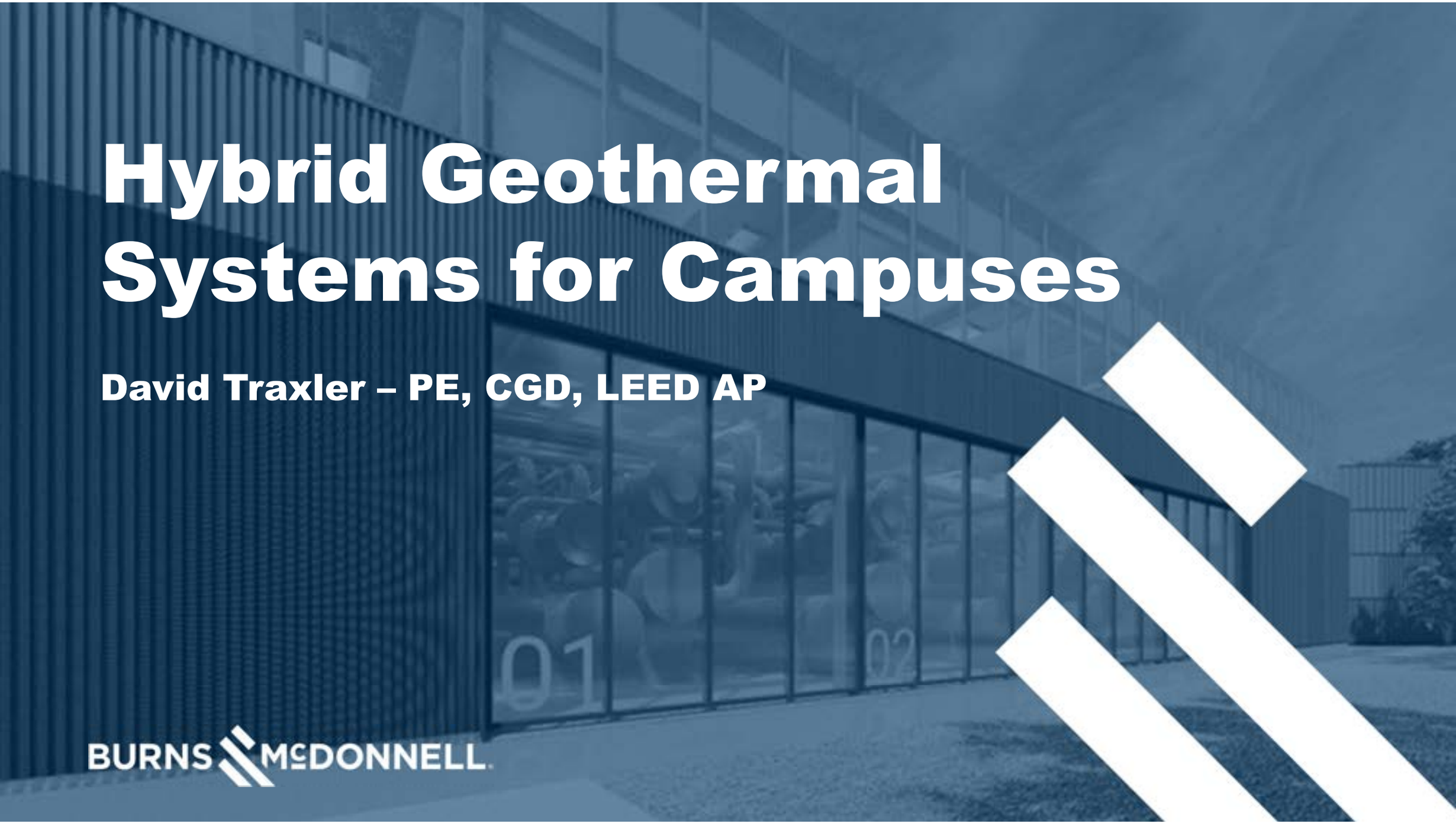


Hybrid Geothermal Systems for Campuses

David Traxler – PE, CGD, LEED AP

BURNS McDONNELL

Housekeeping Slide

Webinar and Q&A Format

This webinar is scheduled for one hour, including the presentation and approximately 15 minutes for Q&A, which will take place throughout the webinar. If needed, the webinar will extend past the hour to answer as many audience questions as we can.

This webinar will be recorded

and streamed on the IDEA website within 24 hours of the conclusion of this webinar. Registrants will also be sent a follow-up email with links to the recording and presentation slides. A link to the presentation slides is also provided in the chat box if you want to print out and follow along.

How to Submit Questions

Please submit questions via the “Q&A” box during the presentation portion of the webinar. The Q&A icon can be found in the menu bar at the bottom of your screen. Questions will be reviewed by IDEA and posed to the presenters by the host at the conclusion of their presentation.



If you are having audio or video issues, please send a note via the Chat Box to our host, Jason Beal.

Presentation Outline



What is Geothermal Heating and Cooling



Why Use Geothermal



Why Use a Hybrid Geothermal system



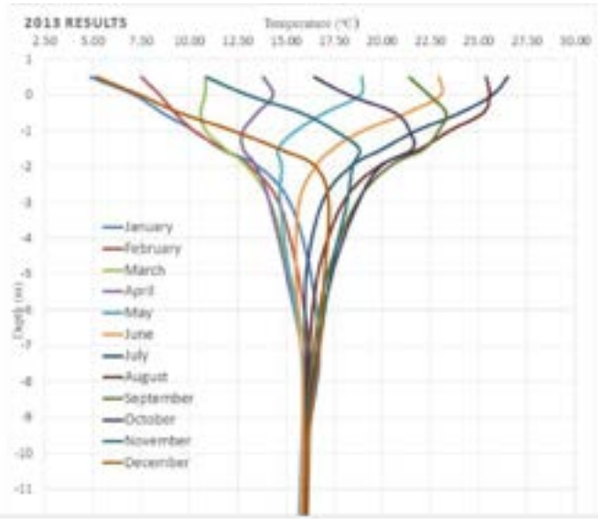
Different Types of Hybrid Systems



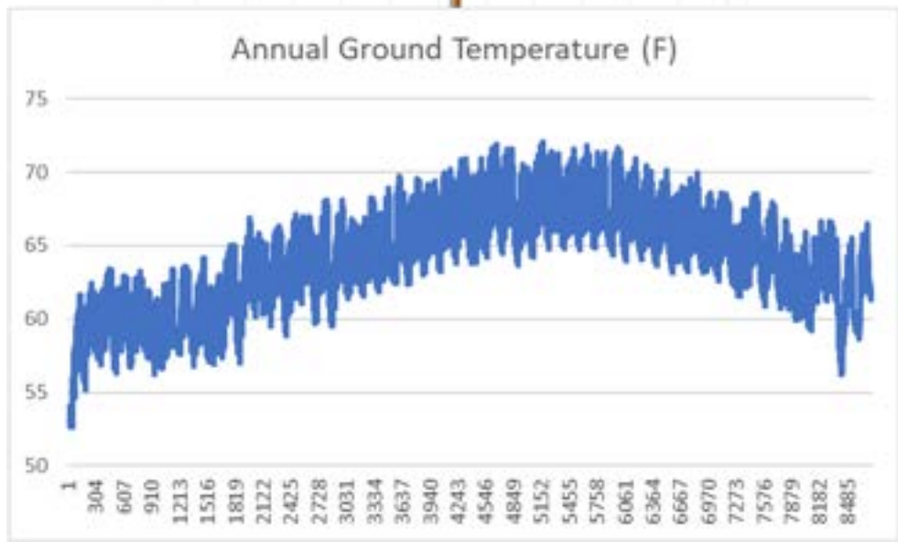
Applications

What is a Geothermal Heat Pump?

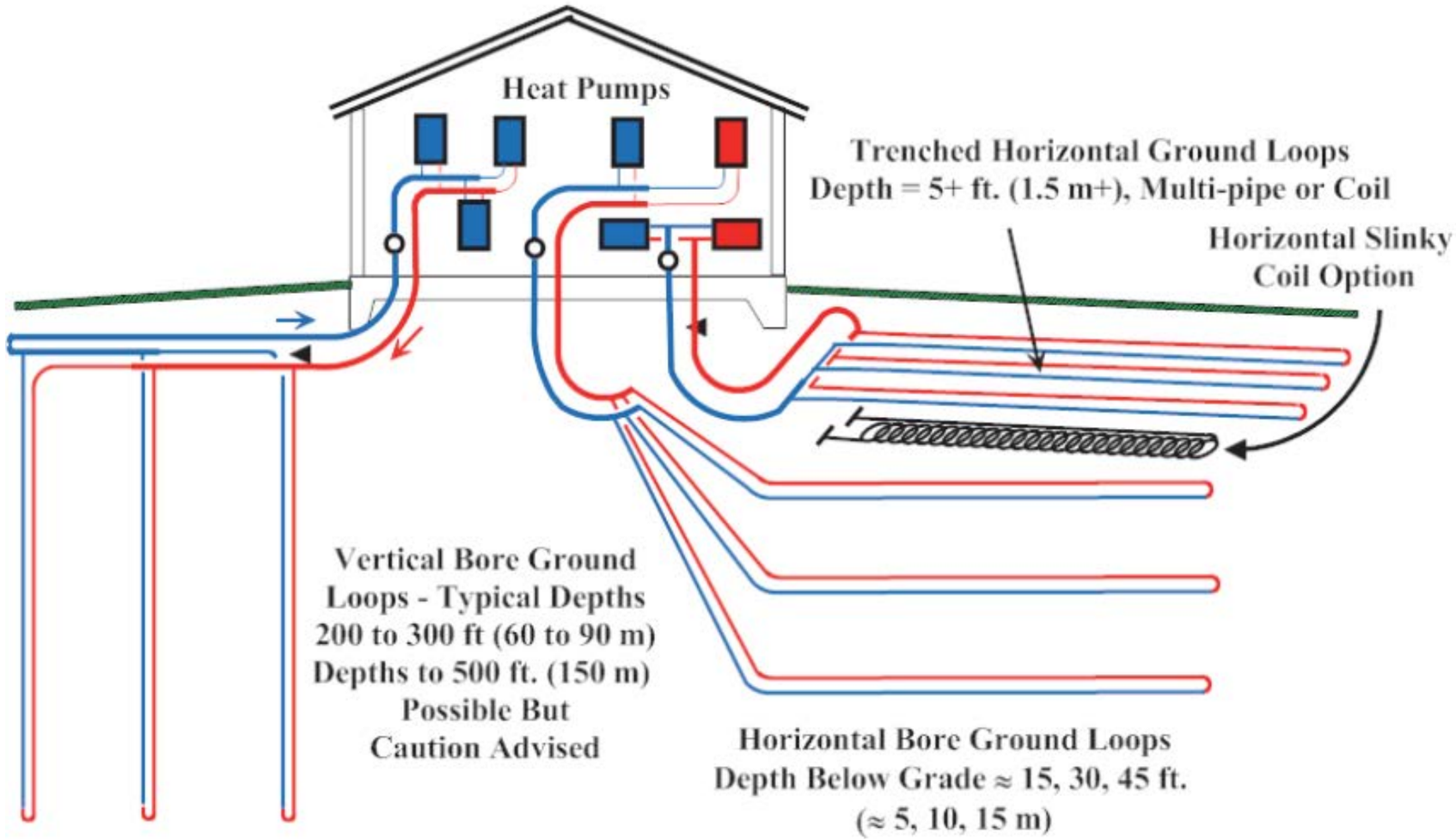
- Heat pumps move energy from an energy source to a point of use
  - Ground Temperature is relatively constant year-round, providing more energy than an air source heat pump



- The ground stores heat energy (Thermal Battery)
  - Reject building heat into the ground during summer
  - Extract building heat out of the ground during winter

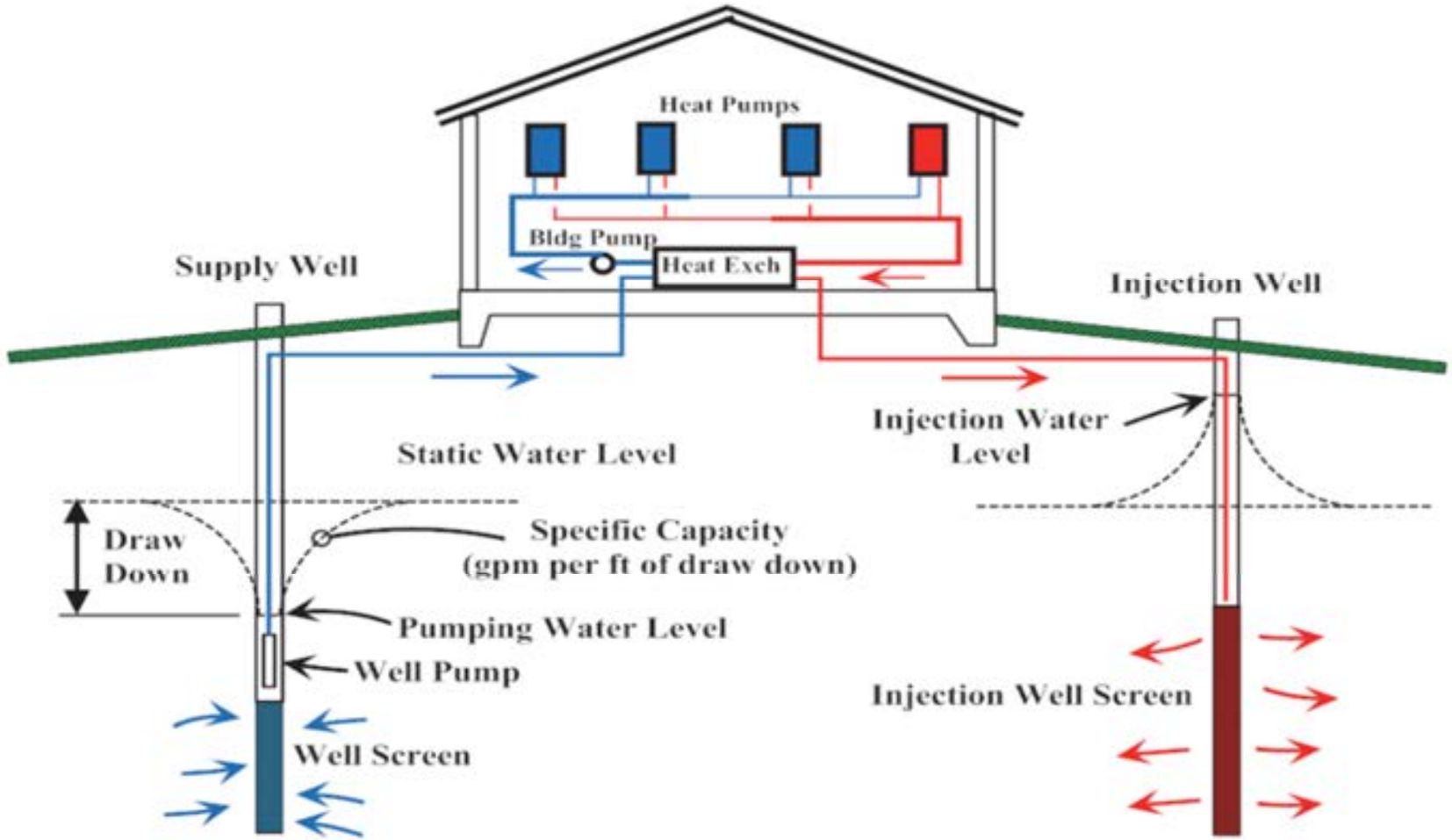


Ground Heat Exchangers



Geothermal Heating and Cooling – Kavanaugh and Rafferty

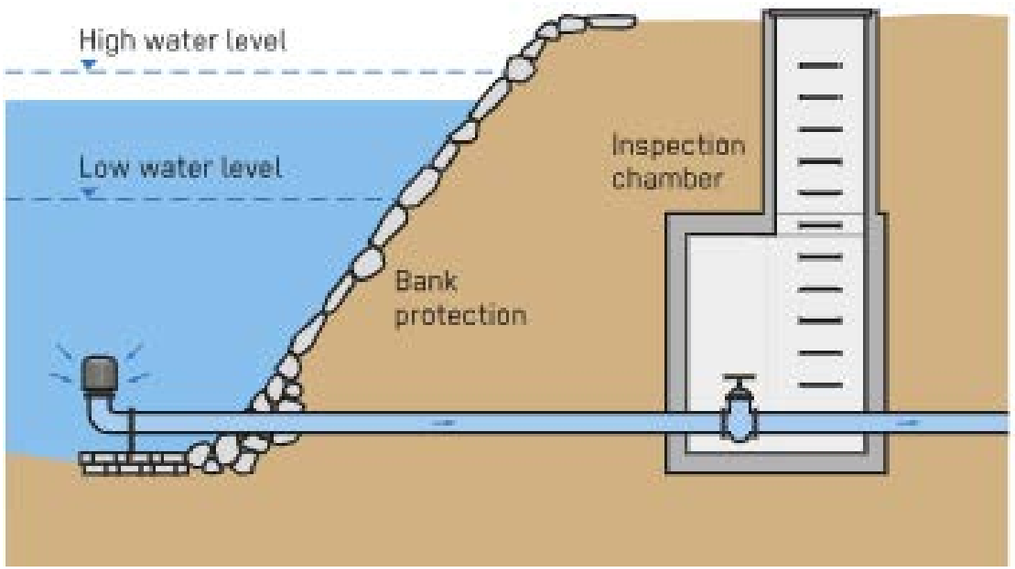
Ground Water

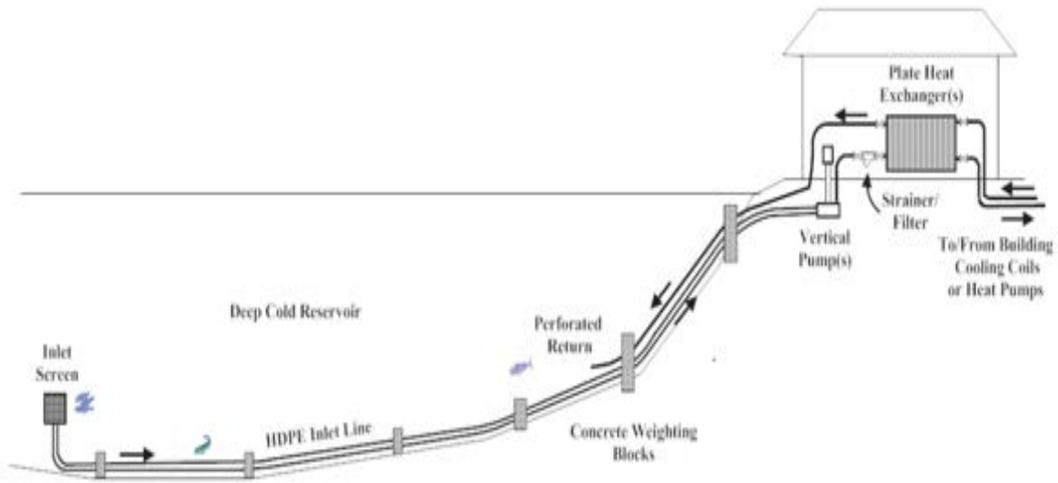


Geothermal Heating and Cooling – Kavanaugh and Rafferty

River or Lake Water Cooling

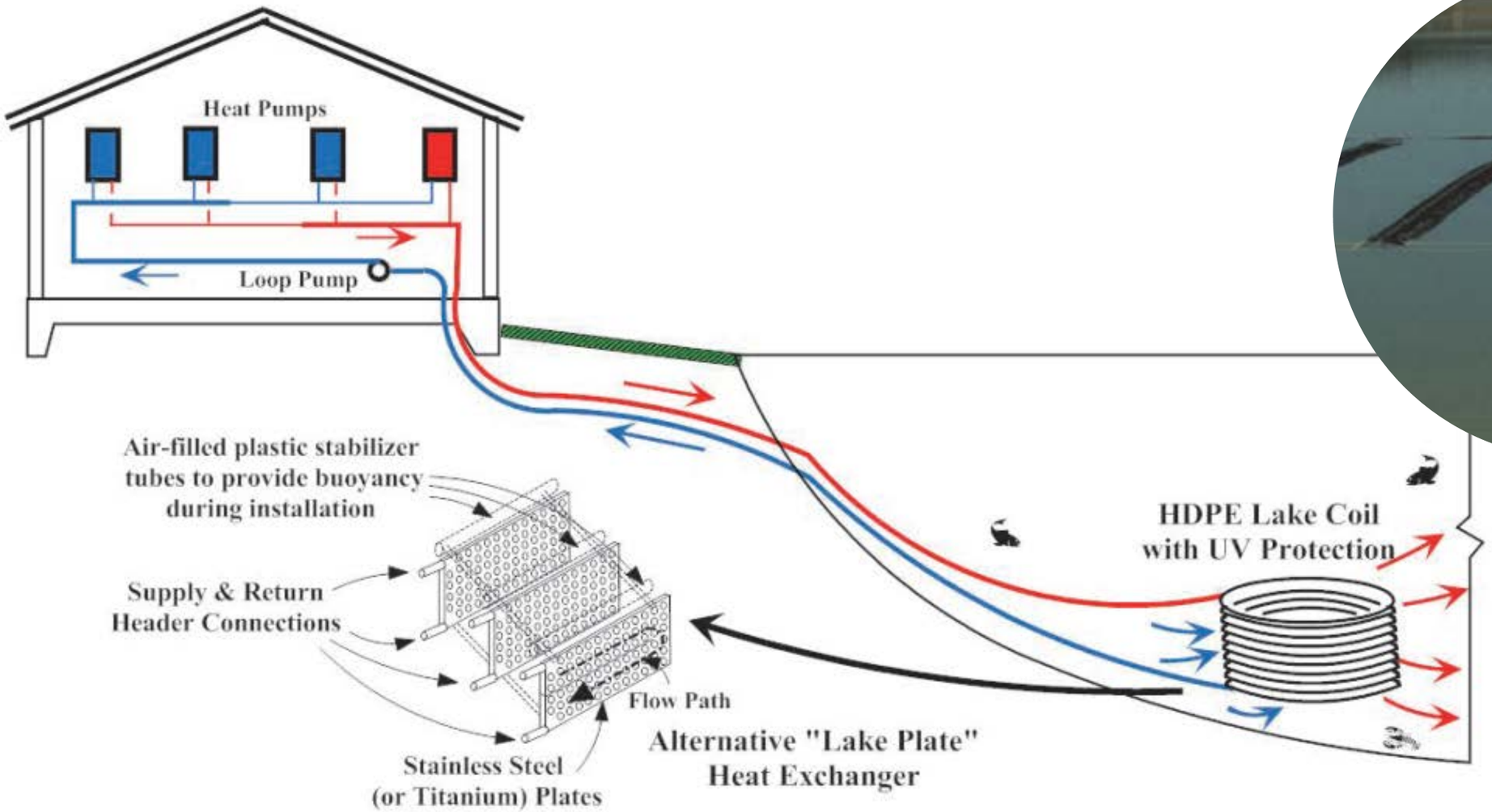
- Lake Water Cooling – Northern Climate Water Temps, 45F (FEB) – 53F (AUG)
- Connect to heat pumps for year-round heating and cooling
- Could use for compressor less cooling for even higher efficiency

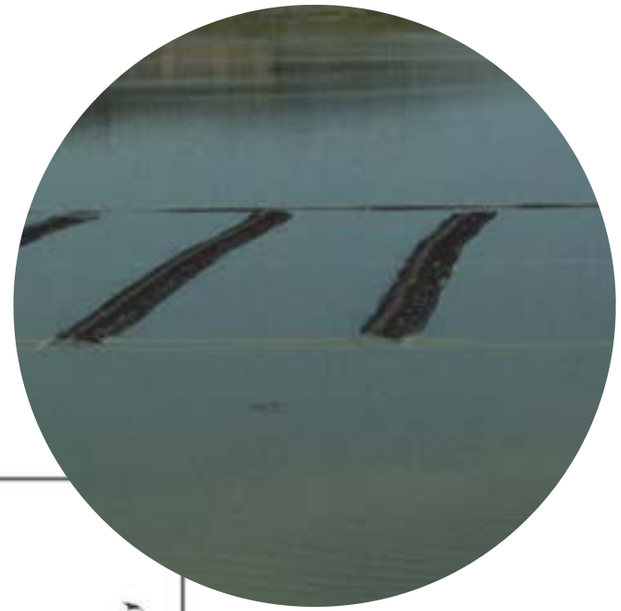




Geothermal Heating and Cooling – Kavanaugh and Rafferty

Surface Water Heat Exchangers





Geothermal Heating and Cooling – Kavanaugh and Rafferty

Why Use Geothermal

1. Most efficient way to heat and cool buildings
2. Reduces or eliminates on site fossil fuel consumption
3. Reduces or eliminates potable water use for cooling systems
4. Reduces maintenance

Why Use Geothermal - Heating Source Comparison

Space Heating Comparison

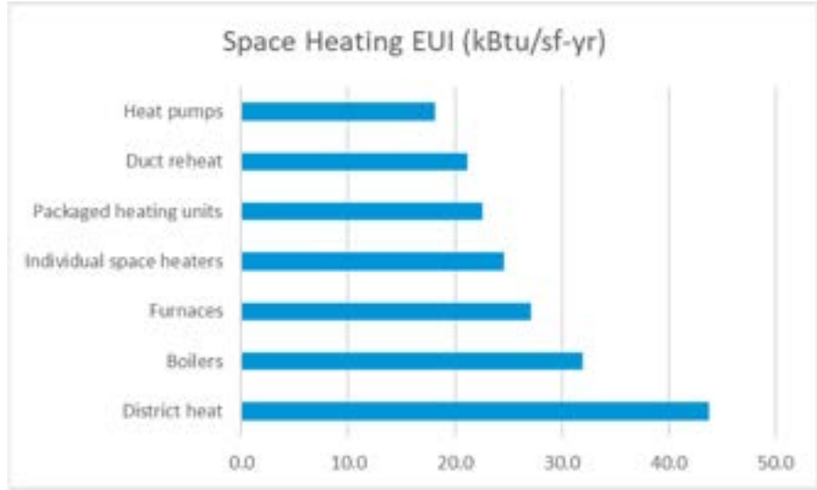
- Boilers vs District heat – 27% Energy Savings
- Heat Pumps vs District heat – 59% Energy Savings

Geo vs. VRF - ASHRAE Headquarters

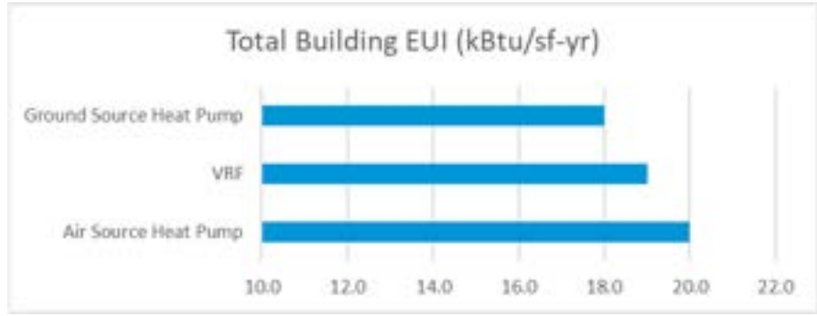
- ASHP used 41% more energy in Cooling Season
- ASHP used 172% more energy in Heating Season
- GSHP electrical demand was 0.85 w/sf vs 1.9 w/sf for ASHP

ASHRAE Headquarters Side Notes

- Pump Differential Pressure Setting was changed from 20 psi to 8 psi.
- Reducing Pump Power from 17% to 7% Increased Heating COP from 3.3 to 4.8 (45% efficiency increase!)



2018 Commercial Building Energy Consumption Survey - DOE



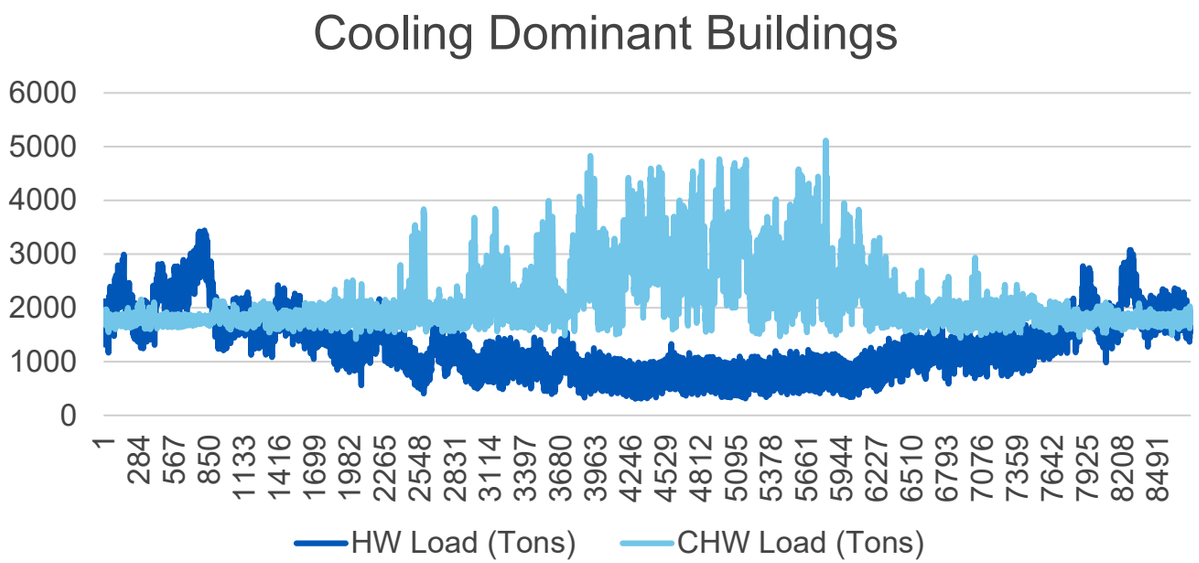
New Building Institute Net Zero Energy Buildings

Why Use a Hybrid Geothermal System

1. Peak load supplement
2. Large difference between the heating and cooling energy consumption
3. Reduced land area
4. Reduced cost

Why Use a Hybrid Geothermal System

When there are large differences between the heating and cooling loads



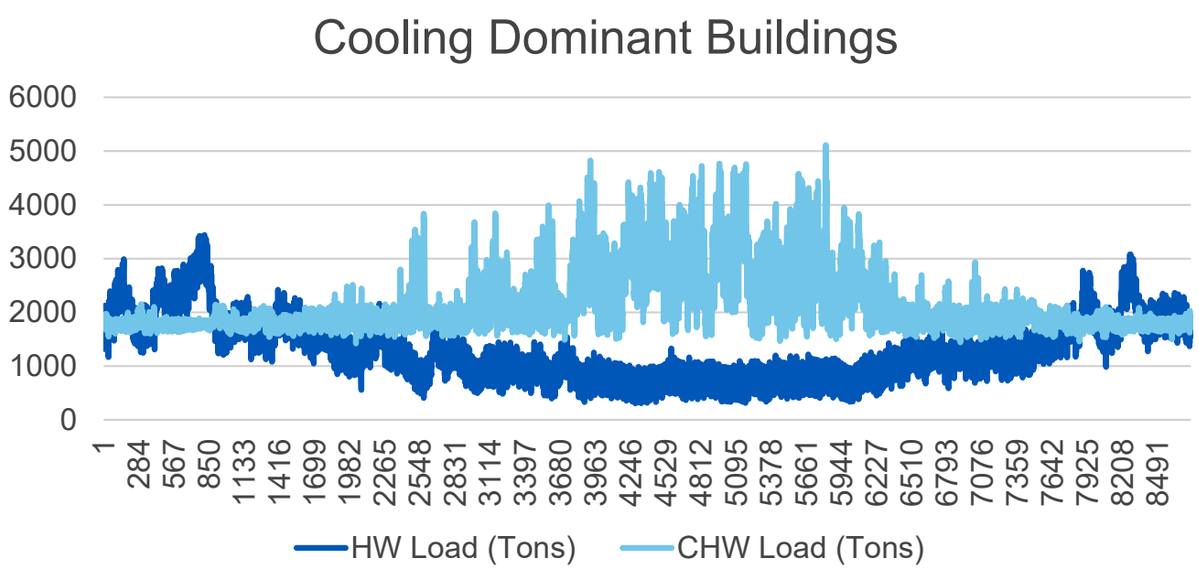
	HW Load (Tons)	CHW Load (Tons)
Max:	3441	5115
Total:	10,944,598	19,360,344

Why Use a Hybrid Geothermal System

Borefield Cost:

Borefield Designed for Heating Load – 650 bores at 600 feet deep – $11.7 Million

Borefield Designed for Total Load – 1300 bores at 600 feet deep – $23.4 Million

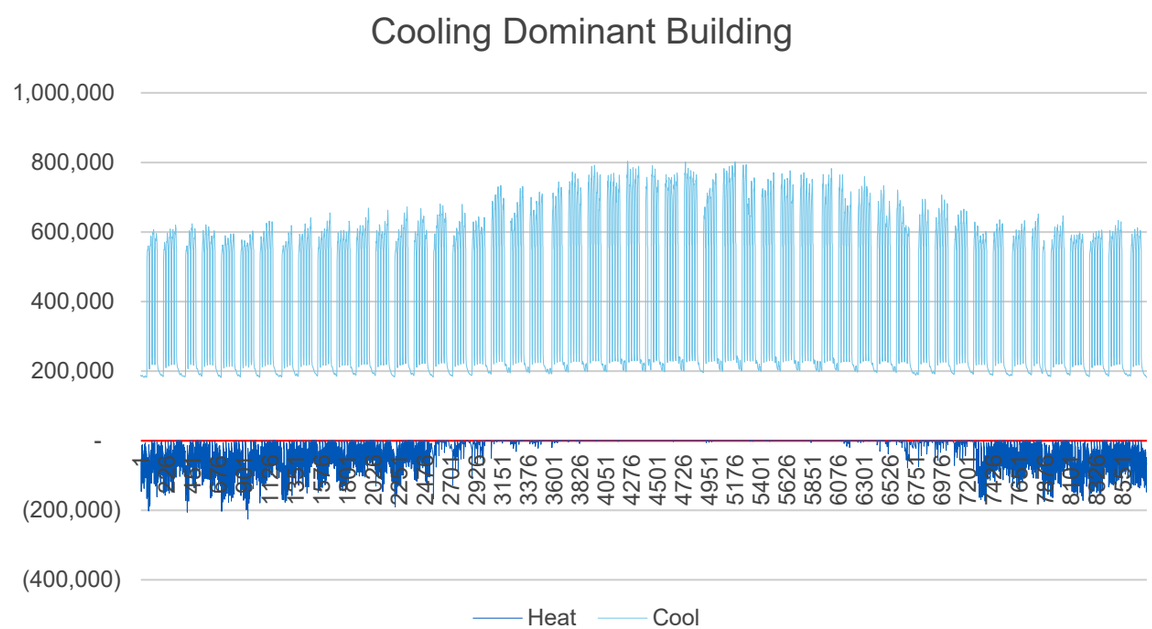


	HW Load (Tons)	CHW Load (Tons)
Max:	3441	5115
Total:	10,944,598	19,360,344

Why Use a Hybrid Geothermal System

Reduce Cost

	Traditional	Hybrid
Bores Required:	70 @ 400 feet deep	40 @ 400 feet deep / dry cooler
Bore field Cost @ $30/ft:	$840,000	$480,000
Savings		**$360,000 - 43%**



Hybrid Geothermal Systems

1. Central Hybrid Geothermal System (4th Generation)

Heating and Cooling Equipment is in a plant and distributes hot and chilled water though the campus.

2. Distributed Hybrid Geothermal System (5th Generation)

Heating and Cooling Equipment is in the buildings. Geothermal water is circulated through campus to the buildings.

4th Generation Geothermal System

Central Plant Geothermal Heat Pumps

Benefits

- Can retrofit an entire campus from a single location
- Can reuse existing chilled water and hot water piping network
- Shorter construction schedule

Drawbacks

- Less efficient because of piping thermal losses (10%), increased pumping energy (2-3 times), and the plant always runs.
- Buried piping is more expensive because it is insulated, and 4 pipes are required
- Higher first cost for large central plant equipment
- The energy shared on campus is limited to central plant heat recovery equipment
- Borefield locations need to be close to the plant buildings – less flexibility

5th Generation Geothermal System

Generation 5 – Ambient Geothermal Loop

Benefits

- Easy to expand the system to accommodate future campus growth
- No distribution energy losses. Piping actually gains energy from the earth
- Lower pumping energy, only a single fluid to distribute and can typically run at low flows – Lakeland College pumps operate at 30% capacity most of the year using loop temperature control
- Lower piping costs because pipe is uninsulated HDPE pipe and there are only two pipes instead of 4 pipes.
  - 24” Pre-Insulated Steel Pipe - $2789/ft x 4 = $11,156/ft
  - 24” Insulated HDPE pipe - $415/ft x 4 = $1,660/ft
  - 24” Uninsulated HDPE pipe - $177/ft x 2 = $354/ft
- Flexible borefield locations throughout campus, do not need to be in one or two locations
- Unlimited heat recovery potential

Drawbacks

- Need mechanical room space in each building
- Longer campus conversion process (this may not be a con because then the cost can be spread out over time)
- More equipment to maintain

Gen 4 vs Gen 5 Distribution Cost Comparison

HW and CHW main pipe length of approximately 18,000 ft

Does not include trenching and backfill. Cost is for pipe material and installation only based on RS Means.

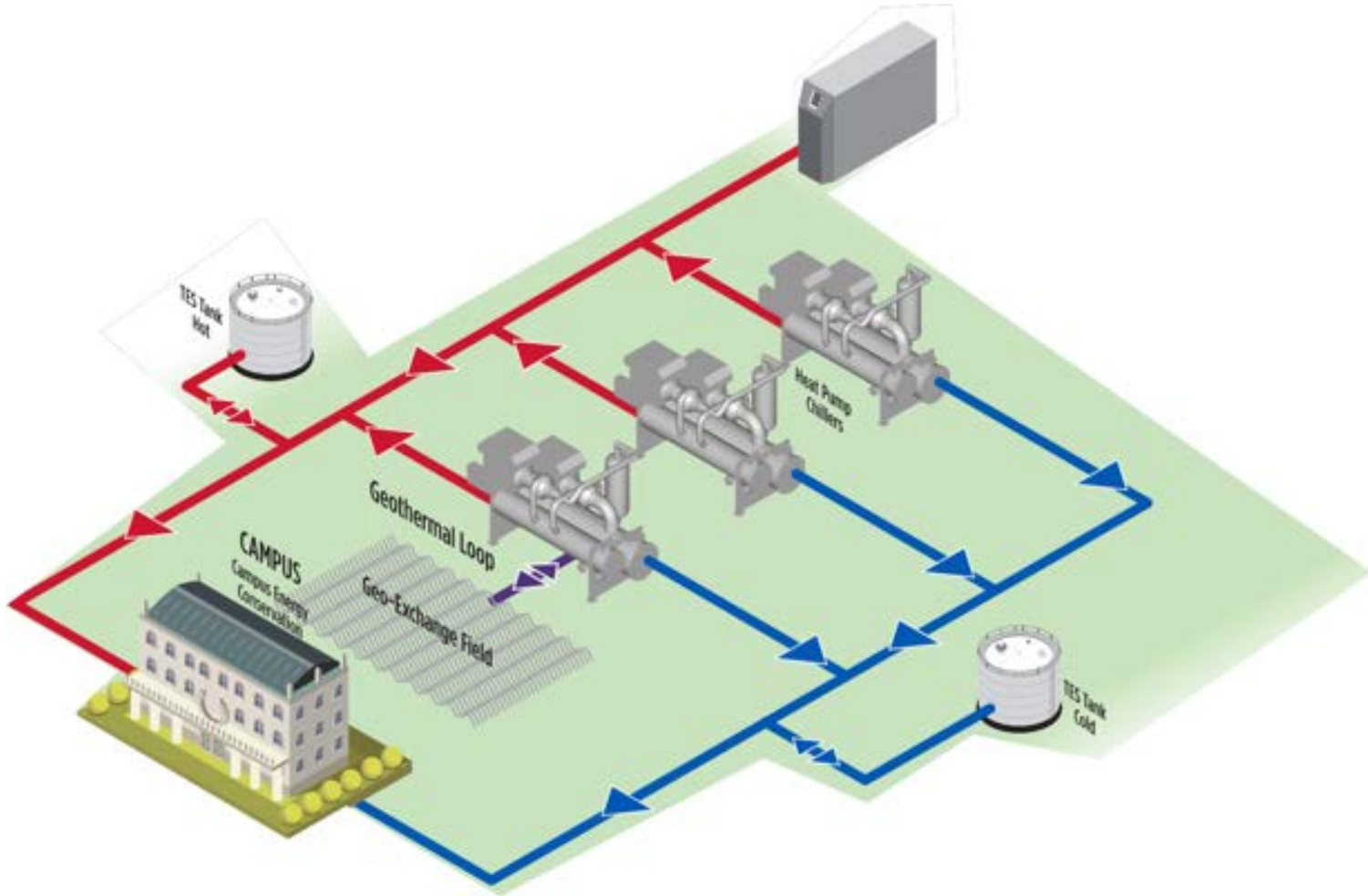
Generation 4 – Hot Water and Chilled Water Distribution

- 24” Pre-Insulated Steel Pipe - $2789/ft x 4 = $11,156/ft – Total Cost = $201 Million
- 24” Insulated HDPE pipe - $415/ft x 4 = $1,660/ft – Total Cost = $30 Million
    - *HDPE pipe pressure rating depends on hot water temperature

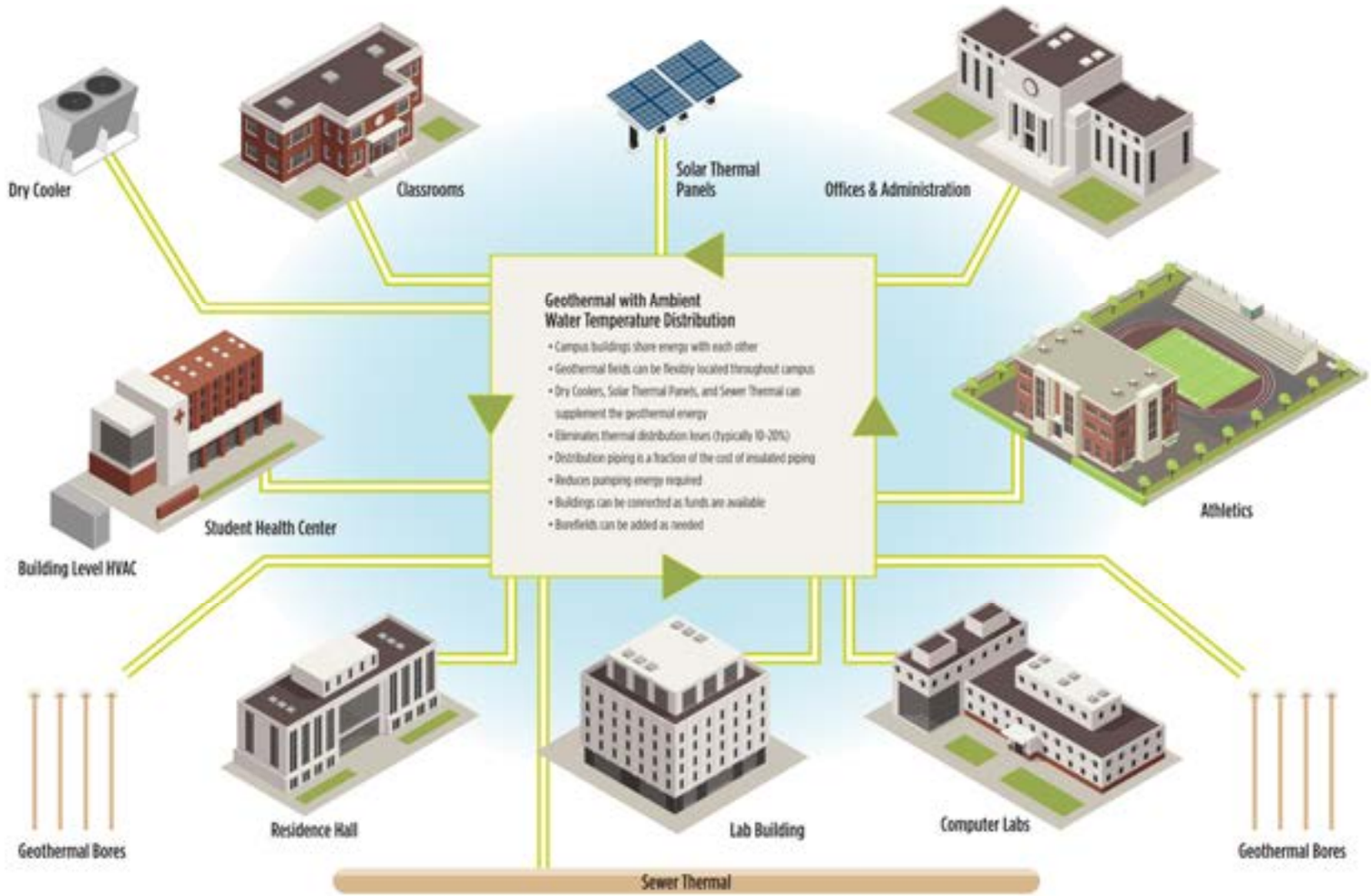
Generation 5 – Ambient Geothermal Distribution

- 24” Uninsulated HDPE pipe - $177/ft x 2 = $354/ft – Total Cost = $6.4 Million

Hybrid Geothermal – 4th Generation



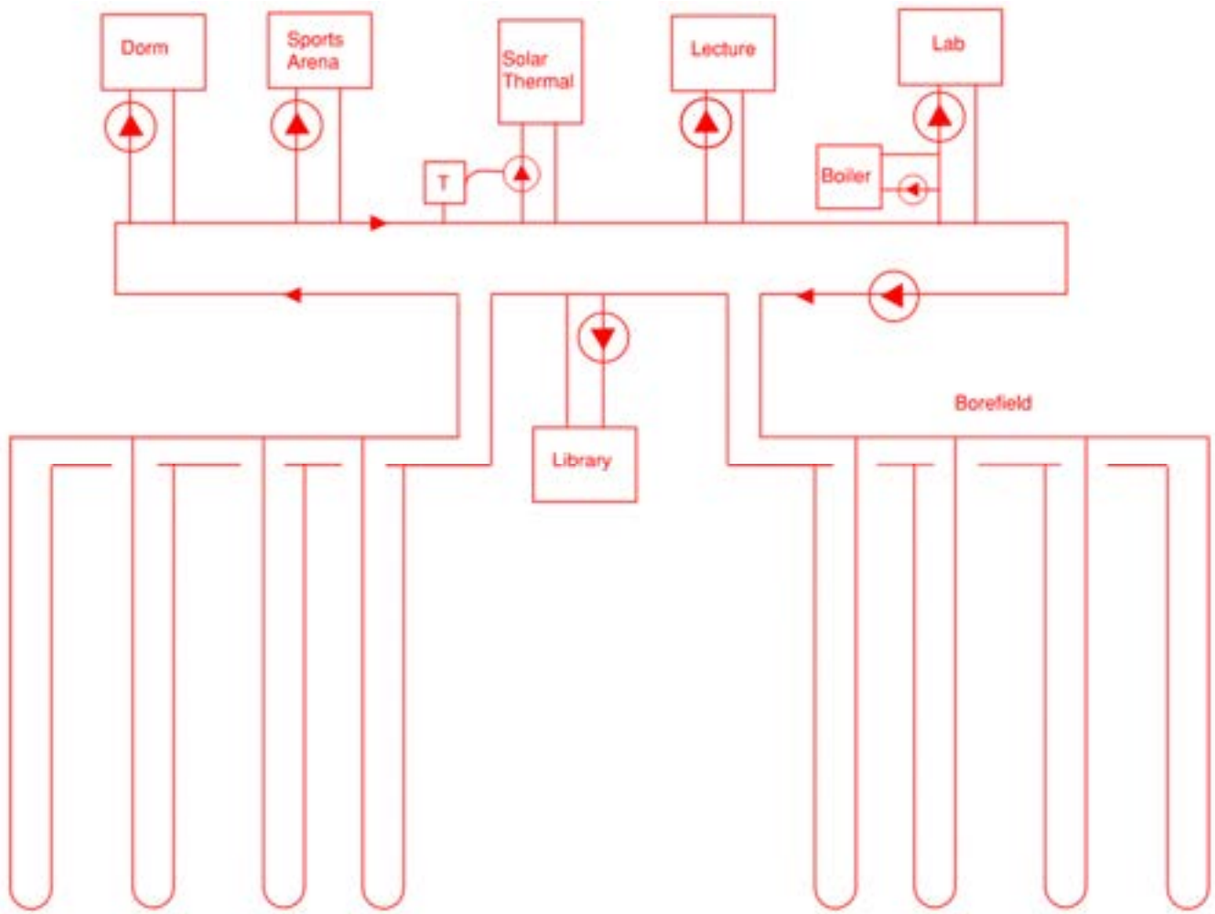
Hybrid Geothermal – 5th Generation



Hybrid Systems – Heating

Heating Dominant Locations

1. **Supplemental Boilers**
   - Operates on demand. When the geothermal water loop is too cold, turn on boilers and inject heat. Fast acting.
2. **Solar Thermal Collectors**
   - Operates on a seasonal basis. Injects heat into the loop during the fall and winter. This provides supplemental heat for the geothermal system to prevent overcooling.



Hybrid Systems - Cooling

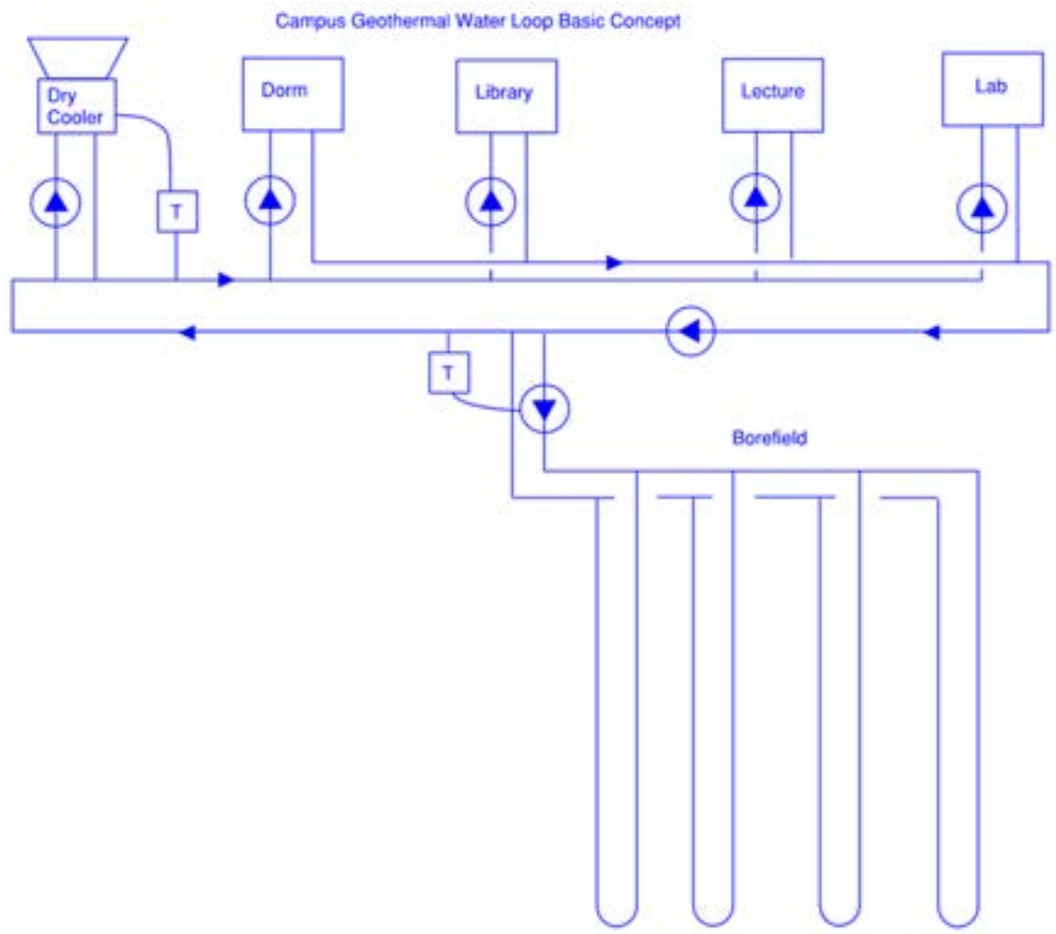
1 **Hybrid with Dry Coolers or Cooling Towers**

2 **Hybrid with Chillers – Air Cooled or Water Cooled**

Hybrid Systems - Cooling

Cooling Design:

- Dry coolers operate when OA temp is 5-10F lower than geothermal water temp
- Dry cooler can be enabled during the cooling season and disabled during the heating season



Hybrid Systems – Cooling

Whisper Valley Development | Austin, TX

Design

- No large bore field!
- One bore on each lot, houses share energy as needed
- If geothermal water temperature is hotter than air temperature, the cooling tower and central pump turn on



Hybrid Systems – Dry Coolers/Cooling Towers

Cooling Design

- Ground heat exchanger coupled with dry cooler or fluid cooler
- Subtract peak heating loads from peak cooling loads
- Size cooler for a minimum of 1.3 times the difference between the peak heating and cooling loads
- Size cooler for 2.1 times the difference for optimal performance
- Operate dry cooler when the outside air is 5-10F cooler than the geothermal water.

Advantages

- Lower first cost
- Will not overheat
- Requires less land
- Can be used for hot climate zones not normally suited for geothermal

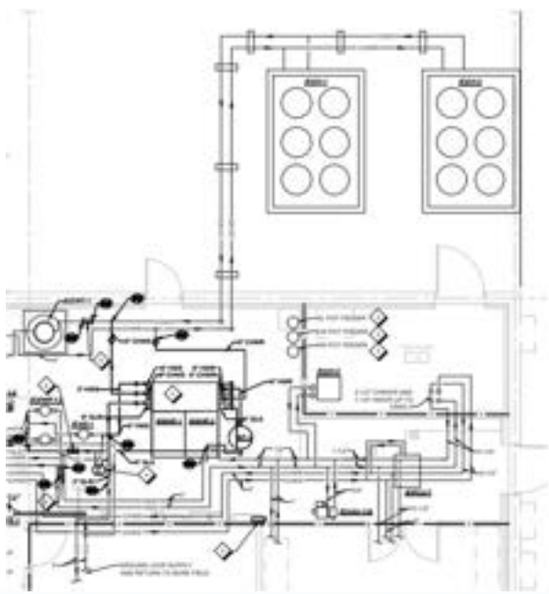
Disadvantages

- Additional maintenance
- Higher replacement costs
- Slightly higher operating costs

Hybrid Systems – Cooling w/ Supplemental Chillers

Cooling Design

- Size Water to Water heat pumps and geo for hot water load
- Lead with geothermal heat pumps for all loads
- When geothermal water is higher than 75F, turn on air-cooled chillers for stage 2 cooling



Advantages

- No boilers needed
- Will not overheat
- Requires less land

Disadvantages

- Additional maintenance
- Higher replacement costs
- Slightly higher operating costs

Princeton University

Utility System Key Attributes

- Chilled Water – 20,000 Tons
- Steam – 300,000 PPH
- Power Generation (CHP) – 15 MW
- Power Generation (Solar) – 4.5 MW (AC)
- Chilled Water thermal energy storage (TES) – 40,000 Ton-Hours
- Chilled Water and Steam Piping – 70,000 LF/13.5 miles



Princeton University

Project Outline

- Conversion from steam to hot water heating
- New 7,000-ton heat pump chiller plant - **TIGER**
- Designed for future expansion
- No combustion/no cooling towers
- New heat pump chiller at West Plant
- New heating hot water distribution network
- Installation of geo-exchange bore fields
- Hot and cold thermal energy storage





Princeton University

Hybrid Benefits

- Reduced borefield size by about 50% while providing about 80% of heating and cooling
- 380,000 MMBTU reduction in natural gas consumption
- 1.6 MW increase in peak electrical load
- 58.7 MGal annual reduction in domestic water consumption (about 600 houses worth)
- 20,000 MTCO2e annual reduction in GHG emissions. Equivalent to taking 4,300 passenger vehicles off the road.



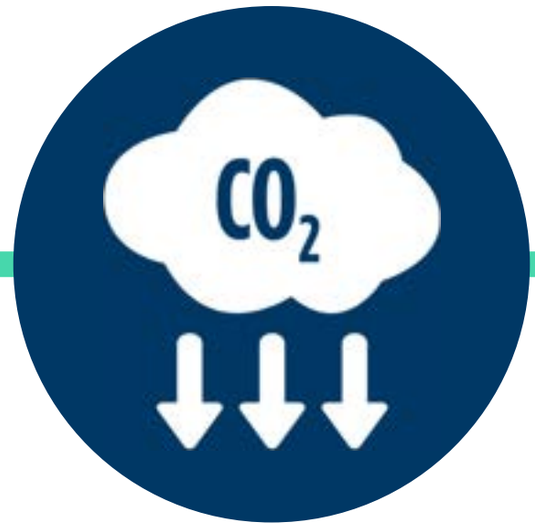
Summary – Hybrid Benefits



Lower first cost



Reduced construction time



Reduced greenhouse gas emissions over traditional systems



High efficiency

QUESTIONS?

BURNS McDONNELL®

What's Next at IDEA?

CampusEnergy2024
BRIDGE TO THE FUTURE
February 20 – 23, 2024
Hilton San Francisco Union Square | San Francisco, CA

CampusEnergy2024 registration
https://bit.ly/CampusEnergy24Reg

Preliminary Technical Program now online
https://bit.ly/IDEACampus24Ed

Looking to exhibit or sponsor? Contact Tanya Kozel at tanya.idea@districtenergy.org to reserve space.

IDEA2024
District Energy for Sustainable Cities
June 17 – 20 | Orlando, FL

Call for Presentations for IDEA2024, taking place in Orlando, **June 17-20, 2024 is now open!** Deadline to submit is December 1, 2023.

Submit Abstract: https://bit.ly/CFP-IDEA2024

Upcoming Online Webinars

Wed, November 8 – **"Best Practices in District Energy/CHP: Project Life Cycles:" –** Part 1 of a 4-part Project Life Cycles series; 2:00-3:30pm EST.
https://bit.ly/IDEABestPractices

Thursday, November 9 – District Energy Women's Initiative Virtual Meetup - https://bit.ly/DEWINov9

Wed, November 29 – "IDEA Geothermal Symposium" at 1:00pm EST (online)
https://bit.ly/IDEA-GeoSymposium

As always, registration is free to all.

If you can't make it, register anyway and the recordings will be sent to you the next day.

INTERNATIONAL DISTRICT ENERGY ASSOCIATION