BTES) uses boreholes piped in series and arranged in concentric circles to store warm and cold water. The water is used to heat and cool a building when paired with a water source heat pump. This video explains the importance of concentric circles and how the system operates. **Number of Views during the Project – 2,027**
- How Aquifer Thermal Energy Storage Works - <https://youtu.be/4tznGprNKhU> Aquifer Thermal Energy Storage (ATES) utilizes underground Aquifers to store warm and cold water. A building can use this system paired with water source heat pumps to heat and cool the building. This video shows how an ATES system operates throughout the year with different weather conditions. **Number of Views during the Project – 905**
- Borehole Thermal Energy Storage for Generating Electricity (BTESe) Video – <https://youtu.be/hZx-2OTB6cE>

This video is a brief overview of Underground Thermal Energy Storage (UTES) systems and how they could be used for electrical production. It discusses UTES in combination with an Organic Rankine Cycle (ORC) electrical generator to produce electricity and using UTES as a thermal battery to store energy for months. UTES systems generally have increased resiliency due to their underground placement. Therefore, even in severe weather like tornados or hurricanes, power is still available and consistent. The model shown in this video uses a specific type of UTES know as Borehole Thermal Energy Storage(BTES) coupled with concentrated solar collectors and an Organic Rankine Cycle generator. **Number of Views during the Project - 313**

- Aquifer Thermal Energy Storage Systems - <https://youtu.be/rbPqMOtpkLs>

Advanced Learning Video - Aquifer Thermal Energy Storage (ATES) uses aquifers to store warm and cold water. The water is used to heat and cool a building when paired with a water source heat pump. This video explains the construction process and also gives insight into the installation and operation of the system. **Number of Views during the Project – 94**

#### **4.5 CREATION AND DISTRIBUTION OF QUARTERLY NEWSLETTERS AND FACT SHEETS**

The quarterly newsletters and fact sheets were created and sent to individuals who opted into a mailing list. The newsletters began in the 3<sup>rd</sup> quarter of 2020 and continued through the 2<sup>nd</sup> Quarter of 2021. The quarterly newsletters contained updates concerning current and future Underground Thermal Energy Storage Projects. Each Newsletter and the number of recipients is detailed herein. **The average number of recipients for the newsletter/factsheets was 145 exceeding the 100 minimum level listed in the Demonstration Plan.** Four newsletters are shown below.

## 4.5.1 3rd Quarter 2020 Newsletter #1 – 104 Recipients



Hello {{ contact.FIRSTNAME }} {{ contact.LASTNAME }},

Andrews, Hammock, and Powell partnered with the DoD and ESTCP present This fact sheet about Underground Thermal Energy Storage(UTES). For more information about UTES, upcoming events, and out recent activity please visit our website.

### Recent Activity



#### Gulf Power Naval Air Station Pensacola FL

In 2018 AH&P partnered with Gulf Power to implement UTES as a DoD facility Energy Conservation Measure (ECM). Naval Air Station Pensacola (NASP) was chosen as a candidate to implement the UTES project. At NASP the 3900's series

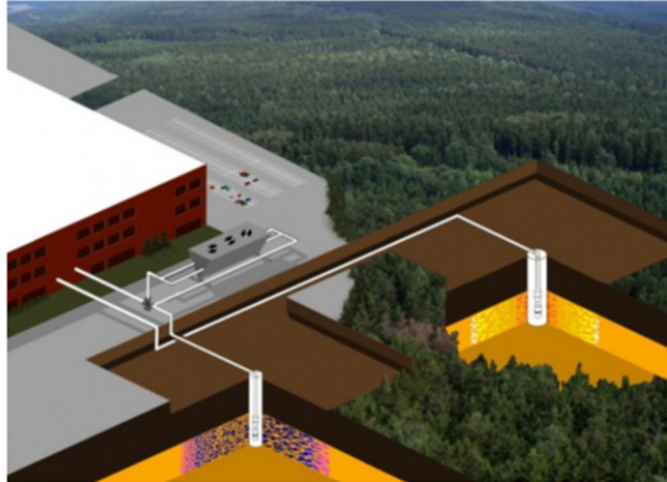
of buildings was chosen as a candidate to implement an ATEs system. The 3900's series of buildings is currently served by a central chilled water plant and local hot water heating and domestic water heating boilers. After locating some abandoned irrigation wells on base a decision was made to implement ATEs for 4 buildings (3901, 3902, 3903, & 3904) close to the abandoned irrigation wells. The project is currently in the modeling and design stages. Water well drillers are scheduled to remove the old irrigation pumps and piping from one of the abandoned wells and attempt to rehab the well. If the well is able to be rehabbed, it will be utilized as a pumping well for an aquifer pumping test (APT). The driller will then install one monitoring well close by the abandoned irrigation well. This monitoring well combined with other existing wells in the area will allow the water level to be monitored in multiple nearby wells during the APT. The APT, and water level data will then be analyzed to determine to specific yield GPM/Ft drawdown of the formation and will assist with the design of the production wells. If the abandoned irrigation well is able to be rehabbed and is able to supply sufficient water for the ATEs system, the two abandoned irrigation wells will be repurposed as ATEs wells in the ATEs design.



### **Dominion Energy**

This year AH&P has teamed with Dominion Energy to demonstrate a direct chilled water ATEs as part of a Utility Energy Service Contract. A location has not been chosen for the project, but it will likely be in the Virginia area. This project will utilize

groundwater for direct cooling to significantly reduce energy and/or water consumption. The ATEs system will store chilled water in the ground for direct use during the cooling season.



### Geothermal Analysis Ft. Benning, GA

The geothermal analysis project at Ft. Benning has been completed but is anticipated to go to phase two. The results of Phase 1 of the geothermal analysis established the hydraulic conductivity of the Main Post area of Ft. Benning. The hydraulic conductivity was estimated to be low enough that it is not feasible to implement ATES on a large scale on Main Post. However, phase 2 would allow additional exploratory drilling at the previously drilled 8" well, exploration drilling near the river, and an aquifer pumping test for the existing golf course well to determine if there are more productive zones in the Main Post area.

[More Information](#)

[ATES-BTES Feasibility Software](#)

Want to see if an ATES or BTES system would be feasible for your project? follow the link below to a software that can determine feasibility.

## Events



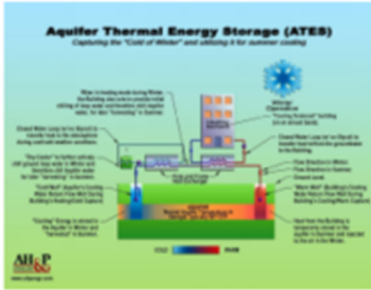
### Free On Demand Webinar

Webinar about Underground Thermal Energy Storage for Geothermal Heat Pumps

[Watch](#)

### Upcoming: Free Live Webinar

A Free Live Webinar over Aquifer Thermal Energy Storage (ATES) design, and construction. The date has not been determined yet, but notifications will



be sent out to those who complete the form below when a date is decided

[Sign-Up](#)

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 250 Charter lane suite 100  
 Macon, GA 31210



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## 4.5.2 4th Quarter 2020 Newsletter #2 – 159 Recipients



Hello {{ contact.FIRSTNAME }} {{ contact.LASTNAME }},  
Andrews, Hammock, and Powell has partnered with the DoD and ESTCP to present This Newsletter/Fact Sheet about Underground Thermal Energy Storage(UTES). For more information about UTES, upcoming events, and our recent activity please visit our website at [uteshub.com](http://uteshub.com).

### Recent Activity



#### Gulf Power Naval Air Station Pensacola FL

As mentioned in the previous newsletter, AH&P partnered with Gulf Power to implement Underground Thermal Energy Storage (UTES) as a DoD facility Energy Conservation Measure (ECM). Naval Air Station Pensacola (NASP) has been chosen as a candidate to implement an Aquifer Thermal Energy Storage

(ATES) system. Recently Andrews Hammock & Powell conducted an Aquifer Pumping Test on the old irrigation wells located near the proposed ATES site. An Aquifer Pumping test was conducted by continuously pumping water out of the well for 48 hours and monitoring the drawdown( specific capacity (GPM/Ft)) of the aquifer,as well as the flowrate. Drawdown is used in designing the well, specifically the pump and screen placement. For an ATES system, like the one being installed at NASP, specific capacity is also used to calculate mounding. Mounding contributes to an increase in pressure while injecting into a well. For our pumping test, the pump was set approximately 87 feet below grade and was operated for 48 hours at approximately 435 GPM.



This test concluded that the specific capacity of the formation is 17.1 GPM/Ft. In addition to the aquifer pumping test, AH&P also conducted a sand test and water chemistry sampling. A Sand Test reveals how much sand the well produces during pumping. Sand injected into the opposite well can clog the screen preventing water from passing through. The water samples taken will be used to determine iron content, turbidity, and PH. The results of the tests are currently being used to design the ATES system.

#### Dominion Energy

As mentioned in previous newsletters, AH&P has teamed with Dominion Energy to demonstrate a direct chilled water ATES as part of a Utility Energy Service Contract. A location for this project was recently chosen tat Fort Eustis in Newport News, Virginia. This is very exciting news and we are eager to begin!



**Marine Corp Logisitics Base,  
Albany, GA  
Bldg, 3700 Phase 1**



### Commissioning

The Marine Corps Logistic Base (MCLB) Albany, GA currently has four state of the art Borehole Thermal Energy Storage (BTES) systems coupled with geothermal systems. The first system was completed in 2015. However, due to recent framework updates, the systems need to be re-commissioned to ensure that the system is still operating as expected.

Phase 1, which consisted of functional testing of the temperaturesensors , pressure sensors, actuator operation, as well as verifying the sequence of operations, was recently completed. There were several issues discovered that are critical for proper operation of the BTES system. The most important being that the original sequence of operations is no longer in use, most of the system is in manual operating modes. The Dry Coolers are not functioning properly for energy storage, energy reduction, or freeze protection. To address these problem's AH&P recommends that the as-built sequence of operations is re-installed, and that hard-wired freeze protection be installed. This additional freeze protection will ensure that if the sequence of operations changes in the future, the dry coolers still have freeze protection. Due to the results of phase 1, a second more in-depth phase of re-commissioning has been planned. Phase 2 is expected to start soon and will include: designing hard-wired freeze protection for the Dry Coolers, reprogramming the system controls, performing a functional performance test on the entire system, and performing annual functional testing.

Want to see if an ATES or BTES system would be feasible for your project? follow the link below to a software that can determine feasibility.

[ATES-BTES Feasibility Software](#)

[More Information](#)

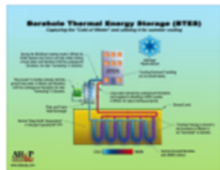
### Events



#### Free On Demand Webinar

Webinar about Underground Thermal Energy Storage for Geothermal Heat Pumps

[Watch](#)



#### Upcoming: Free Live Webinar

A Free Live Webinar over Underground Thermal Energy Storage for Electricity Generation(UTESe) systems. The Webinar will be held on Youtube Live on January 20th, 2021 at 1pm.

[Sign-Up](#)

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250 Charter lane suite 100  
Macon, GA 31210



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### 4.5.3 1st Quarter 2021 Newsletter #3 – 159 Recipients



Hello {{ contact.FIRSTNAME }} {{ contact.LASTNAME }},  
Andrews, Hammock, and Powell has partnered with the DoD and ESTCP to present This Newsletter/Fact Sheet about Underground Thermal Energy Storage(UTES). For more information about UTES, upcoming events, and our recent activity please visit our website at [uteshub.com](http://uteshub.com).

#### Recent Activity



##### Gulf Power Naval Air Station Pensacola, FL (NASP) Project

The Naval Air Station Pensacola Aquifer Thermal Energy Storage System (ATES) Design is moving along and this quarter some big steps have been taken. The Final Drawings and Specifications have been issued for the ATES system as one of the Energy Conservation Measures (ECM's) being considered under the current Utility Energy Service Contract (UESC) between NASP and Gulf Power. Currently in the Investment Grade Audit (IGA) phase, final ECM's are scheduled to be selected in the Fall.



Energy Analysis of the four barracks under consideration has also been completed on this project. The Baseline Analysis was done utilizing Carrier's HAP Software. AQTESolv and other software tools were used to determine the characteristics of the aquifer and it was found to exhibit the high transmissivity values needed. Upon the completion of the Energy Analysis, the ATES System is projected to eliminate 80%-90% of the gas consumption for all 4 Buildings as well as substantial electric savings.

##### US Forest Service HVAC Feasibility TCT - Virginia, USA

The US Forest Service project involves investigating 2 traditional Groundloop Heat Exchanger (GHX) borefields that have been causing some concerns. Two existing individual boreholes will be isolated from the existing GHX borefields. AH&P will then perform 2 Thermal Conductivity Tests to determine the thermal conductivity of the formation. Subsequently, computer models of the building/GHX will be created to determine the optimum configuration of the proposed , expanded GHX's.





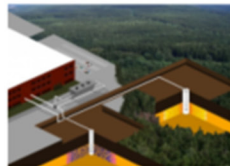
## Stockton University Geothermal Enhancements

The Stockton University project began in January of 2021 and consists of an upgraded design of the existing Geothermal Heat Exchangers (GHX) at several student housing buildings. There will also be an upgraded design to the pumps and control system, as well as the addition of Dedicated Outside Air Systems (DOAS). A site visit was made to the University to complete survey work in order to begin the design process that is presently underway.

[ATES-BTES Feasibility Software](#)

[More Information](#)

### Events



#### Free On Demand Webinars

Webinars related to Underground Thermal Energy Storage (UTES) Systems including BTES, ATES, and Commissioning and TAB are available on the [Federal Whole Building Design Guide Website!](#)  
**Coming Soon:** UTES for electrical storage purposes (UTESe) and UTES as an ECM under a UESC.

[View Webinars](#)



#### Cx and TAB of Geothermal Heat Pump Systems including UTES Webinar

A Free Live Webinar over Commissioning and TAB of Geothermal Heat Pump Systems. The Webinar was held on Youtube Live on March 10th, 2021 at 1pm. Although this Webinar has already been streamed, you can view it at the link below.

[Webinar Link](#)

[View in browser](#)

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#### 4.5.4 2nd Quarter 2021 Newsletter #4 – 159 Recipients



Hello Chuck Hammock ,  
Andrews, Hammock, and Powell has partnered with the DoD and ESTCP to present  
This Newsletter/Fact Sheet about Underground Thermal Energy Storage(UTES). For  
more information about UTES, upcoming events, and our recent activity please visit our  
website at [uteshub.com](http://uteshub.com).

### Recent Activity



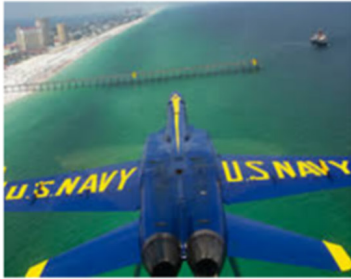
#### Stockton University Geothermal Enhancements

The Stockton University project is moving along at a steady pace, the design is underway, and there will be two vertical boreholes added to each of the existing geothermal fields for the 8 buildings that make up Housing 4 on campus. These boreholes will add capacity to the existing geothermal field and allow for entering water temperatures to maintain stable temperatures. Also, a leak detection plan has been written to locate underground leaks in the geothermal heat exchanger piping for the 6 buildings at Housing 5.

#### Gulf Power Naval Air Station Pensacola, FL (NASP) Project

The Naval Air Station Pensacola Aquifer Thermal Energy Storage System (ATES) Design is making great progress and this quarter General Contractors have recently bid on the ATES Project, which includes a Base Bid & Alternates #1, #2, & #3. After the bidding process, it was determined that the Base Bid and Alternates #1 & #3 will be considered.





The Base bid would include 4 Barracks, 6 ATES Wells, and 2 large Dry Coolers. Alternate #1 would include 2 Barracks, 4 ATES Wells, and 1 large Dry Cooler. Lastly, Alternate #3 will include 1 Barrack, 2 ATES Wells, and a smaller Dry Cooler. AH&P is very excited about this project and its progress. We are hopeful that funding for this project will be in place by Fall of 2021.



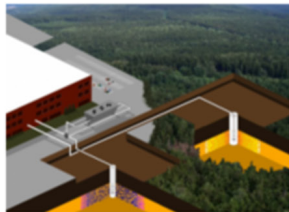
### US Forest Service HVAC Feasibility TCT - Virginia, USA

The US Forest Service project, which involves investigating 2 traditional Groundloop Heat Exchanger (GHX) borefields, has had a change in scope of work. The scope originally called for isolating two existing individual boreholes from the existing GHX borefields. AH&P would then perform 2 Thermal Conductivity Tests to determine the thermal conductivity of the formation. After further discussion, the owner decided to change the scope of work, which now includes drilling two new boreholes (one at each site) in close proximity to the existing borefields, then conducting the Thermal Conductivity Testing. Computer models of the building/GHX will be created to determine the optimum configuration of the proposed expanded GHX's. The owner is currently looking for Contractors to complete the work.

[ATES-BTES Feasibility Software](#)

[More Information](#)

## Events



### Free On Demand Webinars

Webinars related to Underground Thermal Energy Storage (UTES) Systems including BTES, ATES, and Commissioning and TAB are available on the Federal Whole Building Design Guide Website!

**Coming Soon:** UTES as an Energy Conservation Measure under a Utility Energy Service Contract

[View Webinars](#)

#### 4.6 PERSONNEL SATISFACTION WITH LIVE WEBINARS

Participants in each of the six webinars (formerly Regional Workshops prior to Covid) were given the option to receive a Professional Development Hours (PDH) Certificate worth 1.0 hours. To receive the PDH Certificate participants were required to complete a questionnaire located on the [www.UTEShub.com](http://www.UTEShub.com) website. Part of the questionnaire was to rate the webinar based on a scale of one to five stars, with one star being the lowest rating and 5 stars the highest rating. The success criteria for Personnel satisfaction was stated in the demonstration plan to be an average of 3.5 out of 5. This criteria was easily met with the weighted average of the scores below being **4.71 out of 5 stars**. A summary of the Webinar ratings is shown below.

**Table 2. Personnel Satisfaction with Live Webinars**

Webinar	# of Ratings	Average Rating
#1	28	4.75
#2	34	4.65
#3	31	4.65
#4	30	4.83
#5	17	4.65
#6	9	4.67

#### 4.7 PERSONNEL SATISFACTION WITH THE ON-DEMAND WEBINARS

Each of the six webinars were formatted and captions written for upload onto the Whole Building Design Guide (WBDG) Website. Each webinar was uploaded as an On-Demand Webinar. AIA and PDH credits were awarded to the participants after each participant completes the webinar and successfully complete a short test. The participants each have an opportunity to rate the webinar. The ratings and comments were recorded on the WBDG website. Each of the six webinars attendance, ratings, and comments are highlighted below. See the Appendix for more detailed statistics from [www.WBDG.org](http://www.WBDG.org). Of the 305 participants that took the time to rate the courses, **the weighted average, on a 5 point “star” scale, was 4.3 Stars, exceeding the 3.5 minimum Stars specified in the Demonstration Plan.**

# FUNDAMENTALS OF UNDERGROUND THERMAL ENERGY STORAGE (UTES) SYSTEMS

Sponsor: DOD | Course Type: On-Demand | Duration: 1.5 Hour(s) | Date Range: 01/01/2021 – 12/31/2021

## Training Statistics

ENROLLED	COMPLETED*	TRAINING HOURS	AVERAGE SCORE	CREDITS ISSUED
73	47 (64.4%)	109.5 Hours	86	47 AIA LU/HSW 70.5 PDH

[CSV \(/files/tools/crsvv.php?f=DOD\\_DOD09.csv\)](#)

\* Completed training, post-test and survey for certificate/credit.

## Evaluation

QUESTION	RESULT
Overall Satisfaction	8.2
Learning Format	8.4
Authors & Instructors	8.5
Content Quality	8.4
Relevance to Profession/Duties	7.2
Knowledge Level Pre-Course	5
Knowledge Level Post-Course	6.8

Figure 12. Personnel Satisfaction with On-Demand Webinar #1 (Yr 1)

# FUNDAMENTALS OF UNDERGROUND THERMAL ENERGY STORAGE (UTES) SYSTEMS

Sponsor: DOD | Course Type: On-Demand | Duration: 1.5 Hour(s) | Date Range: 01/01/2020 – 12/31/2020

## Training Statistics

ENROLLED	COMPLETED*	TRAINING HOURS	AVERAGE SCORE	CREDITS ISSUED
47	34 (72.3%)	70.5 Hours	88	49 AIA LU/HSW 51 PDH

[CSV \(/files/tools/crsvv.php?f=DOD\\_DOD09.csv\)](#)

\* Completed training, post-test and survey for certificate/credit.

## Evaluation

QUESTION	RESULT
Overall Satisfaction	9
Learning Format	9
Authors & Instructors	9.3
Content Quality	9.2
Relevance to Profession/Duties	7.9
Knowledge Level Pre-Course	5
Knowledge Level Post-Course	7.6

Figure 13. Personnel Satisfaction with On-Demand Webinar #1 (Yr 2)

## BOREHOLE THERMAL ENERGY STORAGE SYSTEMS (BTES)

Sponsor: DOD | Course Type: On-Demand | Duration: 1.5 Hour(s) | Date Range: 01/01/2021 – 12/31/2021

### Training Statistics

ENROLLED	COMPLETED*	TRAINING HOURS	AVERAGE SCORE	CREDITS ISSUED
👤 98	✅ 63 (64.3%)	🕒 147 Hours	📊 89	🌟 63 AIA LU/HSW 🌟 94.5 PDH

[CSV \(/files/tools/crsvg.php?f=DOD\\_DOD11.csv\)](#)

\* Completed training, post-test and survey for certificate/credit.

### Evaluation

QUESTION	RESULT
Overall Satisfaction ⓘ	8.5
Learning Format	8.7
Authors & Instructors	8.7
Content Quality	8.8
Relevance to Profession/Duties ⓘ	7.6
Knowledge Level Pre-Course ⓘ	5
Knowledge Level Post-Course	7.3

**Figure 14. Personnel Satisfaction with On-Demand Webinar #2**

## AQUIFER THERMAL ENERGY STORAGE (ATES)

Sponsor: DOD | Course Type: On-Demand | Duration: 1.5 Hour(s) | Date Range: 01/01/2021 – 12/31/2021

### Training Statistics

ENROLLED	COMPLETED*	TRAINING HOURS	AVERAGE SCORE	CREDITS ISSUED
👤 126	✅ 89 (70.6%)	🕒 189 Hours	📊 87	🌟 89 AIA LU/HSW 🌟 133.5 PDH

[CSV \(/files/tools/crsvg.php?f=DOD\\_DOD10.csv\)](#)

\* Completed training, post-test and survey for certificate/credit.

### Evaluation

QUESTION	RESULT
Overall Satisfaction ⓘ	8.7
Learning Format	8.8
Authors & Instructors	8.9
Content Quality	8.8
Relevance to Profession/Duties ⓘ	7.6
Knowledge Level Pre-Course ⓘ	6
Knowledge Level Post-Course	7.4

**Figure 15. Personnel Satisfaction with On-Demand Webinar #3**

# COMMISSIONING AND TAB OF GEOTHERMAL HEAT PUMP SYSTEMS

Sponsor: DOD | Course Type: On-Demand | Duration: 1.5 Hour(s) | Date Range: 01/01/2021 – 12/31/2021

## Training Statistics

ENROLLED	COMPLETED*	TRAINING HOURS	AVERAGE SCORE	CREDITS ISSUED
60	38 (63.3%)	90 Hours	90	38 AIA LU/HSW 57 PDH

CSV (/files/tools/crsvv.php?f=DOD\_DOD12.csv)

\* Completed training, post-test and survey for certificate/credit.

## Evaluation

QUESTION	RESULT
Overall Satisfaction	8.5
Learning Format	8.6
Authors & Instructors	9
Content Quality	8.8
Relevance to Profession/Duties	7.5
Knowledge Level Pre-Course	6
Knowledge Level Post-Course	7.5

**Figure 16. Personnel Satisfaction with On-Demand Webinar #4**

# UNDERGROUND THERMAL ENERGY STORAGE FOR ELECTRICITY GENERATION (UTESE)

Sponsor: DOD | Course Type: On-Demand | Duration: 1.5 Hour(s) | Date Range: 01/01/2021 – 12/31/2021

## Training Statistics

ENROLLED	COMPLETED*	TRAINING HOURS	AVERAGE SCORE	CREDITS ISSUED
4	2 (50%)	6 Hours	97	2 AIA LU/HSW 2 PDH

CSV (/files/tools/crsvv.php?f=DOD\_DOD14.csv)

\* Completed training, post-test and survey for certificate/credit.

## Evaluation

QUESTION	RESULT
Overall Satisfaction	8
Learning Format	9.5
Authors & Instructors	9.5
Content Quality	9.5
Relevance to Profession/Duties	7.5
Knowledge Level Pre-Course	7
Knowledge Level Post-Course	8

**Figure 17. Personnel Satisfaction with On-Demand Webinar #5**

# UTES AS A UESC AND ENERGY CONSERVATION MEASURE

Sponsor: DOD | Course Type: On-Demand | Duration: 1 Hour(s) | Date Range: 01/01/2021 – 12/31/2021

## Training Statistics

ENROLLED	COMPLETED*	TRAINING HOURS	AVERAGE SCORE	CREDITS ISSUED
7	6 (85.7%)	7 Hours	90	6 AIA LU/HSW 6 PDH

[CSV \(/files/tools/crsvg.php?f=DOD\\_DOD13.csv\)](/files/tools/crsvg.php?f=DOD_DOD13.csv)

\* Completed training, post-test and survey for certificate/credit.

## Evaluation

QUESTION	RESULT
Overall Satisfaction	
Learning Format	
Authors & Instructors	
Content Quality	
Relevance to Profession/Duties	
Knowledge Level Pre-Course	
Knowledge Level Post-Course	

**Figure 18. Personnel Satisfaction with On-Demand Webinar #6**

## 5.0 COST ASSESSMENT

This section is not applicable to a Technology Transfer Project. However estimated costs for implementation of ATES and BTES systems are included herein from Energy and Water Project EW-201135. Under project EW-201135, a Life Cycle Cost Analysis (LCCA) was completed. Costs of various critical components were either tracked or obtained from Contractors so the analysis could be applied to other military installations. Since each demonstration site involved construction funding from the military installation, all costs that could not be tracked directly were obtained from installing contractors.

The critical components relevant to the GHP-UTES technology tracked during the implementation of the demonstration project are listed in Table 7.1.

### 5.1 COST MODEL

**Table 3. UTES Cost Model**

		<b>Cost Element</b>	<b>Data Tracked During the Demonstration</b>	<b>Estimated Costs</b>	
BTES	Geothermal Heat Exchanger Vertical Borehole (GHX) System	<ul style="list-style-type: none"> <li>Capital Cost: \$ per foot of Vertical Borehole</li> <li>Installation Cost: \$ per linear foot of Vertical Borehole</li> </ul>	Total	\$1,207,514	
			\$/ft. Total	\$18.79	
ATES	ATES Cold & Warm Wells	<ul style="list-style-type: none"> <li>Capital Cost: \$ per foot of Vertical Well</li> <li>Installation Cost: \$ per foot of Vertical Borehole</li> </ul>	Total	\$53,742	
			\$/ft Total	\$33.59	
	Horizontal Piping for ATES Wells	<ul style="list-style-type: none"> <li>Capital Cost: \$ per foot of Vertical Well</li> <li>Installation Cost: \$ per foot of Vertical Borehole</li> </ul>	Total	\$25,980	
			\$/ft Total	\$16.24	
TES & ATES	Dry Coolers	<ul style="list-style-type: none"> <li>Capital Cost: \$ per Dry Cooler</li> <li>Install/Shipping Costs:</li> <li>Maintenance Cost:</li> </ul>	BTES Total	\$306,449	
			\$ per Dry Cooler	\$153,225	
			ATES Total	\$16,173	
			\$ per Dry Cooler	\$16,173	
BTES	Heat Recovery Modular Chillers	<ul style="list-style-type: none"> <li>Capital Cost: \$ per Modular Chiller</li> <li>Install/Shipping Costs:</li> <li>Maintenance Cost:</li> </ul>	Total	\$325,000	
			\$ per Chiller	\$65,000	
ATES	WSHPs	<ul style="list-style-type: none"> <li>Capital Cost: \$ per WSHP</li> <li>Install/Shipping Costs:</li> <li>Maintenance Cost:</li> </ul>	Total	\$25,900	
			\$ per WSHP	\$3,700	
BTES & ATES	Pumps & Injection Valves	<ul style="list-style-type: none"> <li>Capital Cost:</li> <li>Install/Shipping Costs:</li> <li>Maintenance Cost:</li> </ul>	BTES Total	\$53,000	
			ATES Total	\$31,661	

**Table 3. UTES Cost Model (Continued)**

		<b>Cost Element</b>	<b>Data Tracked During the Demonstration</b>	<b>Estimated Costs</b>	
BTES & ATES	Pumping Accessories (Air separators, expansion tanks, suction diffusers, etc.)	<ul style="list-style-type: none"> <li>Capital Cost:</li> <li>Install/Shipping Costs:</li> </ul>	BTES Total	Included in Pumps	
			ATES Total	Included in Pumps	
BTES & ATES	Controls and Control Components	<ul style="list-style-type: none"> <li>Capital Cost:</li> <li>Installation Cost:</li> <li>Maintenance Cost:</li> </ul>	BTES Total	\$517,000	
			ATES Total	\$86,400	
BTES & ATES	Maintenance	<ul style="list-style-type: none"> <li>Maintenance Cost/Yr.:</li> </ul>	BTES Total	\$10,000	
			ATES Total		
BTES & ATES	Training	<ul style="list-style-type: none"> <li>Cost of Training</li> </ul>	BTES Total	\$5,000	
			ATES Total	\$5,000	
BTES & ATES	Operational	<ul style="list-style-type: none"> <li>Utility Bills:</li> </ul>	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	<ul style="list-style-type: none"> <li>Cost of Commissioning</li> <li>Cost of TAB</li> </ul>	BTES Cx Total	\$74,000	
			BTES TAB Total	\$56,700	
			ATES Total	\$30,000	

**5.1.1 Cost Elements Description:**

Detailed information about the individual cost elements can be found in the Final Report of EW-201135.

**5.2 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 United States and were still able to achieve a favorable cost analysis. Other regions, where electrical energy costs are higher, will experience a greater annual electrical cost savings. This also applies to natural gas consumption and its associated energy cost. Water consumption is also a key factor that often gets overlooked in a cost analysis. Water consumption costs can help in most regions, especially those with high water usage costs, when water consumption can be substantially decreased, or even eliminated, as established at both sites for this demonstration.

Another cost driver is installation costs associated with drilling wells or boreholes. Some regions of the United States have lower drilling costs than others. This is generally attributed to the law of supply and demand. Areas, such as Texas, have more drillers than Georgia due to the oil and gas industry. As the oil and gas industry ebbs and flows, there are an abundance of drillers available, which has an impact and helps decrease the cost of drilling.

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. Hydrogeology is also important to BTES as high ground water movement impacts the ability to store thermal energy effectively. For ATES, hydrogeology is important as its operation is directly dependent upon the ability of the system to extract and inject groundwater. Geology is almost just as important as it is highly unlikely, for example, for a crystalline aquifer (i.e., rock) to achieve the ability for sufficient groundwater extraction or injection. Some site will have ideal conditions, which will lead to a decrease in capital investments cost. Sites who can achieve lower installation costs with ideal site conditions, along with lower energy/water costs, will benefit the most from the UTES technology.

### **5.3 COST ANALYSIS AND COMPARISON**

See the Final Report of EW-201135 for Cost Analysis and Comparison Data.

## 6.0 IMPLEMENTATION ISSUES

For implementation issues related to the original demonstration, see the Final Report for EW201135. Implementation issues related to the Technology Transfer were primarily limited to the impossibility of holding live seminars/workshops during the global pandemic. This turned out to be a blessing in disguise as the Live Webinars that were substituted allowed us to reach a larger audience and paved the way for the six On-Demand Webinars that are now hosted on the [www.wbdg.org](http://www.wbdg.org) in perpetuity.

## 7.0 REFERENCES

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## APPENDIX A POINTS OF CONTACT

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