Commercial Water Heating Using Gas Absorption Heat Pumps

Oak Ridge National Lab

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ACEEE Hot Water Forum

Portland, OR

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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

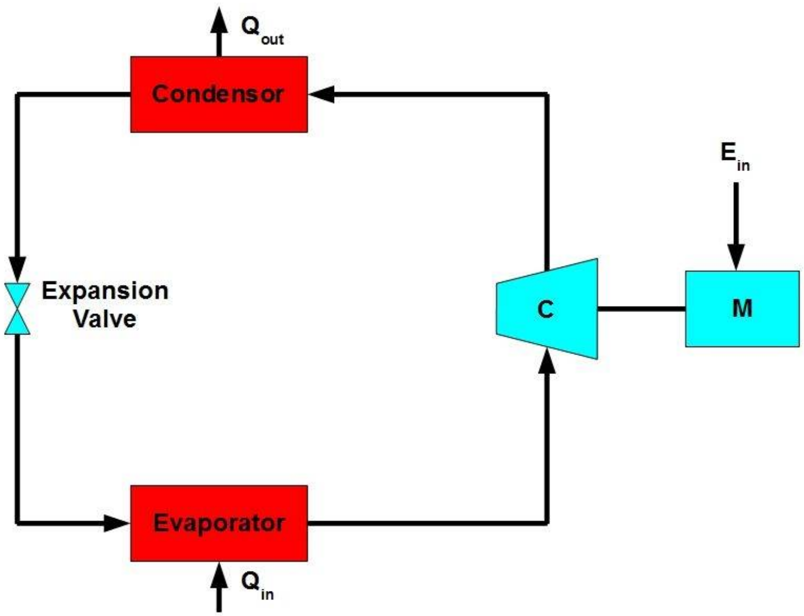
- 7% U.S. Commercial Energy Use (1.2 Quads)
- 9% Canadian Commercial Energy Use
- 5.5% U.S. Commercial Sector CO_2 Emissions

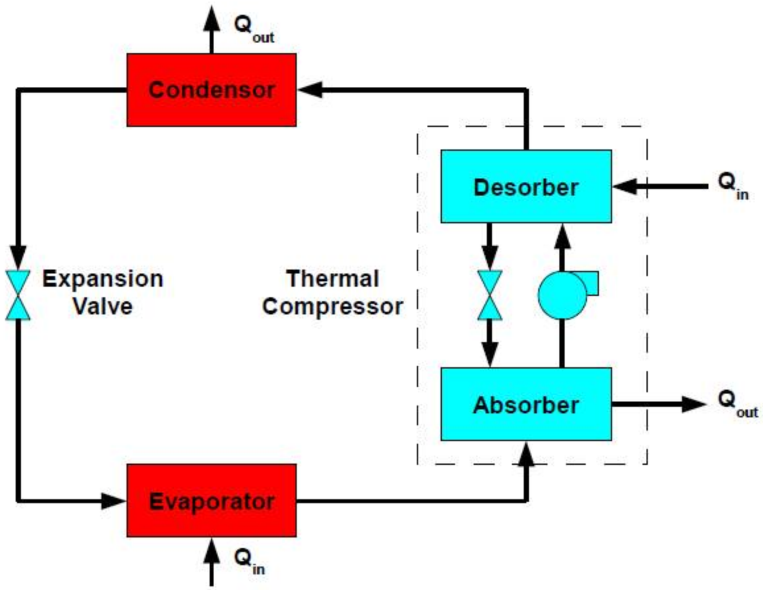
Source: US DOE and NRCAN

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

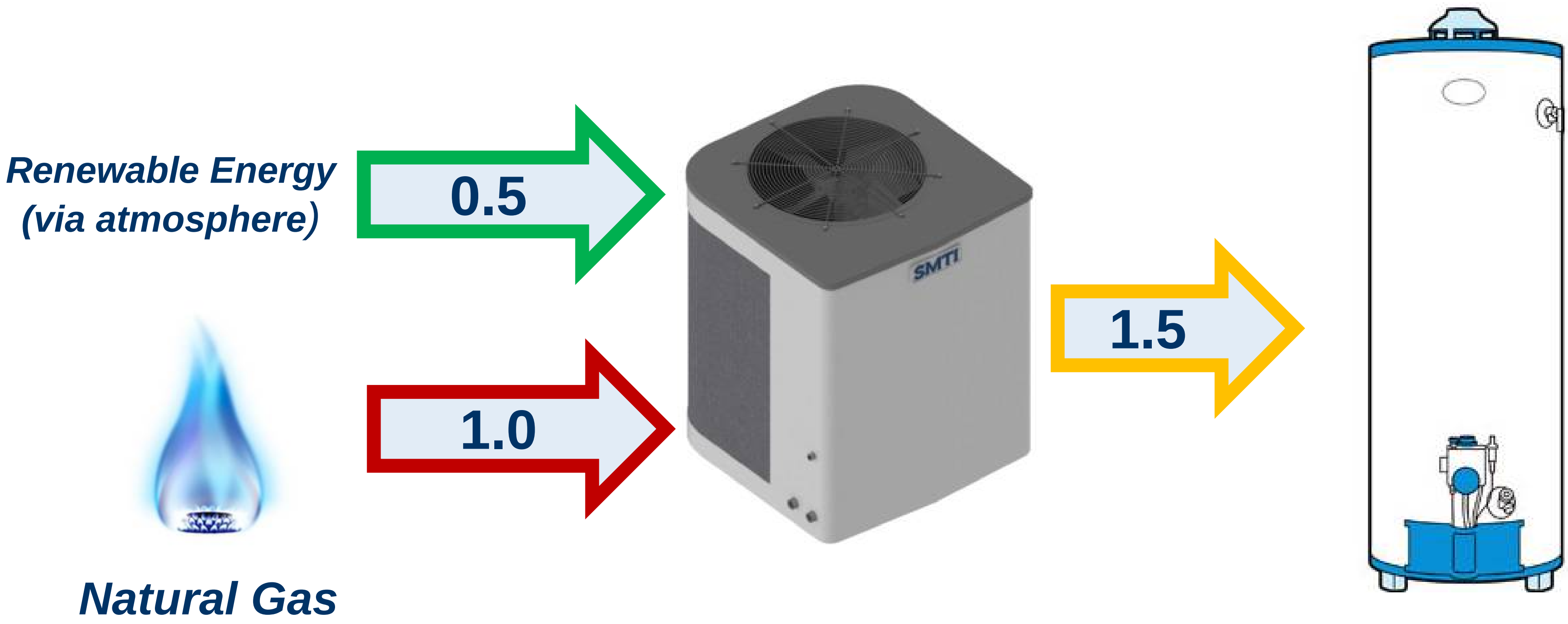
Qheat = ~1.2 x Qevap

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

SMTI

COP_{HHV} = 1.4 at 47/120ºF

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

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

GAHP Development Status

10,000 btu/hr	80,000 btu/hr	140,000 btu/hr
		
Field Testing	Field Testing	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

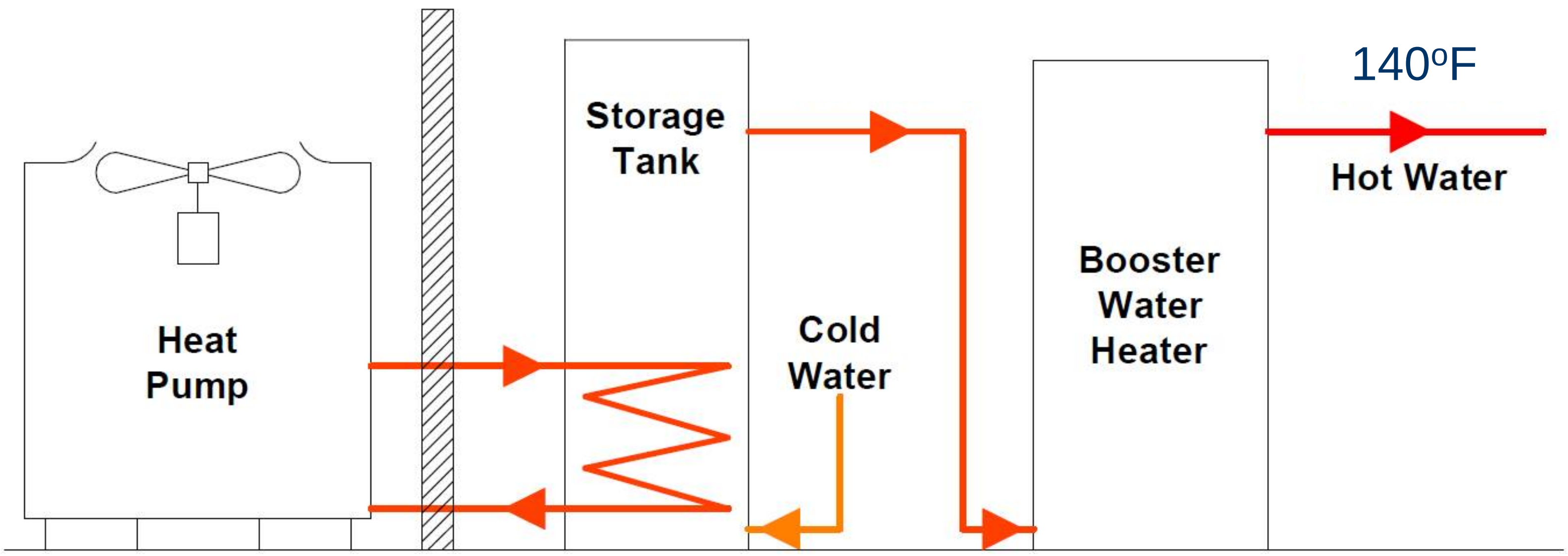
Vs.

140 kBth GAHP + 199 kBth NC Storage

****** Dr. Chris Keinath***

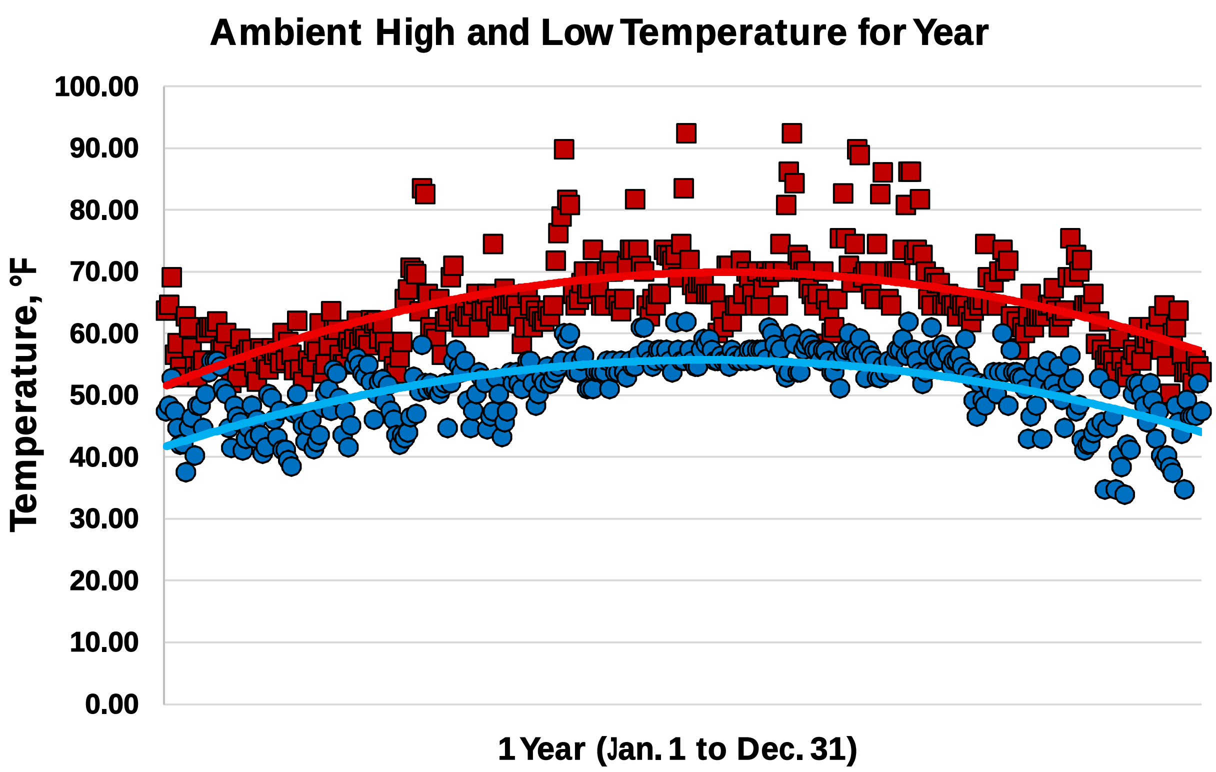
GAHP Commercial Water Heating

Pre-Heater Installation



Ambient Temperature from Energy Plus

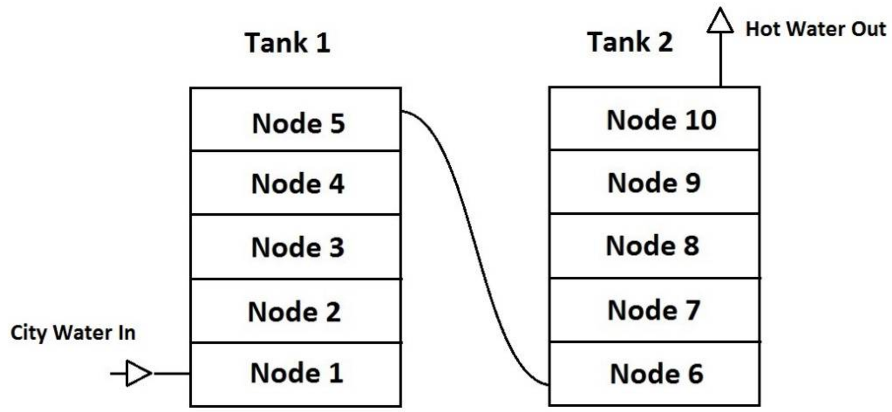
Oakland, California



Yearly Average: 58°F

Engineering Equation Solver Model: Assumptions

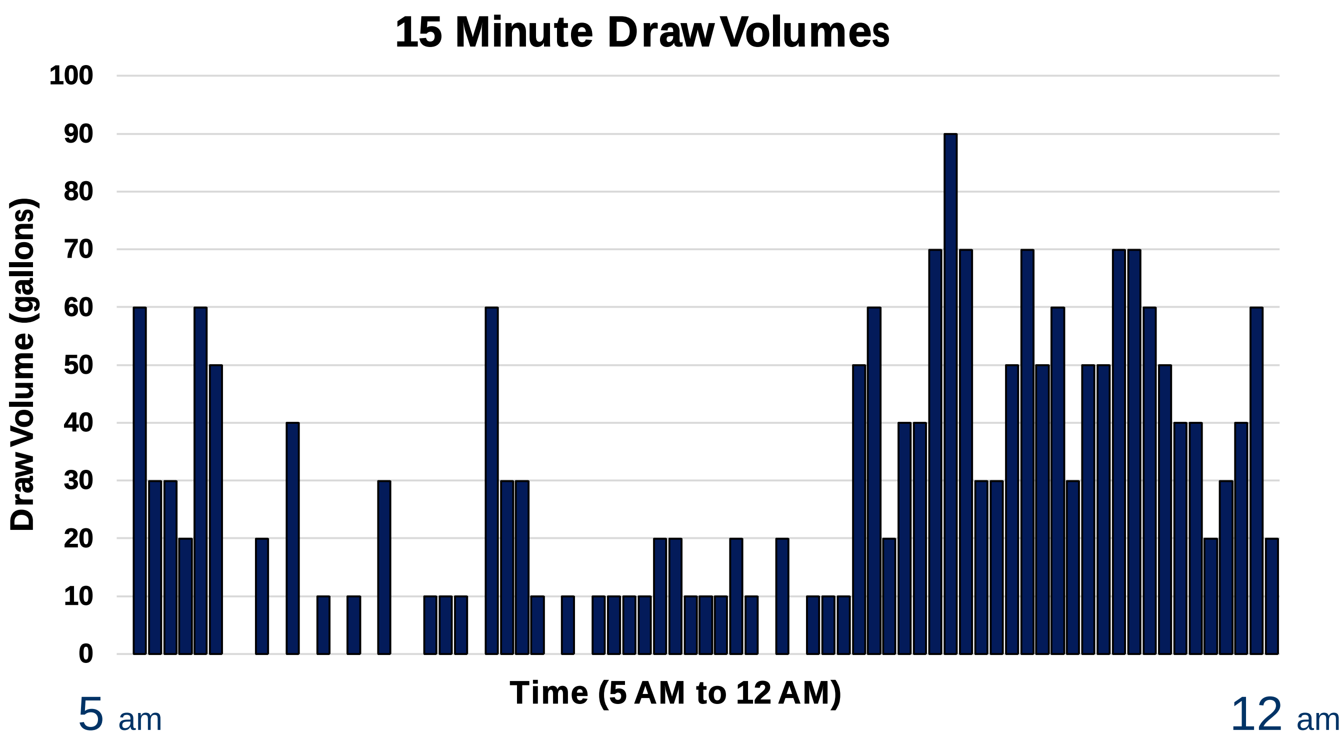
- A hot water draw happens at the start of each 15 minute period
- Water is drawn into the bottom of Tank 1 at 54.7°F
- Water exiting the top of Tank 1 enters the bottom of Tank 2
- COP for the GAHP and Condensing units use ***average*** bottom node temperature for each 15 minute step
- Modulation is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



Commercial Water Heating: Case 1

Simulated Draw Pattern

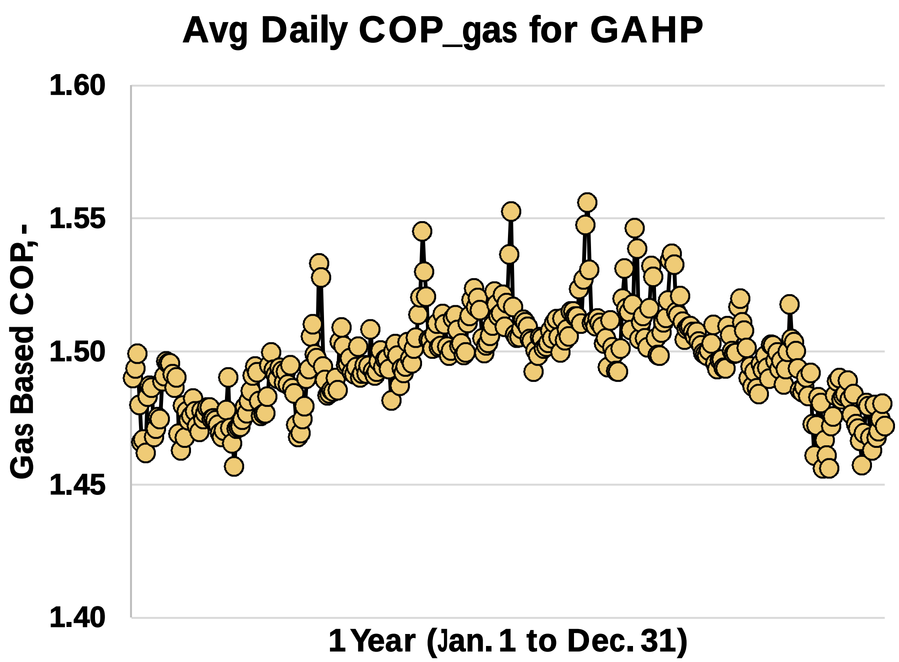
Full Service Restaurant - Daily draw pattern
Daily use: 2080 Gallons of Hot Water

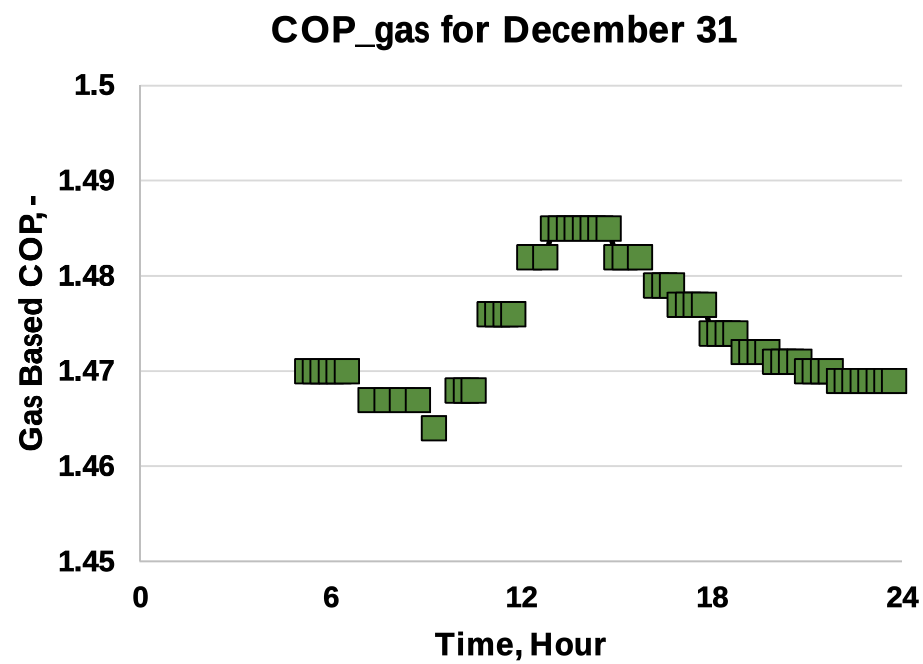


Note: Draw pattern for FSR approximated from data presented by: Pacific Gas and Electric. 2007b. *Energy Efficiency Potential of Gas-Fired Commercial Hot Water Heating Systems in Restaurants: An Emerging Technology Field Monitoring Study.* FSTC Report 5011.07.04. San Ramon, CA.

Commercial Water Heating: Case 1

GAHP Performance





Commercial Water Heating: Case 1

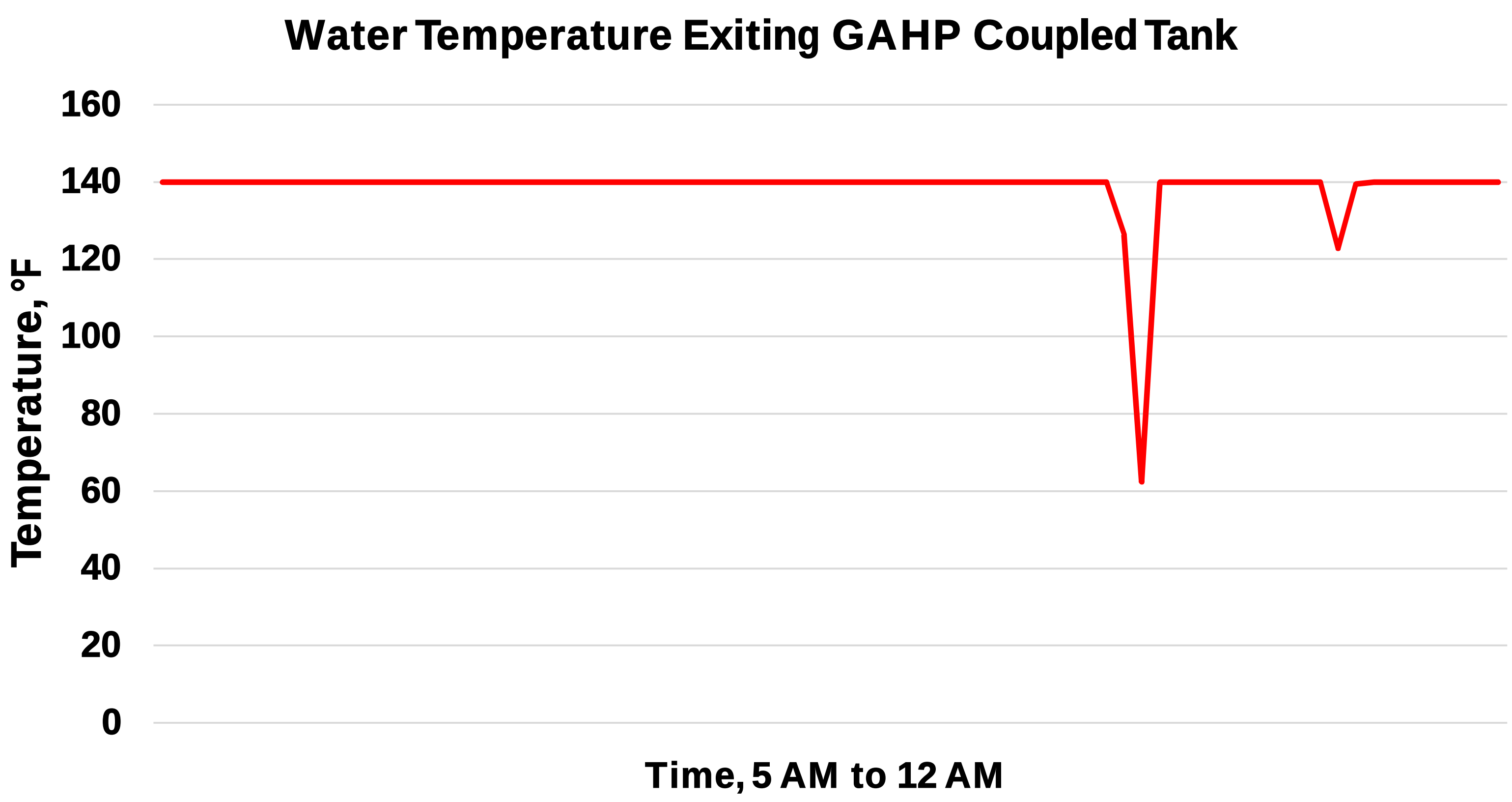
GAHP Pre-Heat

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 Therms	Electricity Used kWh	Cost of Gas $	Cost of Electricity $	Gas Used Therms	Electricity Used kWh	Cost of Gas $	Cost of Electricity $
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

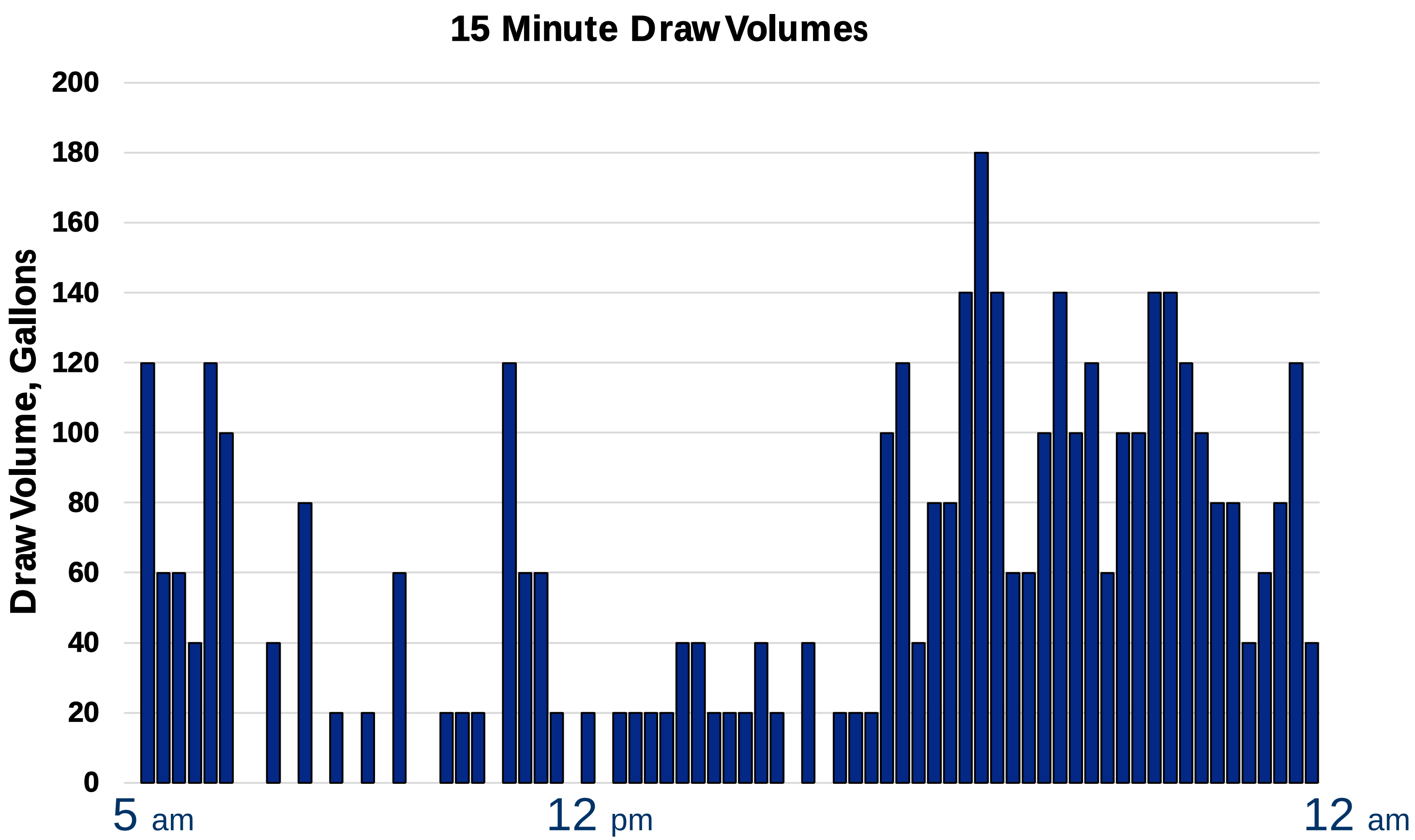
		Condensing Pre-Heat	GAHP Pre-Heat	Annual Savings	% Difference
Total Natural Gas Used	**Therms**	**5,420**	**3,380**	**2,040**	**38%**
Cost of Gas Used	**$**	$5,420	$3,380	$2,040	38%
Total Electricity Used	**kWh**	849	5,092	-4,243	
Cost of Electricity Used	**$**	$102	$611	-$509	
Total Energy Used	**kWh**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

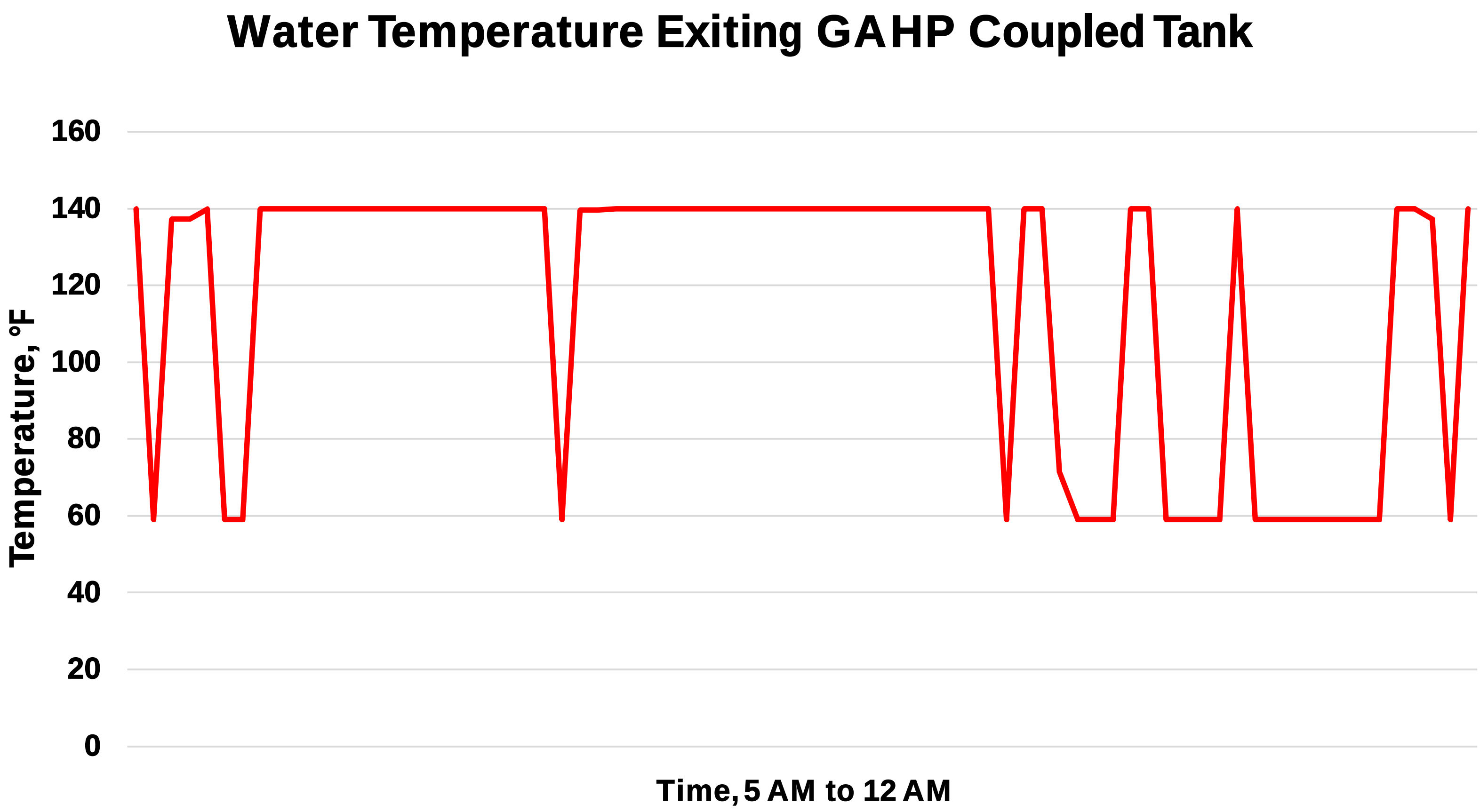
Simulated Draw Pattern

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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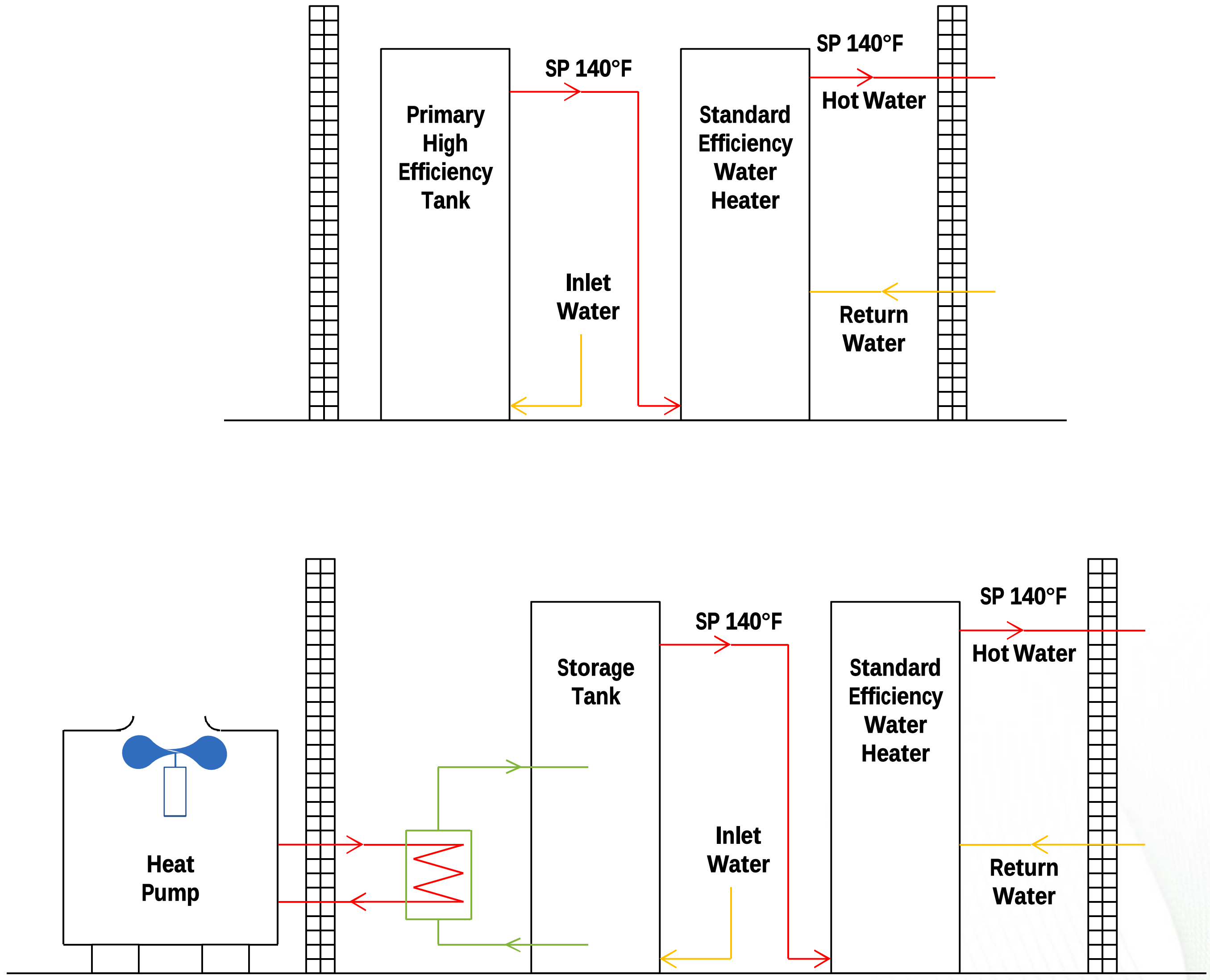
System Configurations



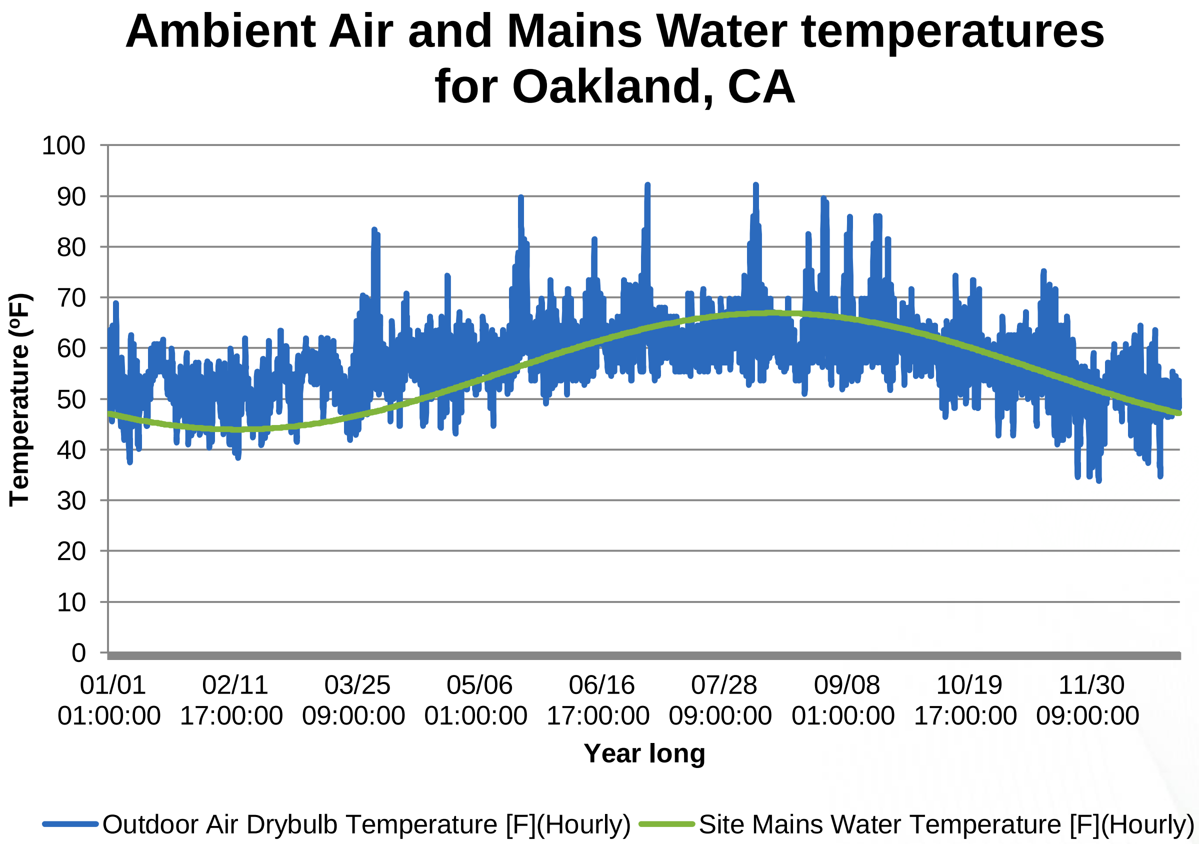
System Assumptions

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

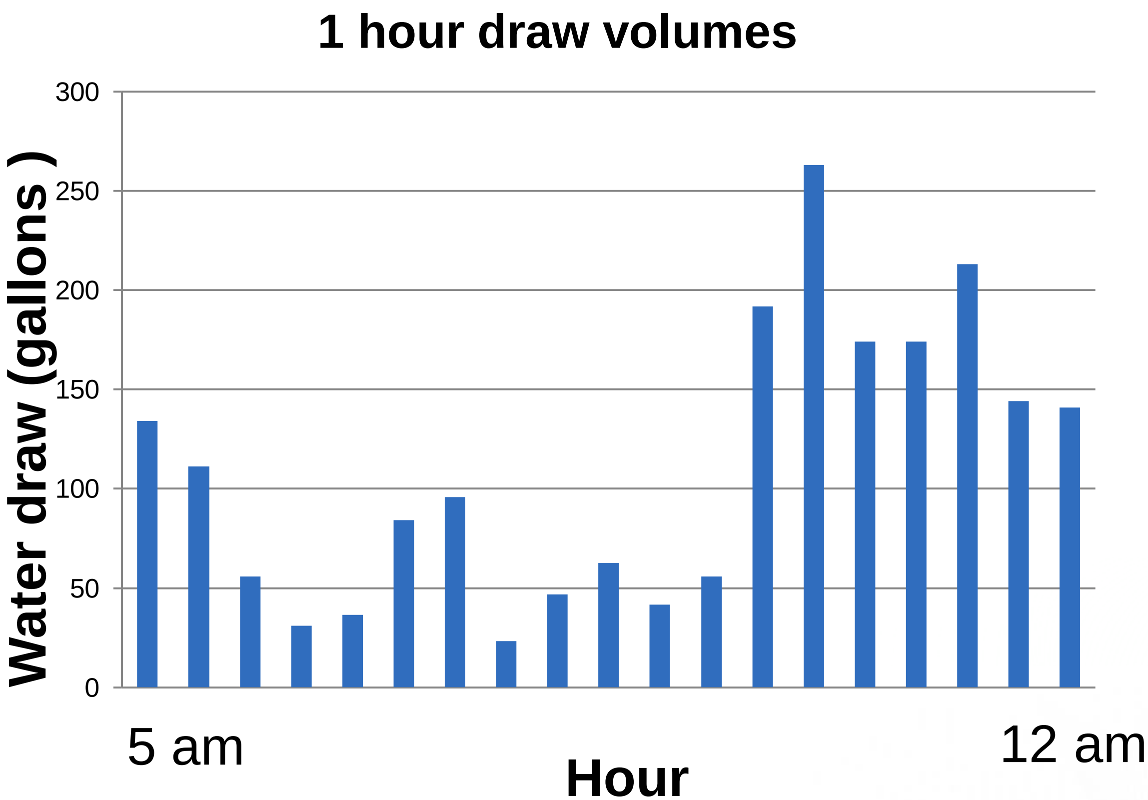
Condensing Tank Pre-Heat

- 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
Temperature (ºF)
100
90
80
70
60
50
40
30
20
10
0
01/01 01:00:00
02/11 17:00:00
03/25 09:00:00
05/06 01:00:00
06/16 17:00:00
07/28 09:00:00
09/08 01:00:00
10/19 17:00:00
11/30 09:00:00
Year long
Outdoor Air Drybulb Temperature [F](Hourly)
Site Mains Water Temperature [F](Hourly)

Daily draw pattern



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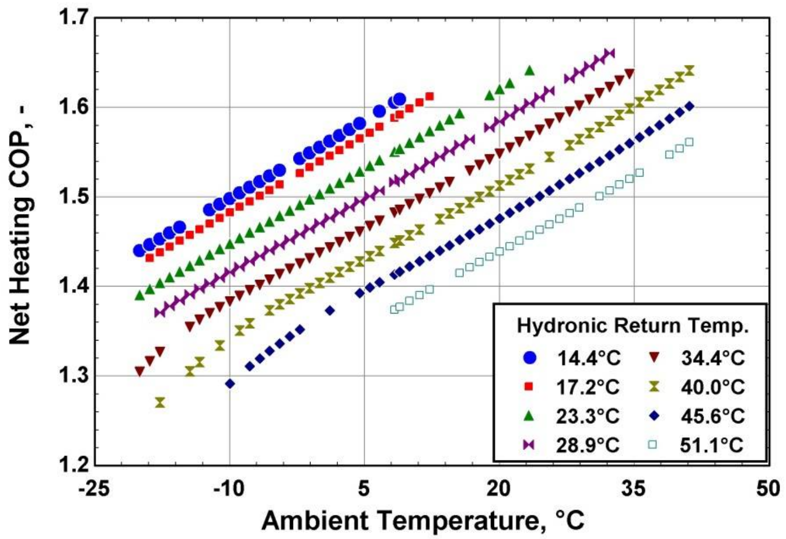
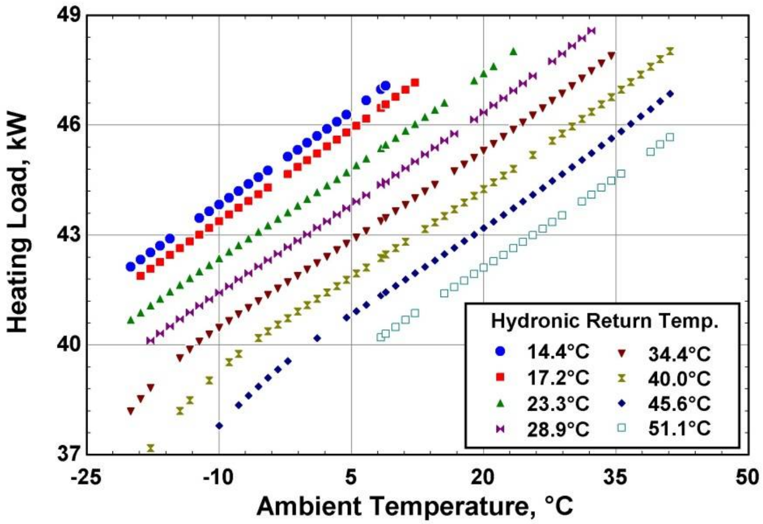
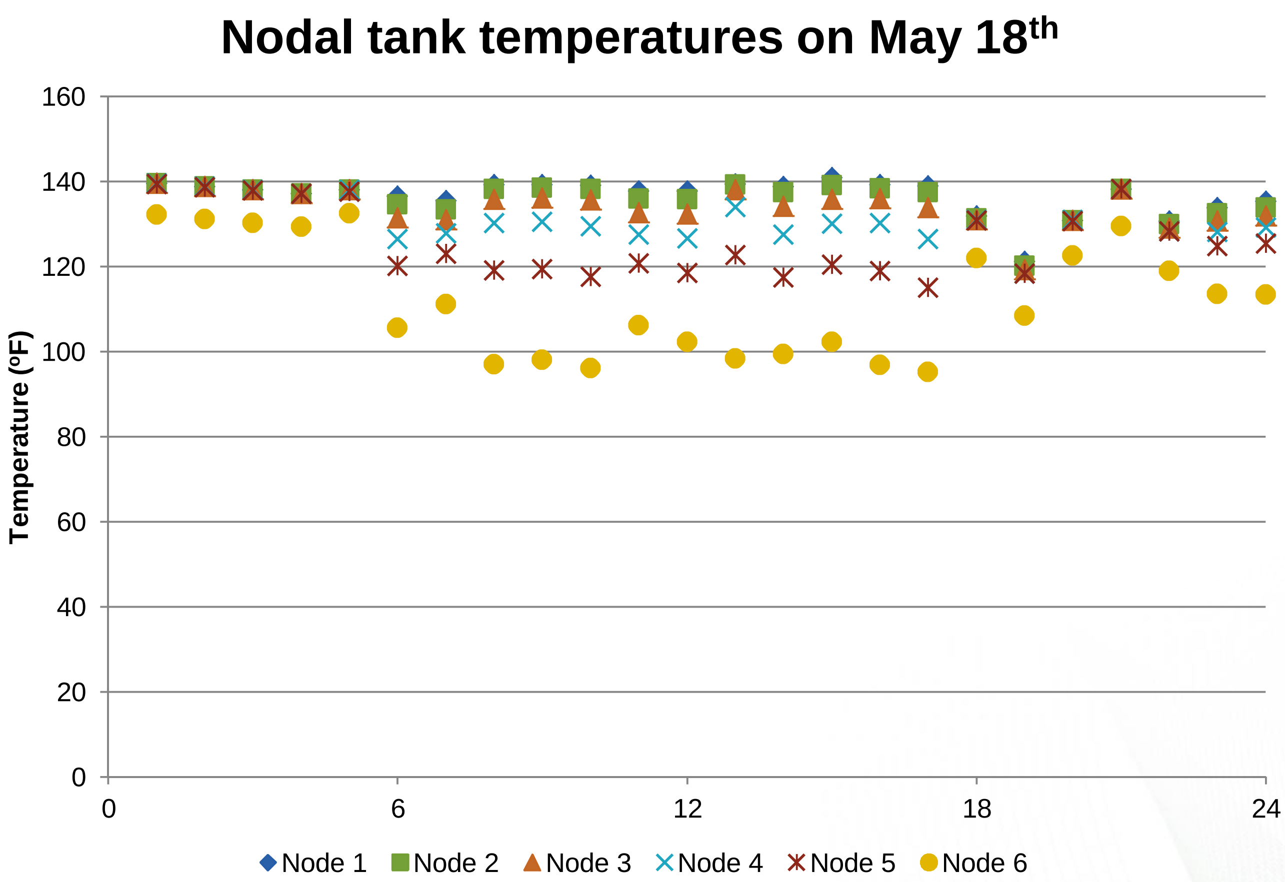
GAHP COP and Heating Load as functions of Hydronic and Air Ambient Temperatures



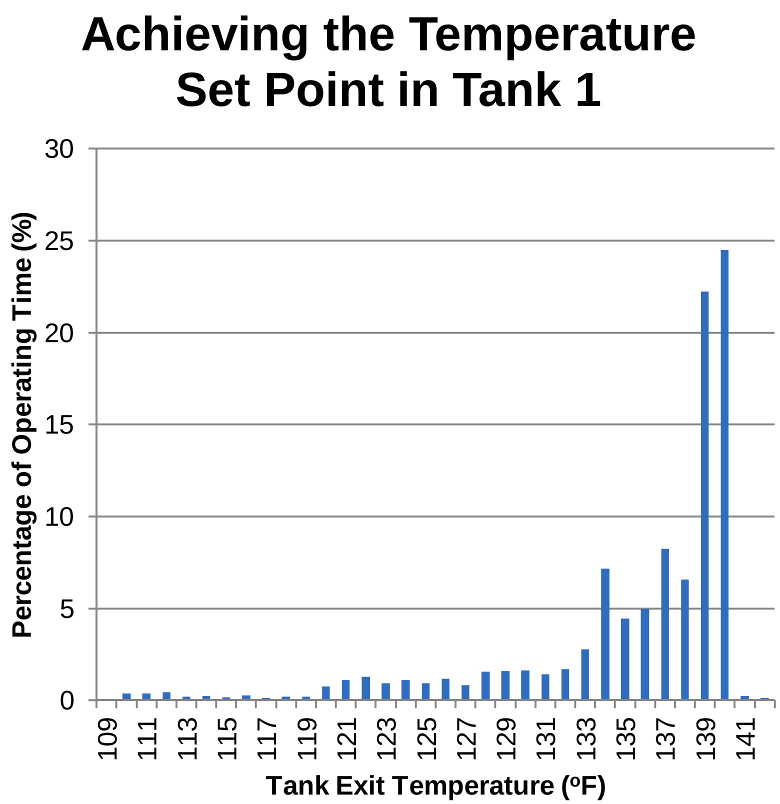


Tank Stratification



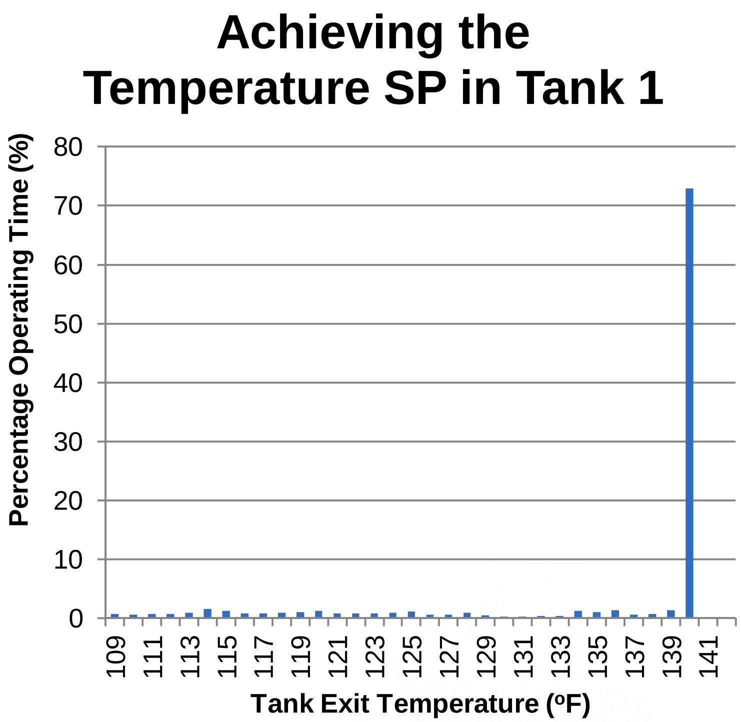
Performance Comparison

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!