Effects of Imbalanced Loads on Long-Term Entering Water Temperatures in Closed Loop Ground Source Heat Exchange Systems

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#### Agenda

- 1 Ground-Source Heat Exchange and Electrification
- 2 Target Entering Water Temperatures for Long-Term System Operation
- 3 Modeling Varying Load Profiles and Thermal Properties
- 4 Summary
- 5 Questions



# Ground Source Heat Exchange (GSHE) and Electrification



#### Ground-Source Heat Exchange (Geothermal)

- Stable subsurface temperatures (Northeast 50-55°F)
- Draw heat from the ground in the winter
- Reject heat to the ground in the summer









#### **Buildings Contributions to Carbon Emissions**



Source: Department of Energy



#### Energy in New England – Shifting from Fossil Fuels

- Stable earth temperatures make GSHE efficient yearround for heating and cooling
- Electrification GSHE replaces local fossil-fuel heating sources using electricity from a "green" grid (declining use of oil and coal)



The amount of electricity produced by generators in New England and imported from other regions to satisfy all residential, commercial, and industrial customer demand in New England. This is called Net Energy for Load (NEL).

Source: www.iso-ne.com



Target Entering Water Temperatures for Long-Term System Operation



#### Target Entering Water Temperatures (EWTs)



Inherent imbalance toward cooling due to higher allowable delta in EWTs; temperature range must be maintained over long-term operating conditions.



## Modeling – Varying Load Profiles and Thermal Properties



## **Bore-field modeling**

- Input parameters
  - Loads (monthly or hourly)
  - Formation thermal conductivity
  - Loop thermal properties (borehole resistance)
  - Circulating fluids (water or water/glycol mix
  - Bore-field configuration/layout
  - Target EWT temperature range

🕆 Borehole Design Project	- Battelle Co	onference Pr	esentatio	n_ Modeling	Runs_031620	22 Σ
Lengths			Temp	eratures		
Total Bore Length (ft): 1 Borehole Length (ft): 5	DOLING 5000.0 00.0	HEATING 15000.0 500.0	Peak Peak	Unit Inlet (°F) Unit Outlet (°f	COOLI : 74.4 F): 81.0	ING HEATING 4 50.8 0 43.5
Calculations	Results	Fluid Soi	I Bore	Pattern E	extra kW   In	formation
Calculate 🔛					COOLING	HEATING
Monthly   Monthly  Prediction Time: 25.0 years	Tota Borel Borel	Total Bore Length (ft): Borehole Number: Borehole Length (ft): Ground Temperature Change (°F):			15000.0 30 500.0	15000.0 30 500.0
C Fixed Temperature	Grou				N/A	N/A
Fixed Length Inlet Temperatures	Peak Peak	Unit Inlet ( Unit Outlet	°F): : (°F):		74.4 81.0	50.8 43.5
74.4         °F         50.8         °F           Borehole Length:         500         ft	Tota Peak Peak	Total Unit Capacity (kBtu/Hr): Peak Load (kBtu/Hr): Peak Demand (kW):			1041.2 1041.2 42.6	1068.2 1068.2 88.8
Grid Layout	Heat Seas	Heat Pump EER/COP: Seasonal Heat Pump EER/COP: Avg. Annual Power (kWh):				4.1 4.4
Borehole Number: 30	Avg.					4.71E+4
Rows Across: 5	Syste	em Flow Rat	e (gpm):		216.9	222.6
Rows Down: 6 Separation: 25.0 ft	Optio	onal Hybrid S	System: (	Off Cooling		Heating
Piping Design		Update Reset	Peaks:	1	0 %	0 %
Piping Builder	5	ummary	Totals:	1	0 %	0 %

Source: Ground-Loop Design (GLD) software



### Bore-field modeling, cont'd

- Design objectives:
  - # of boreholes
  - Borehole spacing
  - Borehole depth/total exchanger length
  - Exchanger type i.e., single Uloop, double U-loop (Quad loop), concentric



#### Contrasting load profiles\*

Month	Monthly Cooling (kBtu/mo)	Monthly Heating (kBtu/mo)
January	12,400	154,774
February	11,339	132,663
March	22,099	68,241
April	25,947	32,545
May	45,437	37,766
June	82,813	25,150
July	77,016	9,065
August	99,950	16,904
September	123,378	17,627
October	34,073	45,532
November	25,002	60,906
December	14,571	108,155
Total	574,024	709,327
Peak Maximum (kBTU)	1,041	1,068
Peak Maximum (tons)	87	89

#### Balanced

 $\frac{annual\ cooling}{annual\ heating} = \frac{574,024}{709,327} = 0.81$ 

Month	Monthly Cooling (kBtu/mo)	Monthly Heating (kBtu/mo)
January	37,199	154,774
February	34,016	132,663
March	66,243	68,241
April	75,211	32,545
May	134,134	37,766
June	238,662	25,150
July	230,662	9,065
August	293,522	16,904
September	312,292	17,627
October	98,900	45,532
November	74,273	60,906
December	42,282	108,155
Total	1,637,396	709,327
Peak Maximum (kBTU)	1,500	1,068
Peak Maximum (tons)	125	89

#### Imbalanced

$$\frac{annual\ cooling}{annual\ heating} = \frac{1,637,396}{709,327} = 2.3$$



\*Typical Commercial/Institutional Buildings

#### Load profile 1 (balanced): 25-year projection of exiting water temperatures





#### Load profile 2 (imbalanced): 25-year projection of exiting water temperatures





#### Ground Source Heat Exchanger Ground Loop Temperature Profile 25 Year Modeling Period

Effects of varying input parameters – loop design (double U-loop vs. single U-loop), increased ground thermal conductivity





#### Summary

- Balanced heating and cooling loads are key to maintaining an acceptable range of EWTs for efficient long-term heat pump operation.
- Target ratio for **cooling:heating** typically is around 0.8 to 0.9 for balanced annual ground exchange loads.
- More favorable thermal properties and double U-loops improve EWTs over time, but typically will not compensate for imbalanced loads.



## Questions?

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