RESPEC

GABESS

(Grid-Amplified Borehole Energy Seasonal Storage)

for the Arctic

Society of Arctic Military Engineer (SAME)

Arctic Industry Forum

February-24, 2025

About RESPEC

RESPEC's Infrastructure group was originally established in Alaska in 1975 (previously PDC Engineers)

120 Alaska-based professional engineers, project managers, surveyors, and support personnel w in-depth experience in working with the military across Alaska and remote and cold regions aro the world

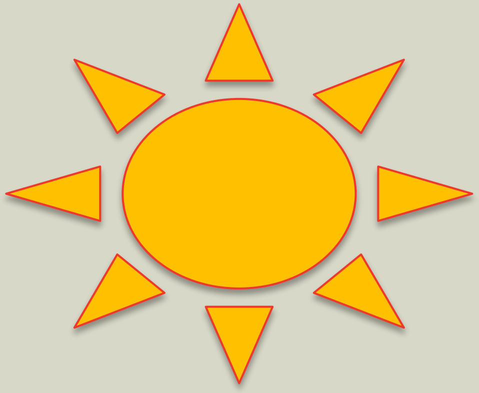
Supported by an additional 500 staff in 30 offic around North America with additional specialtie Water, Energy, Mining, and Data Technology

Partnering with Kitzworks and the RESPEC Energy group to bring thermal storage solutions to clien throughout North America

Topics

1. What is GABESS? (Danny Rauchenstein)
2. How a Site is Evaluated for GABESS (Rand Williams)
3. Subsurface Modeling of BTES (Kevin Kitz)
4. Questions & Discussion

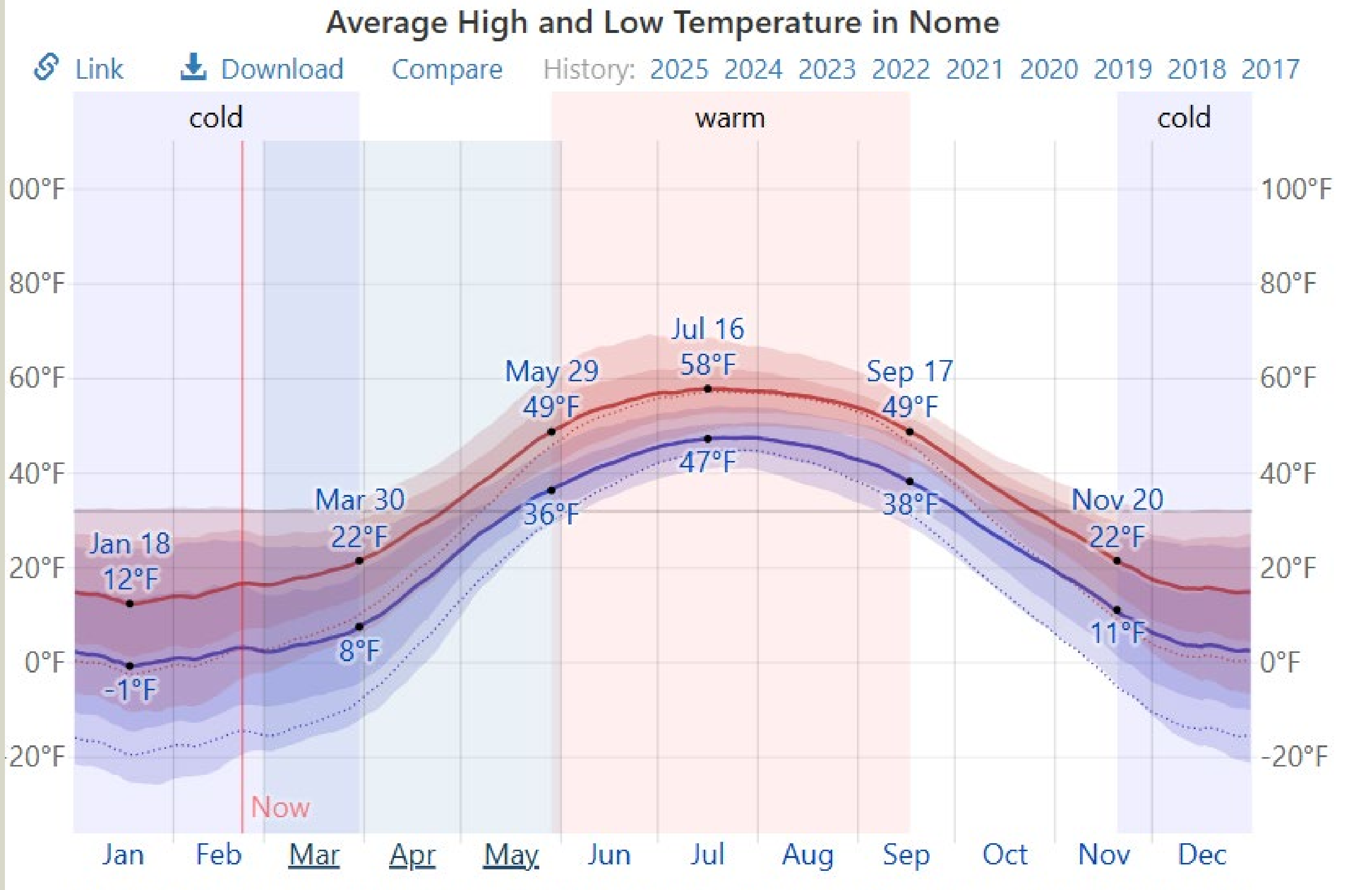
What do These Places Have in Common?



All are viable for
Resilient, secure, and reliable
Yearound
<u>Solar Heated buildings</u>

The key is seasonal Storage

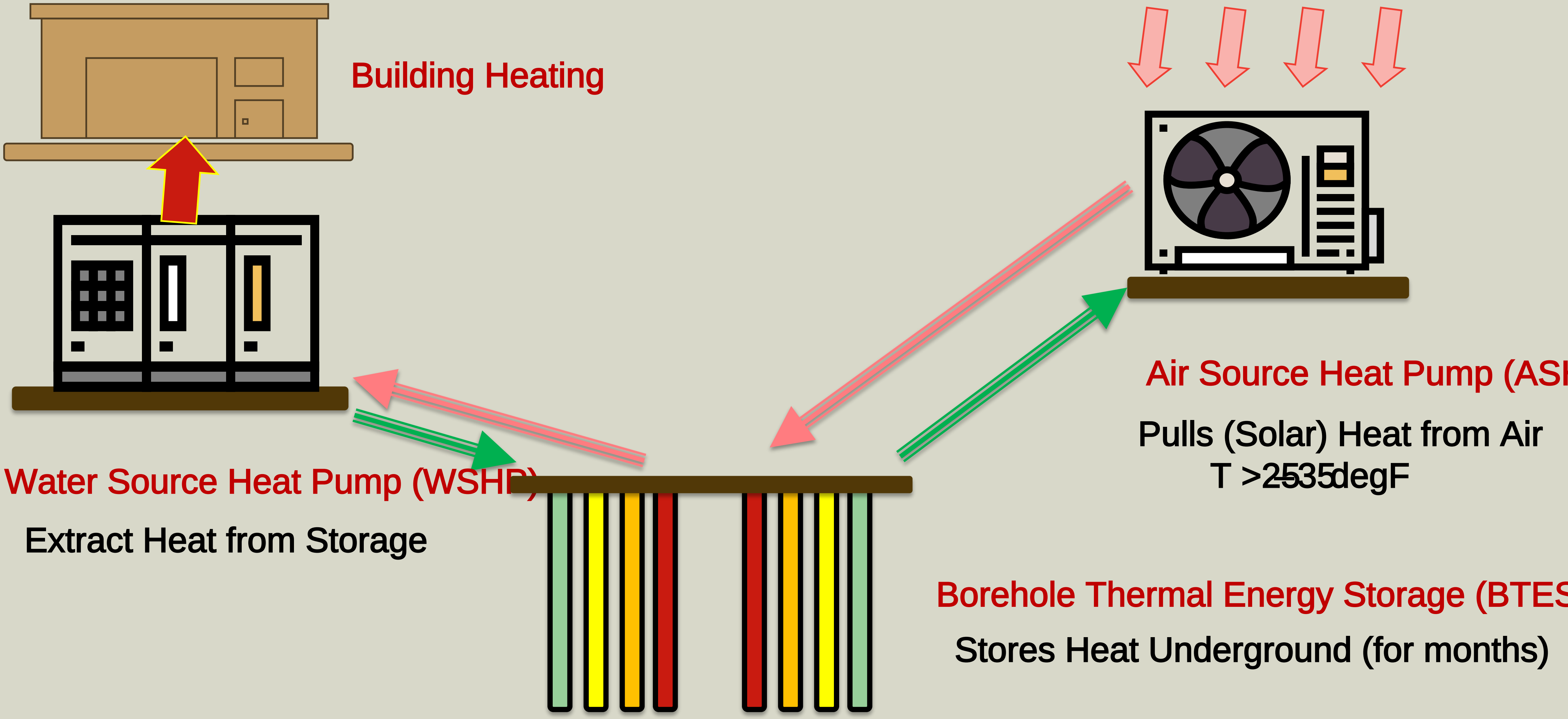
- **Store the heat of summer**
  - A thermal battery
  - Recover for use in winter
- **Seasonal Storage is**
  - Proven technology
  - Low-Tech
  - Secure and Safe
- **GABESS**
  - Grid Amplified
  - Borehole (or Building) Energy
  - Seasonal Storage



The daily average high (red line) and low (blue line) temperature, with 25th to 75th and 10th to 90th percentile bands. The thin dotted lines are the corresponding average perceived temperatures.

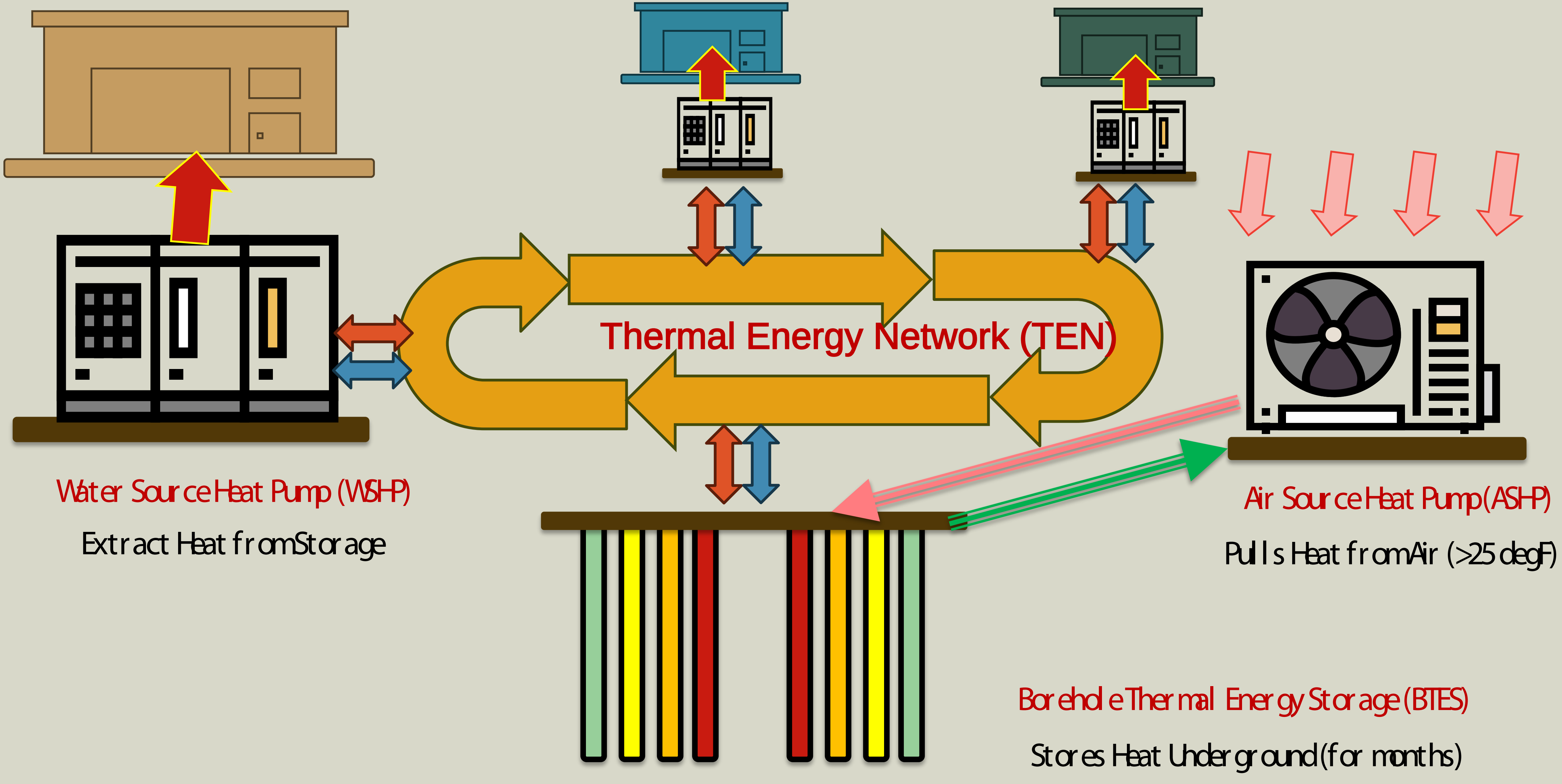
GABESS

Grid-Amplified Borehole Energy Seasonal Storage



GABESS

Works great to link many buildings

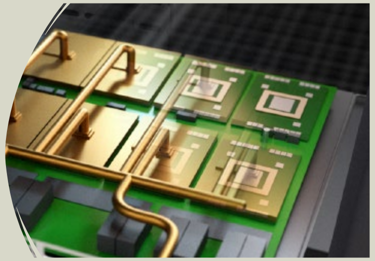


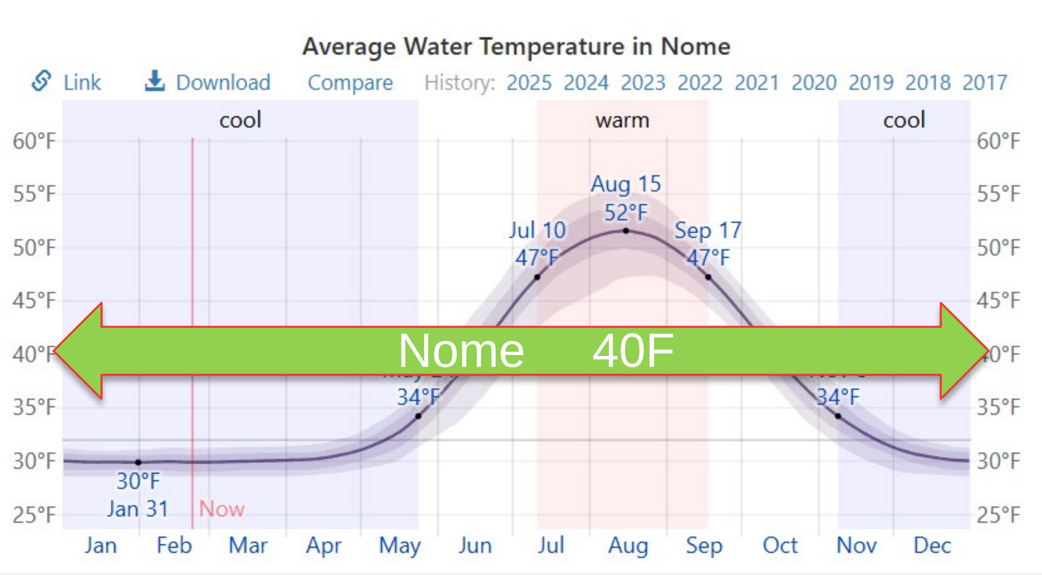
It doesn't have to be an ASHP

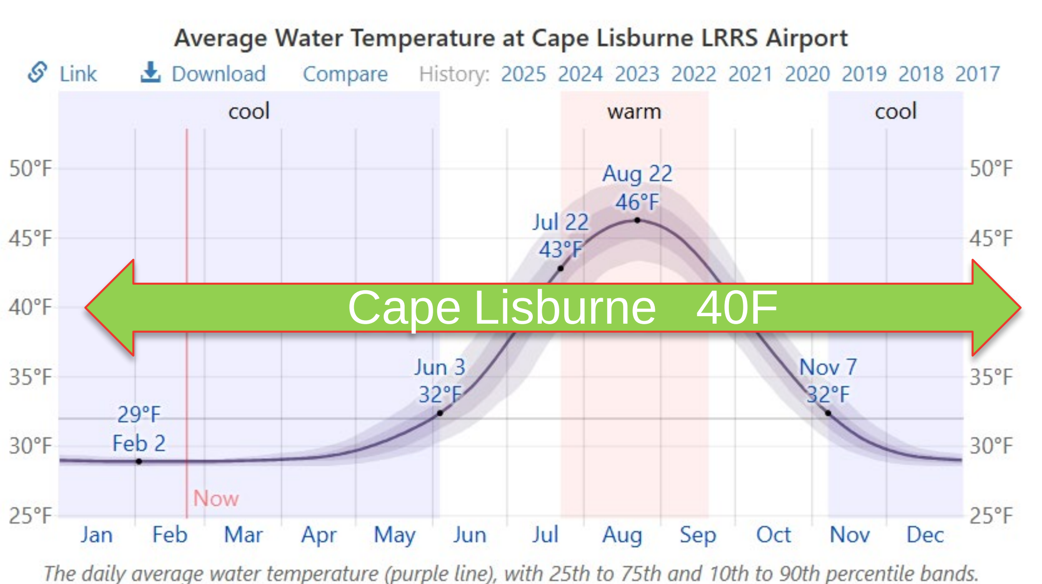
- Water Source Heat Pump
  - River or Ocean
  - Wastewater

- Diesel Generators
  - Jacket water
  - Exhaust gas

- Site Specific Assets
  - Excess wind power
  - Incinerators/landfill gas
  - Computer rooms
  - Other process waste streams
    - Labs
    - Hospitals
    - Industrial/Manufacturing







GABESS Overview

Grid Amplified

- Use a heat pump to store up to 3 – 4 times more heat than the power consumed

Borehole Energy

- The ground is used as a thermal battery to retain the heat

Seasonal Storage

- For seasonal and diurnal heat storage
- Provides way to retain diesel engine waste heat to use in the heating season

Applicability

- Single Buildings and/or Groups of Buildings
- Highly applicable to Extreme Climates (Cold or Hot)

Gabess District energy systems: Building and pipe Network Modeling

Examples from projects

- Vernal, Utah
- Joint Base Andrews

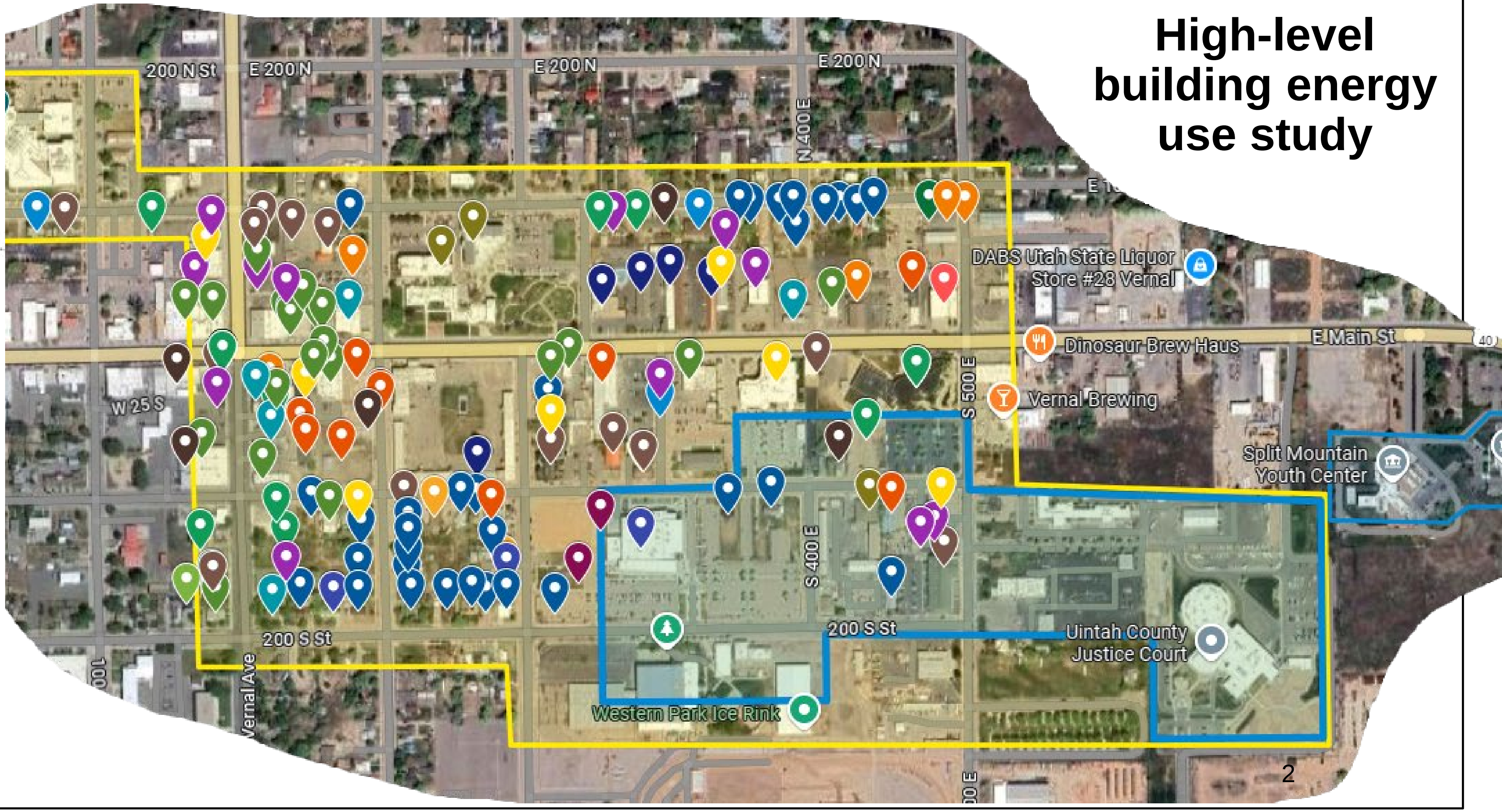
ANSWERING THESE QUESTIO

- WHAT IS THE Building ENERGY LOAD?
- WHAT hvac EQUIPMENT WILL CARRY
- WHAT IS net LOAD ON THE THERMAL
- How will the buildings be connected?

VERNAL UTAH

High-level building energy use study

- SINGLE PRIMARY RESIDENCE(DWELLING)
- RETAIL
- OFFICE
- LOT WITH ESSENTIAL IMPROVEMENTS
- COMMERCIAL UNIMPROVED--VACANT
- AUTOMOTIVE
- Special Use
- FAST FOOD/RESTAURANT
- HOTEL/MOTEL
- MIXED IMPROVED: COMMERCIAL WITH RESI
- COMMERCIAL & INDUSTRIAL BUSINESS
- TEMPORARY
- APARTMENTS
- NON TAXABLE UNIMPROVED LAND
- RESIDENTIAL OVERAGE ETAL
- DUPLEX RESIDENTIAL
- RESIDENTIAL UNIMPROVED--VACANT
- RECREATIONAL PROPERTY--VACANT
- SECONDARY RESIDENTIAL
- SPECIAL USE



The Vernal Building Energy Use Model

Study basis ~885,000 square feet

Property Classification	Net Area in Study (SF)
Unclassified*3 (e.g., Vacant)	-
Small Office	282,910
Medium Office	28,325
Large Office	-
Warehouse	-
Strip Mall Retail	-
Standalone Retail	237,275
Primary School	-
Secondary School	-
Outpatient Healthcare	-
Hospital	100,000
Small Hotel	183,350
Large Hotel	-
Quick-Service Restaurant	52,750
Full-Service Restaurant	-
Mid-Rise Apartment	-
High-Rise Apartment	-
Residential	-

Total ~885,000

- **Uses DOE generic buildings**
  - Limited types of building
  - Assumed HVAC system
- **Many buildings included**
  - Motels
  - Restaurants
  - Office
  - Hospital
- **Some building NOT included**
  - County buildings
  - Data Center
  - Churches
  - Homes & Apartments
  - Mis-identified(?)

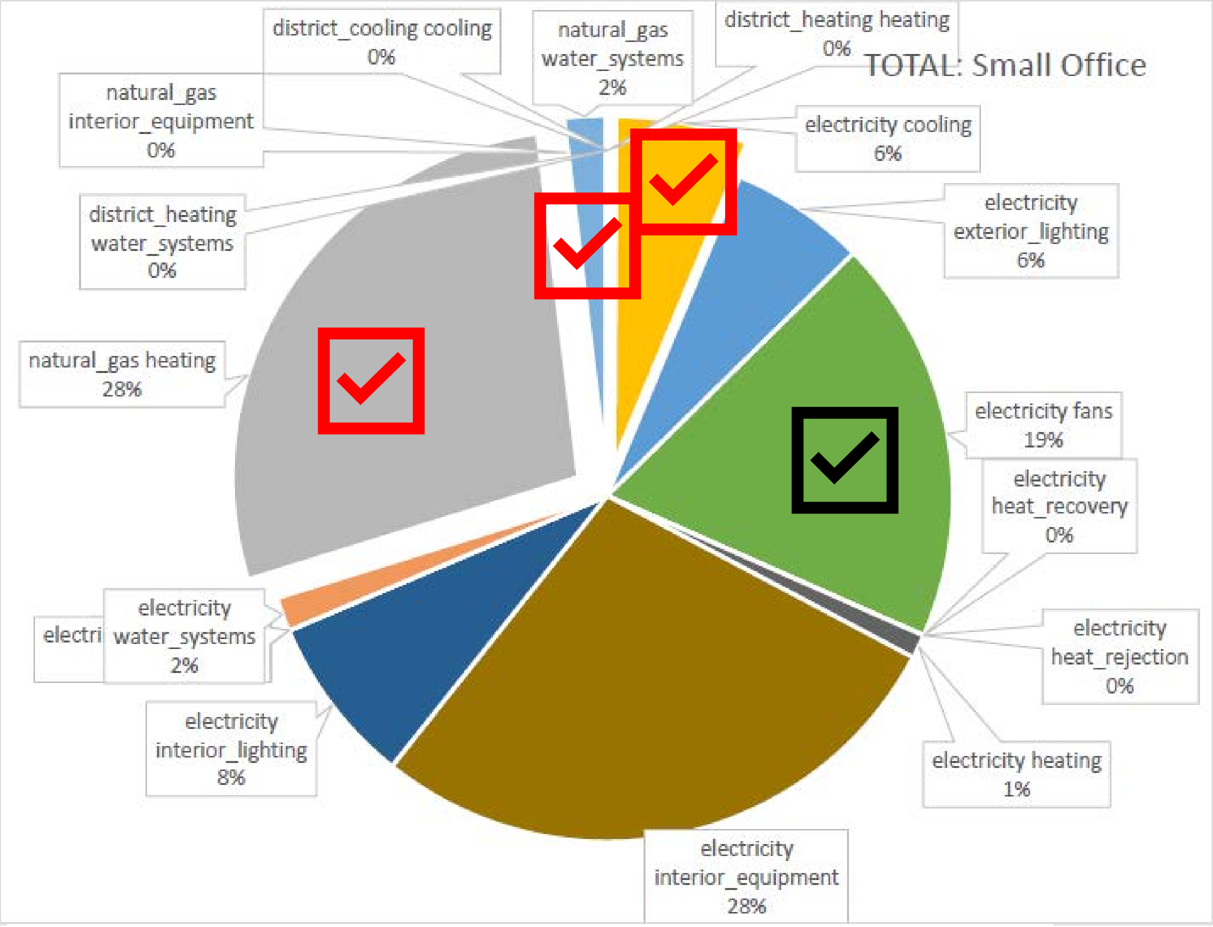
Application:

High-level pre-feasibility study to determine potential viability.

Not a full feasibility study.

Generic Building Energy Prediction

(using DOE Com-Stock software)



Small Office "As-is"

For each building type

- Model Building Performance
  - "As-Is"
  - After-Upgrade
- Calculate Difference
  - Heating, Cooling, Water Heater, Fans

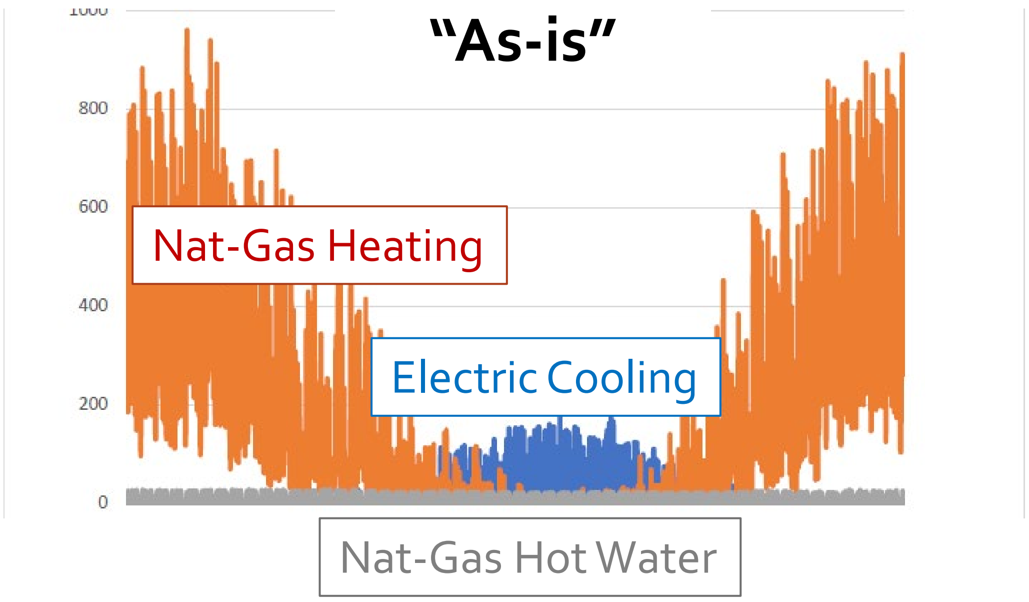
Create System Energy Profile

- Add together for System Heat Flow
- Provide to Subsurface Team

Annual Hourly Energy Use

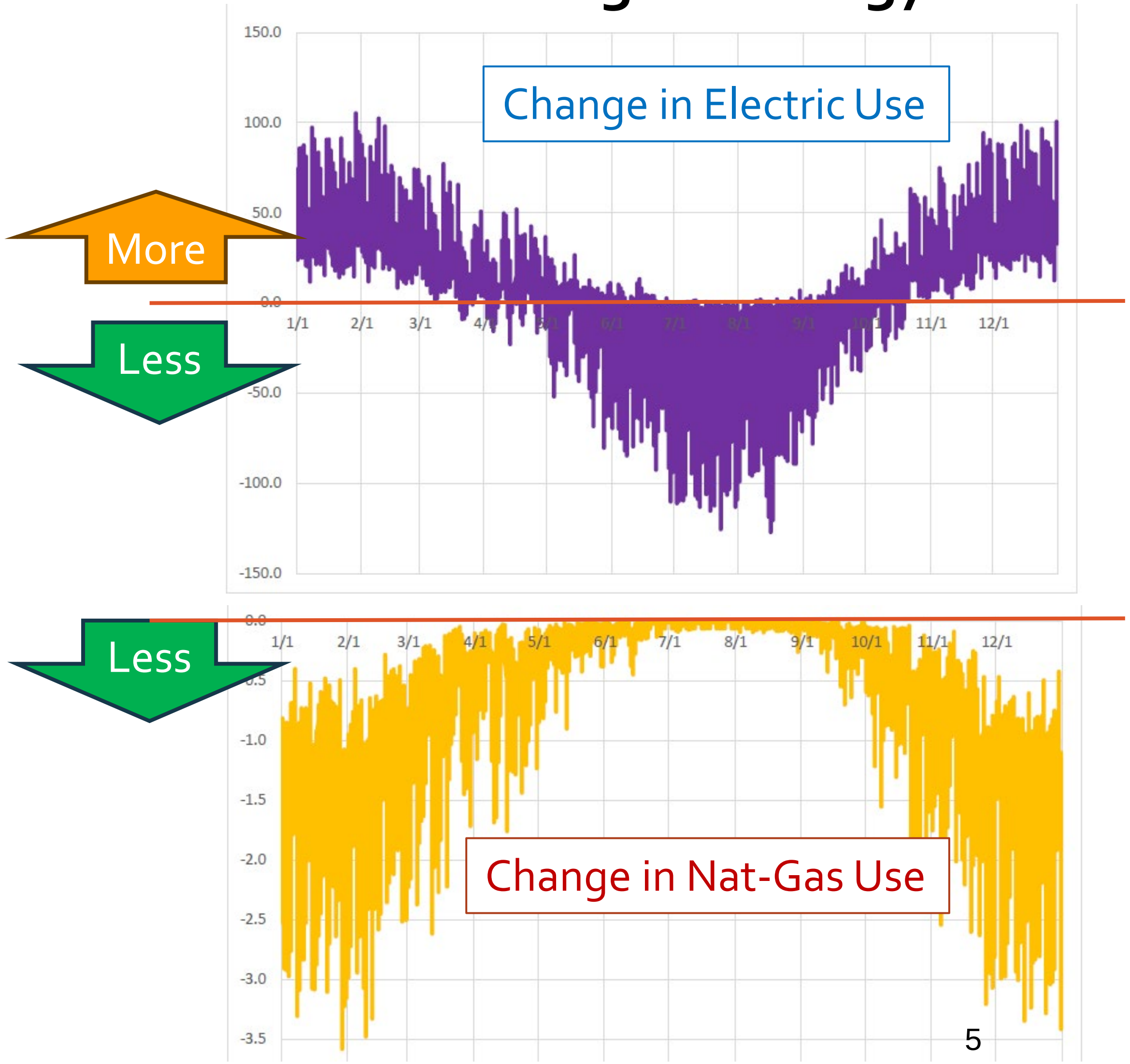
(model for each of building type)

Small Office "As-is"



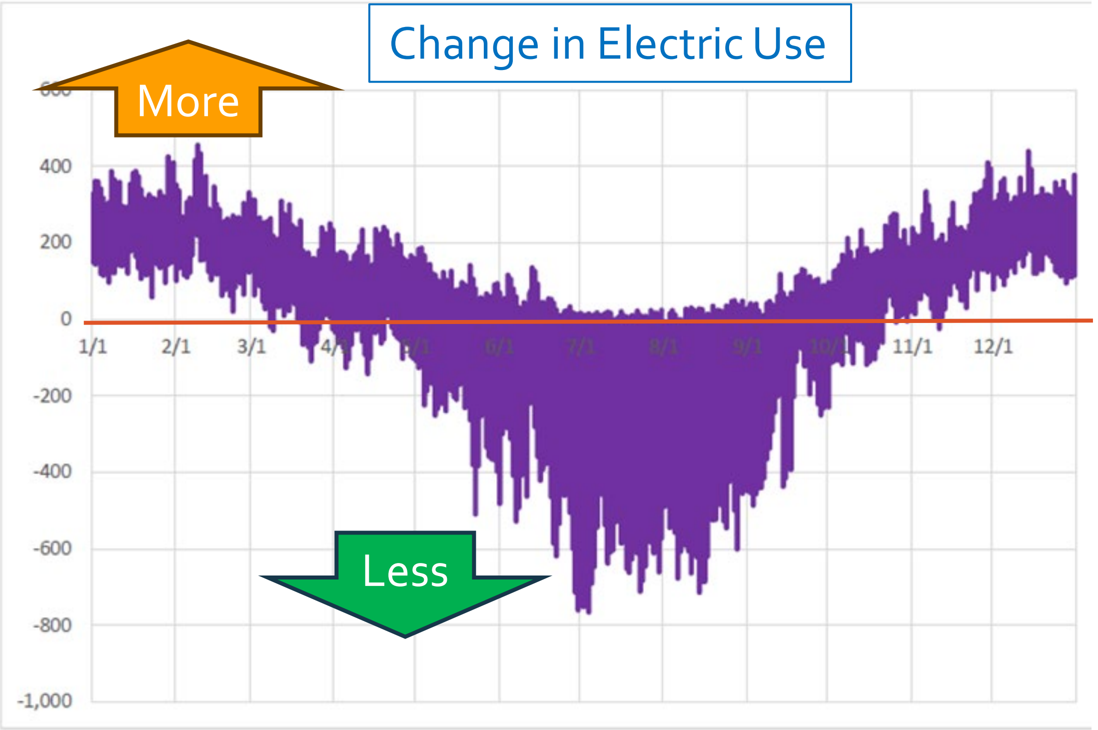
Small Office w/ GHP

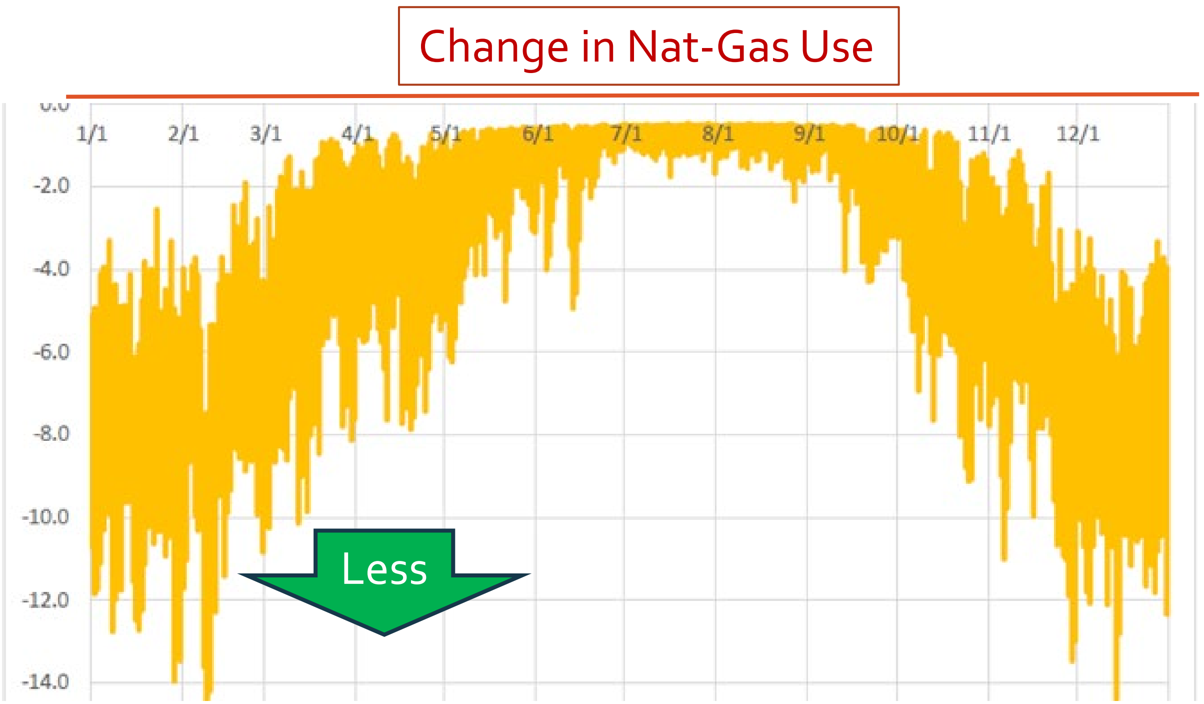
Change in Energy Use



Annual Hourly Energy Use Change

(Sum of all building types)



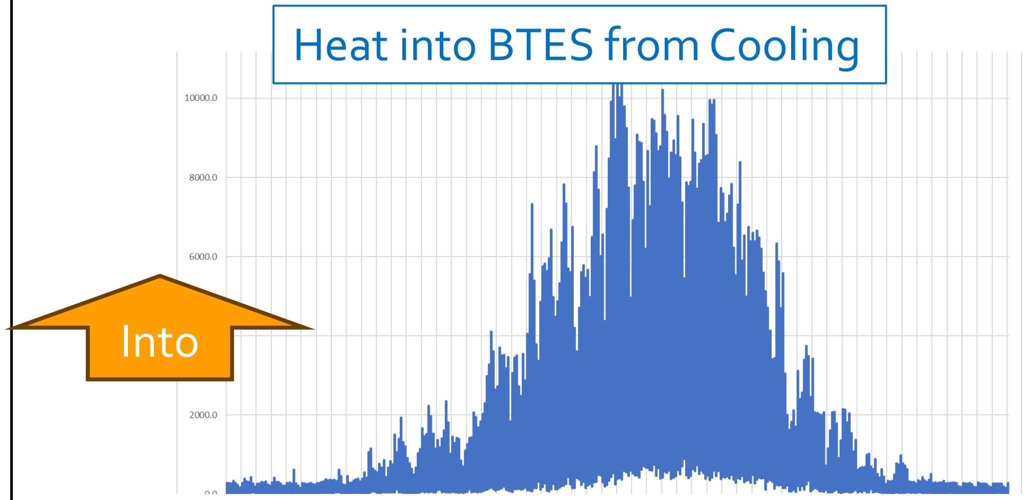


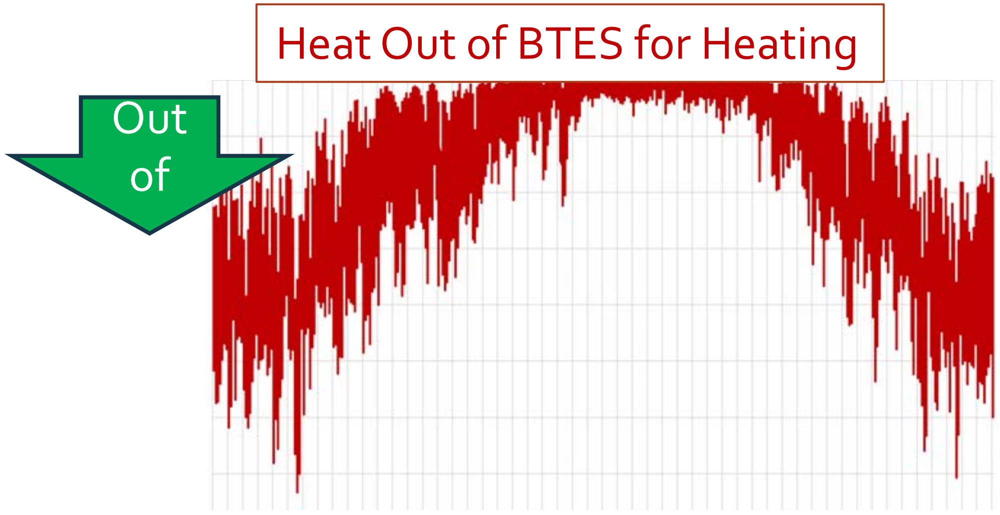
Use changes to calculate building cost reductions

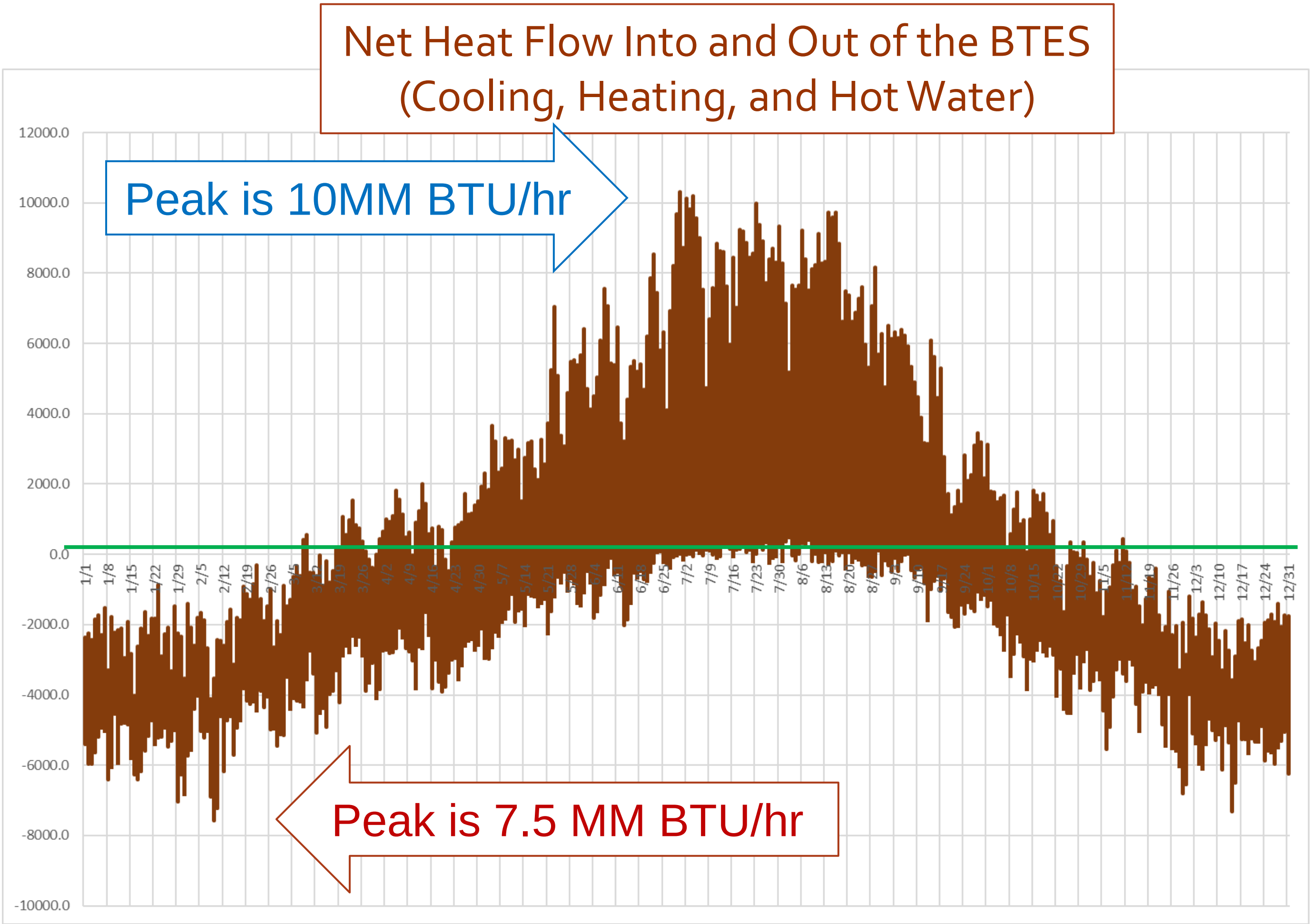
1. Demand Charge Reduction ($/kW) $ 40k/yr
2. Building Energy Cost Savings ($/kWh) $ 28k/yr

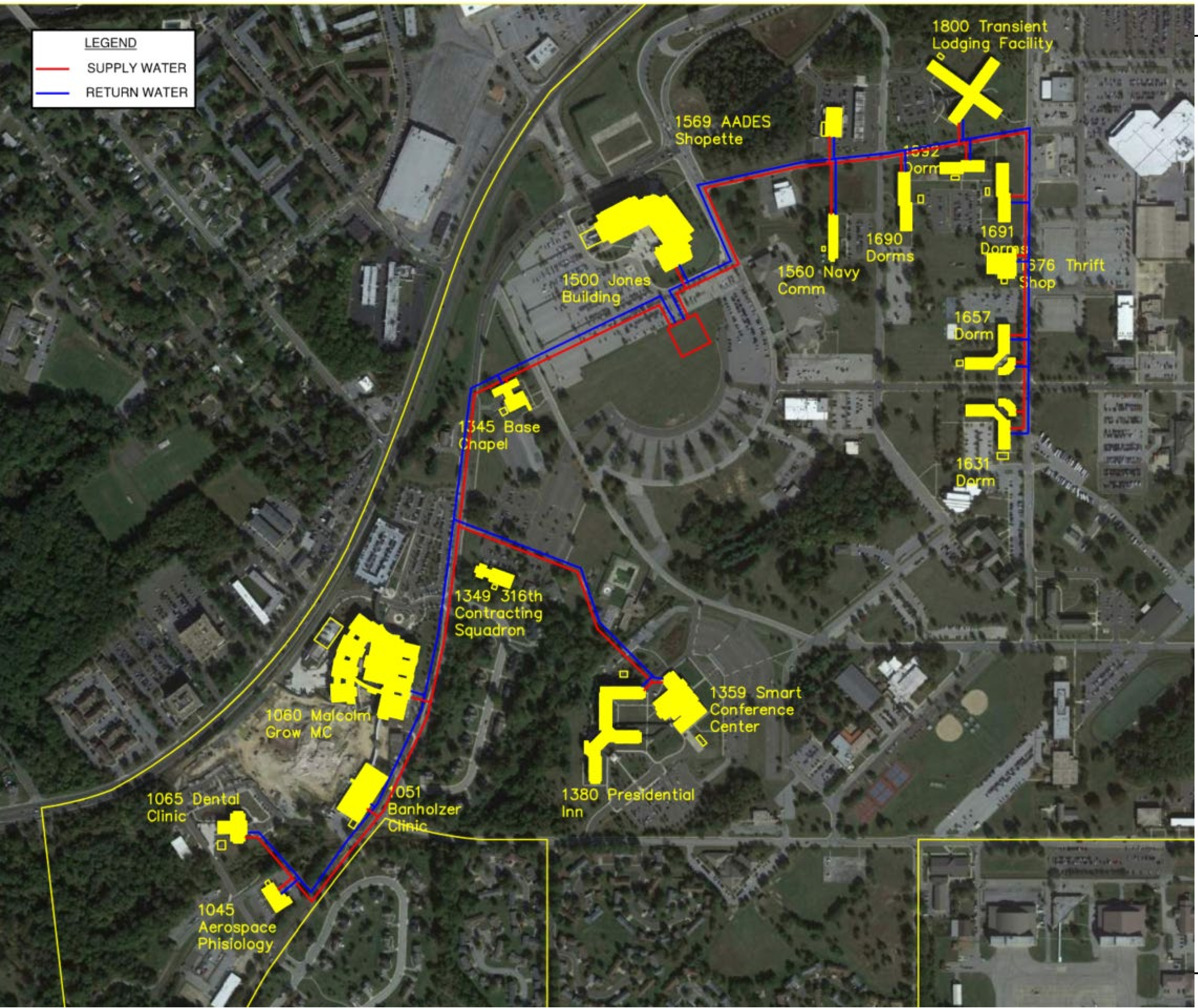
Annual Heat Flow per Hour in and out of BTES

(Sum of all building types)









Joint Base Andrews - Washington D.C.

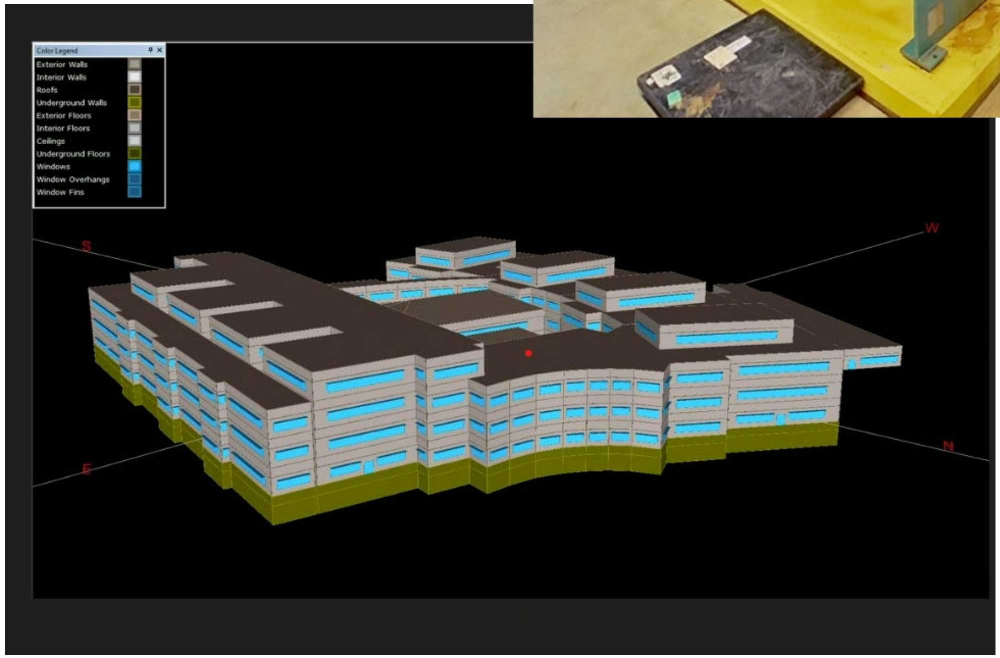
Detailed building energy use

Building Modeling Process

- **Site survey**
  - 3D capture of each Mechanical Room
  - Document existing systems
- **Collect building energy data**
  - Building gas & electric meter data
  - Hourly data from BAS

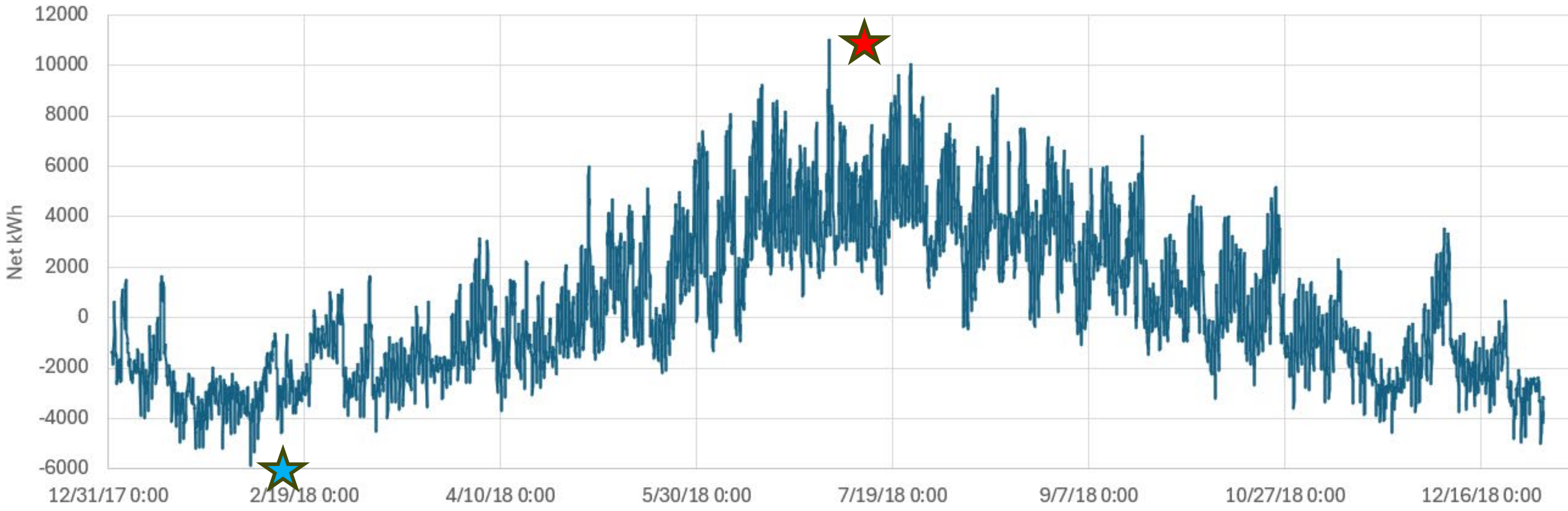
Building Modeling Cont’d

- **Construct 3D models**
- **Calibrate with data from Building Management System**
- **Predict building energy requirements**
  - Include Energy Conservation Measures (ECMs)



Aggregate net energy flow to/from buildings (heating, cooling and hot-water)

- **Peak net cooling load**
  - 11,000 kWh/hr
    - = 34MMBTU/hr
    - = 3,000 tons of cooling
- **Peak net heating load**
  - 6,000 kWh/hr
    - = 20MM BTU/hr
    - = 1,700 tons of heating



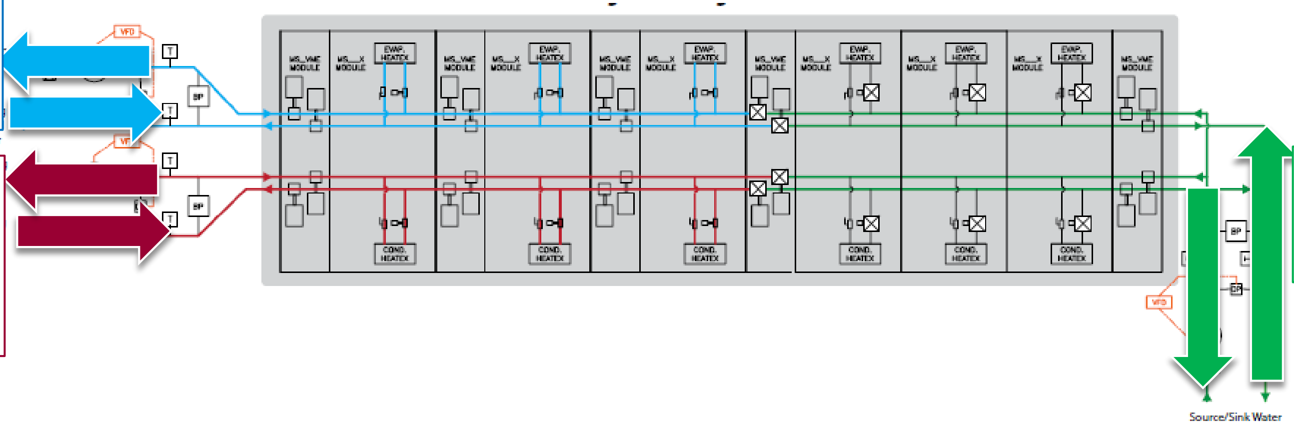
- **Loads include**
  - Energy Conservation Measures (ECMs)
  - Effect of heat pump COP

Multi-mode WSHP are installed in each building

- **6-Pipe Heat Pump provides chilled and hot water for HVAC.**
  - It can provide heat for domestic hot water through a heat exchanger
  - Example: Multi-Stack heat pump (shown)
- **Multiple standardized modules per building**
  - Provides redundancy / resiliency.
  - O&M is efficient
- **Ideally, containerized equipment to reduce cost & on-site disruption of service**

Cold Water to air handlers

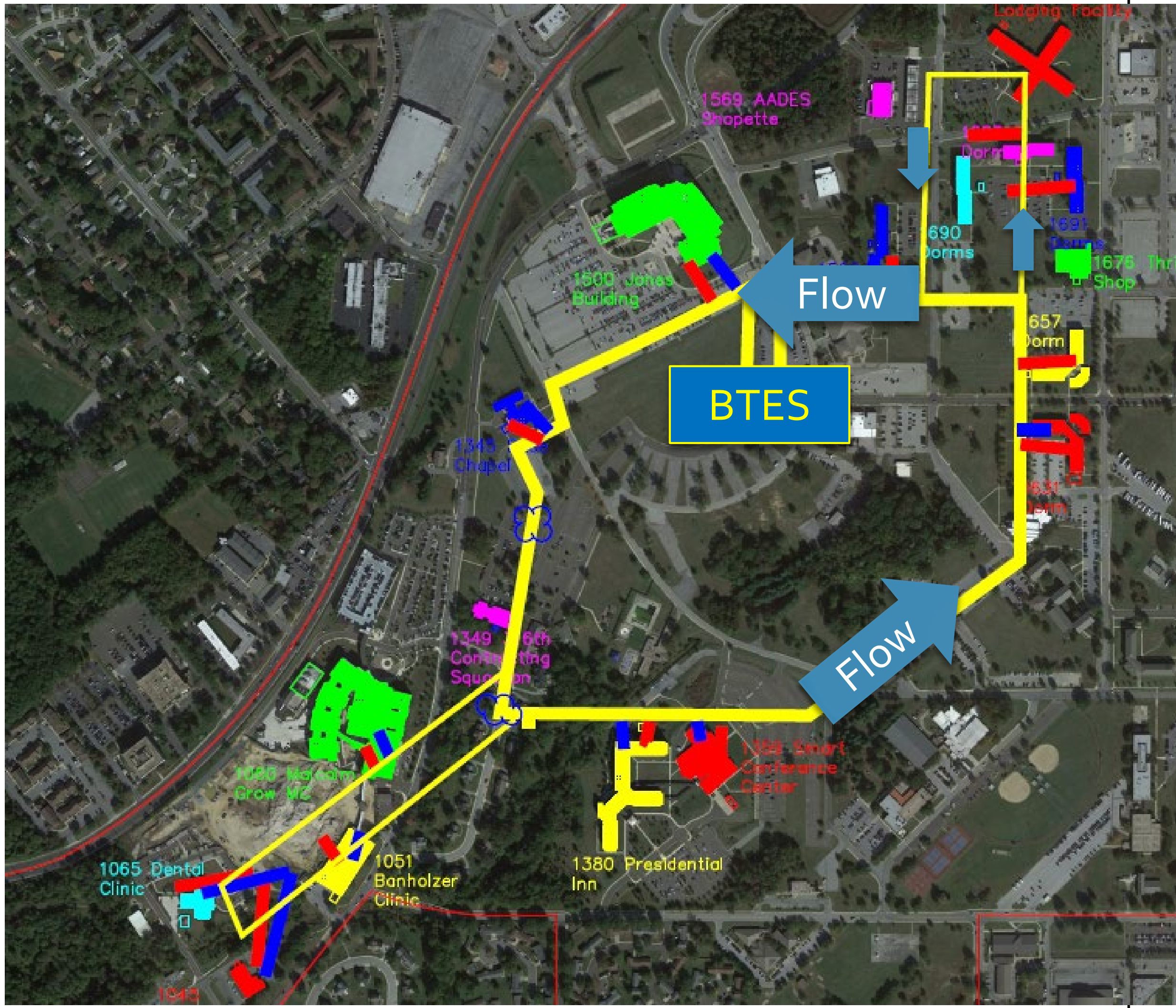
Hot Water to air handlers and zone reheat



Water to/from the TEN

Conceptual Layout of a District Energy System

- **Common Terms roughly the same thing**
  - District Energy System
  - Thermal Energy Network (TEN)
  - Ambient Loop Geothermal
  - 5th Generation Heating and Cooling System
- **Basic Operation**
  - One or two pipes circulate water near each building in a closed loop
  - Each building connects to the piping as its source/sink for a heat pump.
  - The geothermal boreholes (BTES) absorb or give up heat to balance the loads and keep the loop water temperature between 40F and 85F



Pipe Network Optimization

- **Create 5 different pipe layout strategies**
  - Estimate cost and performance
  - Establish additional criteria

- **JBA set the relative weighting factors (Cost =1)**
  - Resiliency and Stability are more important than cost
  - Phasing also important to initially “prove”, and then into steady expansion

Scenario	Description	Estimate	Dynamic Headloss (FT)
1	Tree	$ 5,201,203	85
2	Hub and Spoke	$ 5,866,359	74
3	Two Hub and Spokes - One Pipe	$ 5,637,982	55
4	Two Hub and Spokes - Two Pipe	$ 6,531,846	162
5	Three - Hub and Spokes	$ 7,175,982	99 32 63

Resiliency	Phasing	System Simplicity	Operational Stability	Cost	Expandable
1.6	1.25	0.8	1.6	1	0.95

GABESS

Grid Amplified Building Energy Seasonal Storage

Overview, Value, Application to Cold Climates

RESPEC

SAME Arctic Industry Forum, Anchorage, 2/26/2025

Kevin Kitz
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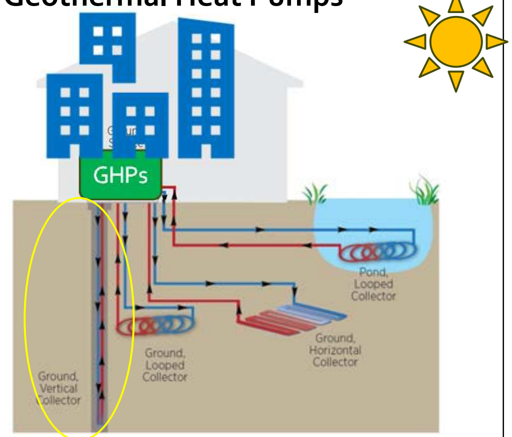
Agenda

- **Geothermal Heating/Cooling Technology**
- Subsurface Modeling
- The (micro)Grid is the Customer
- Arctic Community GABESS Study
- Conclusion
- Questions / Discussion

Geothermal Heat Pumps



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What energy source is used by
(traditional)
Geothermal Heat Pumps?

GHPs <u>efficiently</u> move energy between the building and the ground

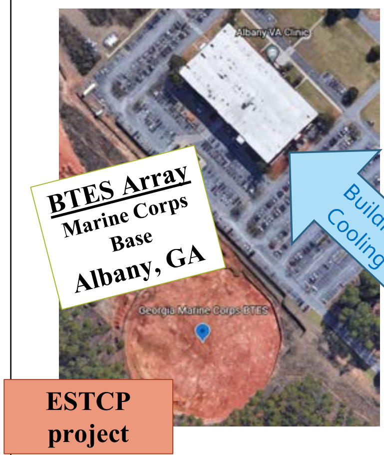
Solar Energy

<u>Geo-Thermos</u>

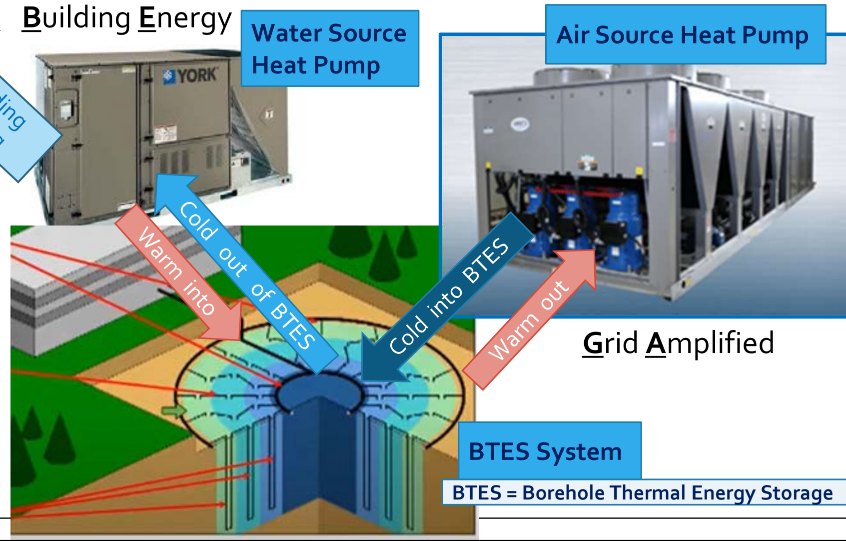
- **Keeps hot things hot and cold things cold**
- **If you want to get something hot out of a thermos, first you have to put something hot into it.**

Credit to Norway BTES researchers for this description

GABESS Integrates 3 Mature Technologies



Building Energy



Grid Amplified

Seasonal Storage

GABESS = ASHP + WSHP + BTES

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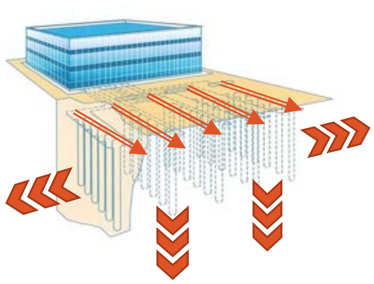
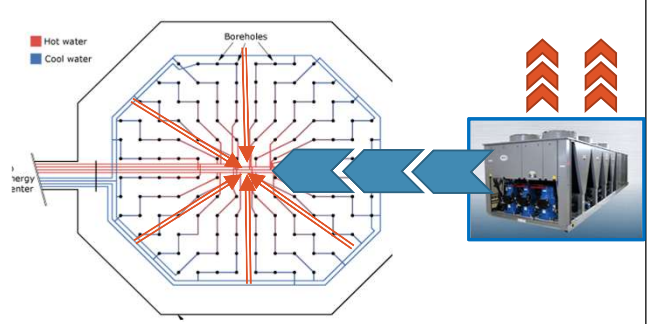
Traditional GHP Array VS GABESS BTES Array

- Many Boreholes ➔ Large CAPEX
- The bigger it is, the worse it does
- Difficult in extreme climate zones

- 20% to 40% reduction in CAPEX
- The bigger the better
- **Best** in Extreme Climate Zones





GABESS = ASHP + WSHP + BTES

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- **Subsurface Modeling**
- The (micro)Grid is the Customer
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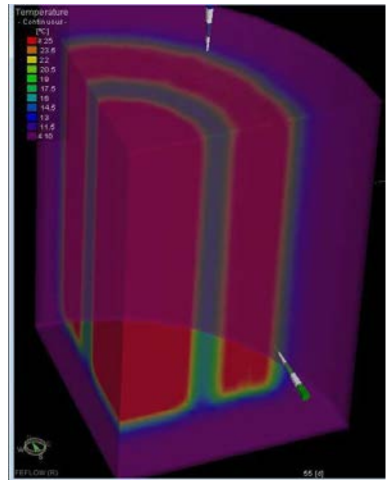

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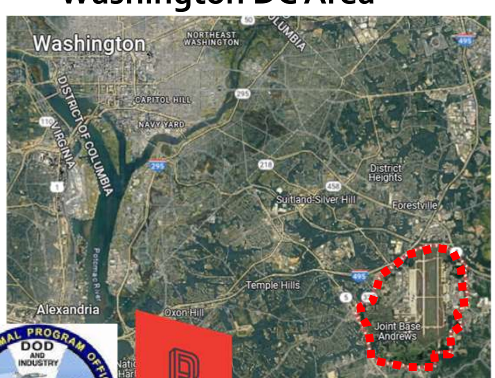
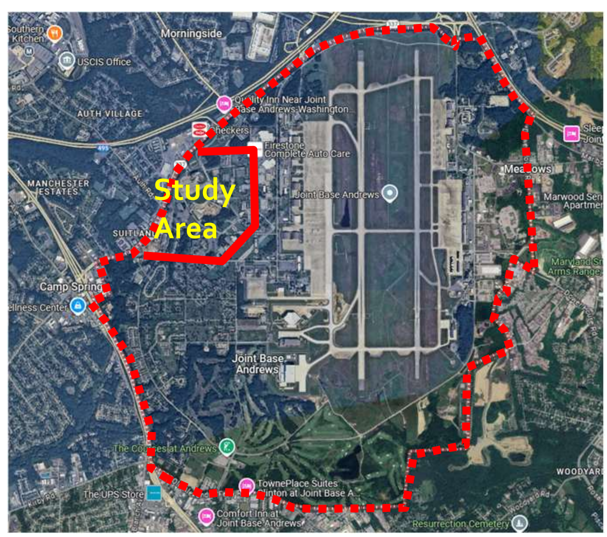
GABESS for Joint Base Andrews

ESTCP

Washington DC Area





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DH GEOTHERMAL

KW KitzWorks LLC

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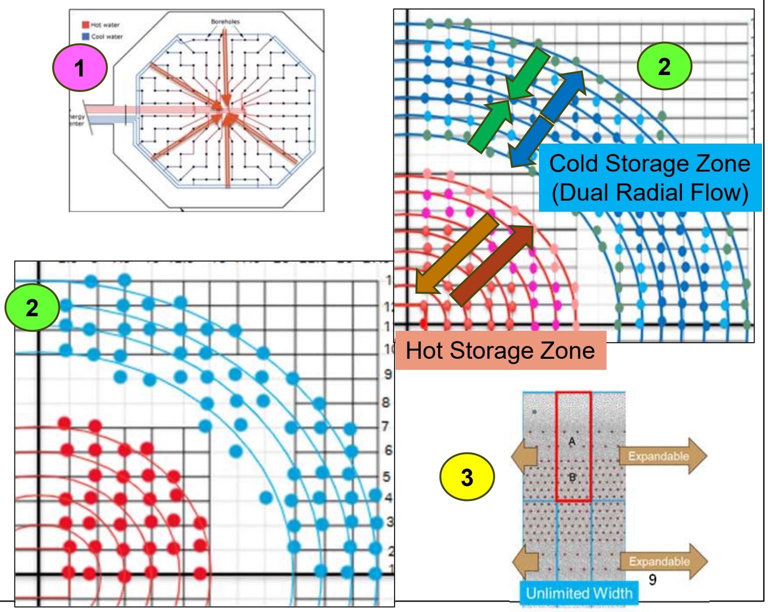
BTES Basic Design Concepts

1 **Operating Systems in N.A.**
- Radial Flow
- Used in Alberta & Georgia

2 **Vernal Options Studied**
- Separate Hot & Cold Zones
  - Each w/ radial flow
- Peak & Base Zones
  - Center serves peak load
  - Outer zone for most load

3 **Joint Base Andrews Study**
- Linear arrangement
  - May work better for Urban areas

GABESS = ASHP + WSHP + BTES



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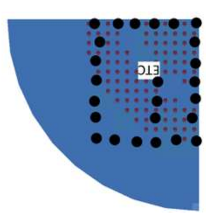
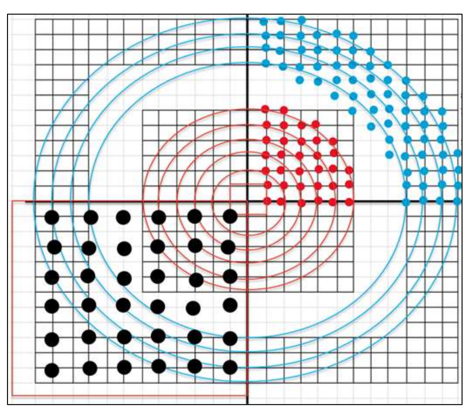
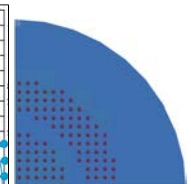
GABESS vs Standard GHP Grid

Spacing = 16'
# boreholes in a quarter array:
Black boreholes: 36
====================
Total 36 x 4 = 144 boreholes







boreholes in a quarter BTES:
Center zone (red): 34
Outer zone (blue): 69
====================
Total 103 x 4 = 412 boreholes

GABESS Performance:
- **1.7 times the energy per borehole per year**
- **4.8 times the building floor area in the same footprint**

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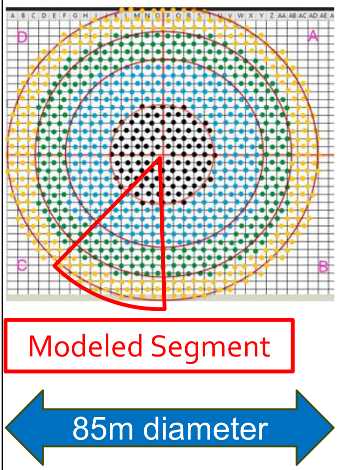
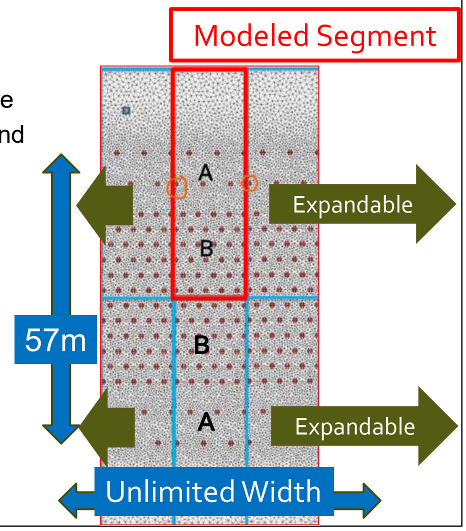
A new BTES concept was developed for JBA (from round to linear)



- **Round BTES**
  - Good for high-T energy storage
  - Round peg, the built env. is square
  - Hard to start small and then expand
  - Wedges are hard to model
- **Linear BTES**
  - Good for low-dT storage
  - Linear fits urban spaces
  - Easy to expand and grow
  - Model is smaller & runs faster



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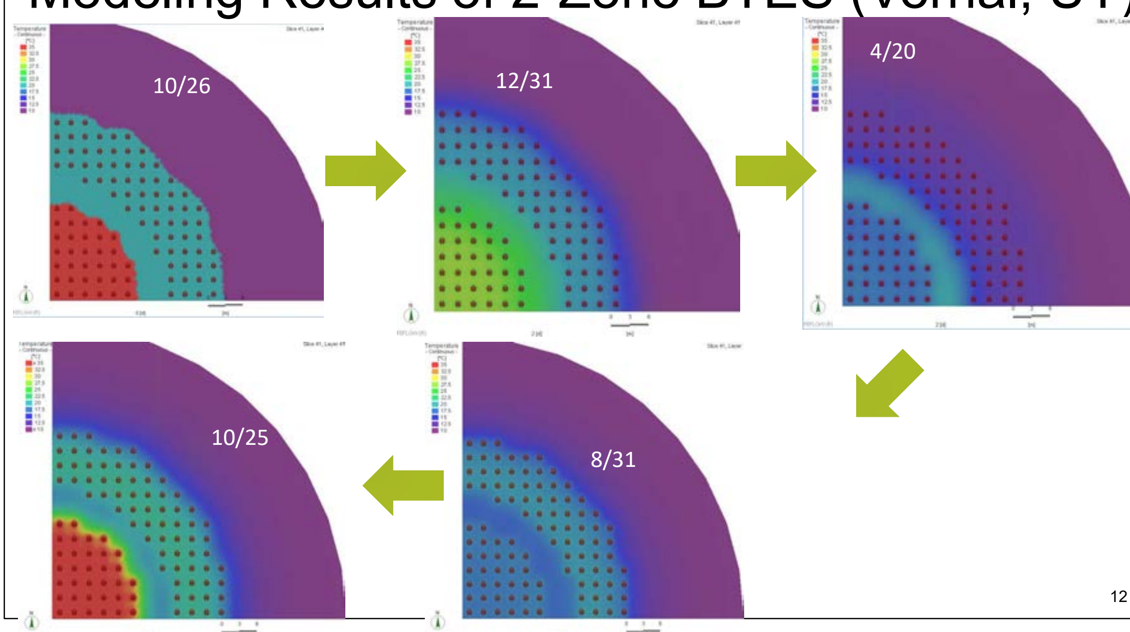
Modeling Results of 2-Zone BTES (Vernal, UT)



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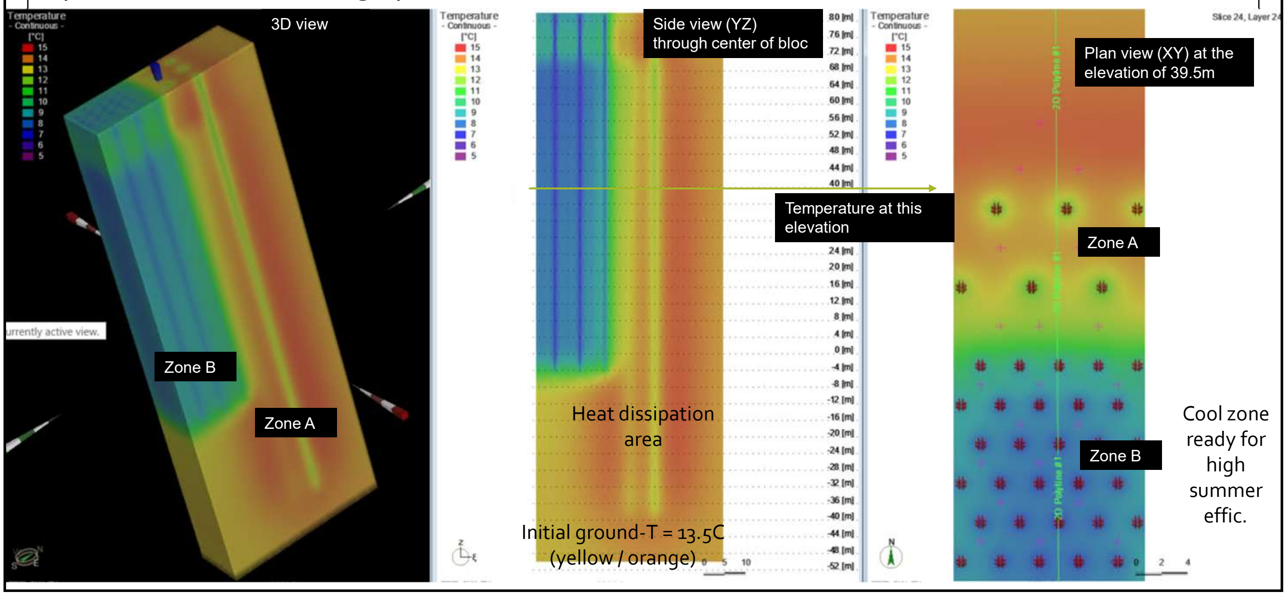
Zone A Dissipates summer heat

(end of winter image)



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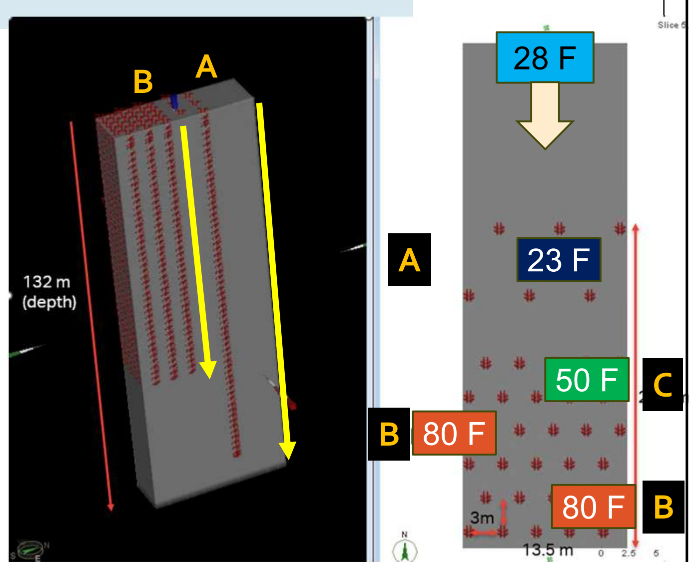
BTES Concept for Cold Climate

(adapted from JBA study)

- **Zone A: Isolates/Insulates**
  - Operating T < background
    - Anti-freeze in plastic tubing
  - Insulates Zone B
    - Absorbs heat from environment so a “negative” heat loss from sides
    - Collects heat leaks from Zone B
- **Zone B (&C): Stores & Supplies**
  - Operates from ~ 35F - 80F
    - Plain water may be OK
  - 6 – 9 months storage capacity
    - Use high dT to meet peak



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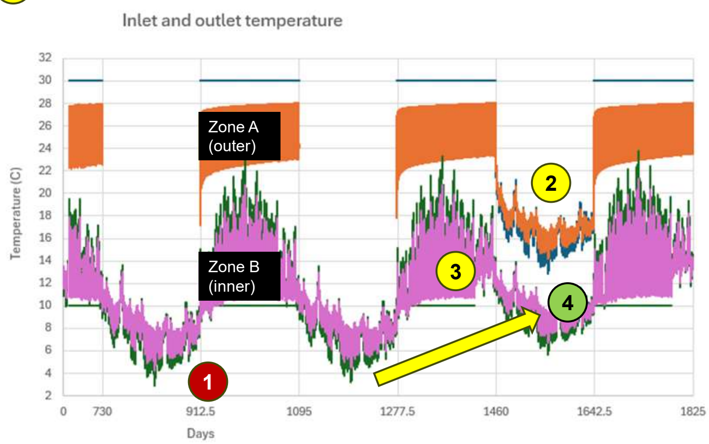
GABESS provides BTES T-control & Utility Value

- **Example: BTES T-control**
  - Problem: Zone B gets too cold, so (1)
  - Serve part of winter heating load with Zone A (2)
  - End night cooling in late summer to store more heat (3)
  - Result: Avg loop T rises by 6C = 11F (4)
    - Zones A + B, combined
- **GABESS Utility Grid Value**
  - Peak Hour demand reduction (high COPs)
    - 30% Vs. Air Source Heat Pumps
    - 400% reduction vs electric resistance heating
  - Seasonal & diurnal grid energy storage
    - 4 – 200+ continuous storage
    - Store for many months
  - Higher roundtrip efficiency than batteries
    - Measured from grid to storage to end use
  - Building Resiliency



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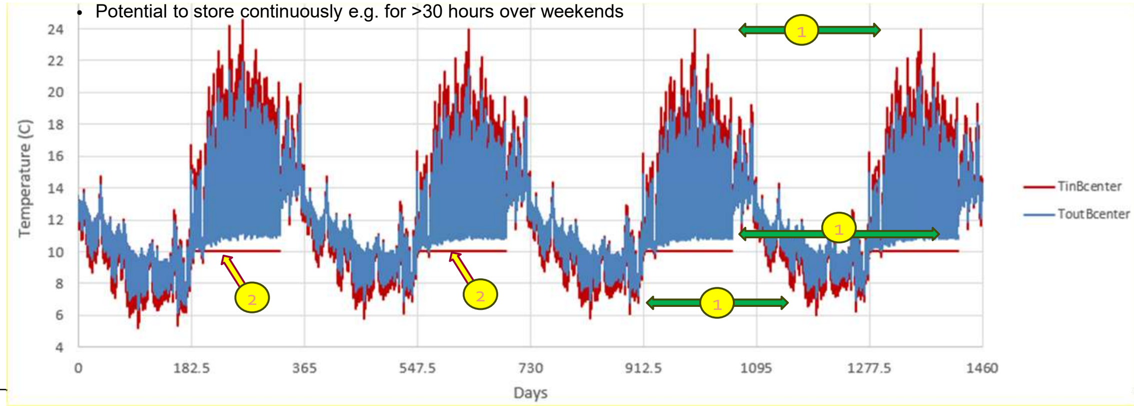
JBA Model Results: Zone B Water In/Out temperatures

(Peak Hours over a 4 year run)

(1) **Temperatures are stable by the end of the 4 year period**
- Peak grid hours are 1PM – 9PM

(2) **Grid energy stored via chilled water from air-cooled chillers**
- 8 hours per day during off-peak
- Potential to store continuously e.g. for >30 hours over weekends



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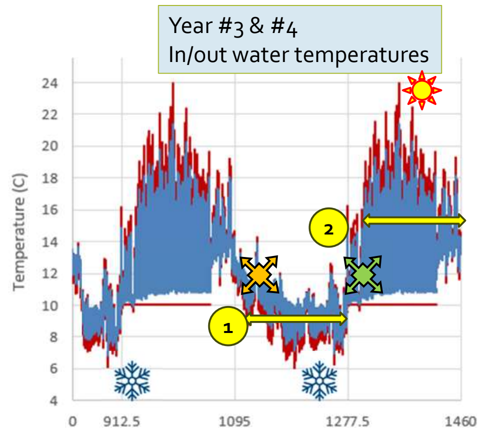
GABESS provides high efficiency and performance

- **Winter average DES loop T ~ 9C = 48F**
  1 Heat pump average COP ~ 4.1
  - heating only
  - All COP values are without the air handler

  Coldest hour COP ~ 3.8
  Early season COP ~ 5.0

- **Summer average DES loop T ~15C = 61F**
  2 Heat pump average COP ~ 7
  - cooling only
  - With simultaneous hot water production, combined COP ~ 10

  Hottest hour loop-T COP ~ 5
  Early season COP ~8



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BTES Modeling Conclusion

- **New BTES Designs Developed**
  - Better shapes
  - Lower Losses
  - More control over temperature

- **TRL 10 (Technical Readiness Level)**
  - Uses only commercially available technologies
  - Same parts, different arrangement

GABESS = ASHP + WSHP + BTES

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Study about:
Grid Cost Reduction via Mass Deployment of GHPs

Agenda

- Geothermal Heating/Cooling Technology
- Subsurface Modeling
- **The (micro)Grid is the Customer**
- Arctic Community GABESS Study
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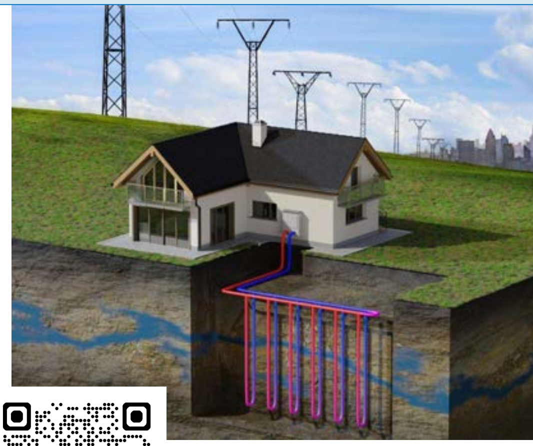
- Questions / Discussion



Links to Study

https://info.ornl.gov/sites/publications/Files/Pub196793.pdf

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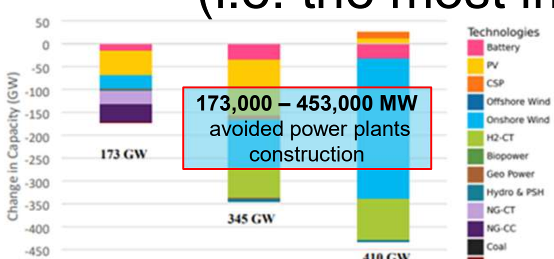
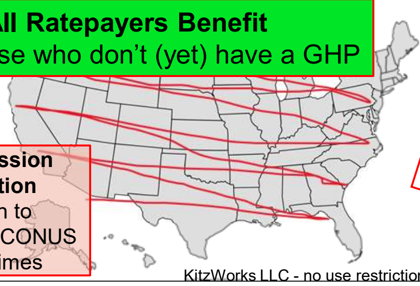
"The Grid" is the Biggest Value Driver for GHPs (i.e. the most important "Customer")



173,000 – 453,000 MW avoided power plants construction

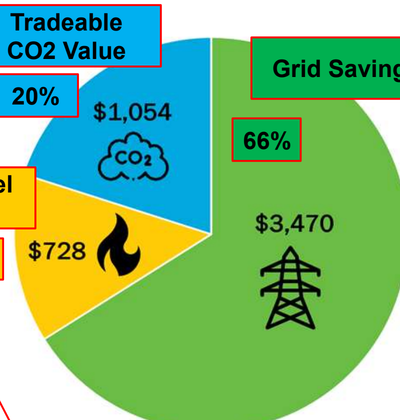
All Ratepayers Benefit
Even those who don't (yet) have a GHP



Transmission Reduction enough to criss-cross CONUS 8 – 16 times

KitzWorks LLC - no use restrictions

We decarbonize for the benefit of future generations, so use their economics



Tradeable CO2 Value **20%**

Heating Fuel Savings **14%**

Grid Savings **66%**

2050 Total Present Value: $5.3 trillion

Data from IGSHPA Townhall Webinar & GHP Impacts Study

KitzWorks Additions/Comments are outlined in red

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Microgrid Value is even larger

- 90+ day underground heat supply
- Reduced fuel storage & use
- May be reduced generation capacity
- ~100% of engine waste heat can be used or stored

GABESS = ASHP + WSHP + BTES

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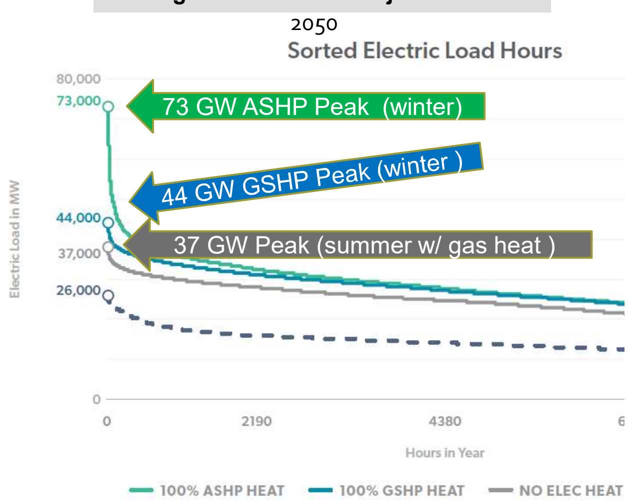
Rhode Island Study of GSHP vs ASHP (2050)

New England
Heating Electrification Projections



Performance & Economic Impact

- **ASHPs Increase Peak Load by 29GW**
  (73 – 44 = 29GW)
- **Family of 4 must pay $23k - $60k**
  - **This is the ASHP cost, not the "grid cost"**

GHPs are MUCH CHEAPER for All Ratepayers
[even those w/o GHPs (yet)]

- **Calculation: Winter Peak is Expensive**
  - New MW at $3MM - $7MM per MW (incl xmission & distrib)
  - Grid Cost = $6k - $15k per person
    - (29 GW) * ($3 to $7 MM) / 15MM people in New England

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Rocky Mountain Power
Investment & Sustainability Goals

2021 Integrated Resource Plan

- **Reduce CO2 from 2005**
  - by 74% by 2030
  - By 98% by 2050
- **Build Plan to 2040**
  - 4,290 MW additional energy efficiency programs
  - 5,628 MW of new solar resources
  - 3,628 MW of new wind resources
  - 6,181 MW of storage - batteries & pumped hydro
  - 2,448 MW of direct load control programs

Rocky Mountain Power Info from
Innovation and Environment (rockymountainpower.net)
PacifiCorp_2021_IRP_Brochure.pdf (rockymountainpower.net)

GHP Benefits to the Grid & Ratepayers

- **Reduce Peak Demand**
- **Demand-Side Planning**
- **More efficient Heating and Cooling**
- **Grid Energy Storage**
- **Transmission & Distribution Reduction**
- **CO2 Offsets**
- **Lowers Rates for All Customers**

GABESS = ASHP + WSHP + BTES

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Tradeable Carbon Value

- **Grid Decarb Goals are Bigger/Faster**
  (vs economy-wide decarb goals)
- **Monetize building CO2 reduction**
  - Aggregate, like other DER attributes
- **Finances GSHP Installations**
  - Tradeable GeoRECs are one option
  - Value = $2k to $14k per home
- **Lowers Consumer Power Rates**
  - RECs allow gas plants to operate w/i RPS targets
    - Cheaper power
    - No stranded asset value
    - Grid extreme weather resiliency/reliability

Same as
SO2 Emissions Trading
(Reduce on-site compliance costs with cheaper off-site sources)

Calculation methodology
- Climate Master Saving Calculator
- GSHPs cuts two homes CO2 by 7 - 13 metric tons/yr
- A combined cycle plant emits .6 m-t/MWh
- 13/0.6 = 21.7 GeoRECs
- Geo-REC value = $30 - $70
- 10 year value = $3k - $14k

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Energy Efficiency is better for GHPs

$$ Efficiency Upgrades $$

The math is simple
Better NPV w/
Year 0 capex reduction

Retrofit for:	Gas or ASHP	GSHP
Monthly energy cost savings	$	$
Up-front drilling reduction		$$$

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Dual Rate-Base Investment Model Concept

EU

Electric Utility Offers GHP Incentive
- Based on value of peak load reduction
- 30 year Rate Base amortization
- Require installer QA/QC

GEU

Geothermal Energy Utility Installs Systems
- Monetizes Utility & Tax Incentives
- Capture other Value streams
- Provide Long-Term amortization (30 – 50 years)
- Provide QA/QC to all installs

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~1MW Diesel Power Load
*** Buildings heat w/ Fuel Oil**

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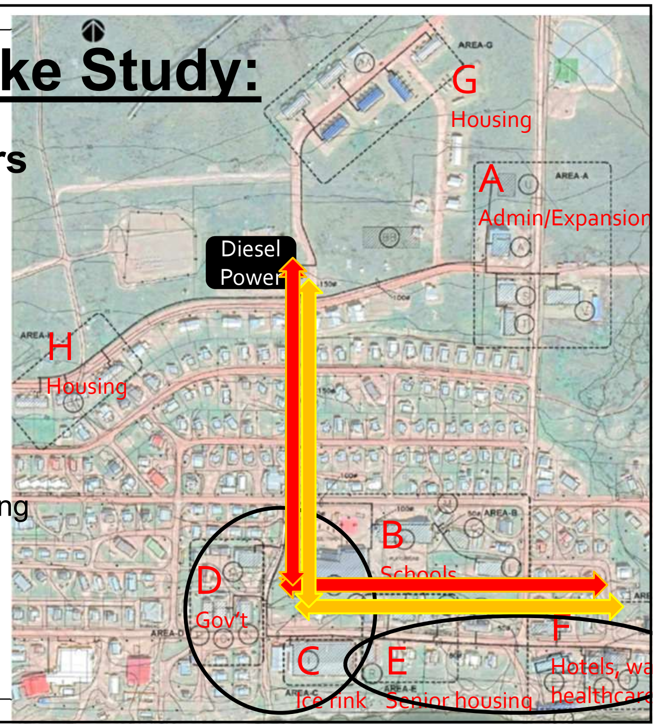
A Previous Baker Lake Study:

- **Identified 8 Large Heat Users**
  - And their peak and annual demand
- **Proposed Serving 4**
  - Generator water jacket heat
  - Peak demand limits capacity
    - Thus, most engine heat is unused
- **Economic challenge**
  - Very high pipe cost
    - Expensive high-T 2-pipe direct heating
    - Mostly "transmission" not "sales"
  - High heat loss
  - 20 – 40 year simple payback



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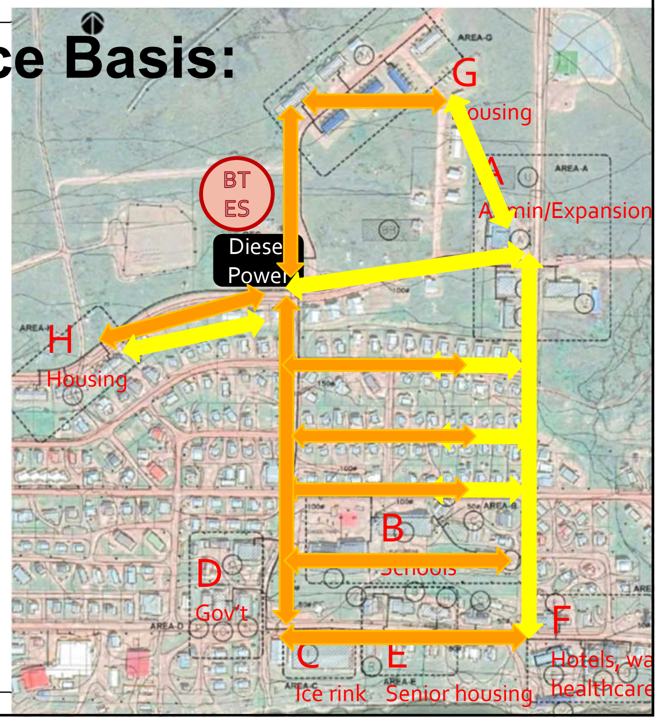
On an Energy Balance Basis: w/ a BTES & WSHPs

- **The BTES**
  - Captures both exhaust & water jacket
  - Stores summer heat for winter use
- **Enables the engine heat to serve**
  - ALL large end users
  - Plus additional businesses & homes
- **Much better Economics**
  - Single inexpensive HDPE pipe
    - Less insulation AND less heat loss
    - Mostly "sales", not transmission
    - Operates at 50F – 80F
  - Far greater total sales
  - Requires more power for heat pumps
    - More power = more heat
    - Engine fuel displaces building fuel



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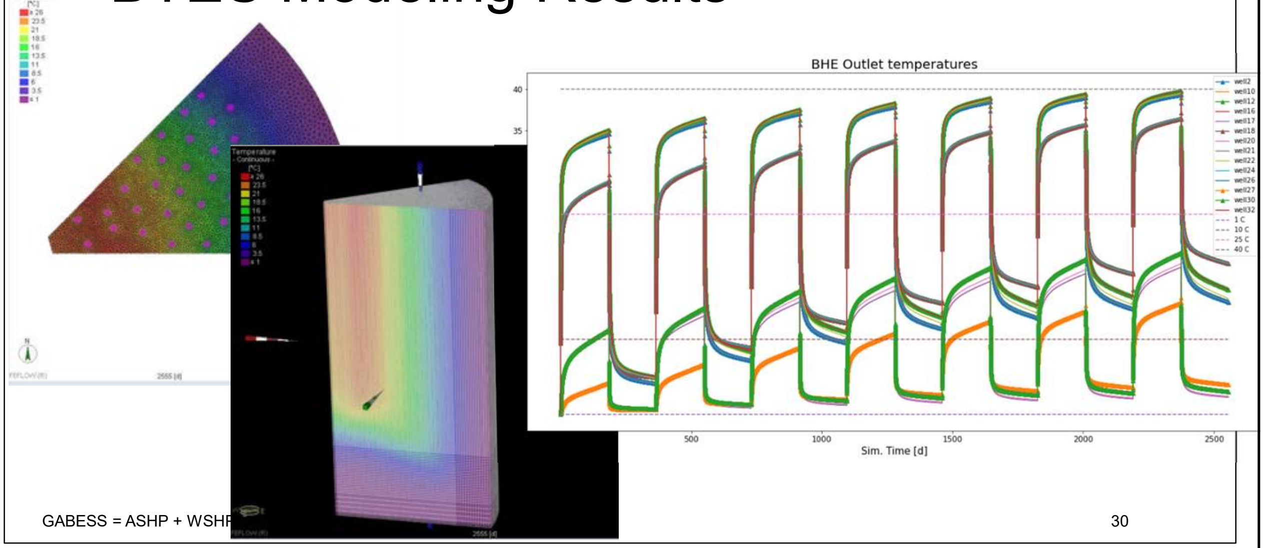
BTES Modeling Results



GABESS = ASHP + WSHP

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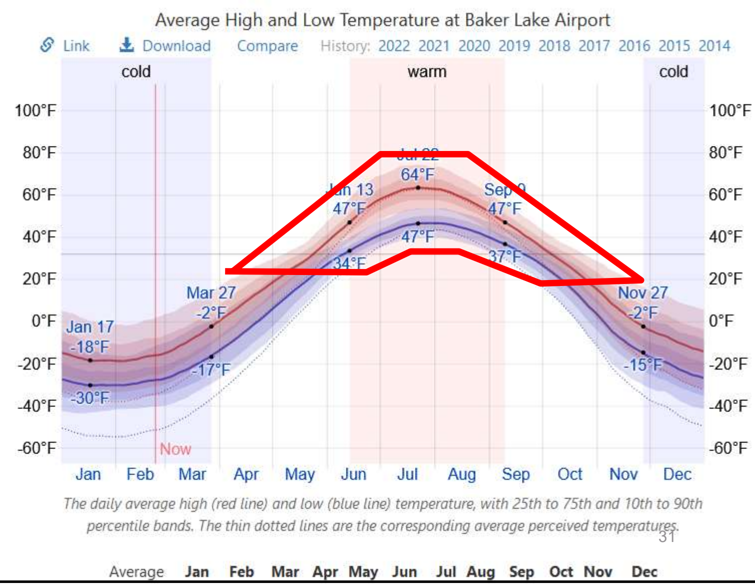
A substantial duration of warm air

- GABESS can store this energy.
- Two cost-effective options for ASHP:
  - Diesel Power
  - High-ROR decarbonization of entire community



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Conceptual Approach

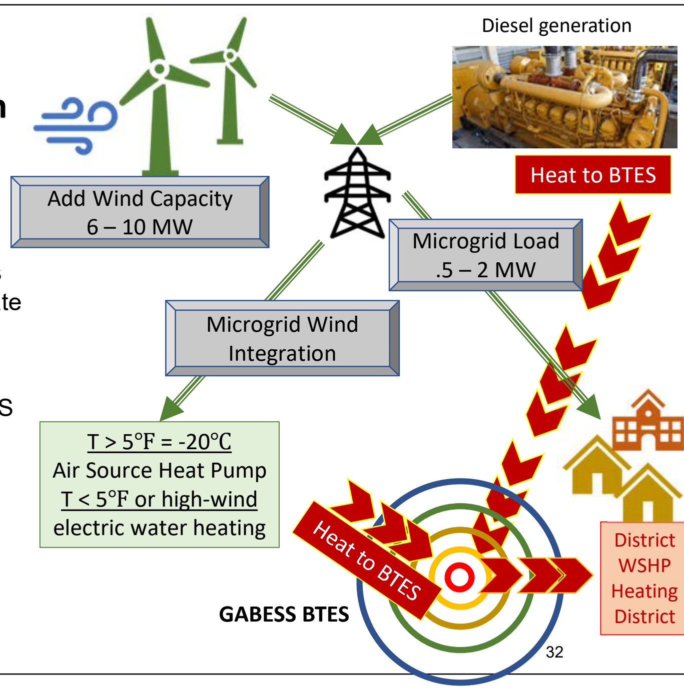
For near 100% decarbonization

Initially Use Engine–Heat
- Large Buildings
- Decarbonize heating

Then Add 6 – 10 MW of Wind Turbines
- Poor Wind speed so need more nameplate
- Cost assumed at 6X CONUS

Then Integrate them
- ASHP replaces most engine heat to BTES
- Electric resistance heat when cold or too much power

Outcome:
- ***Serve All Buildings***
- >90% Heat & Power without fuel oil
- >15% ROI
- Replicable to Other Communities



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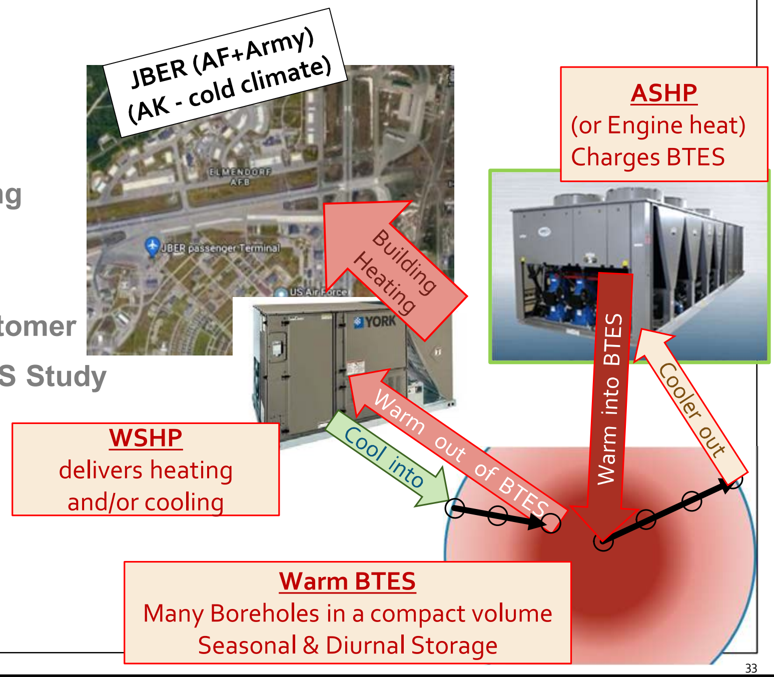

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GABESS Applications:

- **Creates on-site heat resiliency**
  - Efficient Long Duration energy storage
  - Technology Readiness Level – Fully Commercial
- **Grid Cost Reduction**
  - Main Value Driver (peak demand cost & charges)
- **Carbon Value can be monetized off-site**
  - If not a goal at the site location
- **Applicable to Cold, Hot, and Balanced Climates**
  - The more unbalanced the bigger the advantage

GABESS = ASHP + WSHP + BTES

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GABESS for Cold Climates – Alaska Examples

Military:
- Large: Fort Wainwright, Eielson AFB, JBER, Eareckson
- LRRS: Cape Lisburne, Cape Newenham, Cape Romanzof
- Coast Guard: Casco Cove, Kodiak, Sitka, Ketchikan

Urban
- Standalone buildings, or groups of buildings
- Anchorage, Fairbanks, Nome, Dutch Harbor
- Remote small communities

Industrial Heat
- Aleutian fish processing
- Greenhouses

GABESS = ASHP + WSHP + BTES

Adak conceptual District Energy System

1. **Engine**
   1. Capture heat
2. **Fish Plant**
   1. Heat out (hot water)
   2. Heat in (refrig)
   3. Use domestic water to deliver heat?
3. **City Hall**
   1. Heat out (space)
4. **Residential loads**
   1. water & space heat
5. **Water cools**
   1. COP varies along route
   2. Meters account for differences

GABESS

Grid Amplified Building Energy Seasonal Storage

Questions/ Discussion?

RESPEC

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