Underground Thermal Energy Storage (UTES)

(UTES/BTES/ATES/$BTES_e$)

Robins AFB SAME Post

21 AUG 2024

Society of SAME American Military Engineers

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U.S. AIR FORCE

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Presented By:
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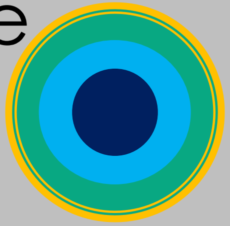
Presentation Outline

- Why consider "Geothermal" systems?
- Overview of "Direct-Use" (typical "American" system) Geothermal Heat Pumps (GHP) architecture vs. GHP systems designed for true thermal storage (historically not done in the US)
- Underground Thermal Energy Storage (UTES)
  - Borehole Thermal Energy Storage (BTES) Systems
  - Aquifer (ATES) Systems
  - Brief overview of CHPs, $BTES_e$, $ATES_e$, SSS, CTES, etc.
- Review of the DoD UTES Demonstration projects
- Briefing on current DoD project with Clemson University for ht-BTES or $BTES_e$ for electrical power generation from an underground thermal battery

Primary Differences: "Direct Use" Geothermal vs. UTES Geothermal

- Direct Use: Typical American ***closed loop*** piped in a grid with parallel flow or is a "one-way" ***open loop*** that can't capture waste heat/"cool"
- Geo still used at Heat Sink & Heat Source but optimized to deliberately store cold or hot.
- Closed loop UTES (BTES) boreholes generally piped as 3-6 boreholes in series for deliberate thermal stratification or zones (bull's-eye)



- UTES (ATES or BTES) has the capability to reverse the flow to "charge" or "discharge" its stored thermal resource

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Underground Seasonal Thermal Energy Storage (USTES) via Boreholes or Aquifers

- **Cooling Dominated Buildings**: Capture the "cold" of winter (or process "waste cool")and store it in underground formations or aquifers and "harvest" it in summer to cool the building
- **Heating Dominated Buildings:** Capture the "hot" of summer or waste/solar heat and store it in underground formations or aquifers and "harvest" it in winter to heat the building
- **Balanced Buildings:** Do Both!!!
- In reality, all good USTES will do some Diurnal Storage (UDTES) so overall they are simply ***UTES*** Sys.

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DoD's ESTCP Program

ESTCP
Environmental Security Technology Certification Program

Proposal Cover Page

FISCAL YEAR 2011 RESEARCH PROPOSAL COVER PAGE
ENVIRONMENTAL SECURITY TECHNOLOGY CERTIFICATION PROGRAM (ESTCP)
(THIS FORM MAY NOT BE HANDWRITTEN)

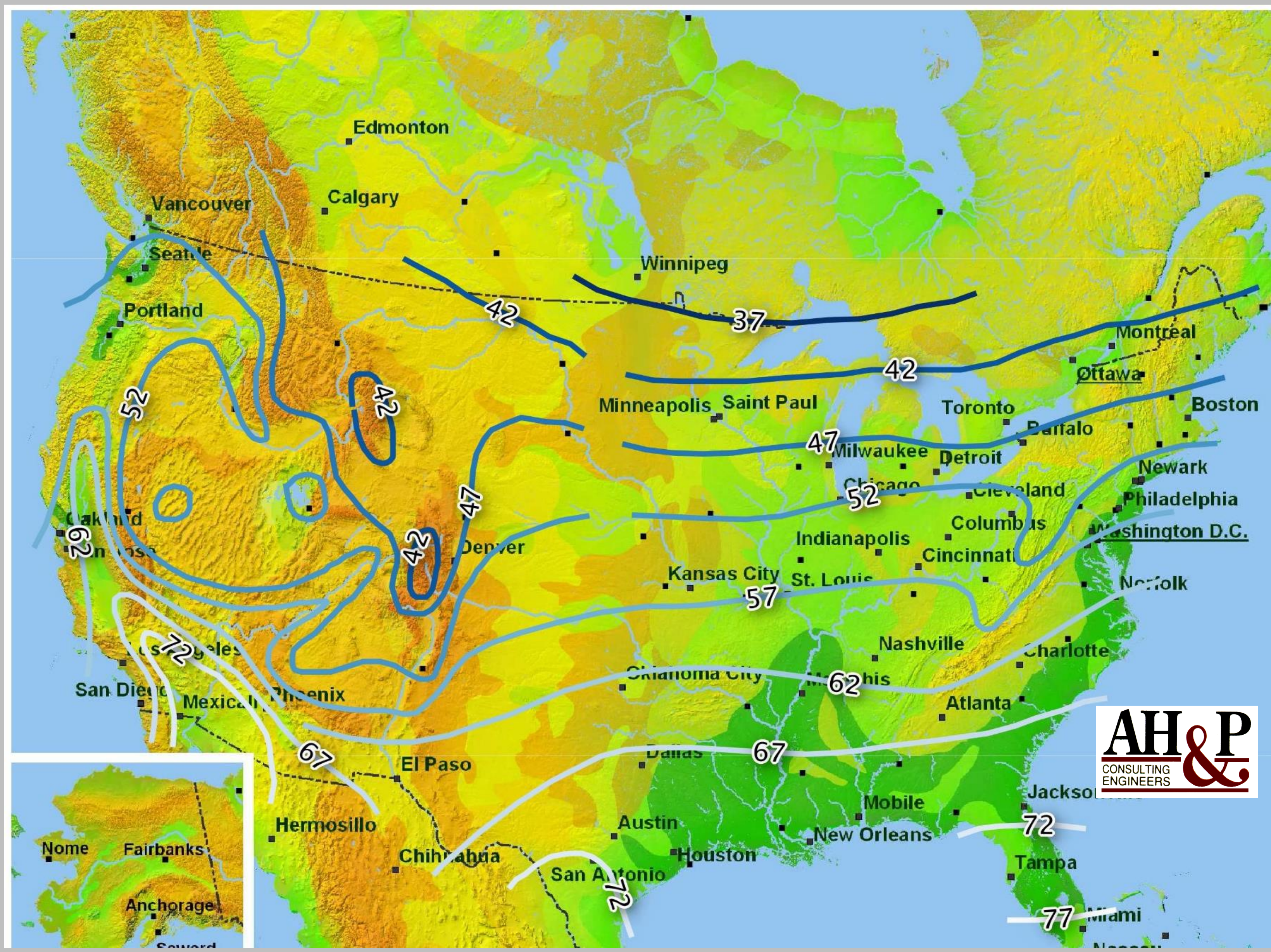
1. Topic Area Number : Topic 4. Energy Efficiency and Renewable Energy for DoD Installations	**2. ESTCP Number:** 11 EB-SI4-021
3. Proposal Title: Coupling Geothermal Heat Pumps(GHP) with Underground Seasonal Thermal Energy Storage(USTES)	
4. Principal Investigator Name: Mr. Charles W Hammock, Jr. **4a.Express Mailing Address:** Andrews, Hammock & Powell, Inc.-Consulting Engineers 250 Charter Lane **4b. City:** Macon **4c. State:** Georgia **Zip:** 31210 **Country:**	**5.Contact Information:** **Phone:** 478-405-8301, Ext. 102 **Fax:** 478-405-8210 **Email:** chammock@ahpengr.com
6. Type of Organization: Business	**6a. Organization Subcategory:** Small

DoD's ESTCP Demonstration Project Description/Goals

Though highly efficient, and utilized around the world, GHPs w/USTES are non-existent in the USA. This project will Demonstrate two viable GHP-USTES architectures that:

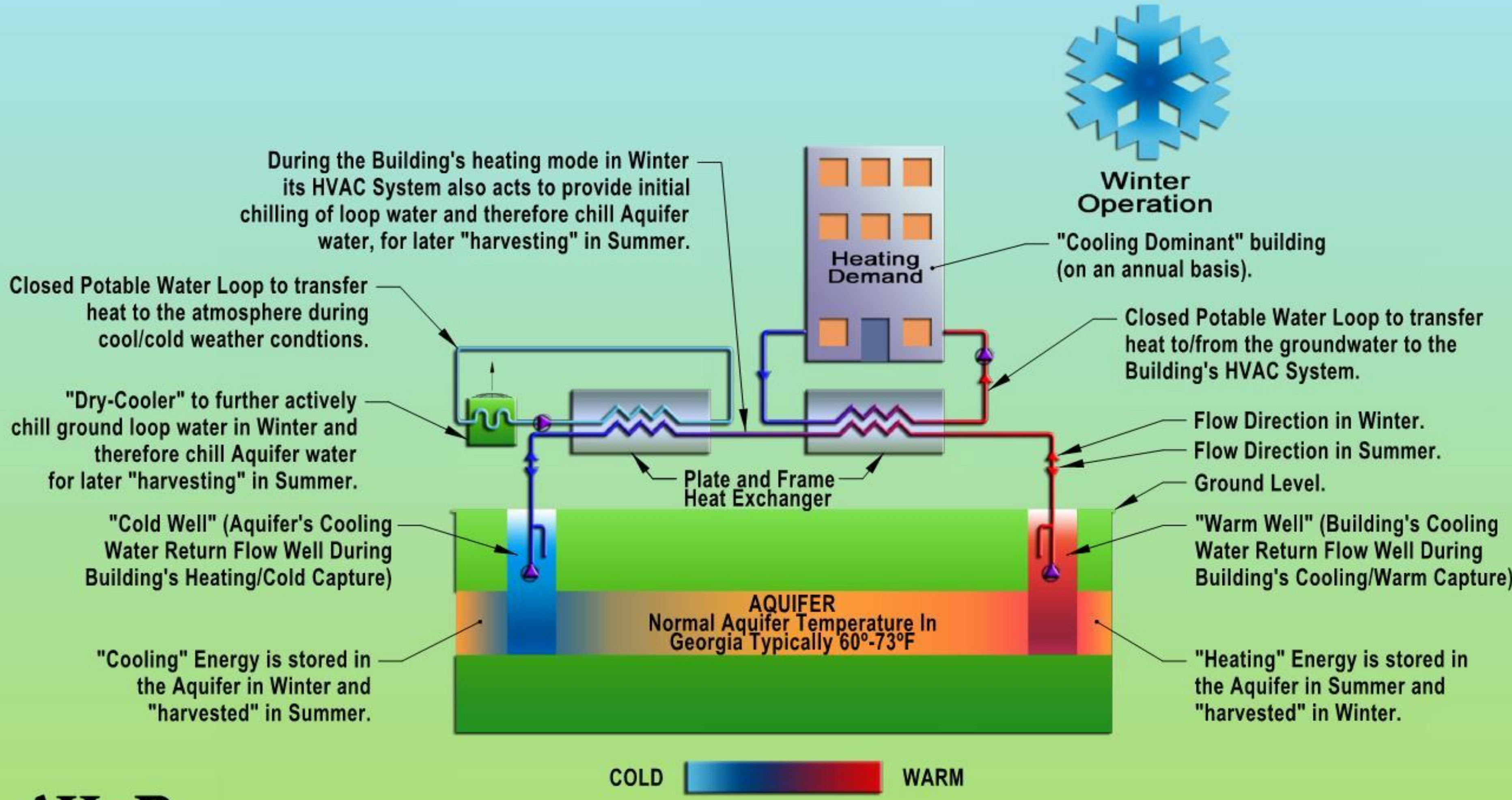
- Reduce installed cost 20% below conventional/full GHPs
- Reduce HVAC energy cost at least 30% below conventional HVAC and at least 10% below full Geo
- Have no on-site emissions, 80%-100% less cooling water consumption, 40% smaller carbon footprint
- Provide Bases a *truly sustainable infrastructure* "inside the fence" (aka Energy Security)

Approximate (+/-3^{O}F) Ground/Groundwater Temperatures



Aquifer Thermal Energy Storage (ATES)

Capturing the "Cold of Winter" and utilizing it for summer cooling



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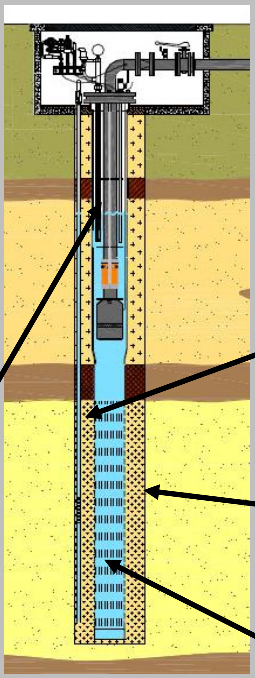
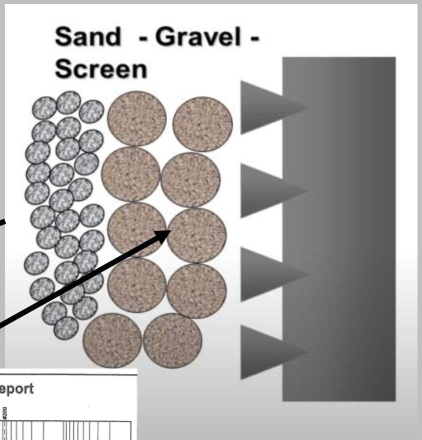
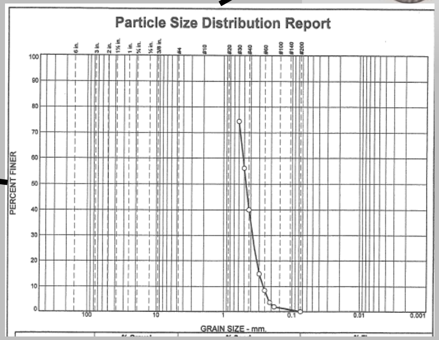
ATES Well Construction

- Well Construction Overview & Material Options
- Well Screens
- "Gravel Pack"
- Pumps





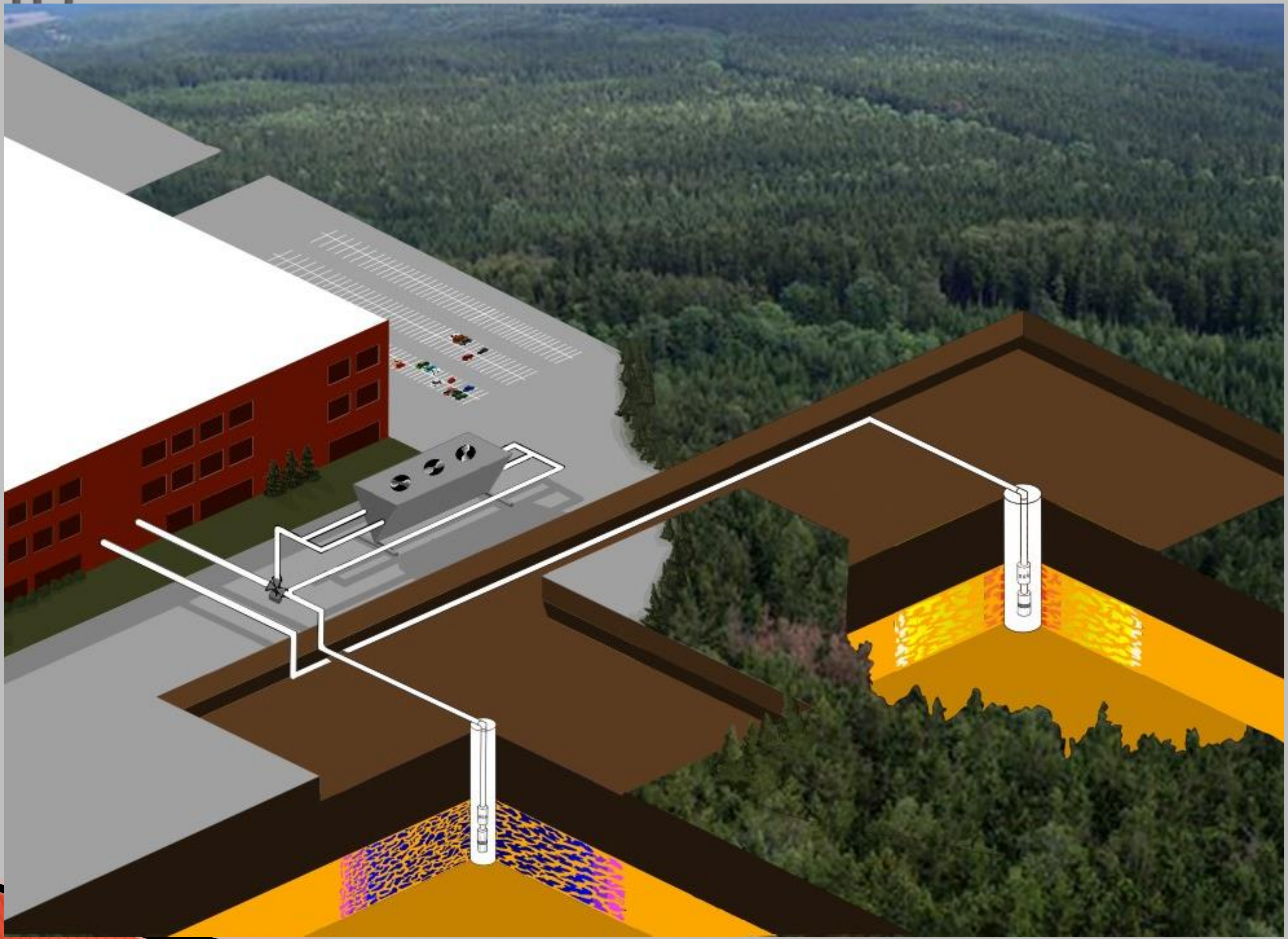


Solvent Welded or Spline Fittings on Drop Pipe

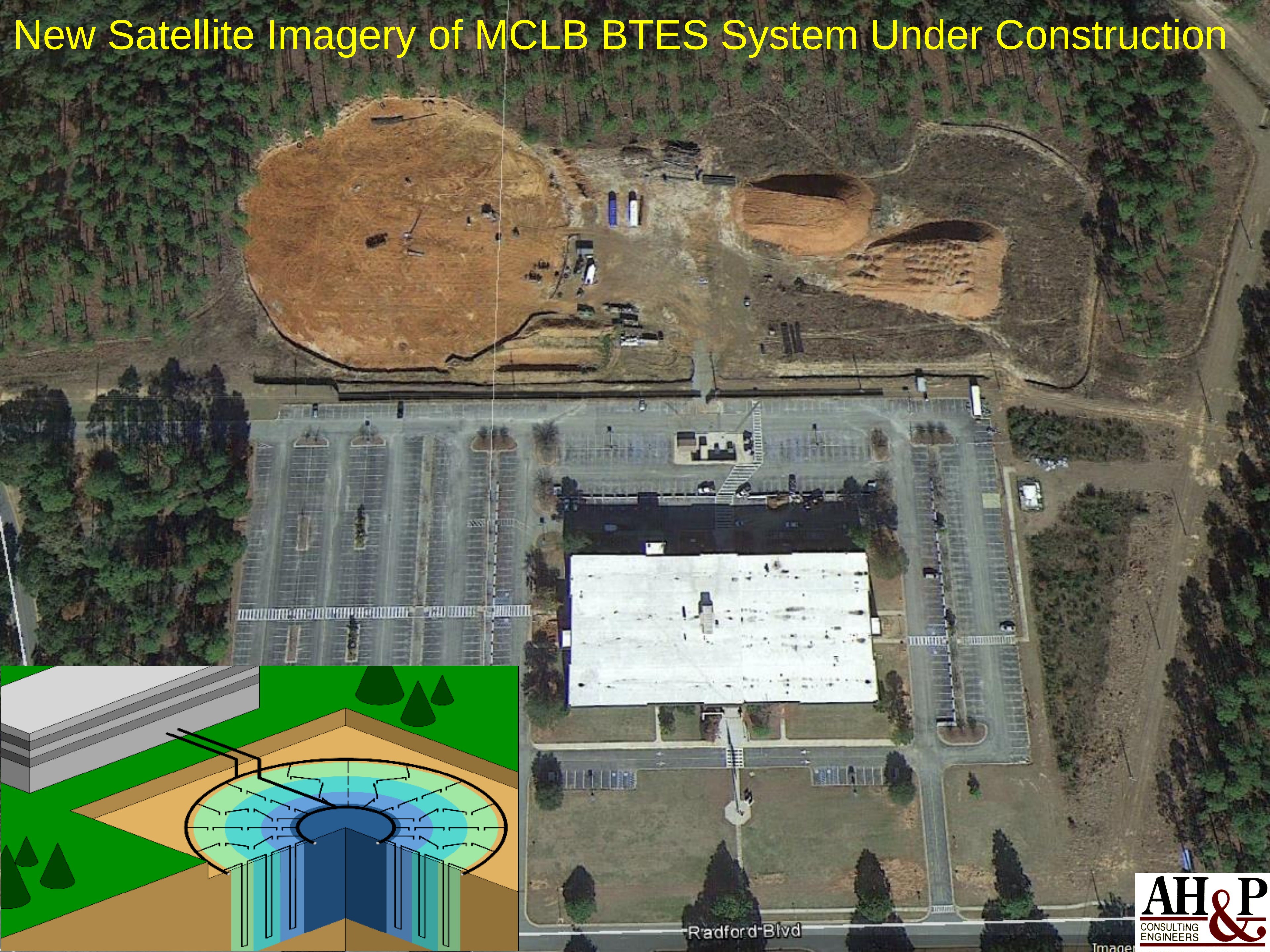
PVC Well Screen with Horizontal Slots

Construction of ATES wells at Ft. Benning

Isometric of an ATES system Illustrating the “”Cold Well” (left) and the “Warm Well” (right)



New Satellite Imagery of MCLB BTES System Under Construction



BTES Construction Progress

Grouting/Drilling/Tremie Rigs, U-Bend, Off-Road Dump Truck

Reversing Valves for BTES

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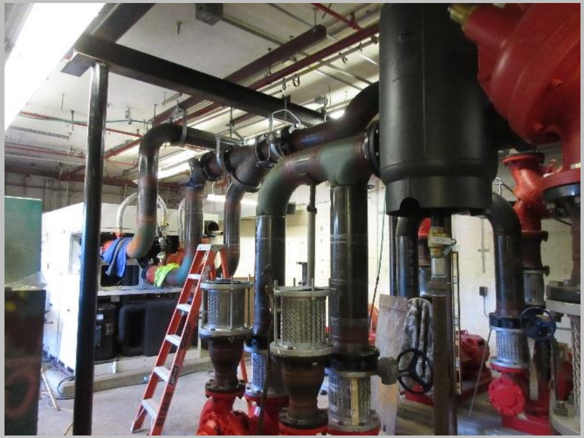
BTES Mechanical Room, Heat-Recovery GHP, DTS Well and Bore-field



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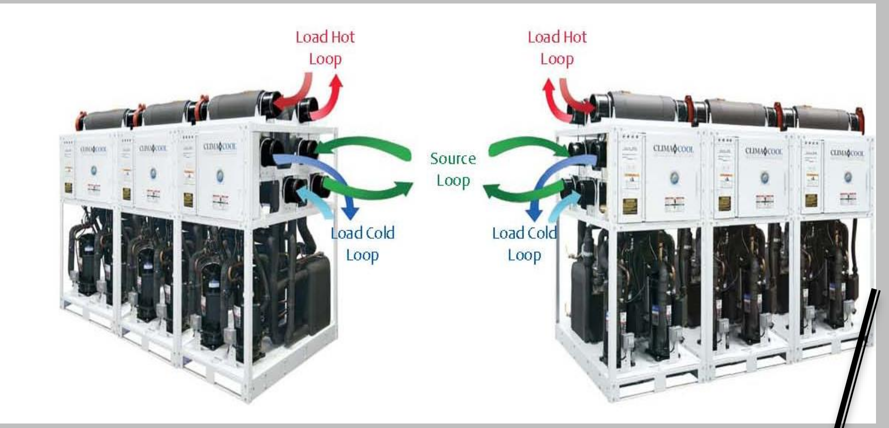
BTES Water-To-Water, Energy Recovery, GHP (Chiller/Boiler)



Utilize free heat to reduce energy consumption
Heat Recovery Model:

- Simultaneous heating/cooling available from each module
- Provides hot water, as high as 135°, utilizing R-410A refrigerant and 170° utilizing R-134a refrigera
- Built in modulating head pressure control

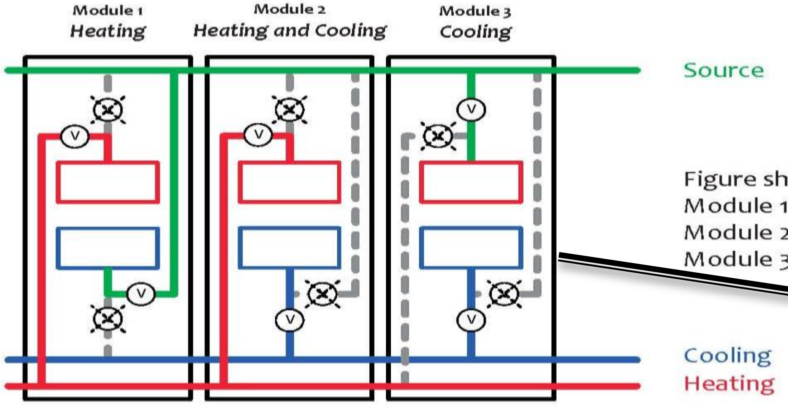


Figure shows a bank of three modules:
Module 1 in Heating
Module 2 in Heating and Cooling
Module 3 in Cooling

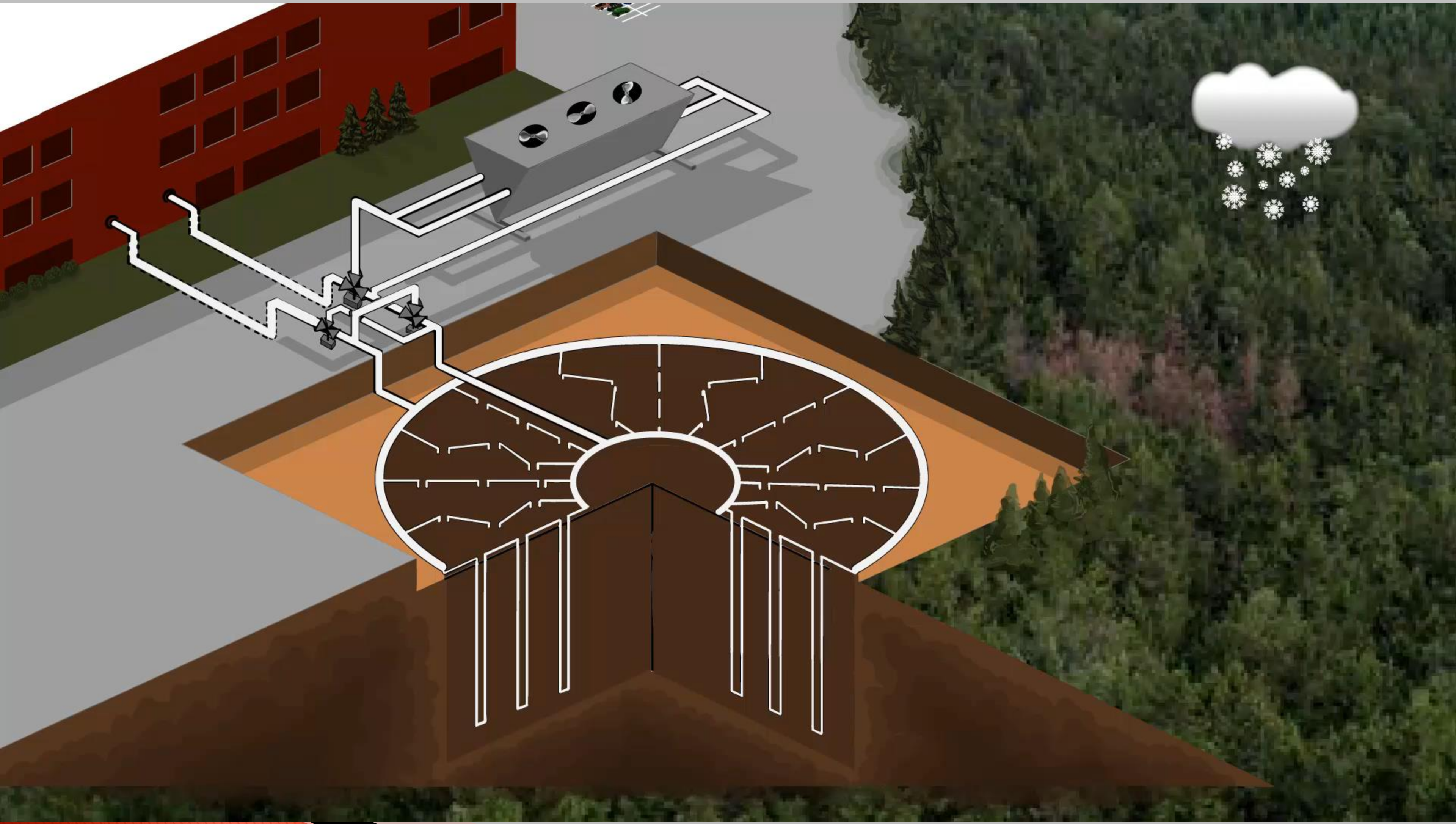
*Simplified single line water circuit shown; V=motorized isolation and control valve

Adiabatic Dry Cooler for BTES/ATES

Application	Heat Reject. COP
Air-Cooled-DX	100
BTES Max	1616
BTES Winter	200-1600
BTES Yr. Ave	200-400
Annual Water Reduction	
BTES	80-100%

Adiabatic Dry-Cooler with: Evaporative Cooling Pads @ Coil Inlets. 18 Compartmentalized ECM Fans. (300 to 1 turndown), Modbus Interface

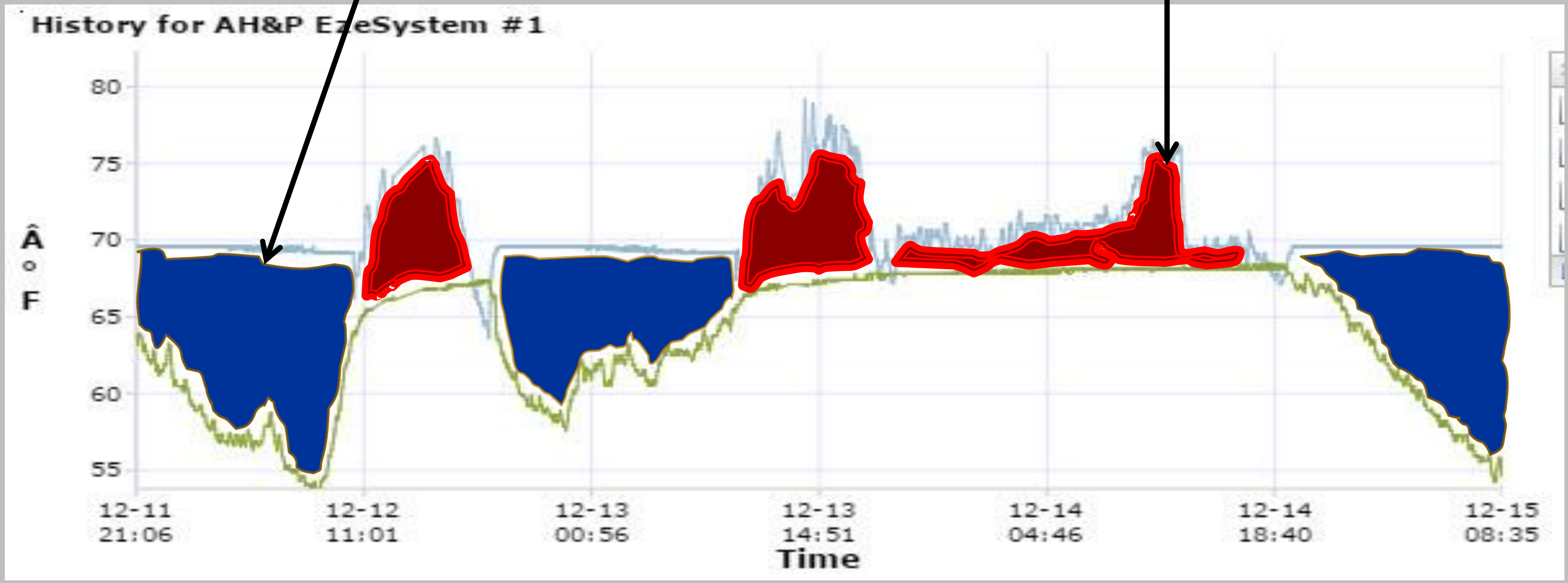
Video Illustration of the “Cold” BTES Systems at the Marine Corps Logistic Base(MCLB) in Albany, GA being “Charged” in winter and “Discharged” in summer



BTES diurnal storage/discharge during "shoulder" periods

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

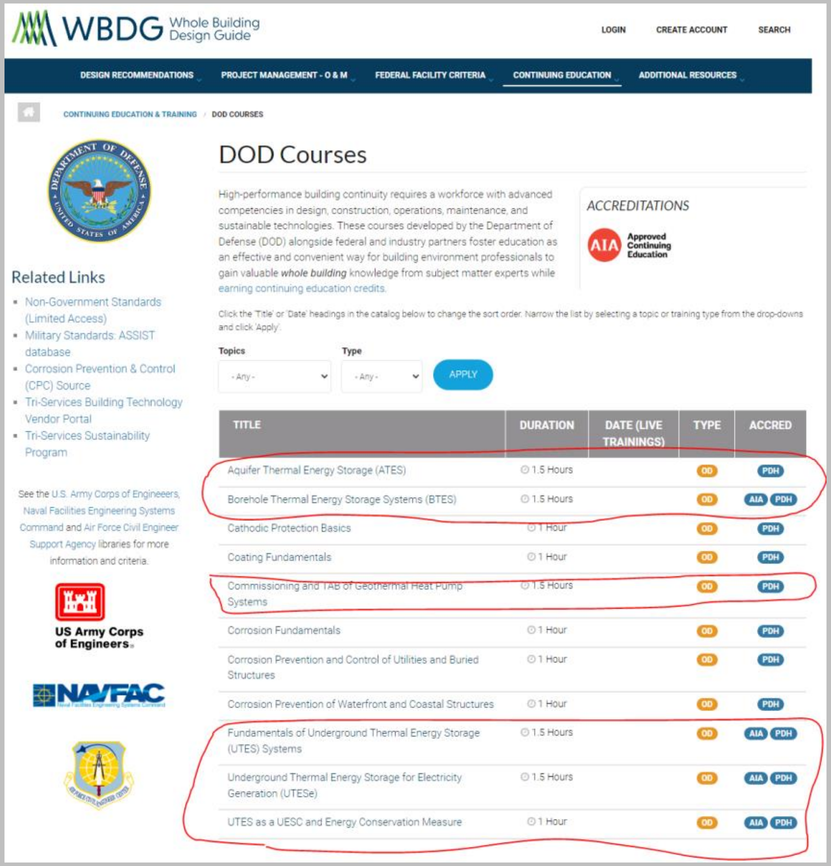
Red shading represents "discharging", (cold usage) or heat being rejected into the BTES (typical)

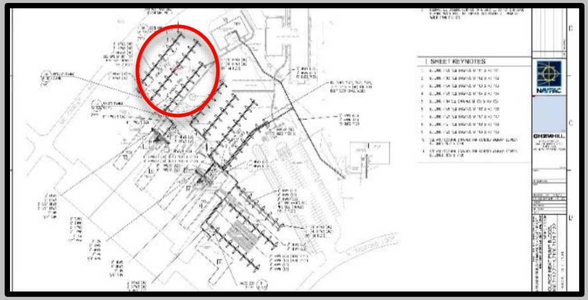


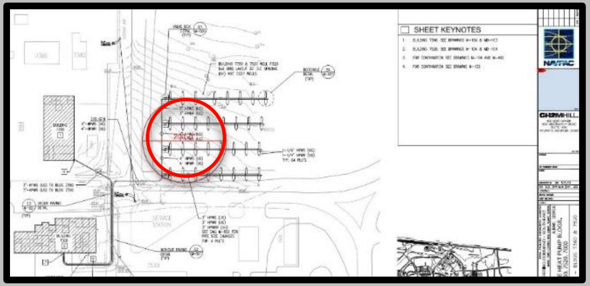
Sample plot of water temperatures during DIURNAL STORAGE times in late fall ("cold-discharging" during the day and "cold-charging" at night)

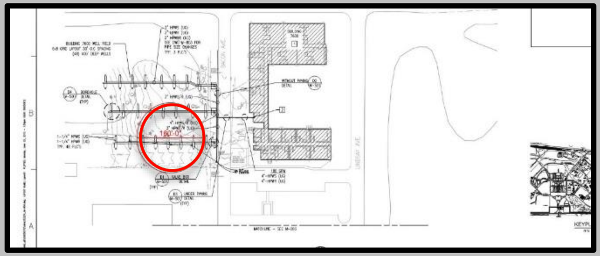
Technology Transfer

- Real world seminars, workshops, educational forums, magazine articles, international cooperation, etc.
- Three more DoD projects at MCLB: BTES-2/3/4
- Active ht-BTES (or $BTES_e$) DoD/ESTCP Project

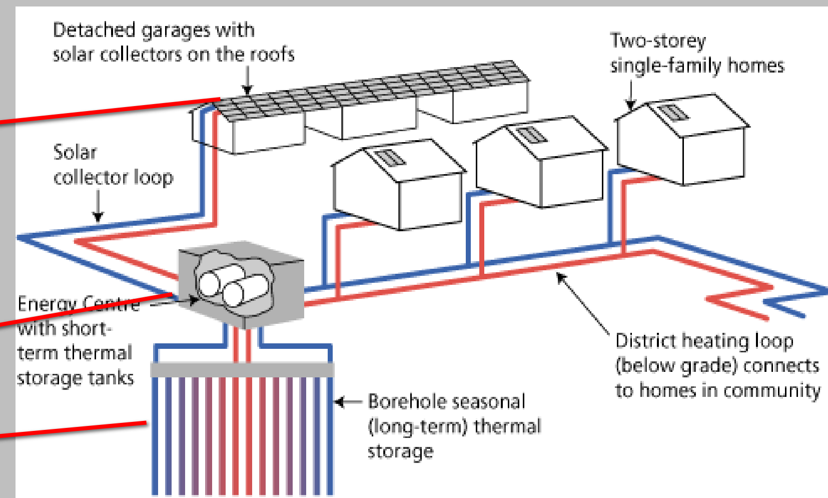




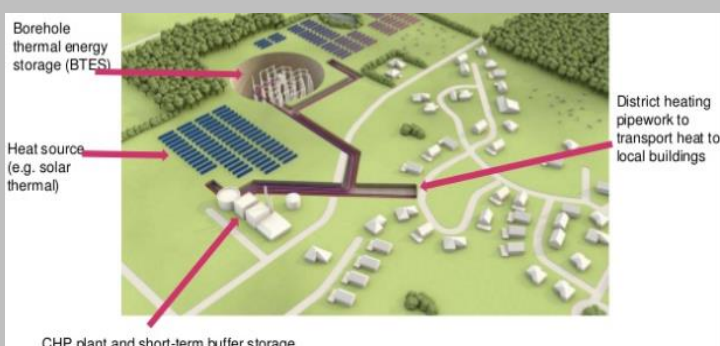


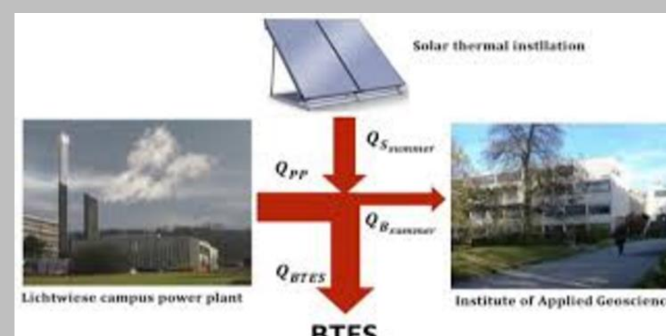


BTES for Non-GHP Applications



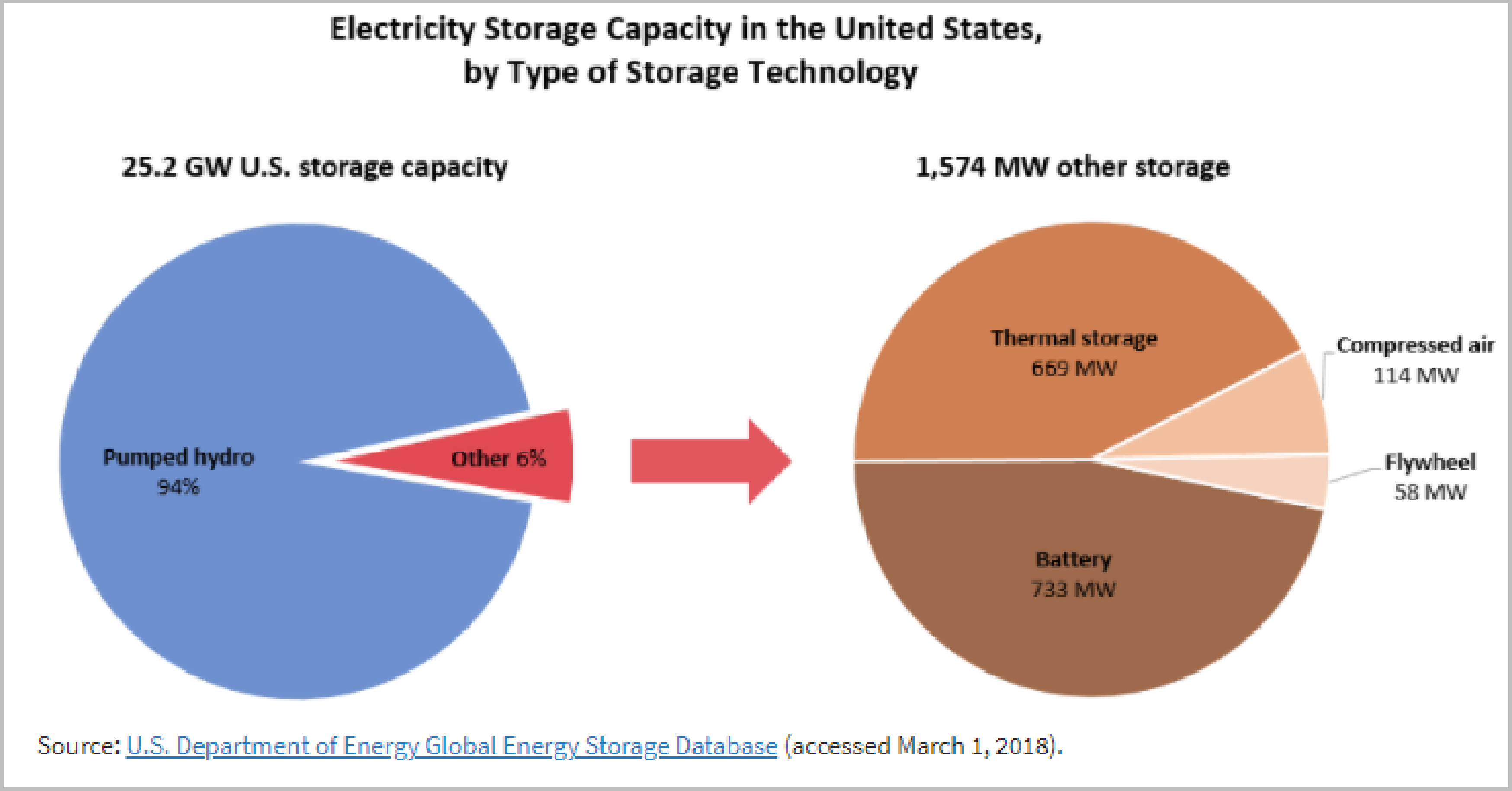
Solar Thermal Application-Drakes Landing, Canada
“Hybrid” with above ground thermal storage and BTES





Combined Heat and Power (CHP) plant with BTES

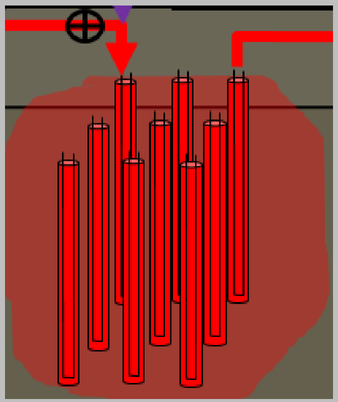
Current Energy Storage in the US



Note: This DOE slide is being investigated further but the % are believed to be accurate. Power is a “rate” often measured in watts (a joule per second) or at scale, Gigawatts-GW, whereas actual “Energy”, might be measured in Joules or Gigawatt-hours. The author may have intended to utilize GWH, not GW for this slide

Why Consider UTES$_e$ Systems?

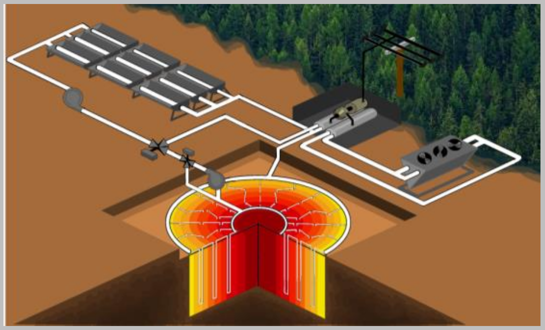
- The storage component ideally is resilient against:
  - Weather like tornados, floods, hurricanes, high winds, earthquakes, tsunamis, fire, etc. and would ideally keep a DoD Base ***powered for days*** when, just for example, when a Hurricane hits a costal Installation
  - Terrorist activities or runaway fire/explosion issues. Underground is as safe as it gets and doesn't require a building or security personnel



- All system components typically produced in the USA, and not potential hostile/interruptible foreign suppliers (supply chain issues)
- Is scalable from kWh to mWh to gWh capacities and can potentially be done at 1/10th the cost (or better) per kWh of storage vs. electro-chemical or other system architectures

Why Consider $UTES_e$ Systems?

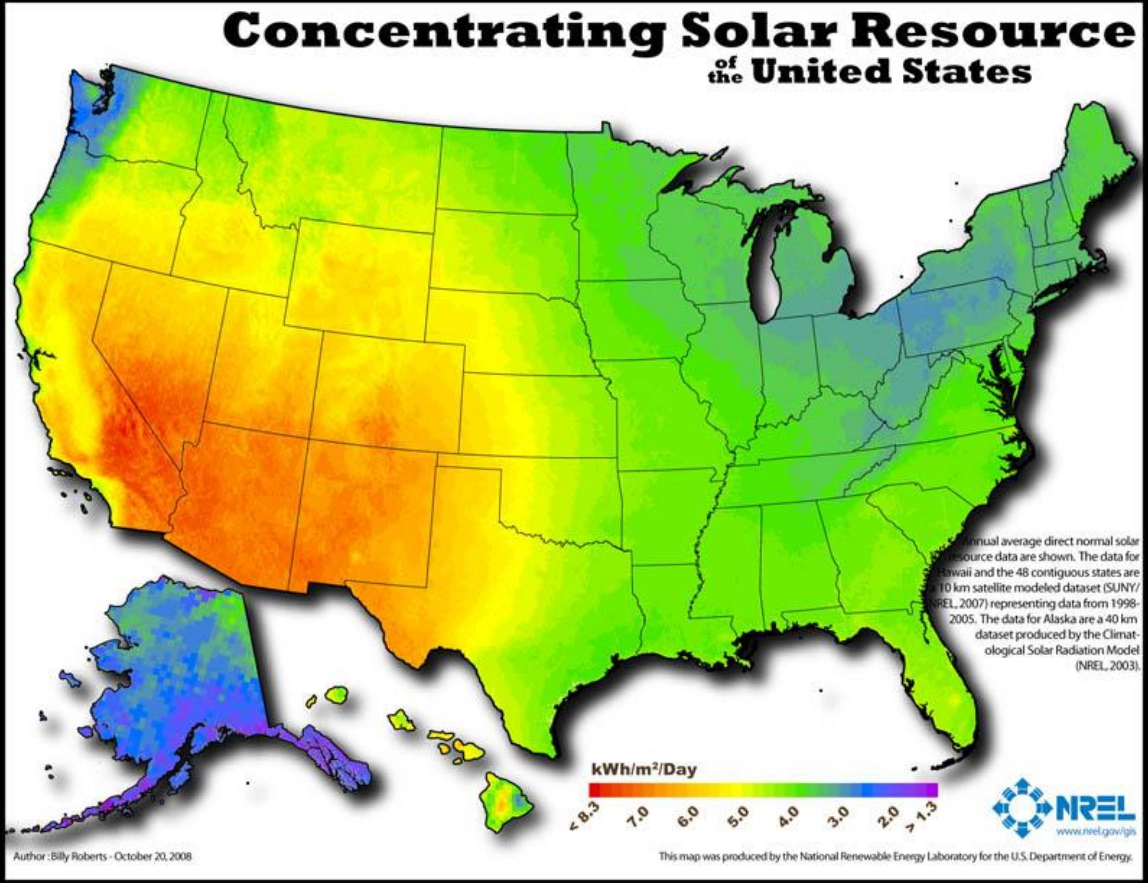
- Utilities and DoD cannot fully count on Solar PV as its output is intermittent and day/week-scale battery systems are unaffordable. Therefore, conventional baseline power systems must be present and capable of covering 100% of the load at all times



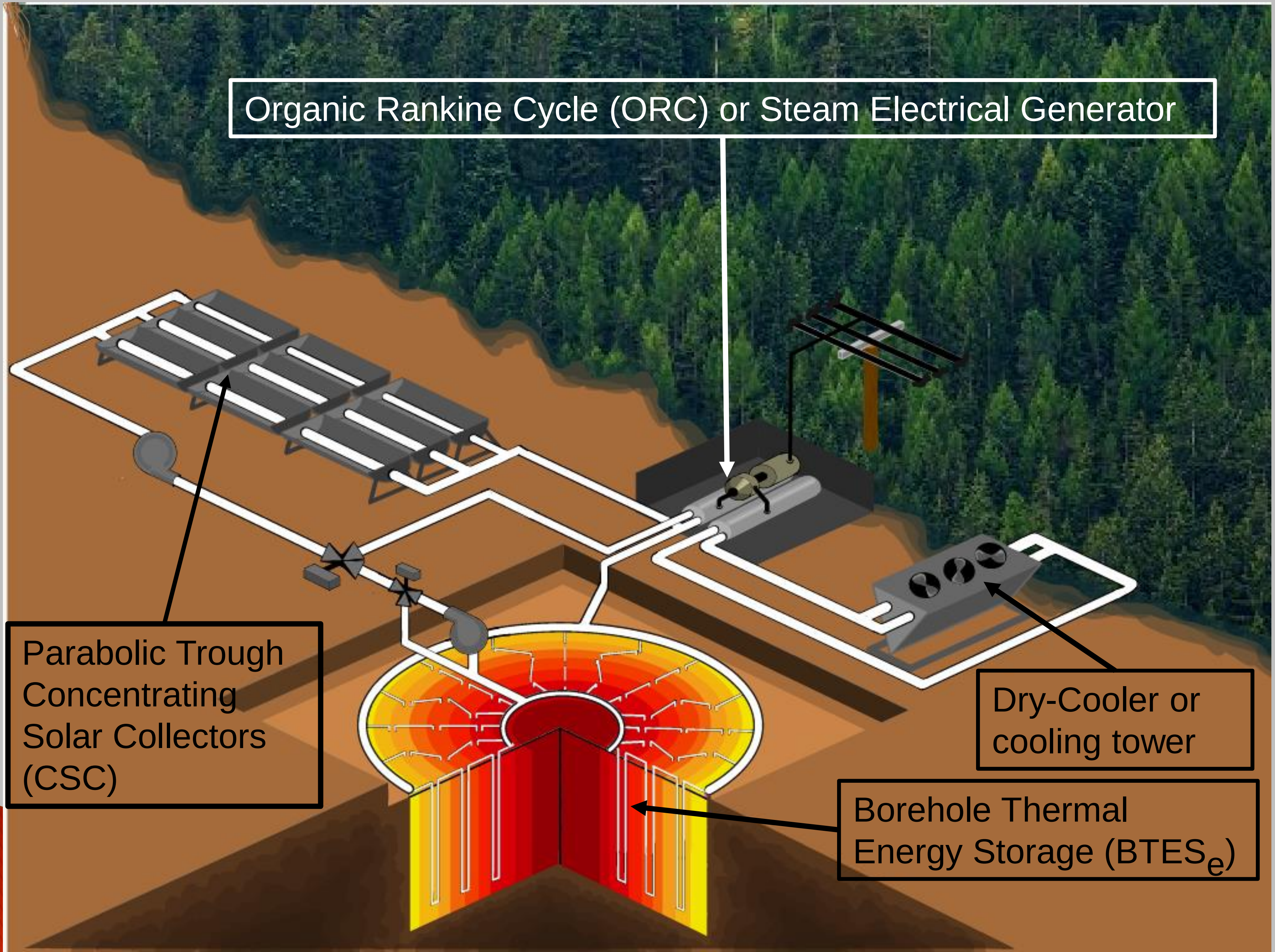
- What are the present alternatives?
  - PV with an assortment of expensive electrochemical battery systems and complicated invertors, etc.
  - Potentially, pumped, compressed or rotational energy like: Pumped hydro, flywheels, solid mass lift/drop, compressed air, etc. Large-scale (i.e. pumped hydro) opportunities are rare/non-existent these days

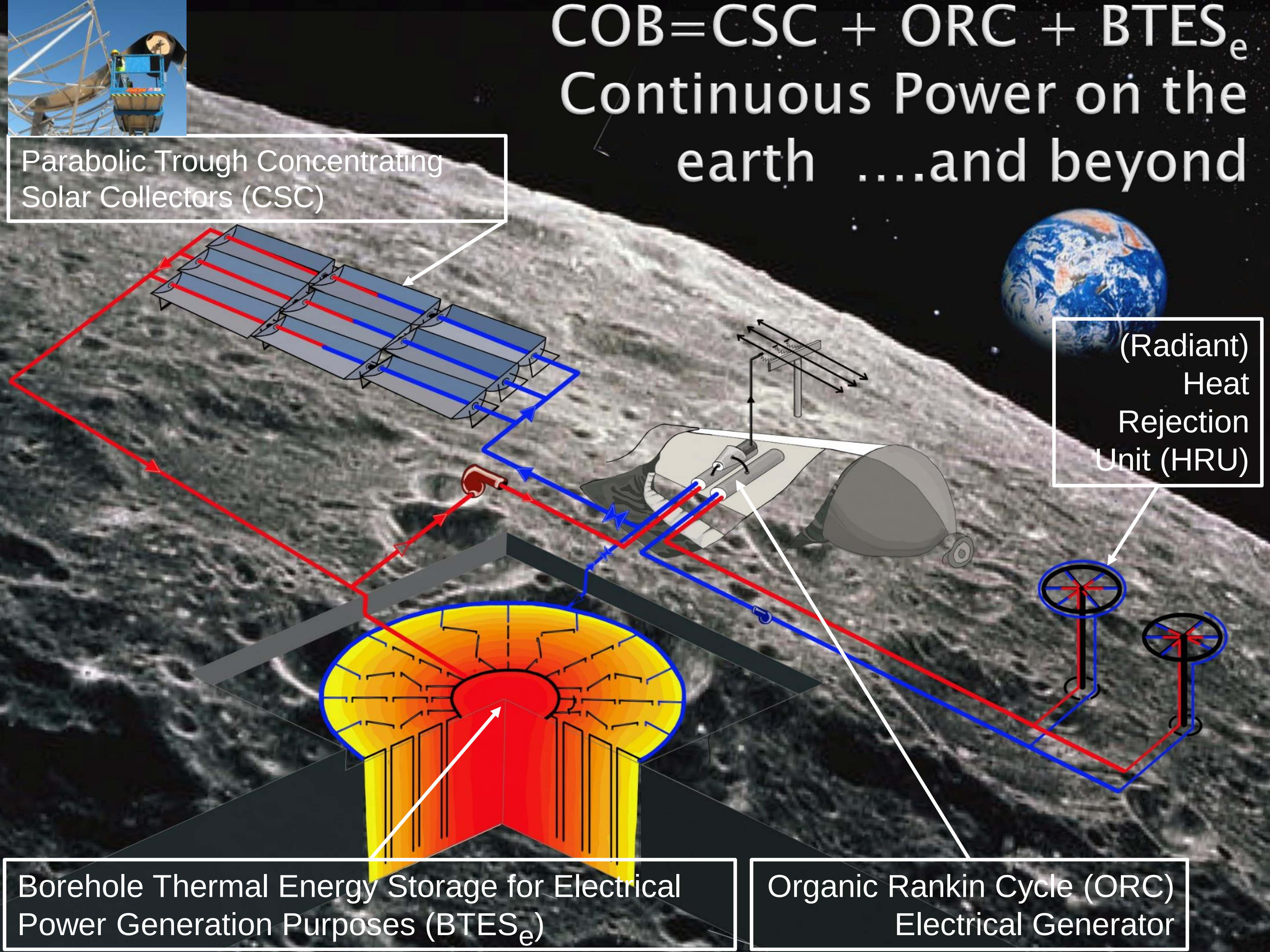
The Solar Resource for $UTES_e$

- Peak solar power is about 1 kW/m^2
- Annual average solar power depends on location; typically seeking 4 $kWh/m^2/day$
- In practical terms, we only get full sunshine ~1/5 of the time
- A photovoltaic array rated for 10 kW only delivers that power ~1/5 of the time
- **It is expensive to store electricity and especially hard at utility scale power level and for extended periods (DoD's says 2 weeks!)**

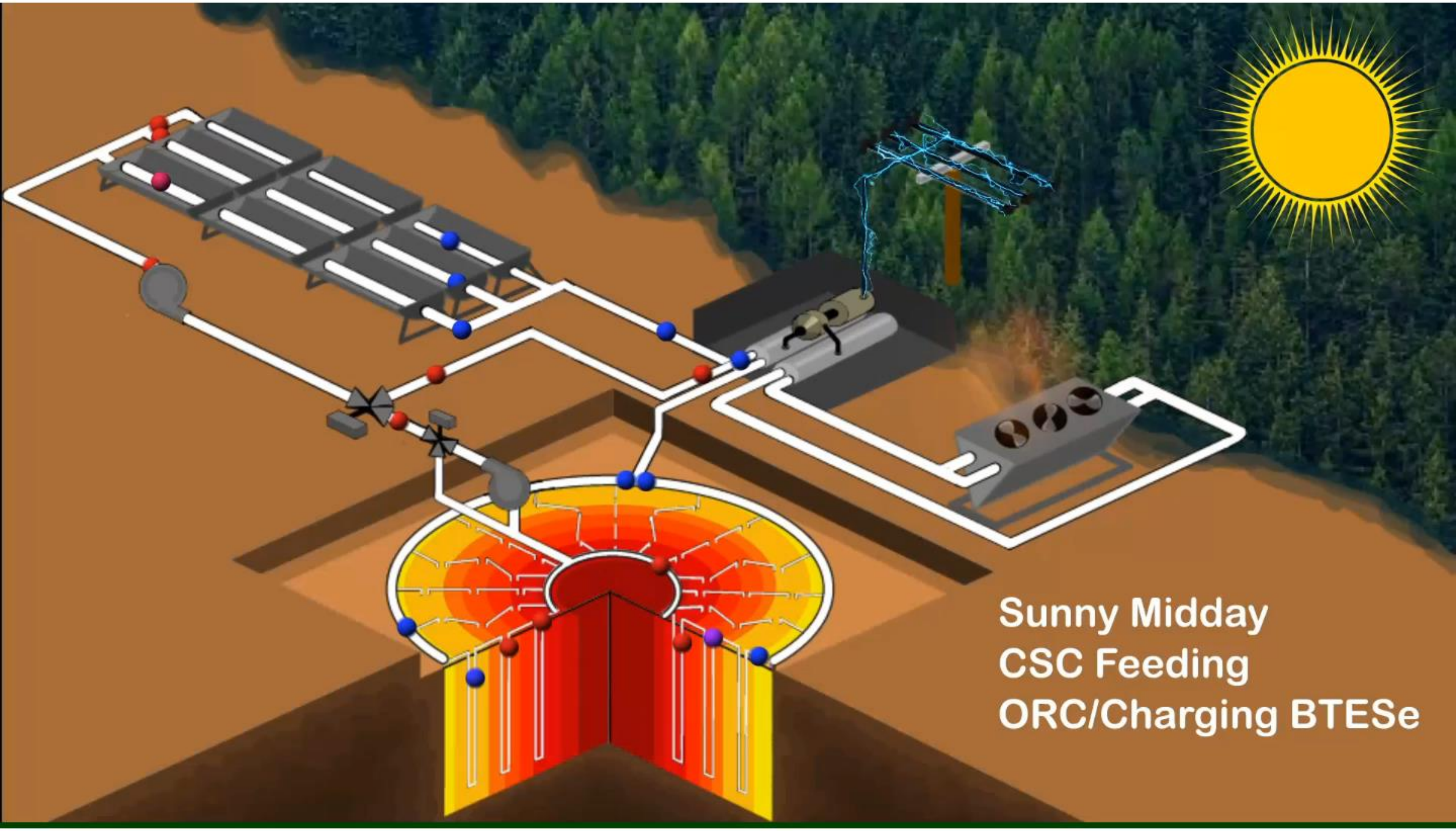


Continuously Active solar powered $BTES_e$ System




COB=CSC + ORC + BTES$_e$
Continuous Power on the earth ....and beyond
Parabolic Trough Concentrating Solar Collectors (CSC)
(Radiant) Heat Rejection Unit (HRU)
Borehole Thermal Energy Storage for Electrical Power Generation Purposes (BTES$_e$)
Organic Rankin Cycle (ORC) Electrical Generator

$BTES_e$ Animation



Clemson & Ft. Moore
ESTCP BTES$_e$ Demonstration

Figure 4. Laboratory setup for testing BHE designs in unconsolidated soils.

35' Long Steel Borehole Heat Exchangers (BHEs) w/DTS and TC Instrumentation

35' Long BHEs are Lowered into Boreholes and grouted with high temp calcium aluminate cement ("Fondag"-ish) with graphite & superplasticizer

Phase 1: U-Bend/7 Borehole/Geological ht-BTES (BTES$_e$) Testing @ Clemson

Why use ATES or BTES vs. Standard Open and Closed Loop GEO at Air Force Facilities??

- Allows you to take same basic open or closed loop GEO that has been used for years and increase its efficiency, if properly modeled/engineered
- Via Cold Capture or Hot Capture, allows Geo to move beyond energy efficiency to a truly renewable architecture. Borefields are smaller
- Can eliminate cooling tower water usage, which often far exceeds dom. water use (2.6 M gal. MCLB)
- Proven technology used outside of the US for decades. Beyond superior source/sink, real storage
- "Direct chilled water" UTES systems, in the right climate(<52°F ground temp), can reduce cooling KWH by 85%

Application Considerations at Air Force Facilities

- Utilize GHPs with UTES, when you need to reduce KWH/KWD/Energy $'s/Water/On-site Emissions
- BTES is 50 state tech, ATES is aquifer dependent. BTESe viability based on your water table depth…***what is it?***
- GHPs/UTES can serve a building via small unitary (water-to-air) GHPs or central chilled/hot water
- Space HW heat most eff. if low temp./heat recovery
- Optimized if dom./process HW loads; Legionella elim.
- Must do TCTs, hourly building/GHX modeling
- Requires Const. Mgmt: Submit. Reviews, grout test, ASTM pressure testing, 4+FPS flush/purge, etc.

Questions? and Answers!

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