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Powering the Future: District Energy/CHP/Microgrids
Sept. 27-29 | Austin Convention Center | Austin, Texas

Clean District Thermal Energy System Master Planning

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Electrification / Decarbonization Goals

- Electrification
  - Convert any energy uses currently provided by fossil fuels to electric based options.
- Decarbonization
  - Converting energy uses that create ongoing carbon emissions to energy sources that have no or little carbon emissions.

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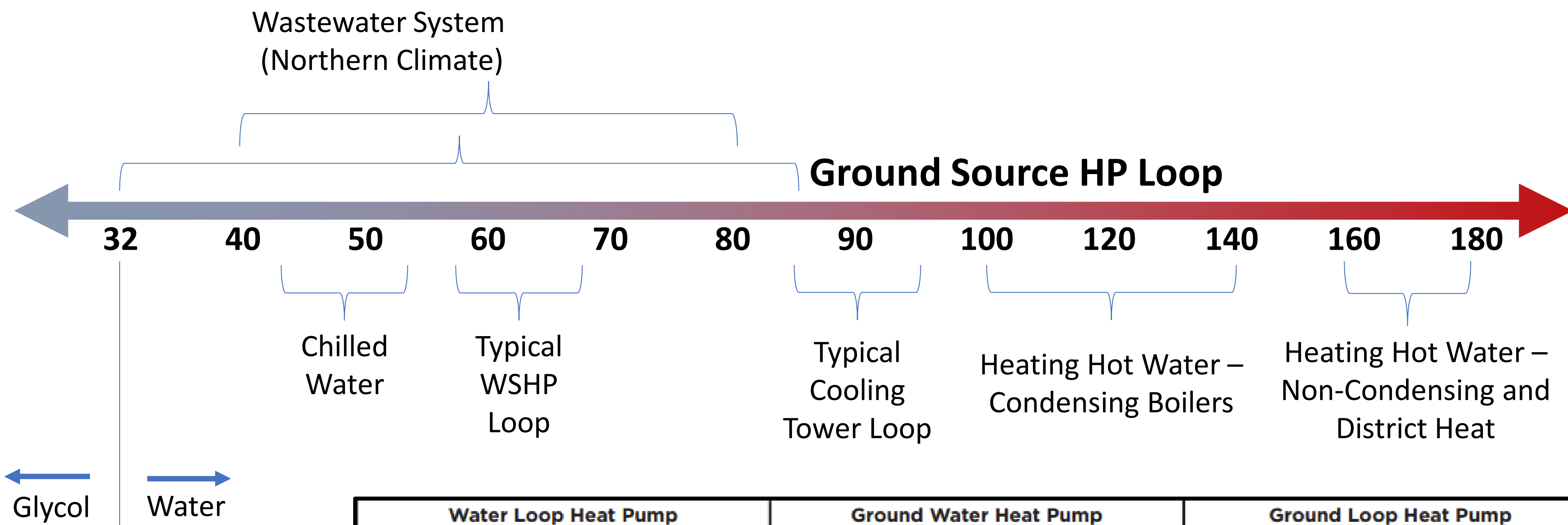
Evolution of District Heating

Gen	Name	Temperature	Features
1G	First generation district heating (1GDH)	<390 °F	• Steam as heat carrier • Coal-fired systems • Concrete pipes
2G	Second generation district heating (2GDH)	>212°F	• Pressurized hot-water • Fossil-based centralized plants
3G	Third generation district heating (3GDH)	~210°F	• Pressurized hot-water • Industrialized substations • Heat storage integration • High-efficient CHP plants
4G	• Fourth generation district heating (4GDH) • Low-temperature district heating (LTDH) • Low-enthalpy systems	120–180°F	• Low-temperature water • Renewables integration • Heat waste recovery
5G	• Fifth generation district heating (5GDH) • District heating and cooling (DHC) • Decentralized heat pump smart grid • Water loop heat pumps systems • Cold District Heating (CDH) • Bidirectional low temperature networks	<85°F	• Heating and cooling supply • Reversible heat pumps substations • Decentralized production • Heat sharing metering

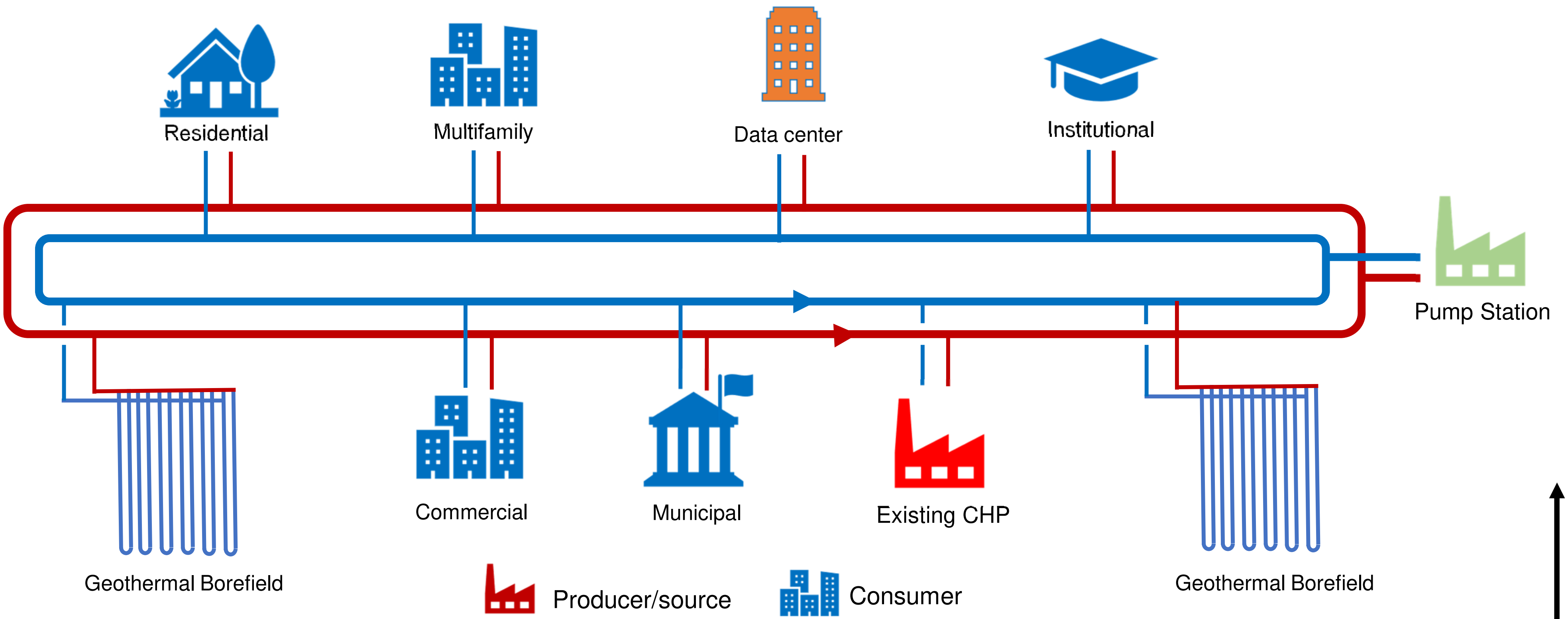
HVAC Temperature Scale



Water Loop Heat Pump		Ground Water Heat Pump		Ground Loop Heat Pump	
Cooling EWT 86°F	Heating EWT 68°F	Cooling EWT 59°F	Heating EWT 50°F	Cooling EWT 77°F	Heating EWT 32°F

AHRI Water Source Heat Pump Rating Points

Clean District Energy System Example

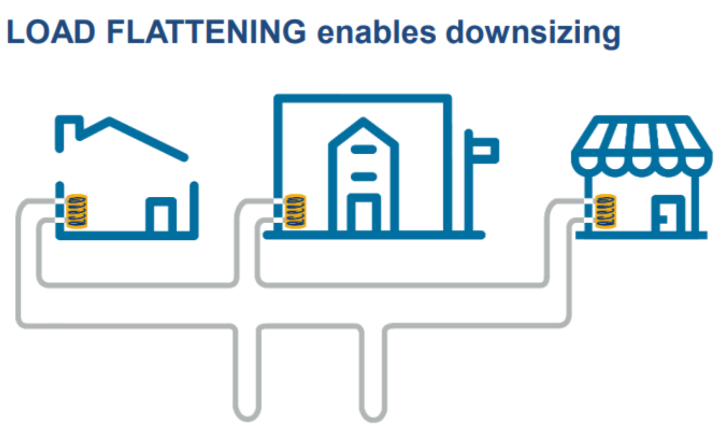


System Comparison

Creating 1000 MBH of Building Heat					
	District ASHP	District Geo	Onsite Geo	WSHP (Boiler/Tower)	NG Fired HW
Site Energy (kBtu)	460	389	371	1433	1509
Source Energy (kBtu)	1444	1222	1165	1070	1150
Utility Costs					
Central Plant	$ 3.11	$ 0.68	$ -	$ -	$ -
Building	$ 9.45	$ 13.07	$ 13.69	$ 15.46	$ 8.53
Total	$ 12.55	$ 13.75	$ 13.69	$ 15.46	$ 8.53
CO2 Emissions*	72.1	61.0	58.1	245.3	281.3

* Assumes Current NY ISO Electrical Generation Mix

District vs Individual Building Scale



Source: NYSERDA PON 4614 Presentation

District Geothermal Systems - Advantages

- Primary heating and cooling source is a ground heat exchanger.
  - Typically vertical boreholes at this scale.
- HDPE Piping has a long lifespan (50-100 yrs)
- Absorbed heat has no associated cost.
- Uninsulated pipe.
- Low grade heat recovery opportunities.

District Geothermal Systems - Disadvantages

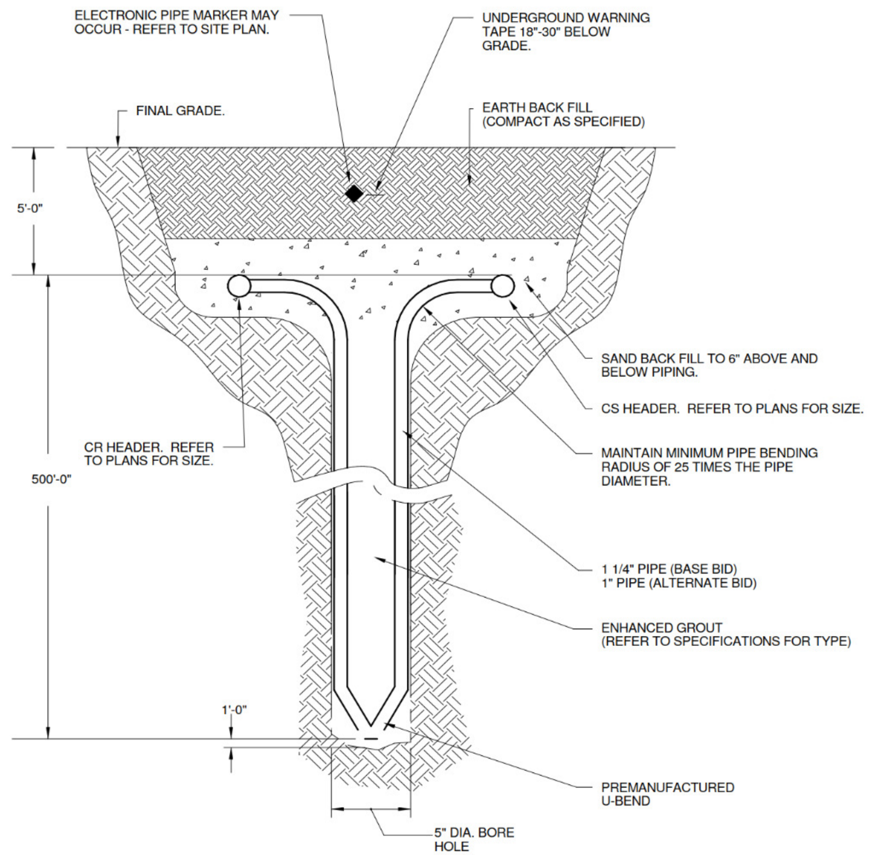
- High Capital Cost.
- Space requirements.
- Requires distributed heat pump equipment to provide heating. Increased and distributed maintenance.
- Lower loop dT could mean higher pump requirements compared to hot water systems.

Planning a Geothermal Based System

- Finding the most balanced load profile.
  - Understand the loads and how they may compliment.
    - (i.e., cooling loads in winter, heating loads in summer)
- Identifying open space
  - Greenfield
  - Parking Lots
  - Building Sites (New Construction)
- Direct application or building system retrofit?

Vertical Boreholes

- DR11 HDPE Piping
- 1 – 1 1/2" Piping
- 5-6" Boreholes
- Filled with cement-based grout.



Demand Side

- Heat Pump Chillers
- Terminal Heat Pumps
- Water to water Domestic Hot Water Heaters
- Water Source HP AHUs and RTUs
- Water Cooled Chillers (Retrofit)

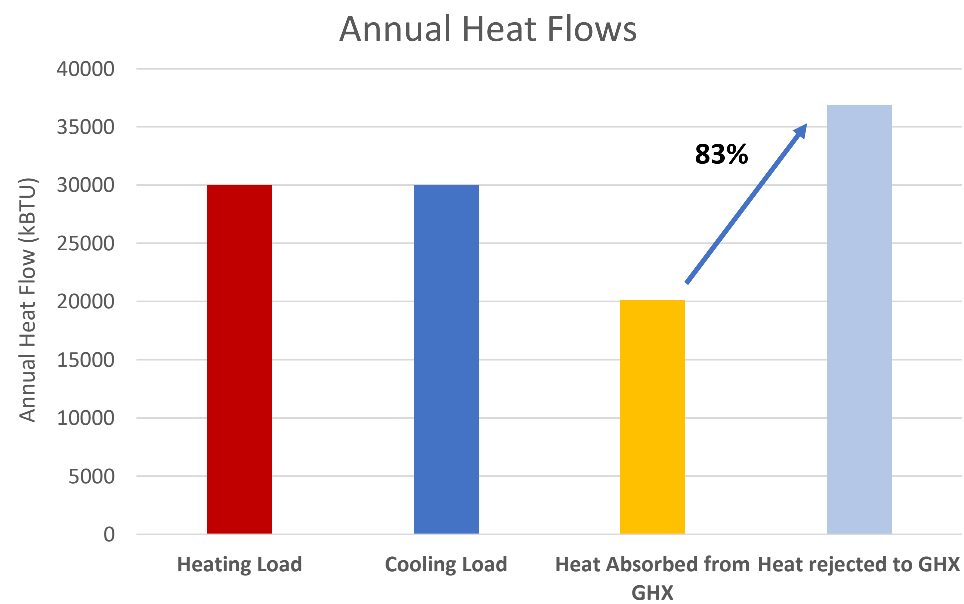
Ground Heat Exchanger Sizing

Variables

- Annual Heating and Cooling Loads
- Peak Heating and Cooling Loads
- Bore Spacing
- Grout Conductivity
- Ground Temperature
- Approach Temperature

GHX – Annual Heat Flows

- Unlike most system types, in addition to the peak design loads the balance of the loads on the GHX over time is a critical component.



Assuming SEER = 15 (Cooling), COP=3.0 (Heating)

GHX – Annual Load

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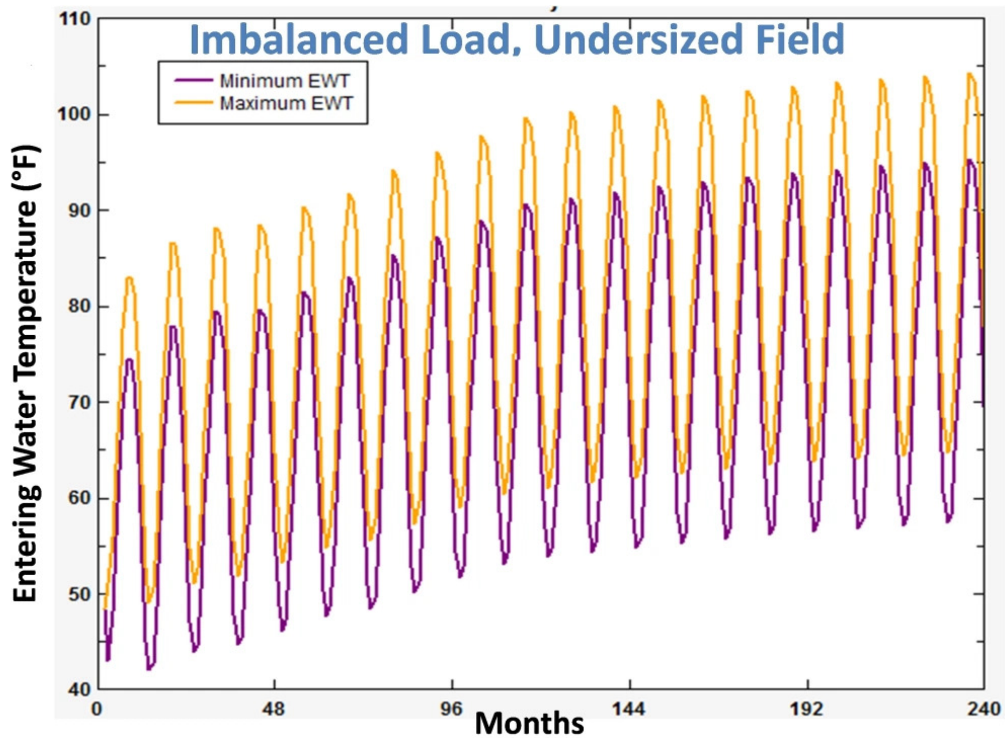

GHX – Annual Load

Variables

- Annual Heating and Cooling Loads
- Peak Heating and Cooling Loads
- Bore Spacing
- Grout Conductivity
- Ground Temperature
- Approach Temperature

$$L_c = \frac{q_a R_{ga} + q_{cond}(R_b + \mathrm{PLF}_m R_{gm} + F_{sc} R_{gst})}{t_g - \frac{\mathrm{ELT} + \mathrm{LLT}}{2} + t_p}$$

$$L_h = \frac{q_a R_{ga} + q_{evap}(R_b + \mathrm{PLF}_m R_{gm} + F_{sc} R_{gst})}{t_g - \frac{\mathrm{ELT} + \mathrm{LLT}}{2} + t_p}$$

	Cooling	Heating
Tg	52°F	52°F
ELT	95°F	30°F
LLT	85°F	35°F

L_C / L_H = 1.95

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Borefield drilling is a messy process.

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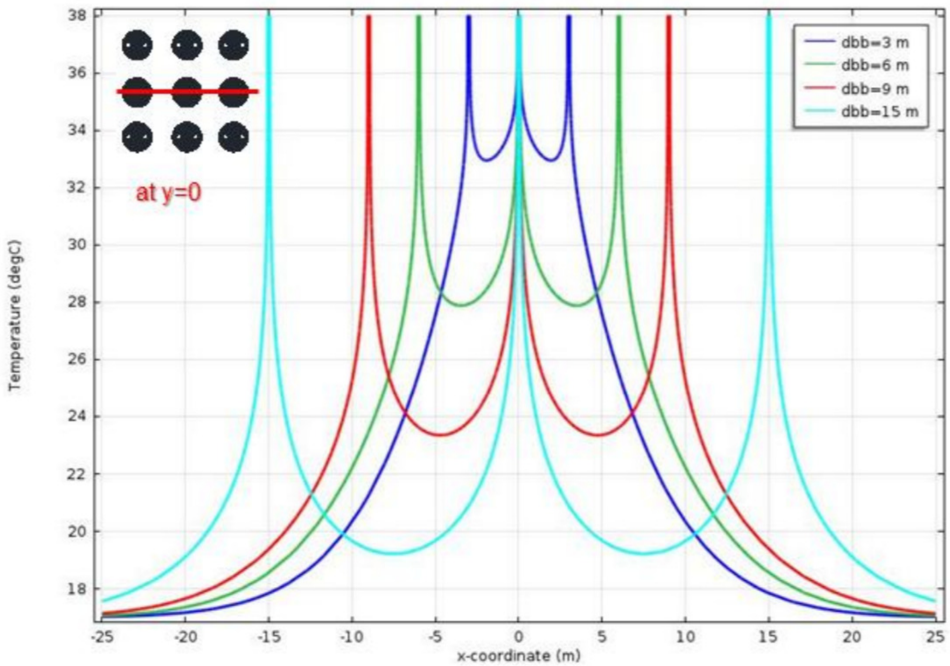
Borehole Spacing

- In large systems, the interior boreholes have thermal interference with each other.
- More spacing increases the capacity but takes up more space.

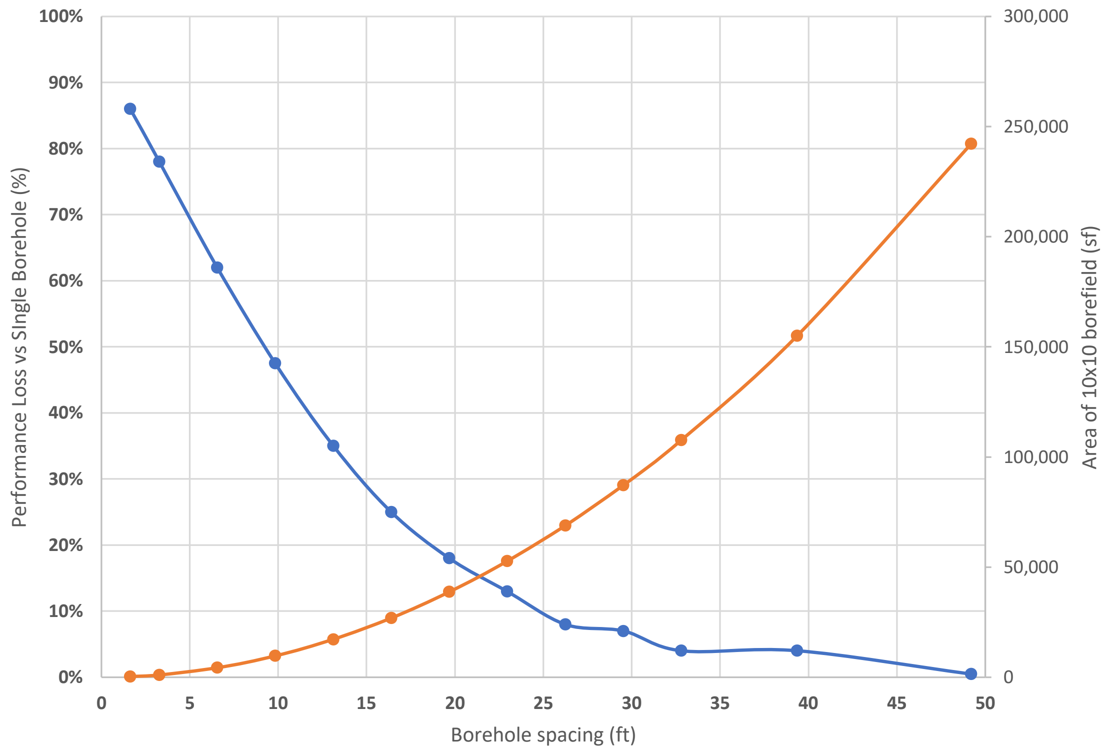


(b) 9 BHEs configuration

Figure 6: Effect of ground thermal conductivity on temperature distribution for 3 BHEs configuration after 6 months.

Borehole Spacing Requirements

- 20 ft is the most common spacing
- Trade performance for spacing -> more boreholes -> higher capacity.



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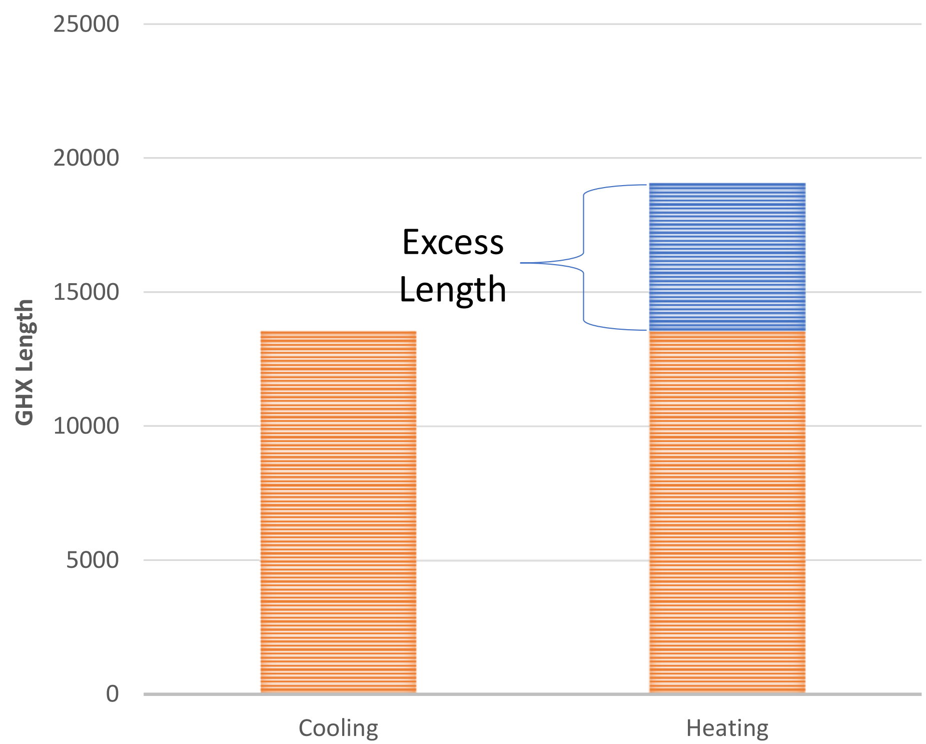
Thermal Conductivity Test

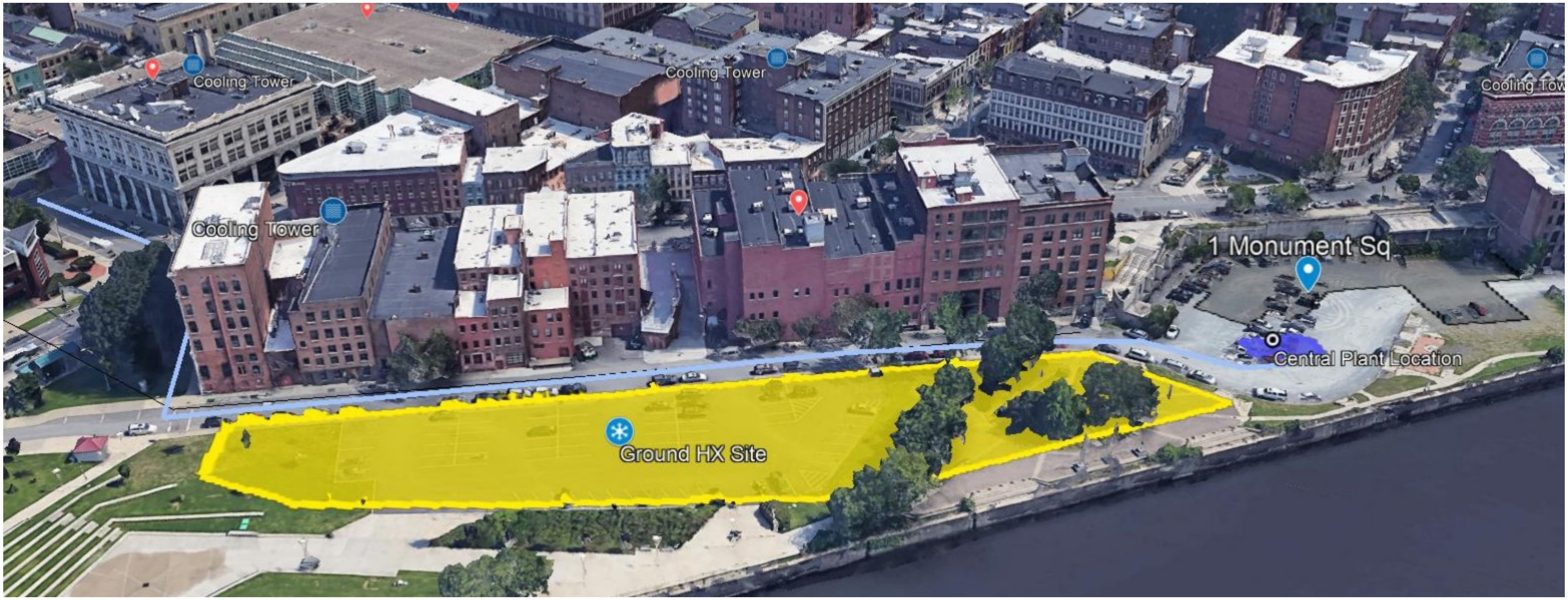
- A single borehole is installed and a rig with a pump and heating element is connected to test the thermal response of the geological formation.
- Info the test provides:
  - Thermal Conductivity
  - Geology
  - Drilling Feasibility
  - Estimate of the amount of casing needed.
  - Ground Water Potential.
- Typically, about $12-15k per location.

Hybrid Solution

- Hybrid systems combined geothermal with and additional a supplemental heating source or heat rejection.
- Goal is to remove the "excess" length and associate space requirements and capital cost.
- Understand if the peak load or annual balance is the limiting factor.



Case Study- Northeast City, Historic Downtown Area



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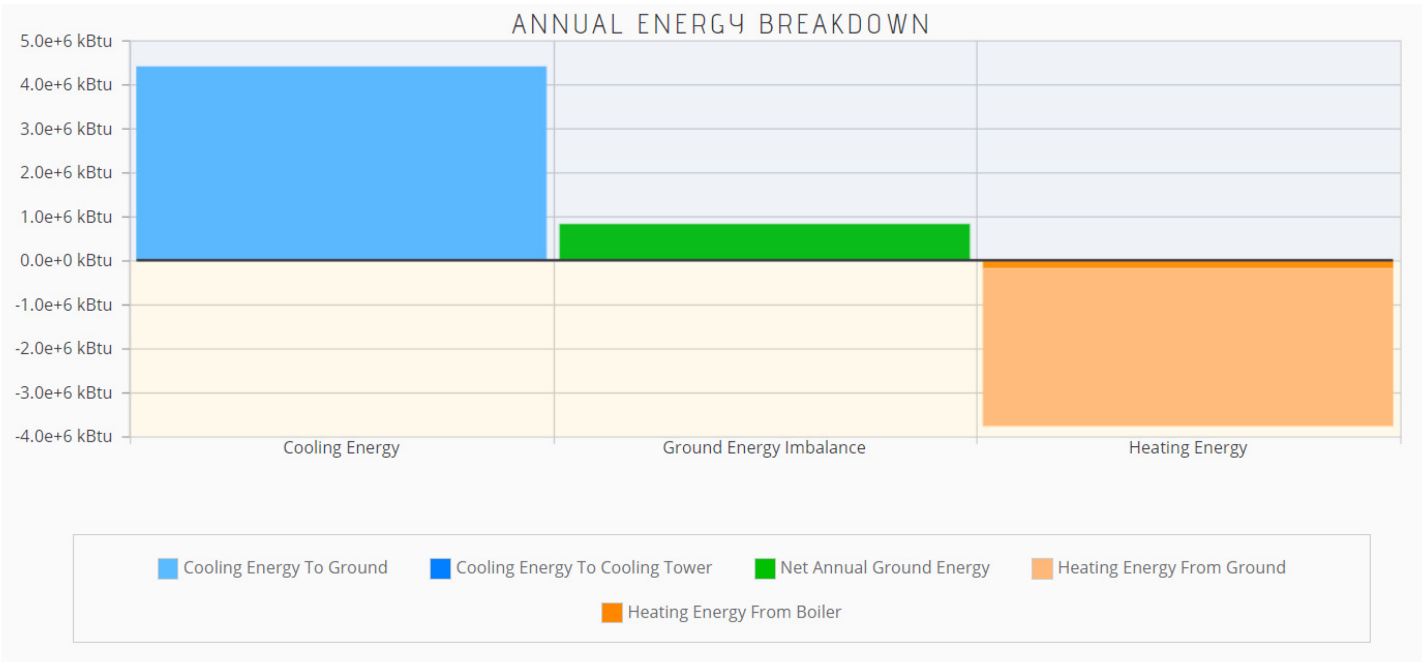
Load Profile

- Load profile consists of 5 buildings, office space, apartments and first floor retail. Most in pre-war buildings apart from one large new construction project
- Aggregate load profile is slightly cooling dominant but limiting design case is heating.

NUMBER OF BORES	156.0	
Y1 LENGTH/BORE (ft)	461.0	763.0
Y20 LENGTH/BORE (ft)	467.0	743.0
DESIGN LENGTH/BORE (ft)	763.0	
Y1 TOTAL LENGTH (ft)	71,864.0	119,101.0
Y20 TOTAL LENGTH (ft)	72,890.0	115,900.0
TOTAL DESIGN LENGTH (ft)	119,101.0	
AVG CC SPACING (ft)	21.2	

Load Profile



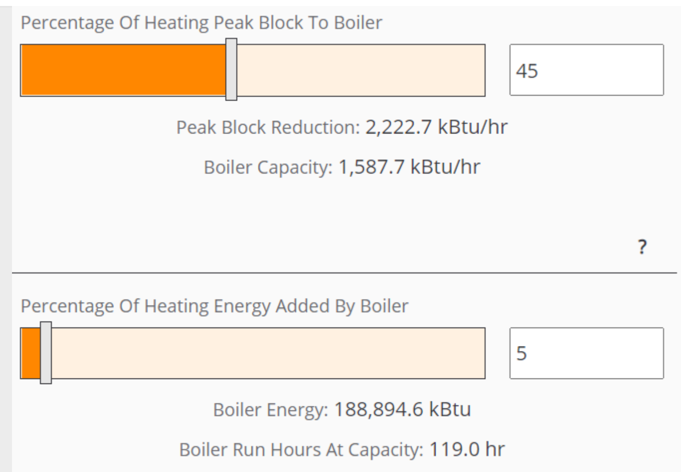
Balancing the Load.

- Hybrid System could reduce the design case from 119,000 ft to 75,000 ft, saves $650k.
- In this case there was not the available space to put in all the boreholes required by a pure geothermal system.

Or…

Number of buildings served can be expanded to utilize all of the cooling capacity.

NUMBER OF BORES	156.0	
Y1 LENGTH/BORE (ft)	459.0	484.0
Y20 LENGTH/BORE (ft)	471.0	456.0
DESIGN LENGTH/BORE (ft)	484.0	
Y1 TOTAL LENGTH (ft)	71,641.0	75,549.0
Y20 TOTAL LENGTH (ft)	73,513.0	71,158.0
TOTAL DESIGN LENGTH (ft)	75,549.0	
AVG CC SPACING (ft)	21.2	



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Types of potential heat sources

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Heat Recovery

Pro	Con
• Free Heat • Increases system efficiency • Recover low grade heat that would not other wise be available.	• Is not firm capacity, will still require backup heat. • Can be expensive to access.

Air Source Heat Pumps

Pro	Con
• Provides Electrified Heat • More efficient than electric resistance heating. • Good solution if balance is the issue not peak capacity.	• Limited market availability at district sizes. • Large footprint. • Also has a peak capacity (low ambient) problem.

Lake/River

Pro	Con
• Carbon Free Source • Permitting Challenges • Good cooling performance	• Geographically Specific • Gets tired. (Icing can occur over if overused) • Heating approach temperatures can be very low.

Thermal Storage

Pro	Con
• Maximizes Equipment Efficiency • Extends equipment capacities. • Take advantage of off-peak utility rates. • Peak Shaving/Demand Response	• Adds controls complexity. • Space requirements for storage tanks. • Capital Cost

Legacy Heating Systems

Pro	Con
• Low Capital Cost (Existing) • Utilizes existing infrastructure with remaining service life. • Can operate at extreme temperatures.	• Uses fossil fuels.

Electric Boilers

Pro	Con
• Low Capital Cost • Small footprint. • Electrified heating. • Can operate at extreme temperatures.	• High operating costs • Can distort monthly demand charges.

Conclusions

- Study was delayed and is still on going.
- Likely solution includes use of wastewater heat recovery to expand system capacity.
- Capacity only becomes an issue after the 3rd building is connected.
- Electric Boilers may be the cost-effective solution.

Summary

- Understand your load profile.
- Look for synergies.
- Maximize use of open space.
- Low temperature (5G) loops open the options for sharing and supplementing energy.

Questions

Thank You!

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