Commercial Water Heating Using Gas Absorption Heat Pumps

Oak Ridge National Lab

Oak Ridge, TN

Patrick Geoghegan, PhD

Stone Mountain Technologies, Inc.

Johnson City, TN

Michael Garrabrant, President

www.stonemountaintechnologies.com

ACEEE Hot Water Forum

Portland, OR

February, 2016

Topics of Discussion

- GAHP Technology Background
- GAHP Development Status
- Energy Use Modeling: Full-Service Restaurant
  - Engineering Equation Solver (SMTI)
  - EnergyPlus (ORNL)

SMTI

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Commercial Water Heating Uses Significant Energy

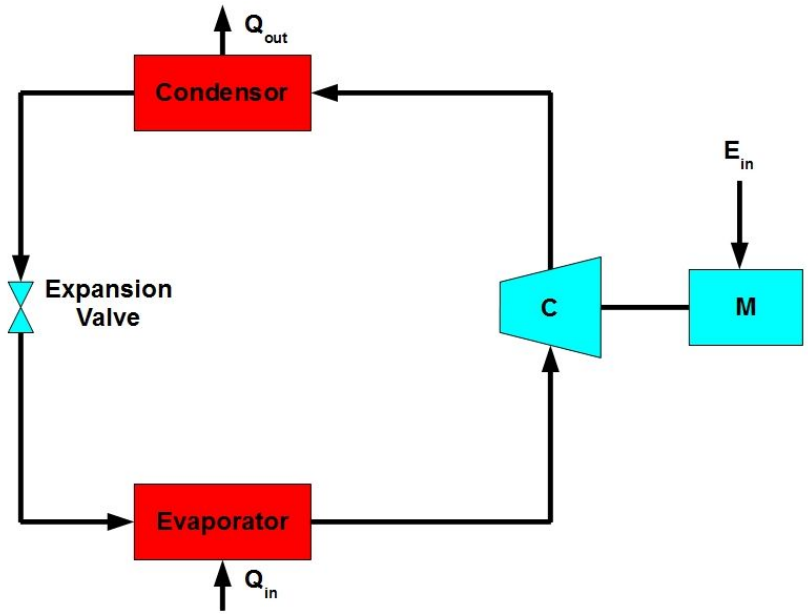
- 7% U.S. Commercial Energy Use (1.2 Quads)
- 9% Canadian Commercial Energy Use
- 5.5% U.S. Commercial Sector CO_2 Emissions

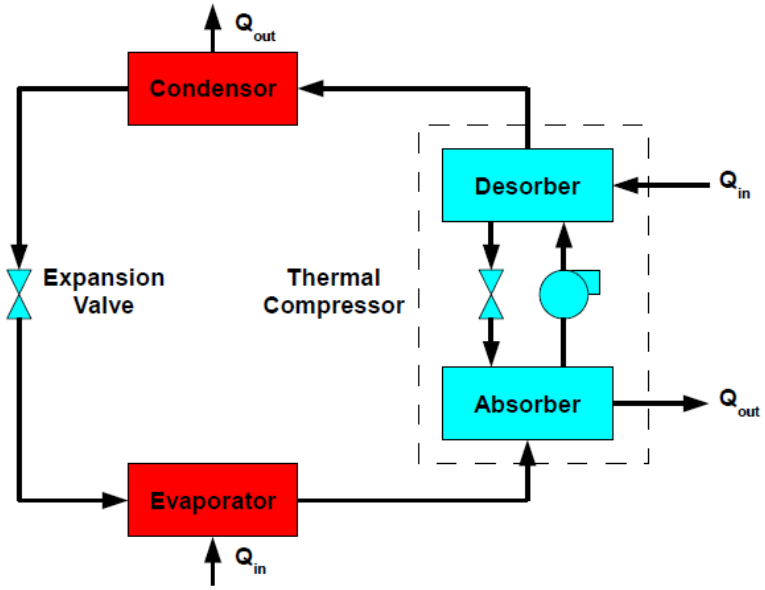
Source: US DOE and NRCAN

Commercial Gas Water Heating Equipment

	Thermal Efficiency	
❖ Non-Condensing:	80 - 82%	
❖ Condensing:	90 – 95%	+15%
❖ Gas Absorption Heat Pump	130 - 160% *(1.3 – 1.6 COP)*	+70%

How Does It Work?





COP_h = Qcond/E_{in} = 3.0-4.0

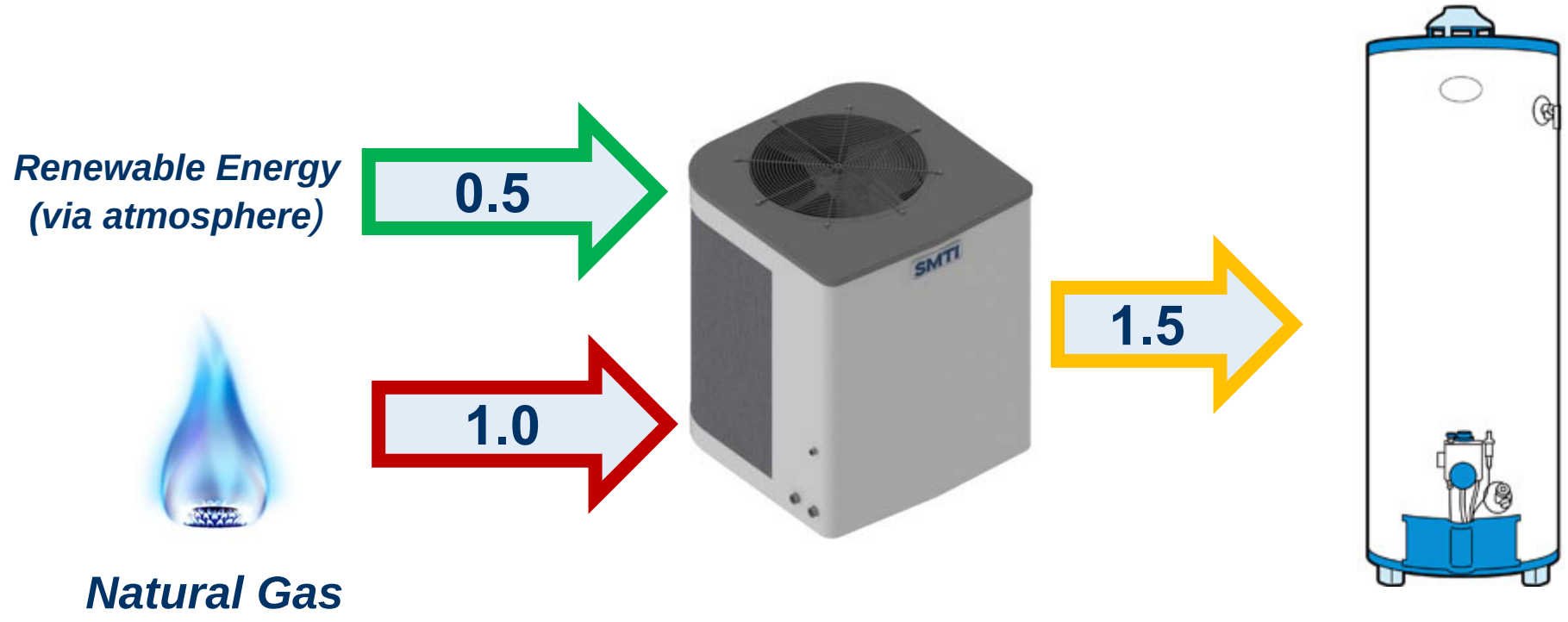
Qheat = ~1.2 x Qevap

COP_h = (Qcond + Qabs)/Q_{in} = 1.4-2.0

Qheat = (Qcond + Qabs) ~ 2.5 times Qevap

Capacity & COP Remain High at Low Ambient Temperatures

Gas Absorption's Renewable Energy Content: 35%



SMTI Gas Absorption Heat Pumps

COP_{HHV} = 1.4 at 47/120°F

- Gas-Fired, Air to Water Heat Pump
- Condensing
- 4:1 Modulation

- 10,000 to 140,000 Bth Heating Output Models
- 20° F Hydronic Differential
- Outdoor Installation (no venting)
- SCAQMD NOx Compliant

GAHP Development Status

10,000 btu/hr

Field Testing

80,000 btu/hr

Field Testing

140,000 btu/hr

Lab Testing

gti

U.S. DEPARTMENT OF ENERGY

neea

ornl
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Energy Use Simulations - Preliminary Results

1. **Using Engineering Equation Solver (SMTI)***
   - ***Case 1: 2080 gpd***
   - ***Case 2: 4060 gpd***
2. **Using EnergyPlus (ORNL)**
   - ***Case 1: 2080 gpd***

199 kBth Cond Storage + 199 kBth NC Storage

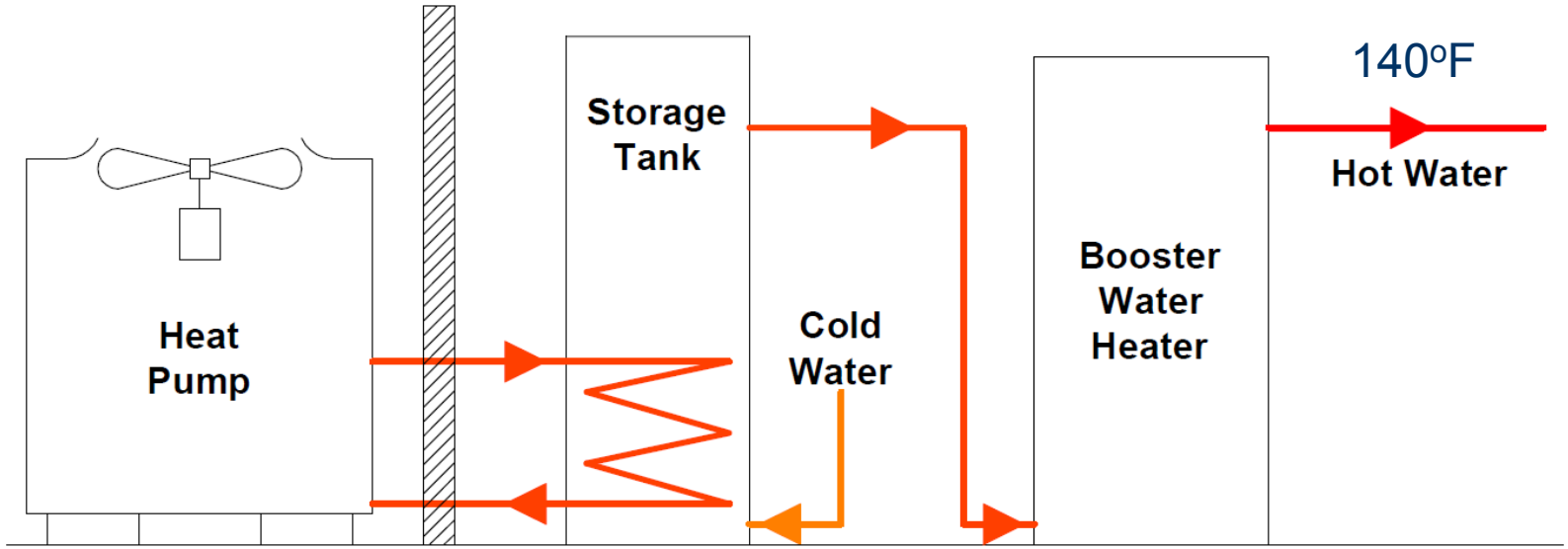
Vs.

140 kBth GAHP + 199 kBth NC Storage

**** Dr. Chris Keinath***

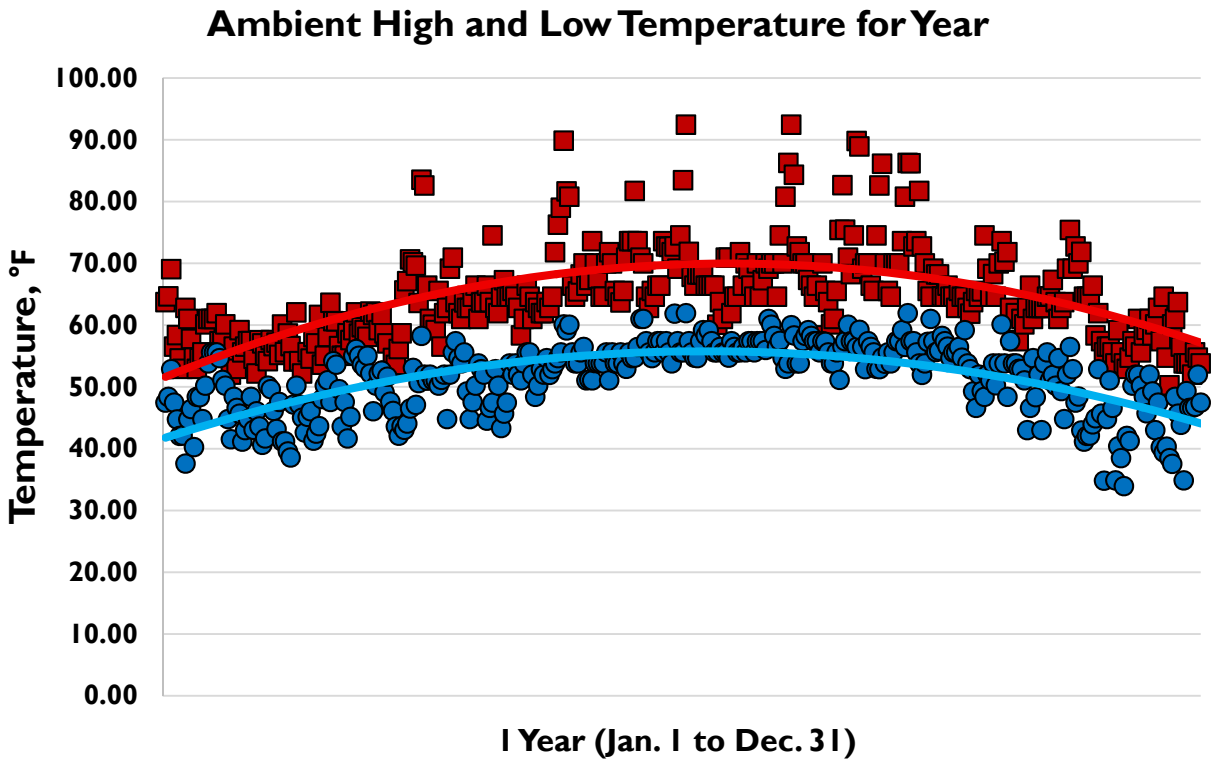
GAHP Commercial Water Heating

Pre-Heater Installation



Ambient Temperature from Energy Plus

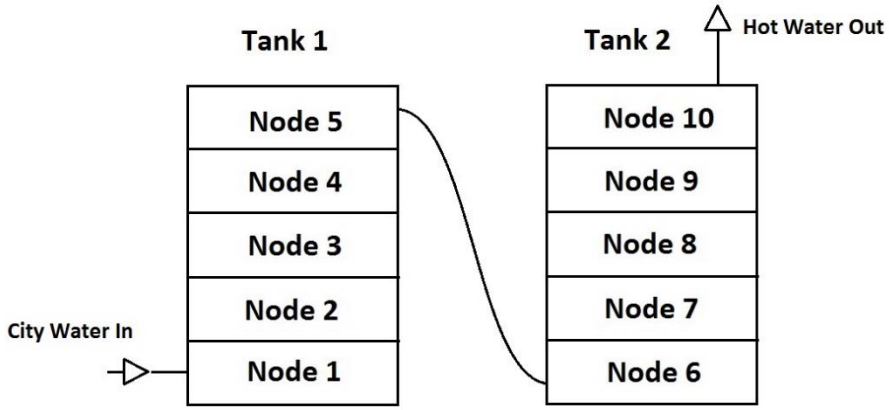
Oakland, California



Yearly Average: 58°F

Engineering Equation Solver Model: Assumptions

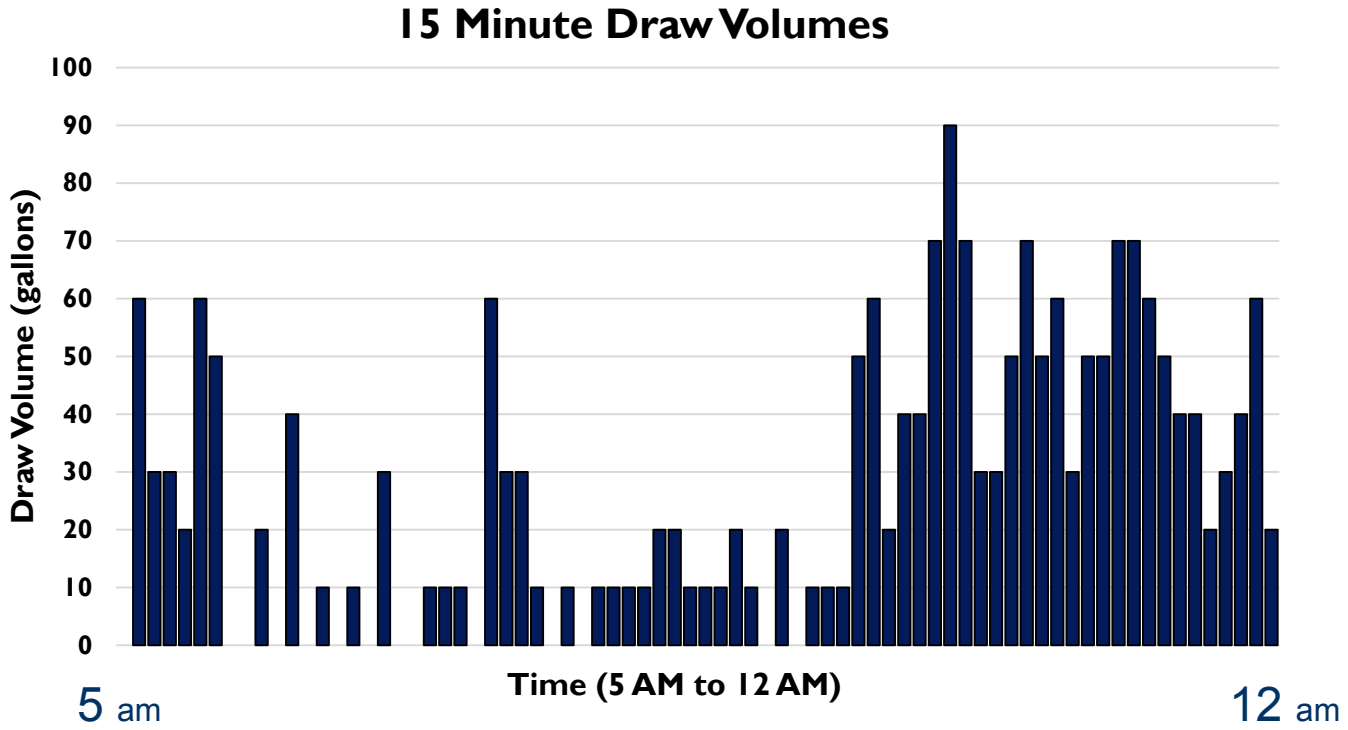
- A hot water draw happens at the start of each 15 minute period
- Water is drawn into the bottom of Tank 1 at 54.7°F
- Water exiting the top of Tank 1 enters the bottom of Tank 2
- COP for the GAHP and Condensing units use ***average*** bottom node temperature for each 15 minute step
- Modulation is neglected
- GAHP electrical load of 900 W, Condensing unit electrical load of 150 W



Commercial Water Heating: Case 1

Simulated Draw Pattern

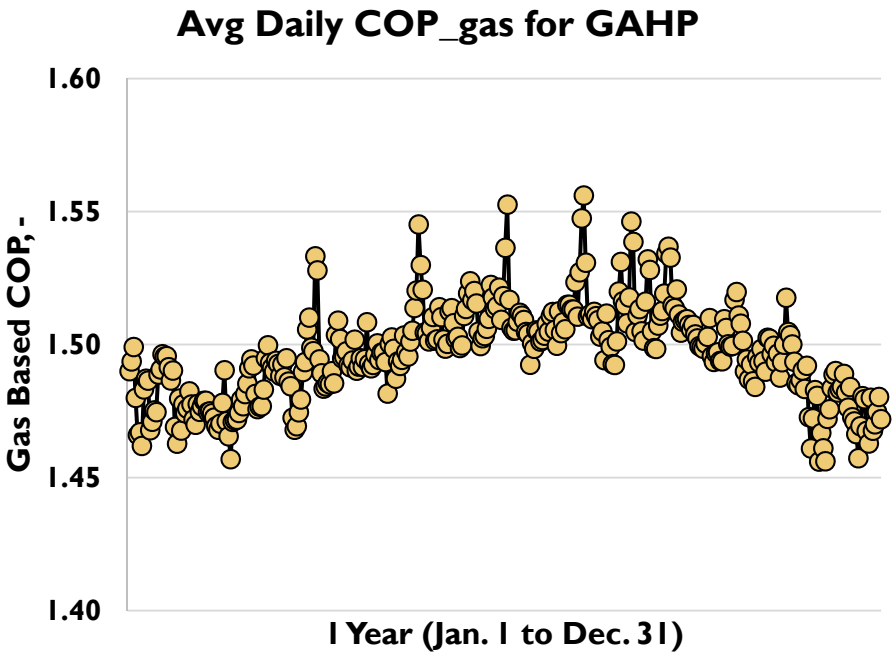
Full Service Restaurant - Daily draw pattern
Daily use: 2080 Gallons of Hot Water

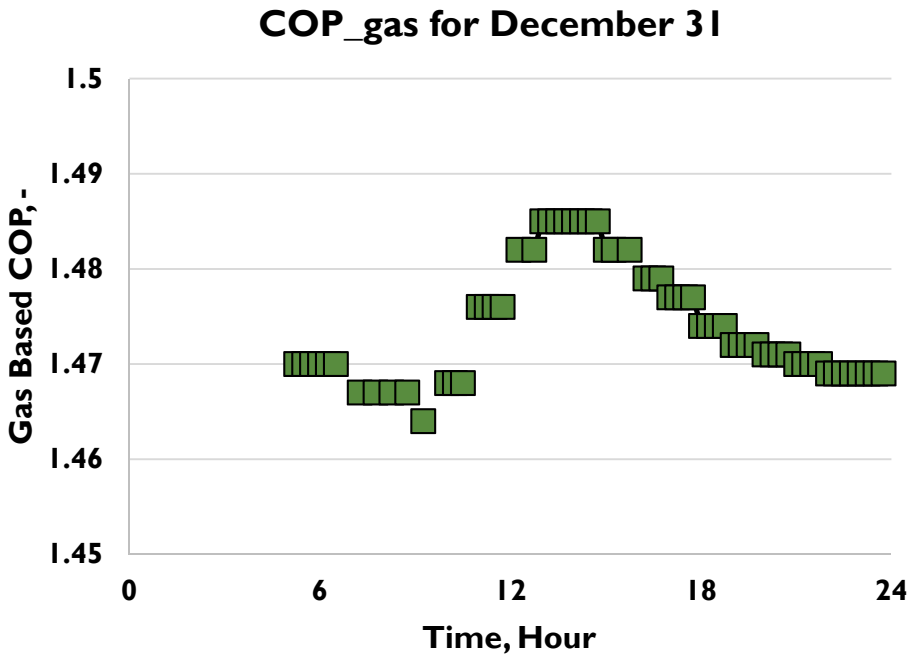


Note: Draw pattern for FSR approximated from data presented by: Pacific Gas and Electric. 2007b. *Energy Efficiency Potential of Gas-Fired Commercial Hot Water Heating Systems in Restaurants: An Emerging Technology Field Monitoring Study.* FSTC Report 5011.07.04. San Ramon, CA.

Commercial Water Heating: Case 1

GAHP Performance





Commercial Water Heating: Case 1

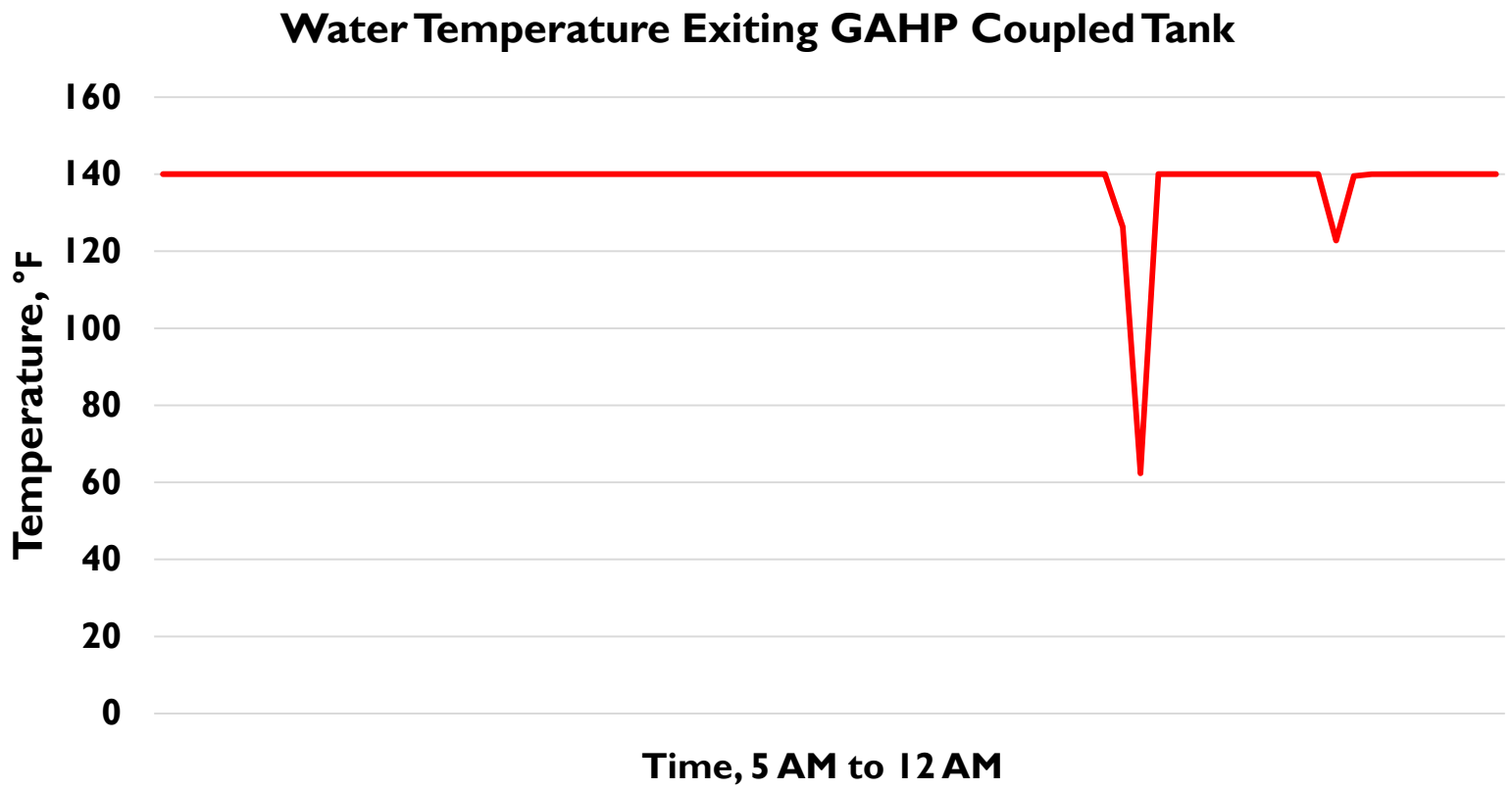
GAHP Pre-Heat

GAHP Avg. Gas COP of 1.53

140 kbtu/hr GAHP Tank unit and 199 kbtu/hr Standard Tank Unit ,2 x 100 gallon tanks								
	Tank 1 (GAHP)				Tank 2 (NC)			
Month	Gas Used Therms	Electricity Used kWh	Cost of Gas $	Cost of Electricity $	Gas Used Therms	Electricity Used kWh	Cost of Gas $	Cost of Electricity $
January	282	432	$282	$52	7.4	0	$7	$0
February	256	391	$256	$47	6.9	0	$7	$0
March	281	432	$281	$52	7.1	0	$7	$0
April	271	419	$271	$50	6.6	0	$7	$0
May	279	432	$279	$52	6.6	0	$7	$0
June	269	419	$269	$50	6.2	0	$6	$0
July	278	432	$278	$52	6.5	0	$6	$0
August	278	432	$278	$52	6.3	0	$6	$0
September	269	419	$269	$50	6.0	0	$6	$0
October	280	432	$280	$52	6.8	0	$7	$0
November	272	419	$272	$50	6.8	0	$7	$0
December	283	432	$283	$52	7.8	0	$8	$0
Total	**3299**	**5092**	**$3,299**	**$611**	**81.0**	**0.00**	**$81**	**$0**
	Total Operating Cost		**$3,991**					

Note: Assumed cost of Natural Gas – $1.00/therm, Electricity $0.12/kWh

Commercial Water Heating: Case 1



Commercial Water Heating: Case 1

Condensing + Non-Condensing

Condensing Tank Unit and Standard Tank Unit, 199 btu/hr Each, 2 x 100 gallon tanks, 2000 gpd								
	Tank 1 (Condensing)				Tank 2 (NC)			
Month	Gas Used	Electricity Used	Cost of Gas	Cost of Electricity	Gas Used	Electricity Used	Cost of Gas	Cost of Electricity
	Therms	kWh	$	$	Therms	kWh	$	$
January	459	72	$459	$9	1.6	0	$2	$0
February	414	65	$414	$8	1.5	0	$1	$0
March	459	72	$459	$9	1.6	0	$2	$0
April	444	70	$444	$8	1.6	0	$2	$0
May	459	72	$459	$9	1.6	0	$2	$0
June	444	70	$444	$8	1.6	0	$2	$0
July	459	72	$459	$9	1.6	0	$2	$0
August	459	72	$459	$9	1.6	0	$2	$0
September	444	70	$444	$8	1.6	0	$2	$0
October	459	72	$459	$9	1.6	0	$2	$0
November	444	70	$444	$8	1.6	0	$2	$0
December	459	72	$459	$9	1.6	0	$2	$0
Total	5401	849	$5,401	$102	19.0	0.00	$19	$0
	Total Operating Cost		$5,522					

Note: Assumed cost of Natural Gas – $1.00/therm, Electricity $0.12/kWh

Commercial Water Heating: Case 1

Comparison between Condensing and GAHP Pre-Heat

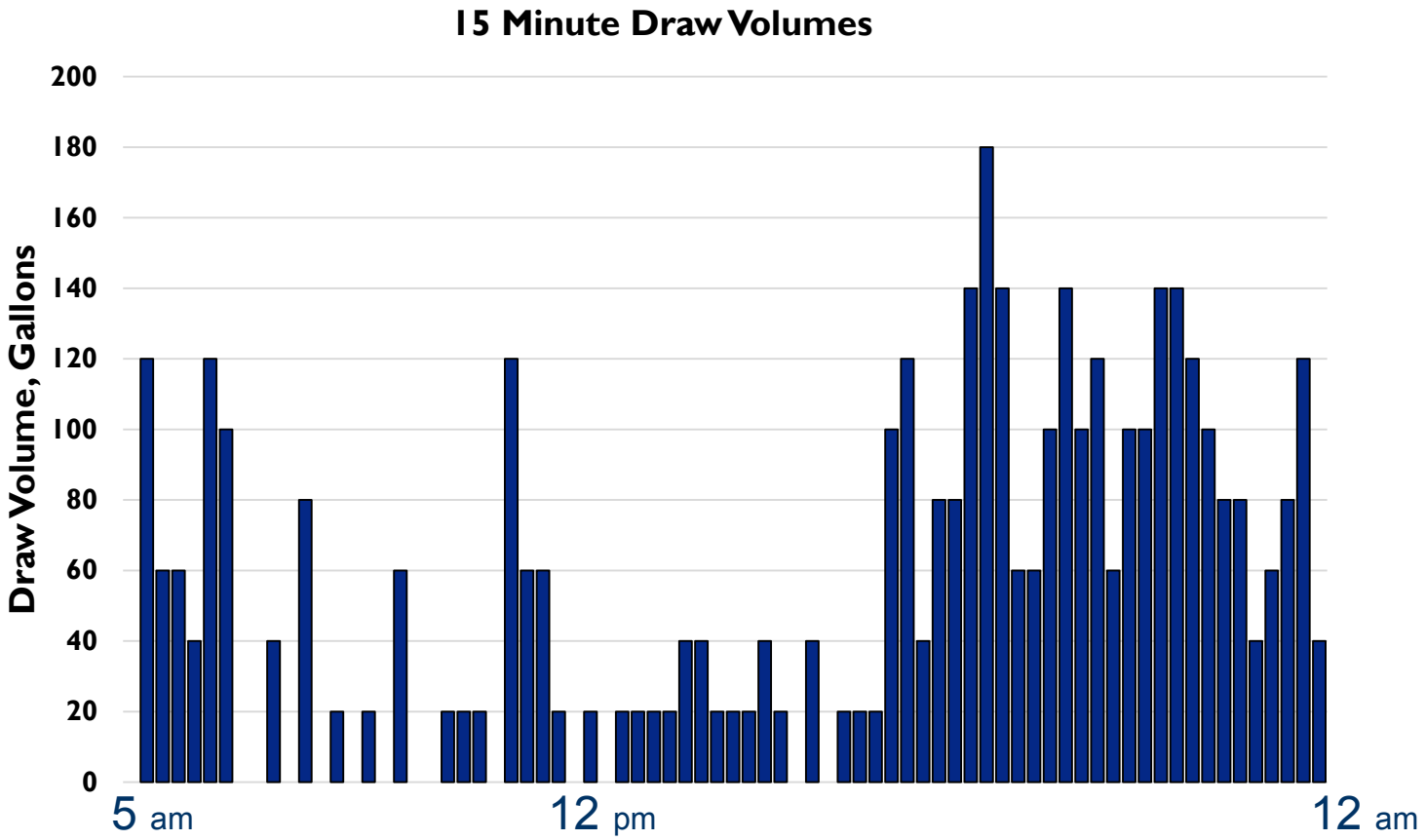
		Condensing Pre-Heat	GAHP Pre-Heat	Annual Savings	% Difference
Total Natural Gas Used	**Therms**	**5,420**	**3,380**	**2,040**	**38%**
Cost of Gas Used	**$**	$5,420	$3,380	$2,040	38%
Total Electricity Used	**kWh**	849	5,092	-4,243	
Cost of Electricity Used	**$**	$102	$611	-$509	
Total Energy Used	**kWh**	159,665	104,123	55,542	35%
Total Primary Energy Used	**kWh**	175,783	123,983	51,800	**29%**
Annual Operating Cost	**$**	**$5,522**	**$3,991**	**$1,531**	**28%**

Note: For Primary Energy Conversion: Electric use multiplied by 3.15, Gas use multiplied by 1.09
Natural Gas = $1.00/therm
Electricity = $0.12/kWhr

Commercial Water Heating: Case 2

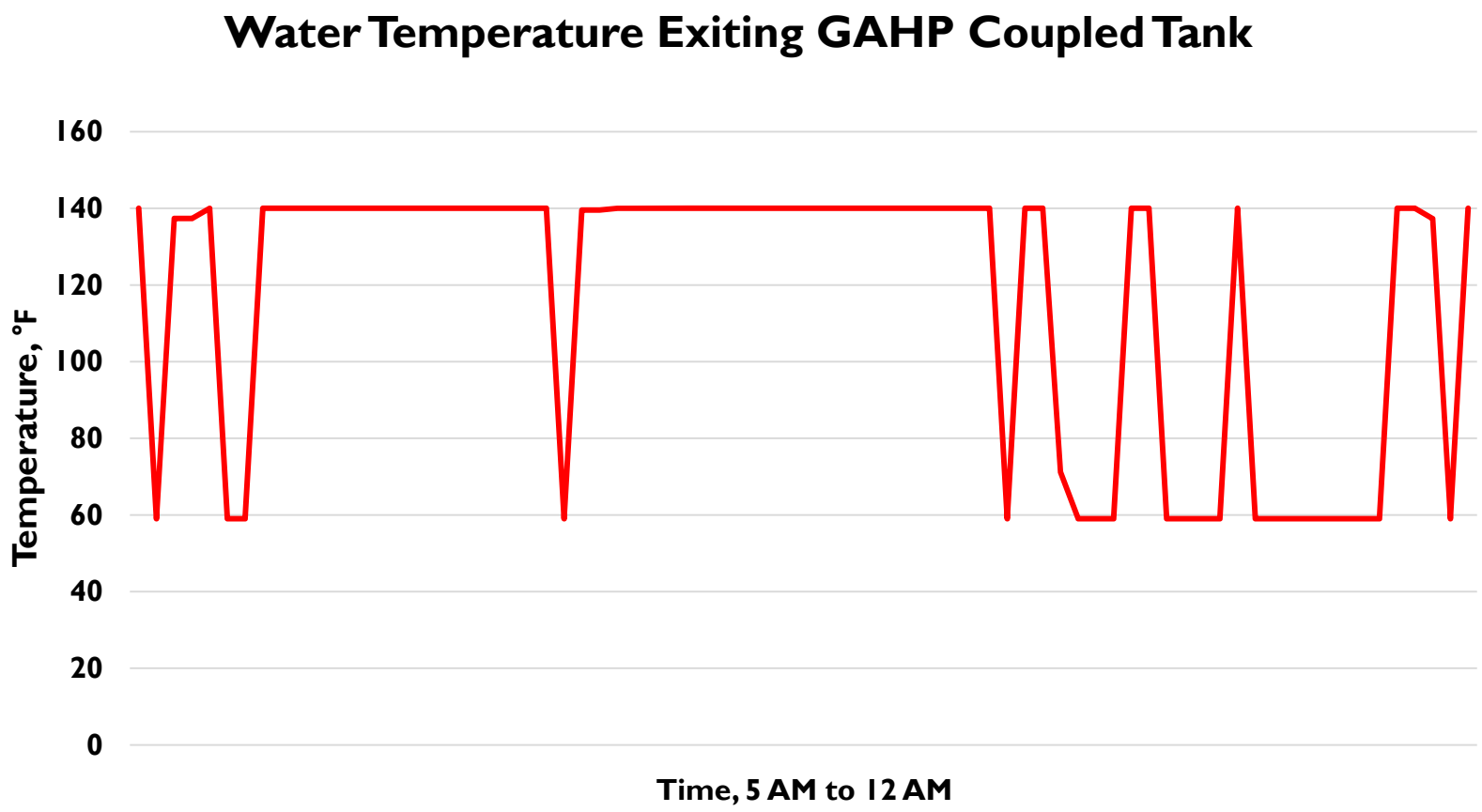
Simulated Draw Pattern

Daily use: 4160 Gallons of Hot Water



Commercial Water Heating

Case 2 Exiting Water Temperature (4160 gpd)



Commercial Water Heating: Case 2

Comparison between Condensing and GAHP Pre-Heat

		Condensing Pre-Heat	GAHP Pre-Heat	Annual Savings	% Difference
Total Natural Gas Used	**Therms**	**10,934**	**7,895**	**3,039**	**28%**
Cost of Gas Used	**$**	$10,934	$7,895	$3,039	28%
Total Electricity Used	**kWh**	876	5,420	-4,544	
Cost of Electricity Used	**$**	$105	$650	-$545	
Total Energy Used	**kWh**	321,229	236,737	84,492	26%
Total Primary Energy Used	**kWh**	351,944	269,209	82,735	**24%**
Annual Operating Cost	**$**	**$11,039**	**$8,545**	**$2,493**	**23%**

Note: For Primary Energy Conversion: Electric use multiplied by 3.15, Gas use multiplied by 1.09
Natural Gas = $1.00/therm
Electricity = $0.12/kWhr

Energy Plus Modeling

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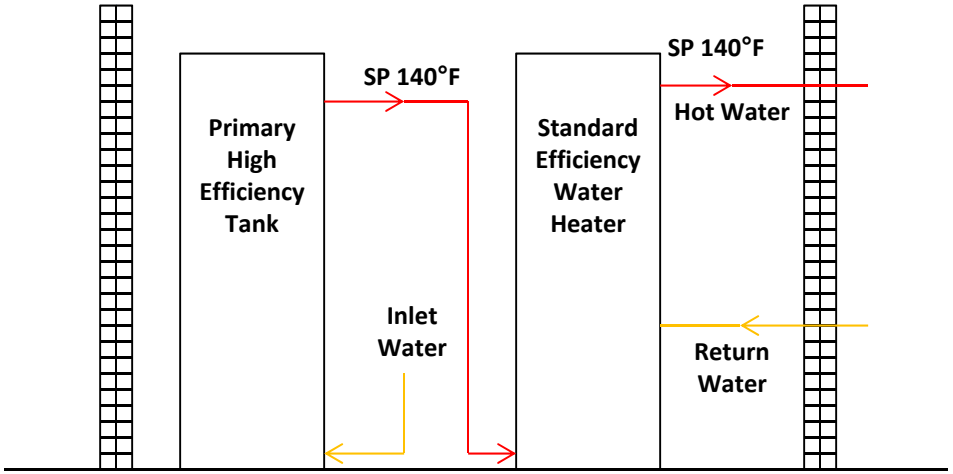
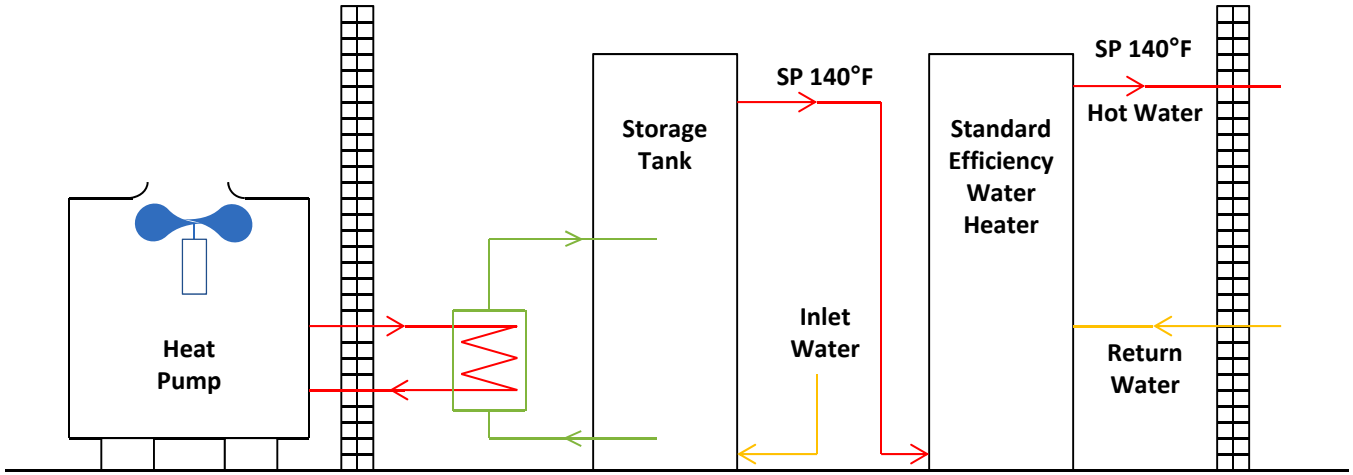
System Configurations





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System Assumptions

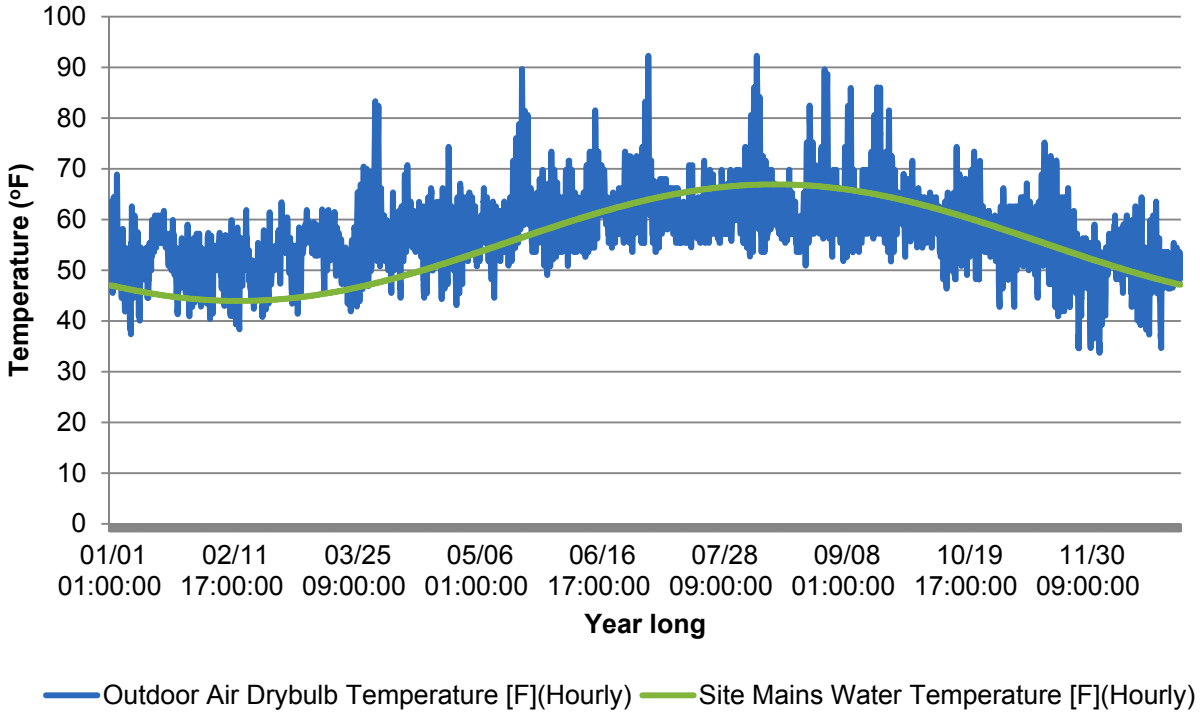
GAHP

- WaterHeater:HeatPump
- WaterHeater:Stratified
- COP related to the ambient air and mains hydronic temperature
- Second tank 80% efficient
- Set Point 140 ^{o}F
- Oakland, CA
- Full service restaurant

Condensing Tank Pre-Heat

- WaterHeater:Stratified
- COP ranging from 98% to 82% depending on Flue Gas Exit Temperature (assumed node 6)
- Second tank 80% efficient
- Set Point 140 ^{o}F
- Oakland, CA
- Full service restaurant

Ambient Air and Mains Water temperatures for Oakland, CA



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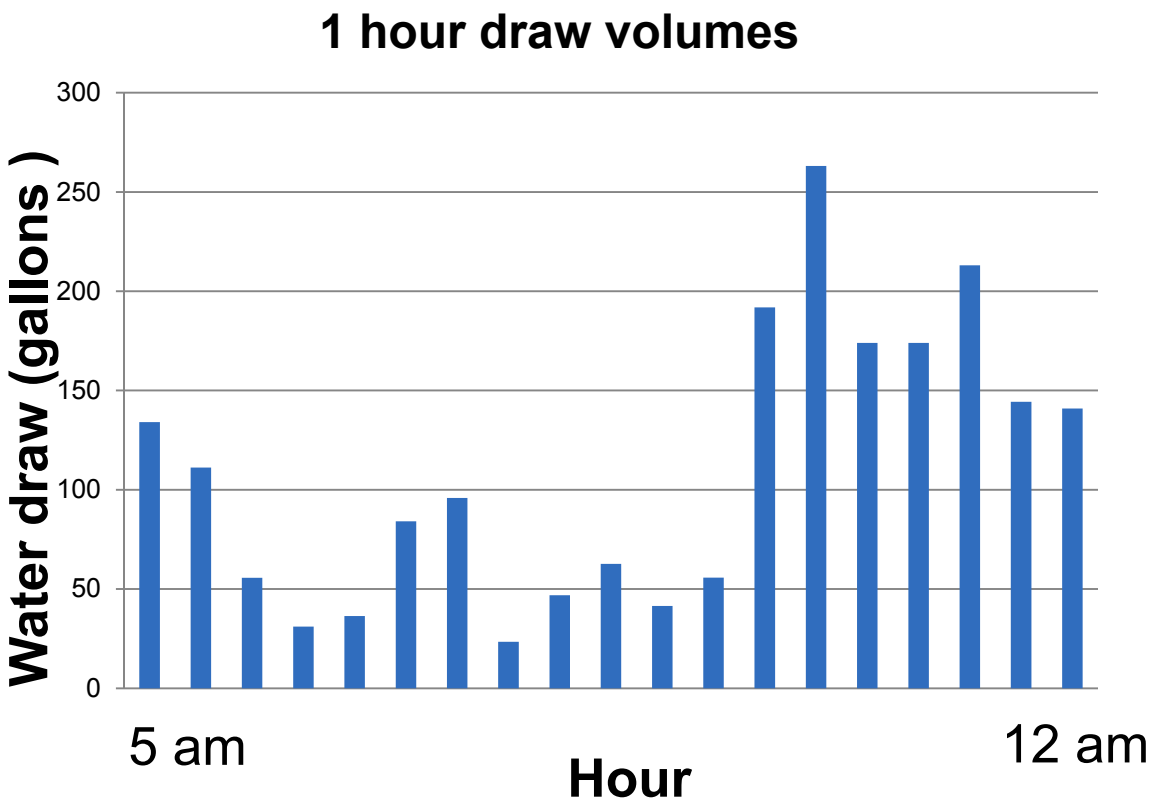
Daily draw pattern



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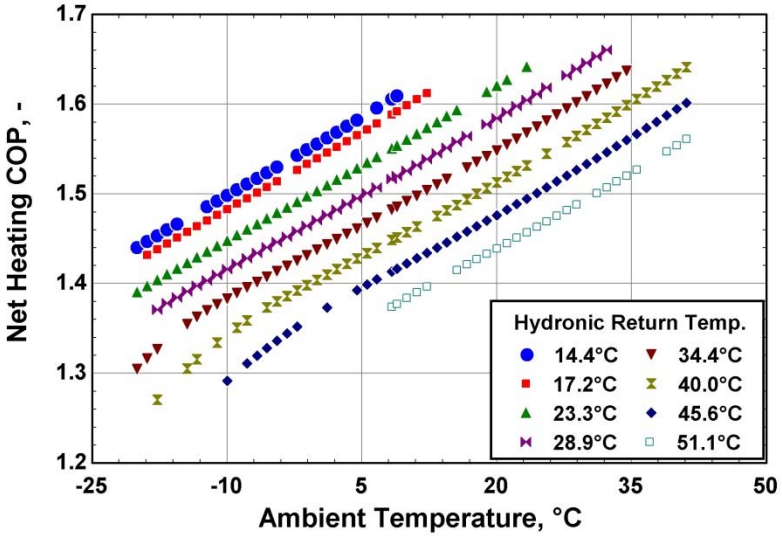
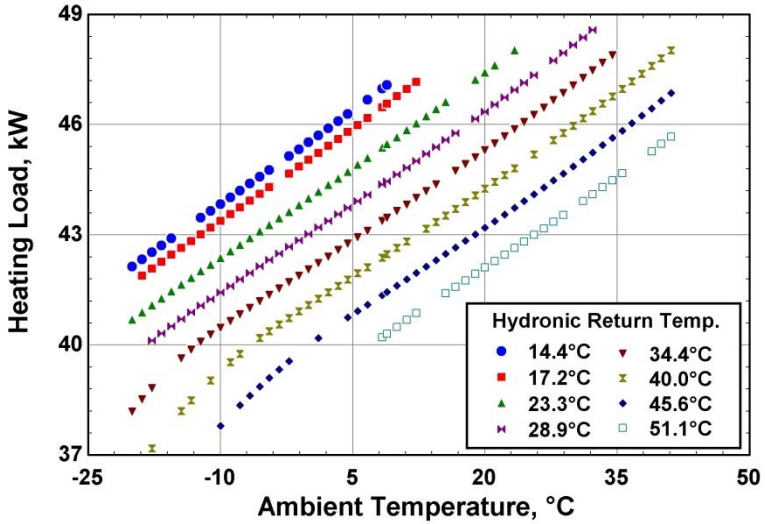
GAHP COP and Heating Load as functions of Hydronic and Air Ambient Temperatures





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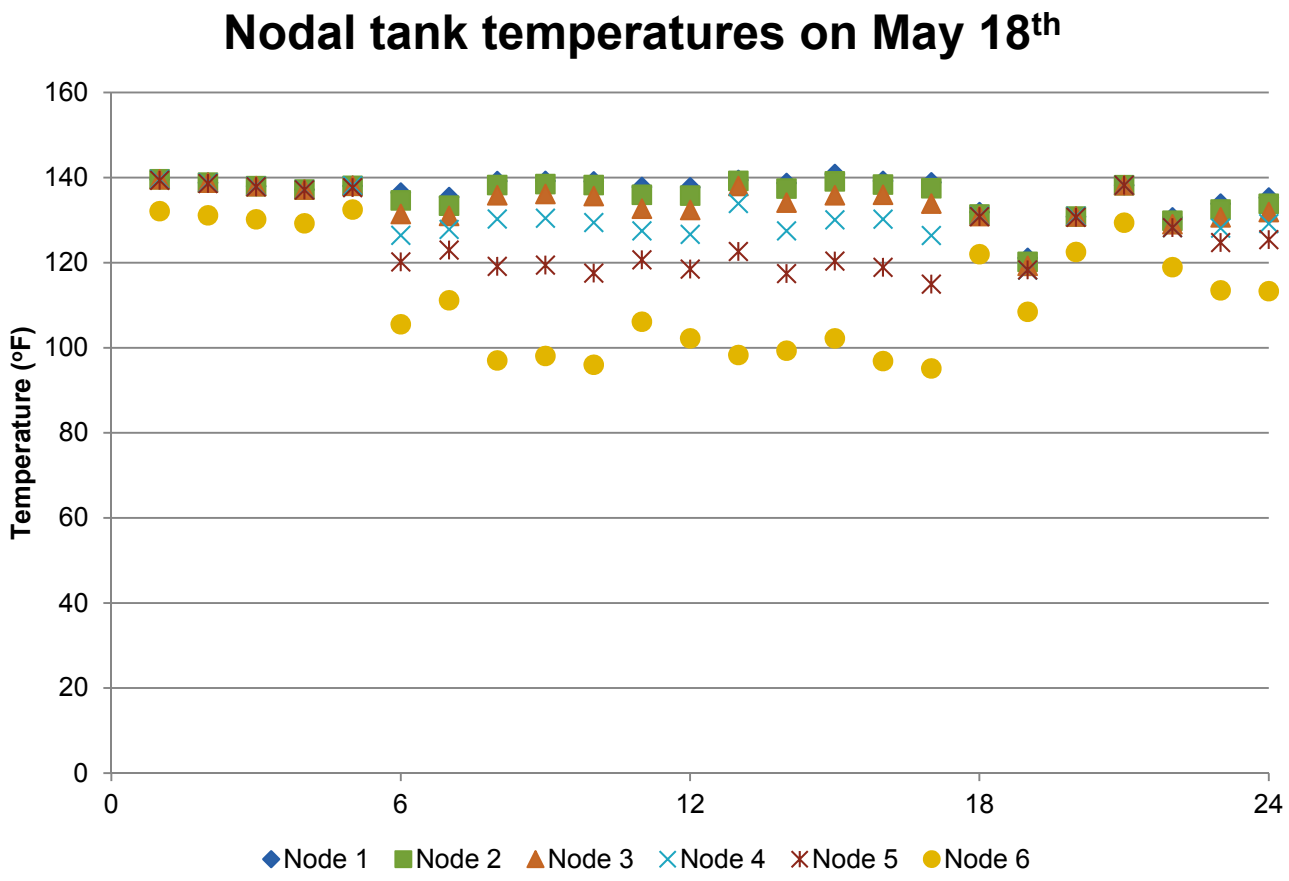
Tank Stratification



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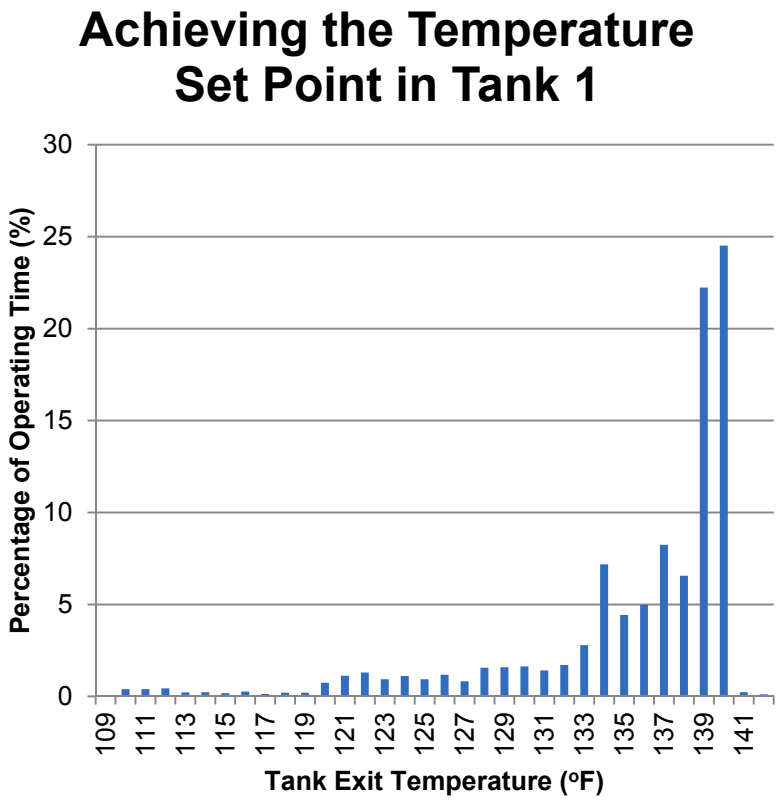
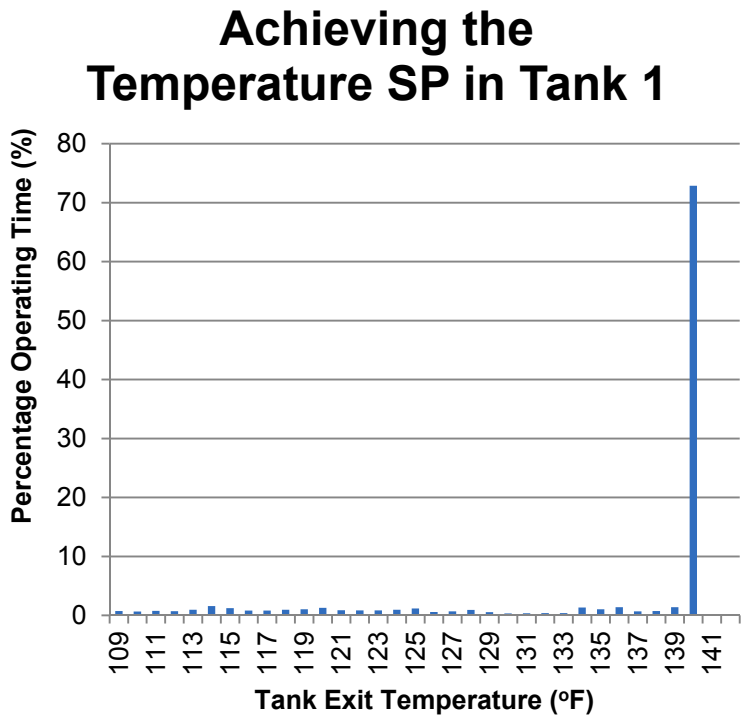
Performance Comparison

GAHP



- Average daily consumption of 1104 ft^3

Condensing Tank Pre-Heat



- Average daily consumption of 1638 ft^3

Assumed 1020 BTU/ft^3

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Future Plans

- Investigate how each regional climate affects the performance
- Explore other water draw data resources
- Better understand the EnergyPlus HeatPump and Stratified models
- Model a water heating tank with internal heat exchanger coil

Thank You!