Thank you for signing in early

The webinar will begin promptly at 12:00 pm ET, 9:00 am PT
SERDP and ESTCP Webinar Series

The webinar will begin promptly at 12:00 pm ET, 9:00 am PT

- You have two options for accessing the webinar
  1. Listen to the broadcast audio if your computer is equipped with speakers
  2. Call into the conference line: 303-248-0285
     Required conference ID: 6102000

- For any question or issues, please email serdp-estcp@noblis.org or call 571-372-6565
Combining Geothermal Heat Pumps with Underground Thermal Energy Storage

June 15, 2017
Welcome and Introductions

Rula A. Deeb, Ph.D.
Webinar Program Coordinator
Webinar Agenda

- Webinar Logistics (5 minutes)
  Dr. Rula Deeb, Geosyntec Consultants

- Overview of SERDP and ESTCP (5 minutes)
  Mr. Timothy Tetreault, SERDP and ESTCP

- Combining Geothermal Heat Pumps with Underground Thermal Energy Storage (55 minutes + Q&A)
  Mr. Chuck Hammock, Andrews, Hammock & Powell, Inc.

- Final Q&A session
How to Ask Questions

Type and send questions at any time using the Q&A panel.
In Case of Technical Difficulties

- Delays in the broadcast audio
  - Click the mute/connect button
  - Wait 3-5 seconds
  - Click the mute/connect button again
  - If delays continue, call into the conference line
    - Call into the conference line: 303-248-0285
    - Required conference ID: 6102000

- Submit a question using the chat box
SERDP and ESTCP Overview

Timothy Tetreault
Energy and Water Program Manager
SERDP

- Strategic Environmental Research and Development Program
- Established by Congress in FY 1991
  - DoD, DOE and EPA partnership
- SERDP is a requirements driven program which identifies high-priority environmental science and technology investment opportunities that address DoD requirements
  - Advanced technology development to address near term needs
  - Fundamental research to impact real world environmental management
ESTCP

- Environmental Security Technology Certification Program
- Demonstrate innovative cost-effective environmental and energy technologies
  - Capitalize on past investments
  - Transition technology out of the lab
- Promote implementation
  - Facilitate regulatory acceptance
Program Areas

1. Energy and Water
2. Environmental Restoration
3. Munitions Response
4. Resource Conservation and Resiliency
5. Weapons Systems and Platforms
Energy and Water

- Smart and secure installation energy management
  - Microgrids
  - Energy storage
  - Ancillary service markets
- Efficient integrated buildings and components
  - Design, retrofit, operate
  - Enterprise optimized investment
  - Advanced components
  - Intelligent building management
  - Non-invasive energy audits
- Distributed generation
  - Cost effective
  - On-site
  - Emphasis on renewables
### SERDP and ESTCP Webinar Series

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For upcoming webinars, please visit

A three-day symposium showcasing the latest technologies that enhance DoD's mission through improved environmental and energy performance

- November 28 - November 30, 2017
- Washington Hilton Hotel
  1919 Connecticut Avenue, NW
  Washington, DC 20009
- **Registration is open**
Combining Geothermal Heat Pumps (GHPs) with Underground Thermal Energy Storage (UTES)

Chuck Hammock
Andrews, Hammock & Powell, Inc.
Agenda

- Overview of GHPs and Thermal Energy Storage (TES)
  - Forms of TES and UTES
  - GHP design and integration

- Research details, results and benefits
  - Details, goals and results
  - Unanticipated technologies utilized
  - Project benefits, future opportunities, conclusions
Thermal Energy Storage

- Sensible, latent or both
- Diurnal, seasonal or both
- Aboveground (TES)
- Underground (UTES)
  - Borehole (BTES)
  - Aquifer (ATES)
- Other UTES
  - Hybrid UTES (TES + UTES)
  - Pit: Seasonal Snow Storage (SSS)
  - Abandoned Mines/Natural Caverns
  - “Energy Piles” (structural/thermal pile)
ESTCP Demonstration

- Sensible-only UTES
- BTES installed at Marine Corps Logistics Base (MCLB), Albany, Georgia
- ATES installed at Army’s Fort Benning, Georgia

Image Courtesy of IF Tech BV
BTES System at MCLB

- Groundloop Heat Exchanger (GHX) differed from conventional system
  - Three concentric thermal zones
  - Boreholes piped in series
  - Reversible water flow
  - Optimized for storage not “direct use”
  - Rejects heat at night and winter
BTES versus Conventional GHX

Circumferential headers

Radial sub-headers

Three thermal zones
ATES System at Fort Benning

- Design differed from conventional “open loop geothermal”
  - Every well is capable of extraction and injection
  - Reversible water flow
  - Dedicated warm and cold wells
  - Summer waste heat is winter heat source
  - Winter “waste cool” is summer cool source
ATES Extraction and Injection Well

- Confining clay layer
- Injection valve
- Submersible pump
- Intake filter screen with “gravel” pack
- Bedrock (granite)

Image Courtesy of AH&P/IF Tech BV

Natural gamma radiation: CPS
GHP Description

- A heat pump that uses the earth
  - Ground source heat pump (GSHP)
  - Geo-exchange system
  - Earth-coupled heating and cooling system
- Not used for electricity production
- Always involves a compressor
- Typically water-to-air or water-to-water
Water-to-Air GHP

Heat pump used at ATES project was similar to illustration

Image courtesy of IGSHPA/AH&P
Water-to-Water GHP

6-Pipe modular heat recovery GHP used at BTES project was similar to illustration.

Figure shows a bank of three modules:
- Module 1 in Heating
- Module 2 in Heating and Cooling
- Module 3 in Cooling

*Simplified single line water circuit shown; V=motorized isolation and control valve.

Images courtesy of Clima-Cool Corp.
GHPs “Harvest” the Advantages of Underground Geology

- Ground/aquifer is a superior heat sink, heat source
- Can store energy underground
- Underground “utilities”
  - Better energy security
  - Natural disaster immunity
  - Longevity

Foreground: BTES
Background: Tornado damage
Q&A Session 1
Research Details, Results and Benefits

- Project details
- Project goals and results
- Complementary technologies utilized
- Technology transfer successes
- Future opportunities for DoD and beyond
- Conclusions
Capturing building “waste cold” and “cold of the winter air” into extracted groundwater, reinjecting it, and storing it in the aquifer for summer cooling purposes (likewise heat)
ATES Extraction and Injection Well

- VFD/fiber optics comm/power backboard
- ATES well (400’ deep)
- Pitt containing piping components and injection valve controller
Adiabatic Dry Cooler for BTES/ATES

<table>
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<tr>
<th>Application</th>
<th>Heat Reject. COP</th>
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<tr>
<td>Air Cooled DX</td>
<td>100</td>
</tr>
<tr>
<td>BTES Max</td>
<td>1616</td>
</tr>
<tr>
<td>BTES Winter</td>
<td>200-1600</td>
</tr>
<tr>
<td>BTES Yr. Ave</td>
<td>200-300</td>
</tr>
<tr>
<td>Annual Water Reduction</td>
<td>BTES 80-100%</td>
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BTES adiabatic dry-cooler with: Evaporative cooling pads @ coil inlets. 18 compartmentalized ECM fans. (360 to 1 turndown), Modbus interface
BTES Schematic

Capturing building “waste cold” and the “cold of the winter air” into the geology/aquifer for summer cooling purposes
Aerial View of the BTES Construction
Plan View of the BTES
Section View of the BTES Sub-Header
Goals

- Reduce HVAC energy
  - By 30% vs. conventional HVAC
  - By 10% vs. conventional GHP/GHX designs
- Reduce tower water consumption by 80-100%
- Reduce on-site emissions by 100%
- Reduce GHX construction cost by 20%
- Reduce source carbon footprint by 40%
- Increase energy security/reduce water maintenance
## Results

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<th>Performance Objective</th>
<th>Metric</th>
<th>Data Requirements</th>
<th>Success Criteria</th>
<th>Results</th>
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<tr>
<td>Facility GHP-USTES HVAC Energy Usage vs. Conventional HVAC</td>
<td>Energy Intensity (MMBtu/ft² or kWh/ft²)</td>
<td>Actual metered readings of HVAC energy used by installation (baseline and demonstration); square footage of the buildings using energy</td>
<td>30% Reduction compared to baseline</td>
<td>BTES: 47.5% Reduction</td>
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<tr>
<td>Facility GHP-USTES HVAC Energy Usage vs. Conventional GHP HVAC</td>
<td>Energy Intensity (MMBtu/ft² or kWh/ft²)</td>
<td>Actual metered readings of demonstrated HVAC energy used by installation versus modeled conventional GHP HVAC; square footage of the buildings using energy</td>
<td>10% Reduction compared to Conventional GHP HVAC</td>
<td>ATES: 52.7% Reduction (Modeled)</td>
</tr>
<tr>
<td>Water Usage by On-Site Conventional Cooling Tower</td>
<td>Water (Gallons)</td>
<td>Actual metered readings of water used by installation (baseline and demonstration)</td>
<td>80-100% Reduction compared to baseline</td>
<td>100% Reduction compared to baseline</td>
</tr>
<tr>
<td>Direct On-Site Greenhouse Gas (GHG) Emissions for HVAC Space Heating</td>
<td>Direct on-site fossil fuel GHG emissions (metric tons)</td>
<td>Measured/calculated release of GHG based on source of energy (baseline and demonstration)</td>
<td>100% Reduction compared to baseline</td>
<td>100% Reduction compared to baseline</td>
</tr>
<tr>
<td>Installed Cost Of GHP-BTES vs. Conventional GHP Systems</td>
<td>HVAC Construction Cost</td>
<td>Construction cost data from construction contractor for both GHP-BTES and alternate conventional GHP design</td>
<td>20% Construction Cost Reduction from conventional GHP systems vs. GHP-BTES systems</td>
<td>33.6% Reduction</td>
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<tr>
<td>Greenhouse Gas Emissions at Source (Power Plant) to power Air-to-Air Heat Pumps vs. GHP-USTES System</td>
<td>Source fossil fuel GHG emissions (metric tons)</td>
<td>Measured/calculated release of GHG at Source (demonstration) versus an Hour-By-Hour model of project building with air-to-air heat pumps (baseline)</td>
<td>40% reduction compared to air-to-air baseline model</td>
<td>BTES: 32.5% Reduction</td>
</tr>
<tr>
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<td>ATES: 26.5% Reduction (Modeled)</td>
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How Were Savings Achieved?

- “Traditional” GHP benefits
  - Superior heat sink
  - Superior heat source

- UTES-BTES/ATES contributions
  - Deliberately stratified cold storage
  - Reversibility
  - Less GHX needed (BTES)

- Complimentary technologies integrated
  - Heat recovery, adiabatic dry-coolers, distributed temperature sensing (DTS)
Temperature Plots of Inner, Middle and Outer Borehole Delta T’s

Sample plot of water temperatures differentials across three boreholes in series, “charging” the BTES in late fall with “cold”. The teal line is the delta T across the inner borehole, the green the middle borehole and the blue the outer borehole. The most heat transfer is occurring exactly where it is needed …. at the core of the BTES
BTES Diurnal Storage

Discharge During “Shoulder” Periods

Blue shading represents “charging”, (cold storage) or heat being removed from the BTES (typical)

Red shading represents “discharging”, (cold usage) or heat being rejected into the BTES (typical)

Sample plot of water temperatures during DIURNAL STORAGE times in late fall (“cold-discharging” during the day and “cold-charging” at night)
BTES Seasonal Storage

Cold Storage During Winter Months

Sample plot of water temperatures during SEASONAL STORAGE times in winter ("cold-discharging" during the day and "cold-charging" at night)

Blue shading represents “charging”, (cold storage) or heat being removed from the BTES (typical)
BTES Cold Discharge

Borehole Receiving Heat During Warmer Periods

Red shading represents “discharging”, (cold discharge) or heat being received by the BTES (typical)

Sample plot of water temperatures during cold discharging-only mode in early fall
BTES Reversing Valves
Less GHX Needed!

66 Ton BTES
BTES-2 MCLB Albany GA

183 Ton BTES
BTES-3 MCLB Albany GA

56 Ton BTES
BTES-4 MCLB Albany, GA

BTES-5 VA
Perry Point, MD

“Oval” BTES-5, VA
Complimentary Technologies

- Unanticipated “discoveries” along the way
  - Adiabatic dry-coolers
  - R410a heat-recovery 6-pipe water-to-water GHPs that efficiently deliver “free” 110°F space heating hot water
  - Fiber optic based DTS
Distributed Temperature Sensing (DTS)

Using fiber optic cable as a continuous temperature sensor
DTS Cable/Well Layout at BTES

DTS cable routed in 9 DTS wells
Layered Thermal Conductivity Test/ Distributed Thermal Response Test (DTRT/LTCT)

- Marines Corps Logistics Base, Albany GA
- One of the first ever conducted in U.S.
- 110 m u-bend borehole heat exchanger adjacent to BTES
- A 72-hour LTCT was conducted between May 12 and 14, 2015 and heat pulse tracked via DTS
- Layer-by-layer K values measured
LTCT/DTRT Downhole Temperatures

Outlet water from the U-bend (surface)

Bottom of the U-bend (Axis of Symmetry)

Inlet water into the U-bend (surface)

This contour diagram shows the fluid temperature along the whole heat exchanger over the time observed. Right hand side is after elements de-energized.
Video of BTES DTS System

Heat is Pumped into a test well May 2015 for 72 hours

Next, residual heat flows from the test well into parts of the BTES over 10 days

https://www.youtube.com/watch?v=Xrqex73F_ic
Project Benefits

- Demonstrated to the skeptics that energy efficiency could increase while simultaneously increasing energy security and HVAC reliability
- “Technology transfer” could be achieved in months, not years
- The water-energy nexus was real. A “slider bar” could be provided
Future Opportunities

- BTES is a 50 state technology
- ATES is dependent on the availability of a suitable aquifer, but holds the promise of even higher efficiencies
- “Direct ATES”, the direct storage of chilled water in the aquifer has achieved 85% energy savings in Europe and is applicable in the northern half of the US
- DTS applications go beyond BTES/ATES and include environmental applications, heat detection, dam seepage monitoring, electrical power cable monitoring and more
Conclusions

- Consider GHPs with UTES
  - Reduce utility costs, kWh, kWd, on-site emissions, water consumption, on-site fossil fuel consumption, maintenance cost and improve reliability
  - Increase the energy security of your base/campus, infrastructure and facilities
  - Want to leave your workplace/profession better off than when you arrived (leave an enduring legacy)
  - Catch up with international GHP advances and then, reliably move the state-of-the-art forward
Conclusions

- DoD demonstrated the next generation of GHPs that can improve energy efficiency and enhance energy security.
- It is important that each of us take initiative and contribute to our field and move the HVAC industry forward.
- ESTCP’s success with EW-201135 helps DoD end-users to confidently move their location forward towards success!
For additional information, please visit: https://www.serdp-estcp.org/index.php/Program-Areas/Energy-and-Water/Energy/Distributed-Generation/EW-201135

Speaker Contact Information
chammock@ahpengr.com; 478-405-8301
Q&A Session 2
The next webinar is on June 29, 2017

Future Vulnerabilities to Alaskan Ecosystems and Tools for Permafrost Assessment
Survey Reminder

Please take a moment to complete the survey that will pop up on your screen when the webinar ends.