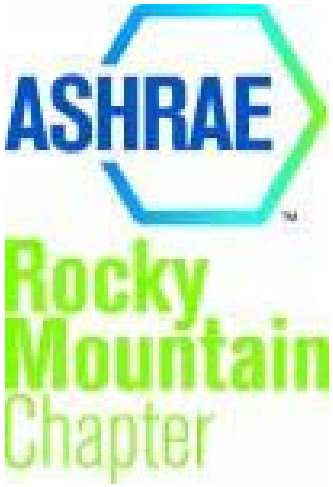
Commercial Scale GSHP Performance



April 19, 2013

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Defining “Performance”:

- Mechanical system efficiency
- Installation cost
- Operating cost
- Maintenance cost
- Ground heat exchanger (GHX)

Commercial GSHP Performance

Typical aspects of most commercial and institutional facilities:

- Cooling dominant from internal gains – reject more heat annually (cooling) than is necessary for space heating
- Reasonably consistent or predictable occupancy and operating schedules

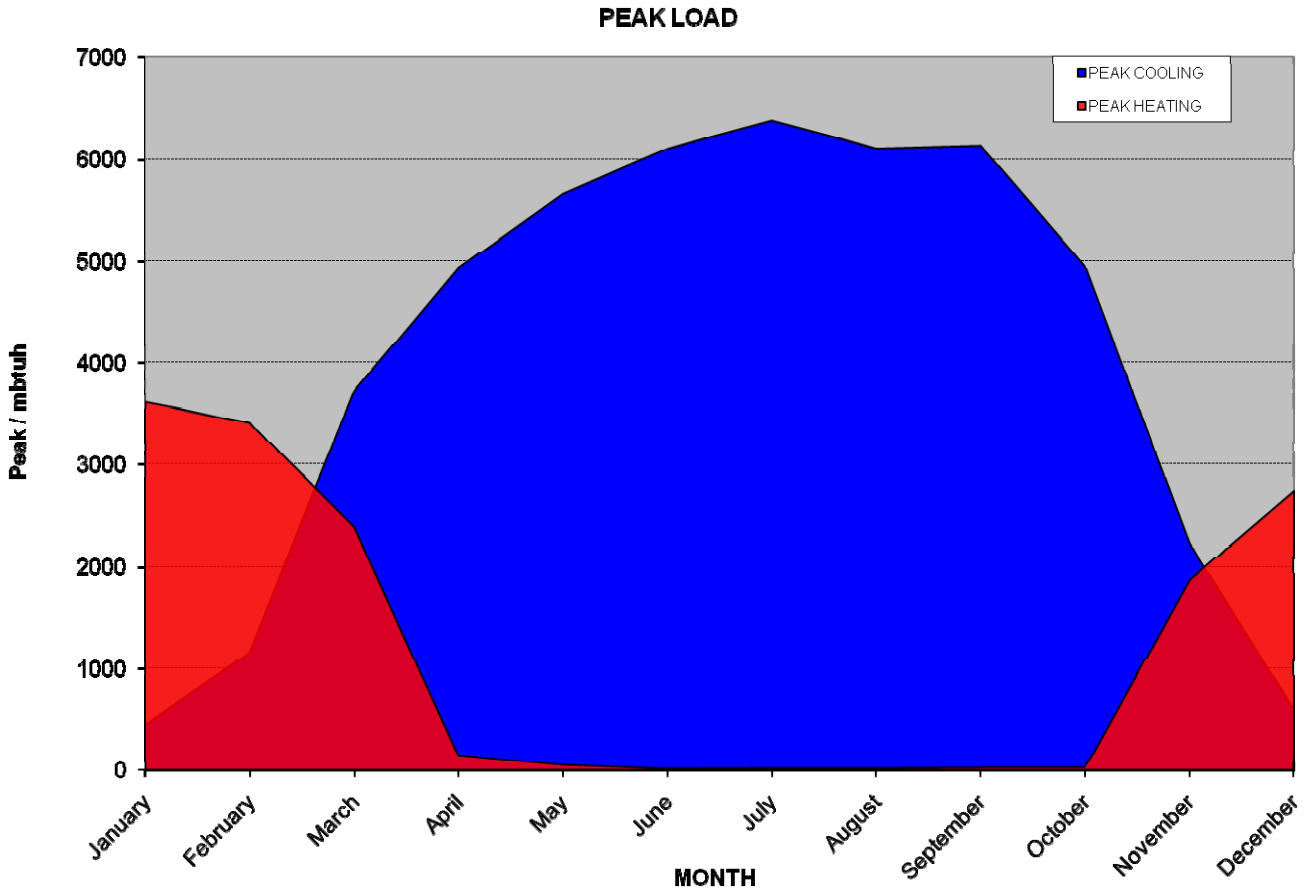
Larger scale projects are often easier to justify a GSHP system due to economy of scale, load overlap, type of use, etc.

Commercial GSHP Performance

	TOTAL COOLING	PEAK COOLING	TOTAL HEATING	PEAK HEATING	Monthly Load Factor	
	kbtu	kbtuh	kbtu	kbtuh	Cooling	Heating
January	137447.2	450.4	931119.6	3606.8	0.41	0.35
February	130833.0	1162.1	608594.5	3405.3	0.17	0.27
March	174874.4	3720.0	150887.4	2389.6	0.06	0.08
April	225185.8	4936.3	6570.2	146.9	0.06	0.06
May	955145.0	5658.8	2645.9	52.5	0.23	0.07
June	1526992.2	6104.0	1769.9	15.0	0.35	0.16
July	1865169.6	6381.1	1518.5	20.4	0.39	0.10
August	1754550.3	6107.2	1627.6	19.9	0.39	0.11
September	1280501.9	6134.0	2188.0	26.0	0.29	0.12
October	447068.4	4955.4	4150.8	28.7	0.12	0.19
November	159262.1	2231.4	183852.9	1868.1	0.10	0.14
December	153326.5	598.1	352224.0	2735.3	0.34	0.17
Total/Maximum	8810356.4		2247149.2			
Highest Peak Monthly Load:			6381.1	3606.8		
Peak Tons			531.8	300.6		
Reality Check, btuh/sq. ft.:			18.2	10.3		
			peak	peak		
Annual Equivalent Full Load Hours:			1380.7	623.0		

Example load profile, 350,000 ft² retail facility

Commercial GSHP Performance



Example load profile, 350,000 ft² retail facility, peak loads

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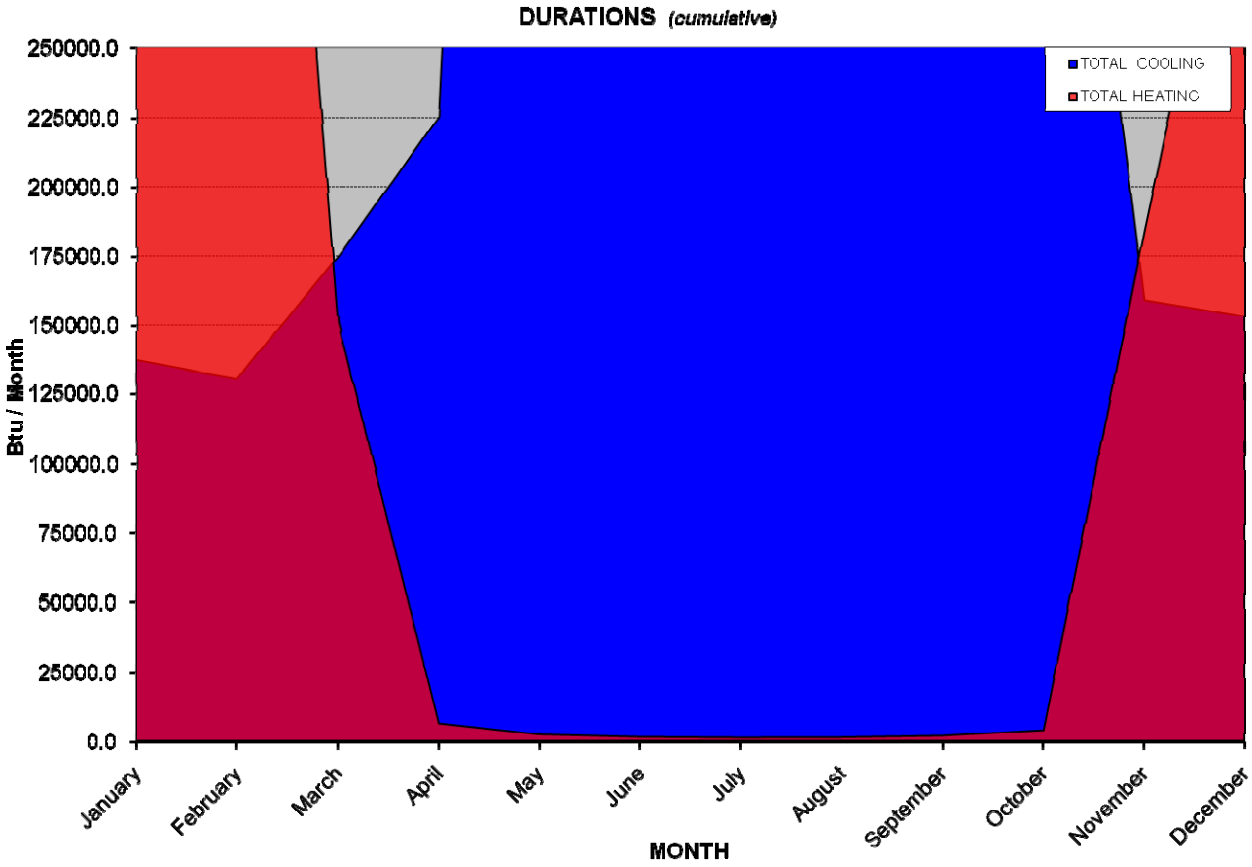

Example load profile, 350,000 ft² retail facility, total annual loads

Commercial and school facility load profiles may be taken advantage of when combined with appropriate heat pump and loop strategies:

- Load sharing
- Decoupled ground loops to take advantage of load sharing and reduce pumping costs
- Shed heat for other uses – domestic hot water, snowmelt, process use, etc.

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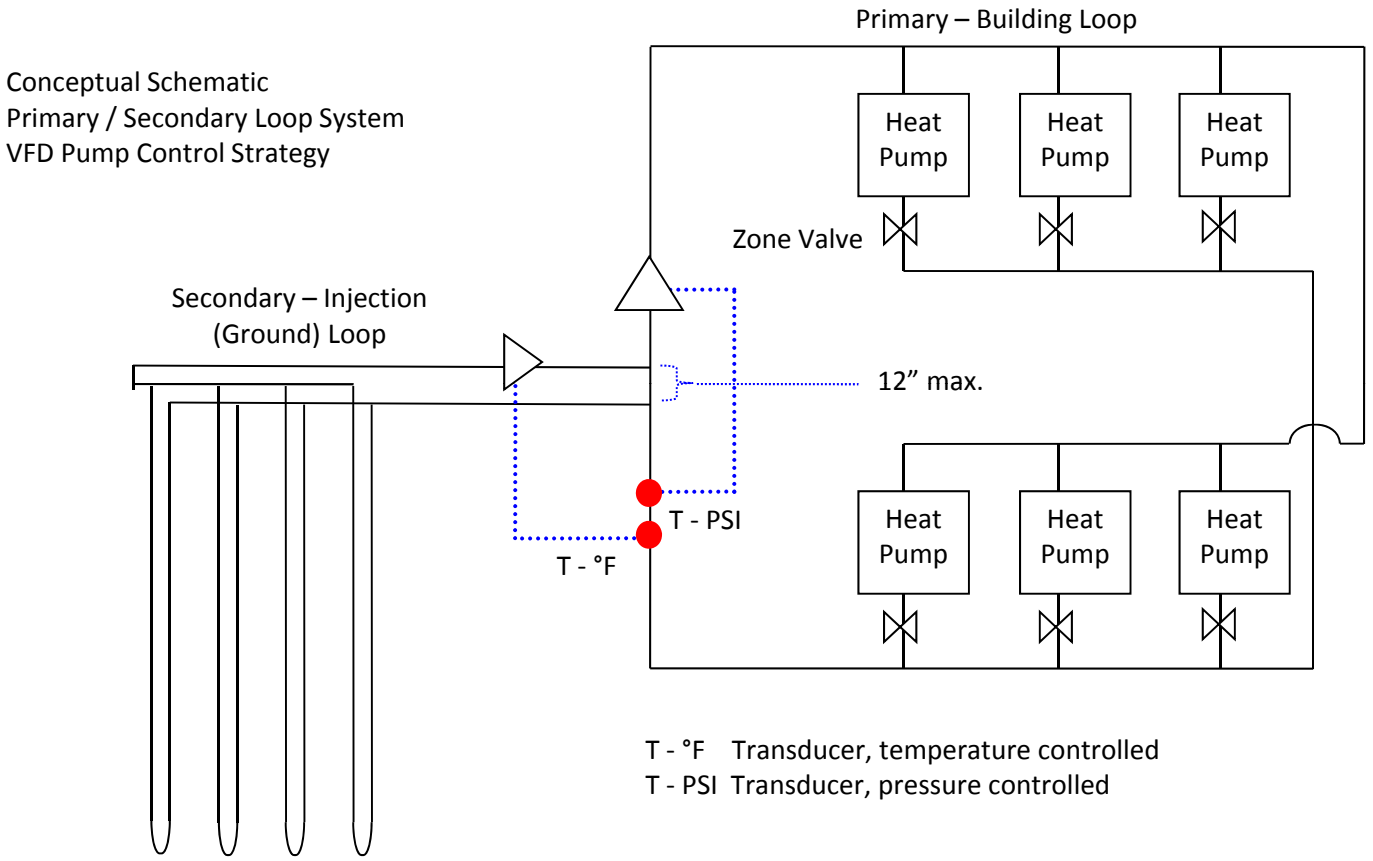
Moving heat for efficiency

The average sheet of ice for a hockey rink can heat two or more Olympic size swimming pools, with heat to spare, the only additional cost being fluid pumping

Commercial GSHP Performance



Simple strategy for load sharing – packaged extended range heat pumps capable of digesting a wider EWT temperature range, tied to decoupled ground loop, with minimal automated valving/controls

Commercial GSHP Performance

Larger projects where specific zone conditioning is necessary tend to have similar installed costs per ft^2:

- Centralized boiler/chiller servicing hydronic VAV systems - $25 to $35+ per ft^2
- Centralized boiler/chiller servicing conv'l WSHP systems - $25 to $35+ per ft^2
- Closed loop mechanical system – centralized or distributed GSHP units - $25 to $40 per ft^2 - *inclusive of ground loop installed cost*
  - Exceptions: Areas with difficult drilling conditions, contractor inexperience/fear of GSHP systems, etc.

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Killing installation cost efficiency of a GSHP system

Most significant reason GSHP systems come in over budget – the dreaded “Rule of Thumb” factor.
No substitute for doing it right.

Commercial GSHP Performance

Citizenship & Immigration Services, Centennial, CO
3 story, 46,000 ft², 56 x 400’ boreholes, 2-pipe HP system
WSHP conventional installed cost - $21 per ft² ($966k)
GSHP installed cost, including loop - $18 per ft² ($828k)
Completed 2008

Commercial GSHP Performance

Are accurate loads important? In this case, $176,000 savings as a result of a more detailed load analysis.

Josephine Commons Phase 1, Lafayette, CO
86,000 ft², 50 x 400’ boreholes, 3-story mixed use & duplex units, serviced by community loop
Prelim. loop cost, 90 holes x 400’ - $4.60 per ft² ($396k)
Final loop cost, revised loads - $2.56 per ft² ($220k)
Phase I completion 4th quarter 2012, Phase II start 2013

Commercial GSHP Performance

An often overlooked ground loop option for closed loop systems are horizontal heat exchangers where space and conditions permit.

Delaware Air National Guard, Newcastle, DE - 2009

Commercial GSHP Performance

Surface water closed loop systems are very 1st cost competitive against dry loop options when a pond, lake, cistern, etc., is available.

Paepke Events Center, Aspen Events Center, Aspen, CO - 2010

Commercial GSHP Performance

Where conditions are appropriate, open loops may be more economically viable. Beware – pumping costs for source and reinjection wells may harm operating cost efficiency.

Physical/controls efficiency advantage of GSHP system, 100% driven by ground loop, by what is eliminated:

- Cooling tower or chiller, boiler
- Associated pumps, automated 2- and 3-way valves, electrical service, other related infrastructure
- Substantially reduce control points, controls architecture and sequence of operation detail
- Reductions also eliminate associated maintenance, and life-cycle replacement costs of components replaced by GHX
- Indirect savings for some projects – reduction in structural and/or architectural considerations for components replaced by GHX

Advantages of elimination of conventional components as a result of replacement by the ground loop:

- System simplicity
- Ease of operation by owner
- Reduction of maintenance
- Lower operating cost

Most energy ratings or calculations describe:

What you pay for

vs.

What you get

Commercial GSHP Performance

- Commercial GSHP systems routinely operate at efficiencies exceeding 400% in the heating mode, regardless of altitude or outside climate conditions – cooling dominated loads typically drive a warm ground loop
- For a comparison, the best conventional furnaces and boilers operate at 90% efficiency, at sea level
- Heating performance is usually rated by a ratio expressed as COP (coefficient of performance):

  COP = Btuh delivered / Btuh consumed

Commercial GSHP Performance

- Commercial GSHP systems routinely operate at efficiencies exceeding 15 EER in the cooling mode, regardless of altitude or outside climate conditions
  - EER = Energy Efficient Ratio, or

    EER = Cooling Btuh capacity / Watts
- For a comparison, the best conventional air conditioners operate at 14 to 15 SEER, but are dependent upon outside air temperature for efficiency
  - SEER = Seasonal Energy Efficient Ratio, or

    SEER = Seasonal Cooling Energy (Btu) removed / WattsHr
- EER and SEER **are not** the same!

GSHP Efficiency – Residential Perspective

GSHP efficiency, the real world:

- 3,200 ft² residence, Montrose, Colorado, $325 per year to heat and cool – ducted, water-air HP, new construction
- 3,600 ft² residence, Gunnison, Colorado, $250 per year to heat – radiant floor, water-water HP, new construction
- 2,700 ft² residence, Golden, Colorado, $355 per year to heat, cool & make 100% of the domestic hot water – forced air, water-air/water HP, retrofit of 25+ year old home
- 4,500 ft² residence, St. George, Utah, $450 per year to heat and cool – ducted, (2) water-air HP, new construction

Each of these examples use separate power meters to monitor the electricity consumed for the GSHP system

Commercial operating costs reduced by GSHP system:

- Typically 40 to 60% or more reduced operating cost compared to conventional systems
- Elimination of maintenance costs for those components replaced by the ground loop
- No maintenance costs for ground loop – no moving parts, and typical 50 year industry warranty on HDPE pipe
- HP lifespan typically 20+ years for key components such as compressors
- Conventional equipment key components typically replaced by ground loop usually require reconditioning or replacement in 10 to 20 years (if these products are even maintained)

Citizenship & Immigration Services, Centennial, CO

Operating Costs to 25 Years	Cooling	Heating	Total
Boiler/Chiller System:	$454,600	$62,450	$517,050
GSHP System:	$188,100	$22,275	$210,375
GSHP Savings Over 25 Years	**$266,500**	**$40,175**	**$306,675**

Annual Operating Costs	Cooling	Heating	Total
Boiler/Chiller System:	$18,184	$2,498	$20,682
GSHP System:	$7,524	$891	$8,415
GSHP Annual Savings:	**$10,660**	**$1,607**	**$12,267**

Excludes maintenance savings, savings on replacement of conventional mechanical components replaced by GHX, etc.

Citizenship & Immigration Services, Centennial, CO

Mechanical Contractor priced all mechanical options

- GSHP system including loopfield installation
  LESS than conventional configuration
  - $18 per ft² for GSHP system including loopfield
  - $21+ per ft for boiler/chiller system
- GSHP also had the lowest…
  - Operating costs
  - Maintenance costs
  - Green house gas emissions

Citizenship & Immigration Services, Centennial, CO

Annual GHG (CO_2) Tons Est.*	Cooling	Heating	Total
Boiler/Chiller (CO_2) Tons:	203.2	13.6	216.8
GSHP (CO_2) Tons:	84.1	10.0	94.1
GSHP Annual Savings (CO_2) Tons:	**119.1**	**3.6**	**122.7**

GHG (CO_2) Tons 25 years	Cooling	Heating	Total
Boiler/Chiller (CO_2) Tons:	5,080.0	340.0	5,420.0
GSHP (CO_2) Tons:	2,102.5	250.0	2,352.5
GSHP Savings 25 years (CO_2) Tons:	**2,977.5**	**90.0**	**3,067.5**

* 1.93 lbs CO_2 per kwh

http://www.eia.doe.gov/oiaf/1605/ee-factors.html

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Commercial GSHP Performance

20 year LCC	Baseline GSHP	Option 1 ACC/VAV	Option 2 WCC/CV	Option 3 WCC/VAV
Initial Cost	**$1,021,257**	**$1,129,286**	**$835,916**	**$1,164,268**
1st year maintenance cost	$7,383	$7,824	$13,651	$7,928
1st year electric cost	$22,138	$23,037	$34,152	$19,448
1st year gas cost	$3,533	$10,963	$23,944	$11,034
Water cost			$385	$385
Total annual O & M costs	**$33,054**	**$41,824**	**$73,826**	**$38,795**
Life Cycle Cost	**$1,498,835**	**$1,734,327**	**$1,912,297**	**$1,728,736**

Nebraska school comparison

- ACC/VAV – Air cooled chiller, boiler
- WCC/CV – Water cooled chiller, boiler

from "Comparative Analysis of the Life Cycle Costs of Geothermal Heat Pumps and Three Conventional HVAC Systems for an Elementary School in Lincoln, Nebraska" – John Shonder, et al, Oak Ridge Nat'l Laboratory

Efficiency of GSHP mechanical operation by owner:

- Dependent upon designer taking advantage of inherent simplicity of extended HP operation
- Controls streamlined to permit ease of use without the need for constant tuning by controls contractor
- Beware of overly complex systems where complexity is sold as a more efficient system
- Excessive setback schedules, etc., can create nuisance lockout situations, comfort complaints
- Keep it simple!!!!!!

Ground heat exchanger performance:

- Typical objective for GHX design is for min and max EWT range to HP system of 35°F to 40°F for heating, 80°F to 90°F for cooling
- Most purpose-built ext'd range HP products can operate between 20°F to 120°F (flow rate critical)

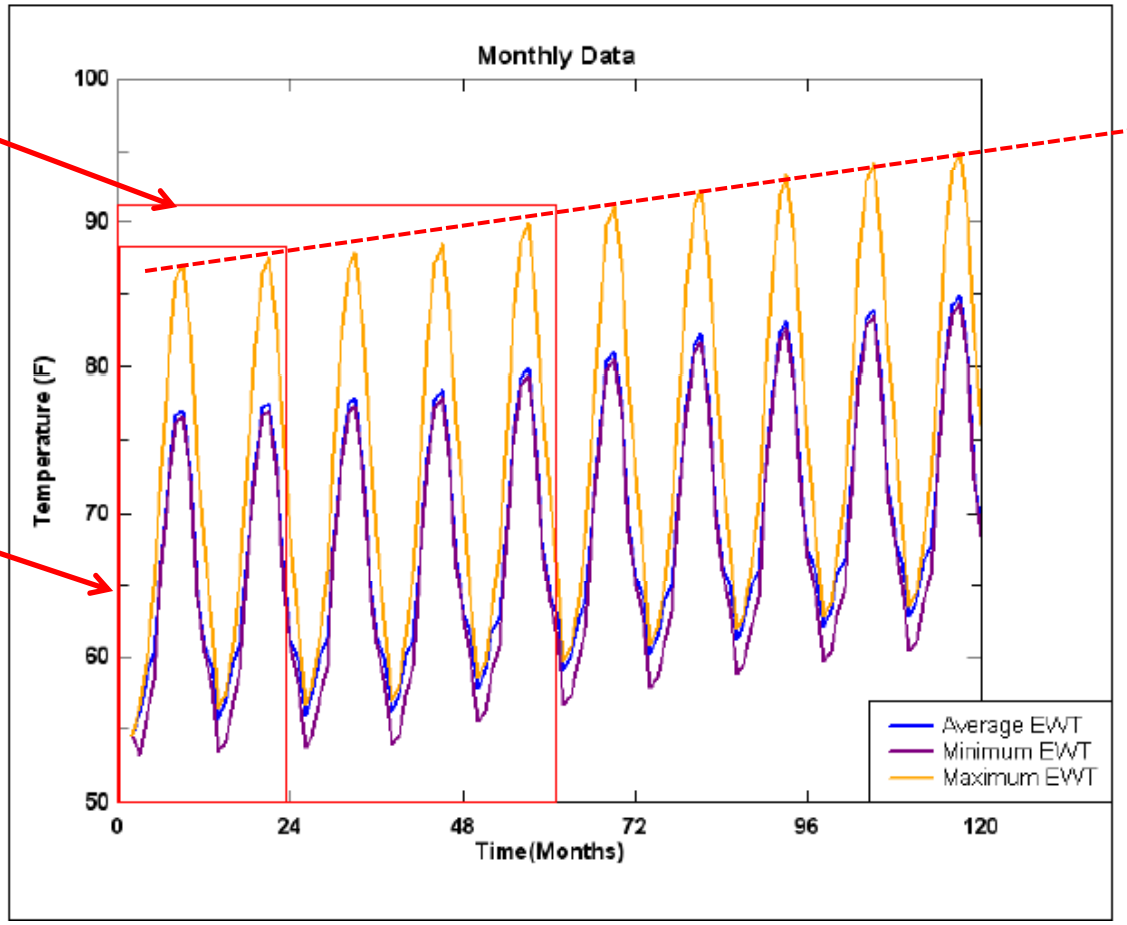
Ground heat exchanger modeling:

- Most cooling dominant loads when modeled on a multi-year ground loop calculation will theoretically project a constant annual increase, suggesting the GHX will eventually overheat, failing the system w/out supplementary cooling regardless of how much loop is installed
- In most cases this is false as the software does not account for core and peripheral heat dissipation of the GHX
- Earth loops want to return to undisturbed conditions when heat rejection capacity drops during usual operating cycles
- Such misinterpretation has resulted in many unnecessary hybrid configurations

Commercial GSHP Performance

Potential worst case

Reality

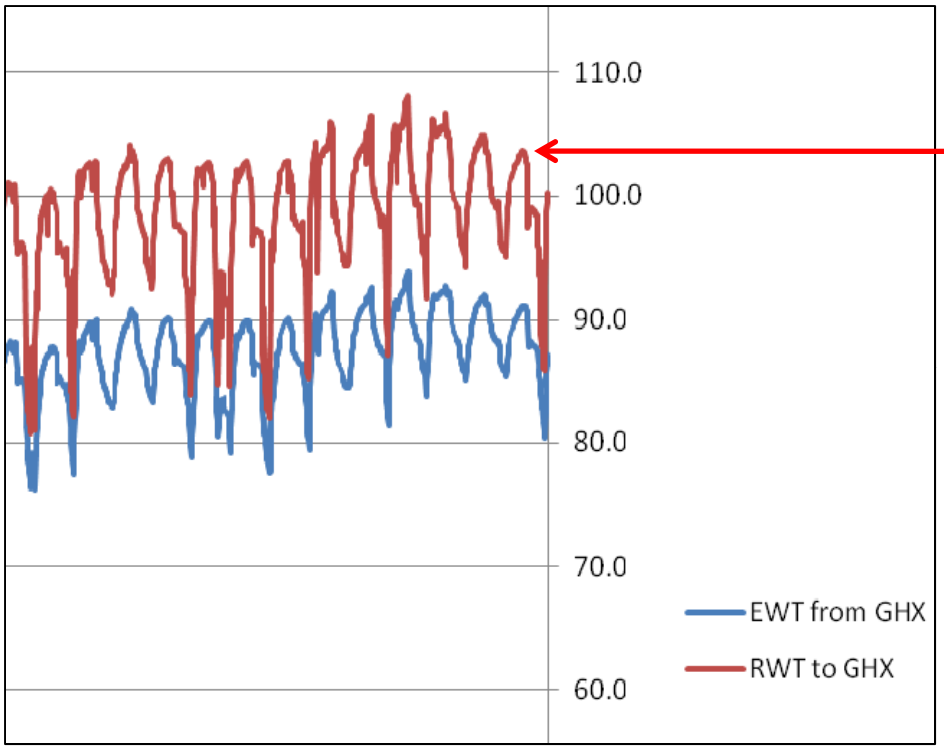


Theoretical slope

350,000 ft² retail facility GHX temperature projection

180 boreholes x 600’

Commercial GSHP Performance
Trending Example



Each peak represents a 24 hour operating cycle

- As the facility rests during the evening, the ground loop temperature immediately begins to drop
- No long term thermal storage!

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