Commercial Water Heating with Gas Absorption Heat Pumps:

Development Update and Impact of Storage Tank Design

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ACEEE Hot Water Forum

Portland, OR

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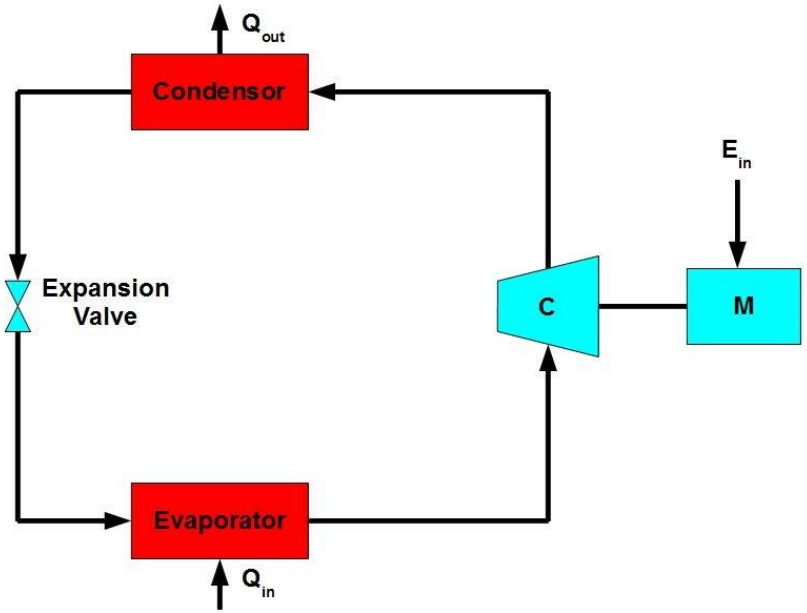
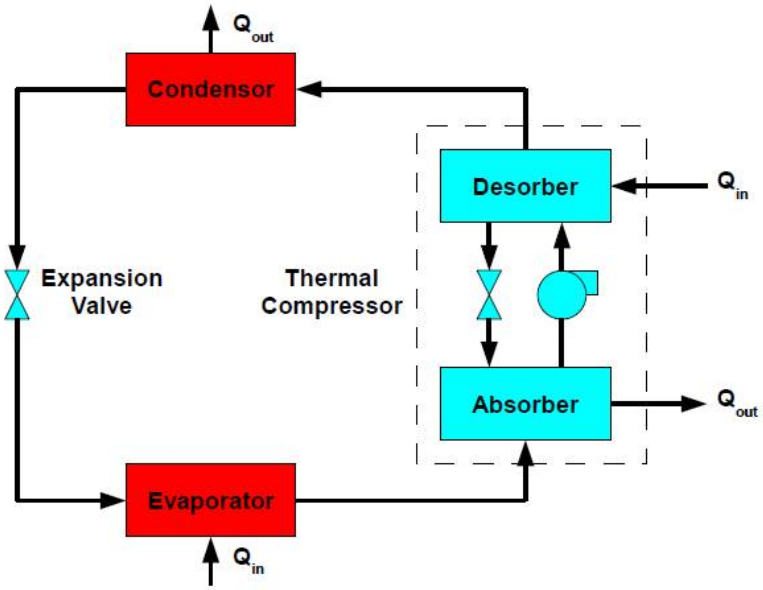
Topics of Discussion

- **GAHP Technology Background**
- **Current State of Commercial GAHP Water Heater**
- **Modelling/Savings**
- **Impact of Storage tank on GAHP Performance**

How Does It Work?





$COP_h = Qcond/E_{in} = 3.0\text{-}4.0$

Qheat = ~1.1 x Qcooling

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

Qheat = (Qcond + Qabs) ~ 2.5 times Qevap

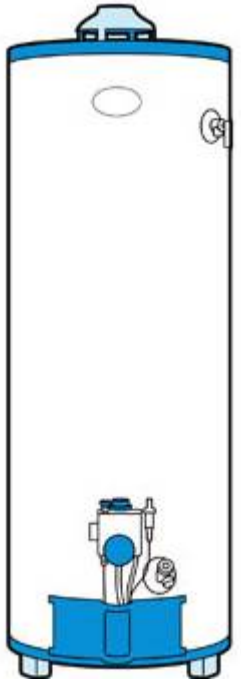
Capacity & COP Remain High at Low Ambient Temperatures

Renewable Energy Content: ~35%

Solar Energy
(via the atmosphere)

0.5

1.5



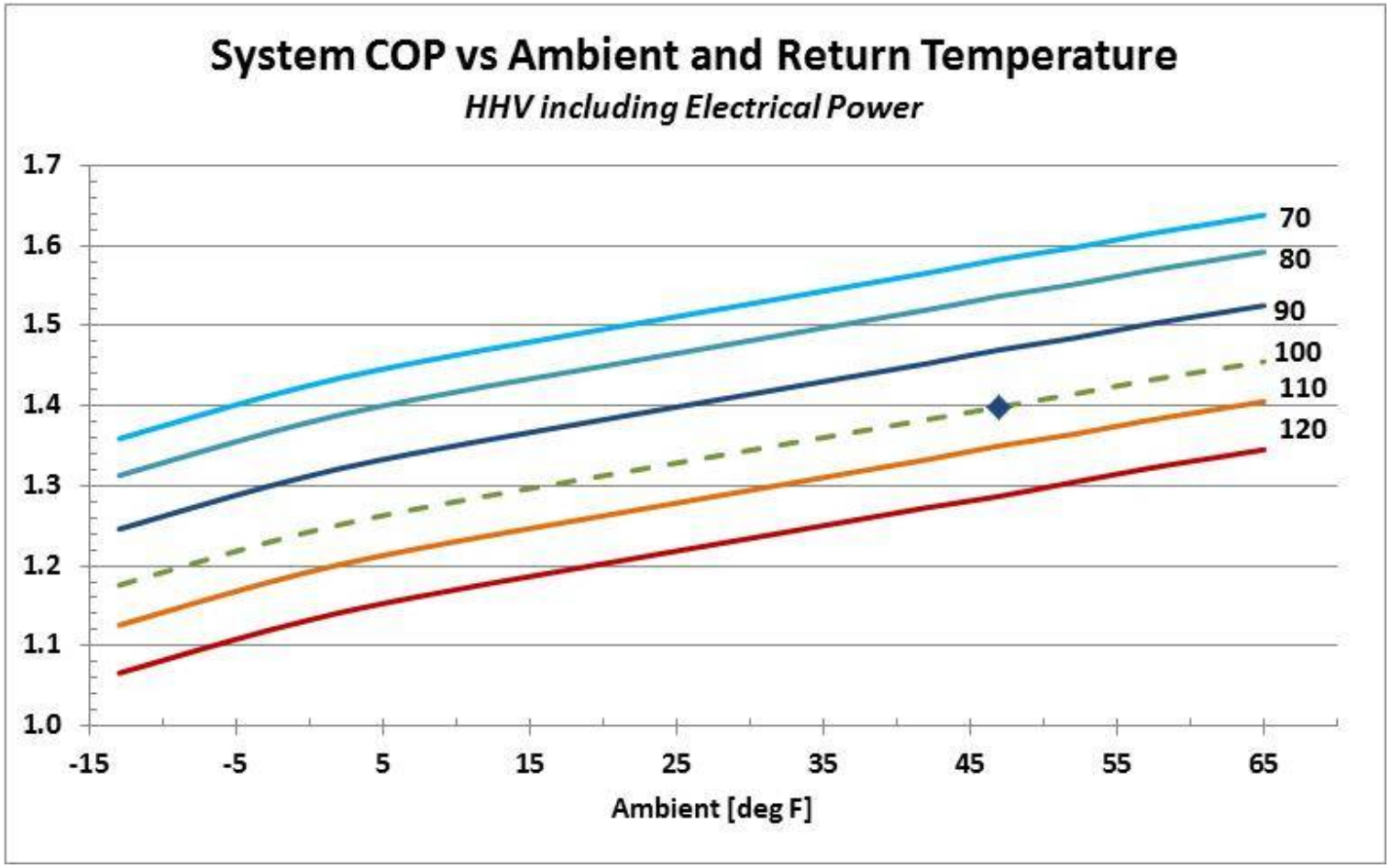
1.0

Fuel Source **

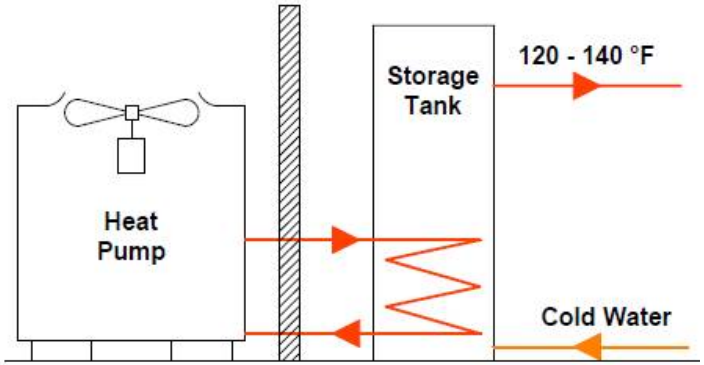
***** Natural Gas, Propane, Fuel Oil, BioDiesel, Renewable Gas, etc.***

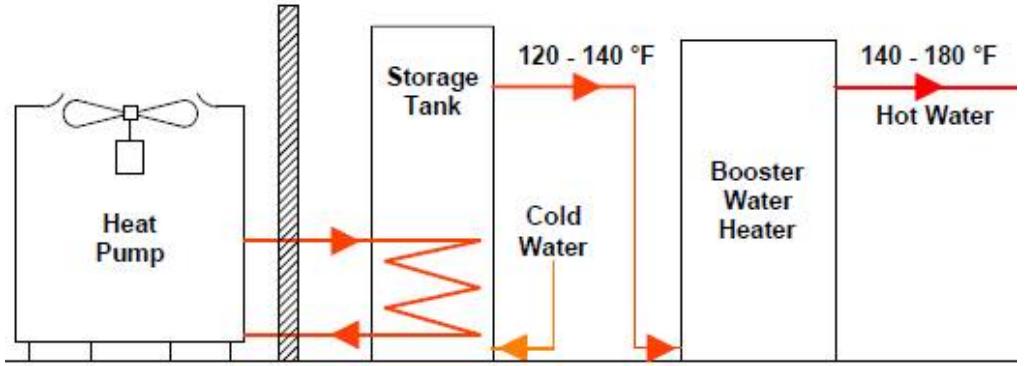
SMTI GAHP Target Performance

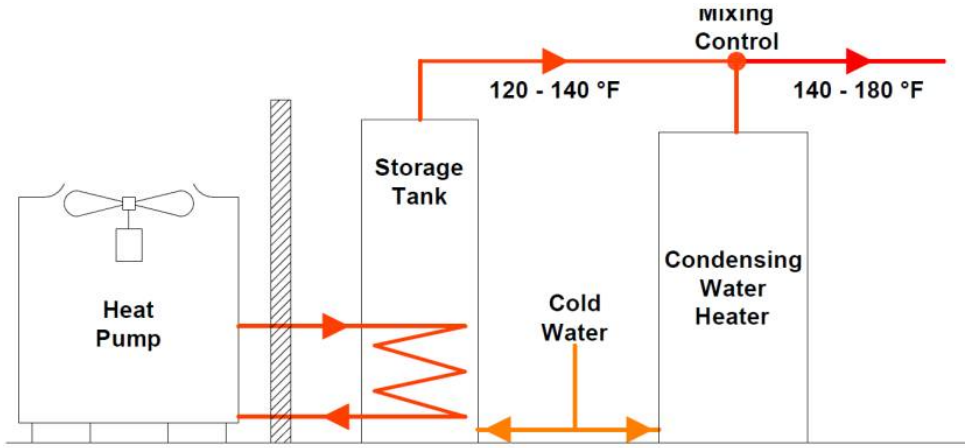
Nominal 20F Rise

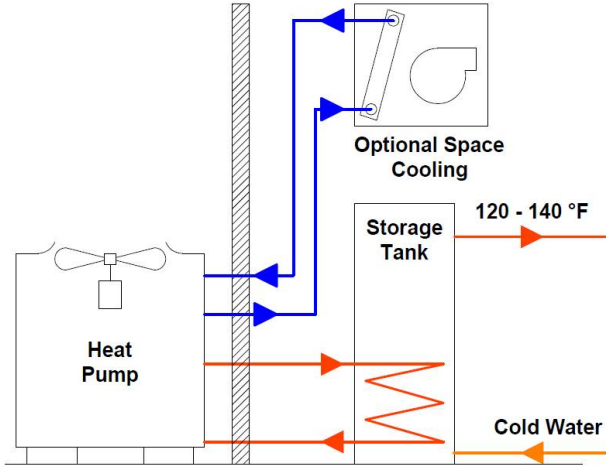


GAHP Commercial Water Heating









SMTI Gas Absorption Heat Pumps

COP_{HHV} = 1.45 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

AO Smith
Innovation has a name.

ornl
OAK RIDGE NATIONAL LABORATORY

GAHP Commercial Water Heater Development

Alpha Prototype **Beta Prototype**

30% reduction in size from Alpha to Beta Prototype

Beta Prototype

Nominal Output :
140,000 btu/hr (41.0 kW)

Gas Input:
97,000 btu/hr (28.4 kW)

Max Supply:
160°F (71°C)

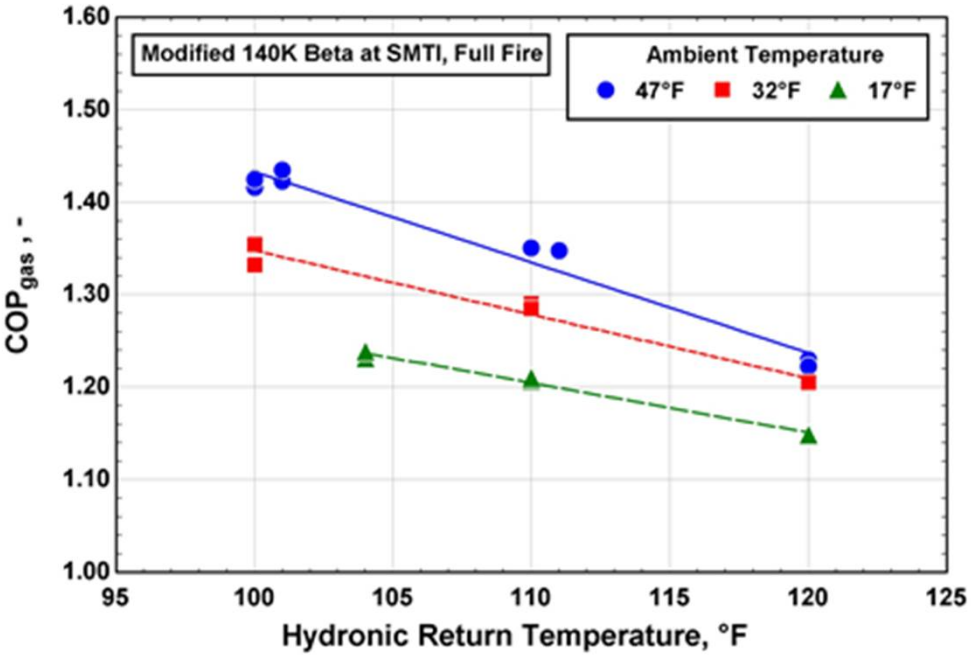
Size:
50” × 40” × 60”

Weight:
~850 pounds

Modulation:
4:1

GAHP Commercial Water Heater Development

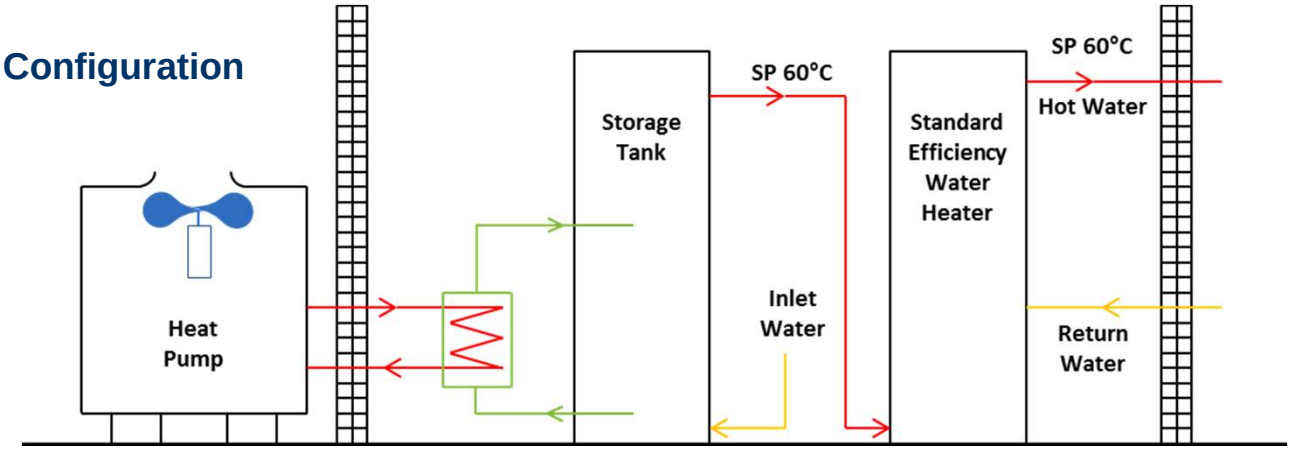
- COP of 1.41 at 47/100°F design (97% of 1.45 target)
- Reliability testing underway



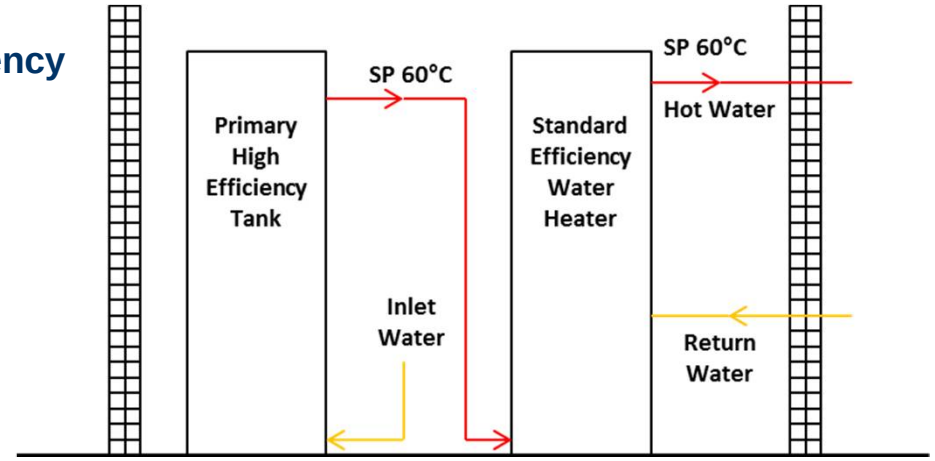
Energy Plus Modeling

Commercial Water Heater Modeling: EnergyPlus

140K GAHP Configuration



Conventional High Efficiency Configuration

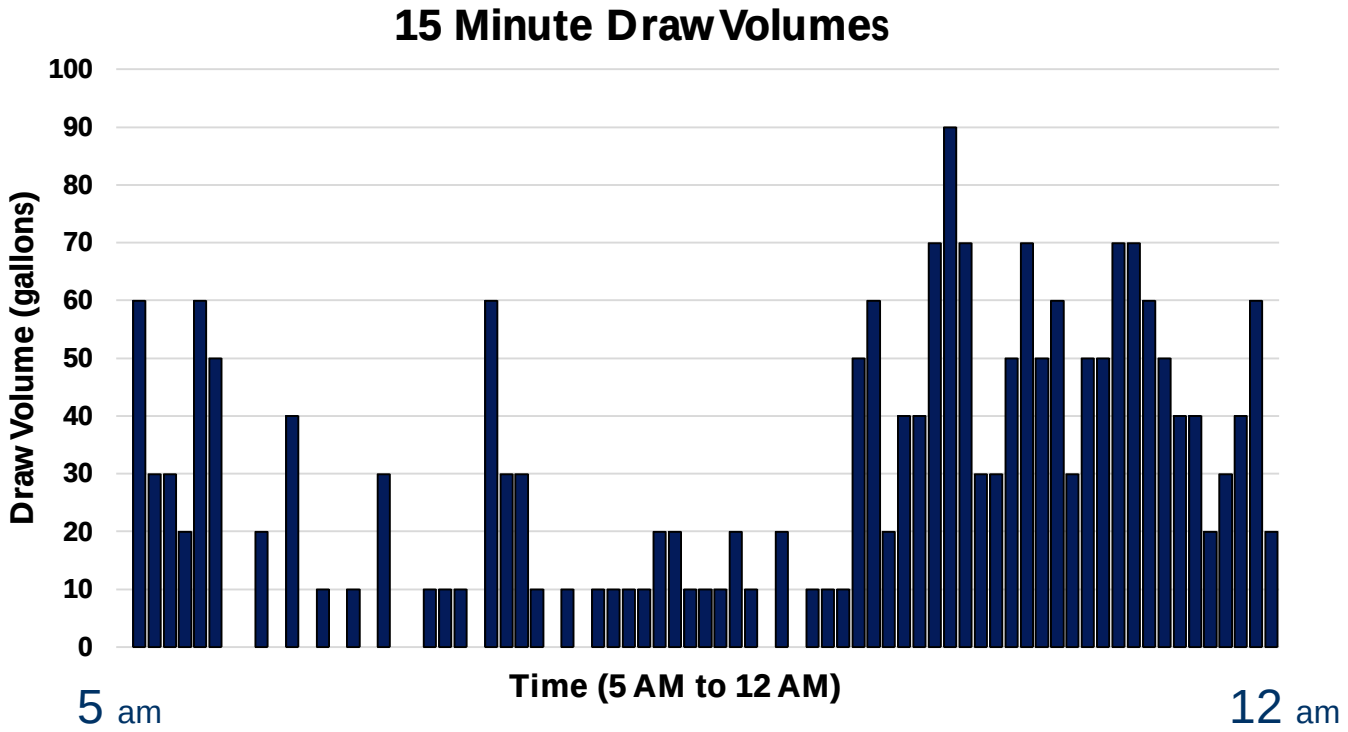


ORNL
OAK RIDGE NATIONAL LABORATORY

*Geoghegan, P., Shen, B., Keinath, C., Garrabrant, M., "Regional Climate Zone Modeling of a Commercial Absorption Heat Pump Water Heater – Part 1: Southern and South Central Climate Zones," *16th International Refrigeration and Air Conditioning Conference at Purdue,* July 11-14, 2016

Commercial Water Heater Modeling: EnergyPlus

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

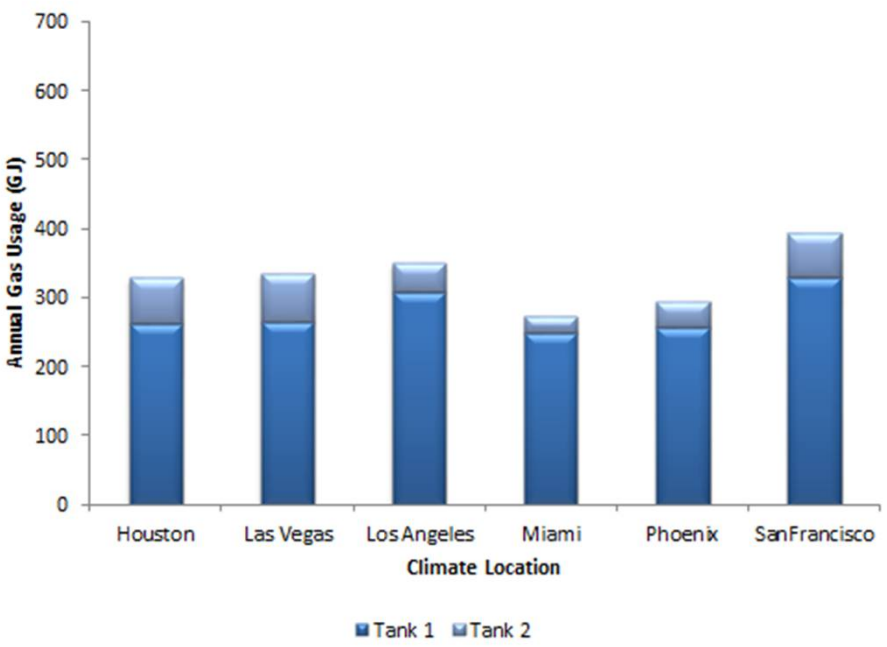


Note: Draw pattern for FSR approximated from data presented by: Pacific Gas and Electric. 2007b. *Energy Efficiency Potential of Gas-Fired Commercial Hot Water Heating Systems in Restaurants: An Emerging Technology Field Monitoring Study.* FSTC Report 5011.07.04. San Ramon, CA.

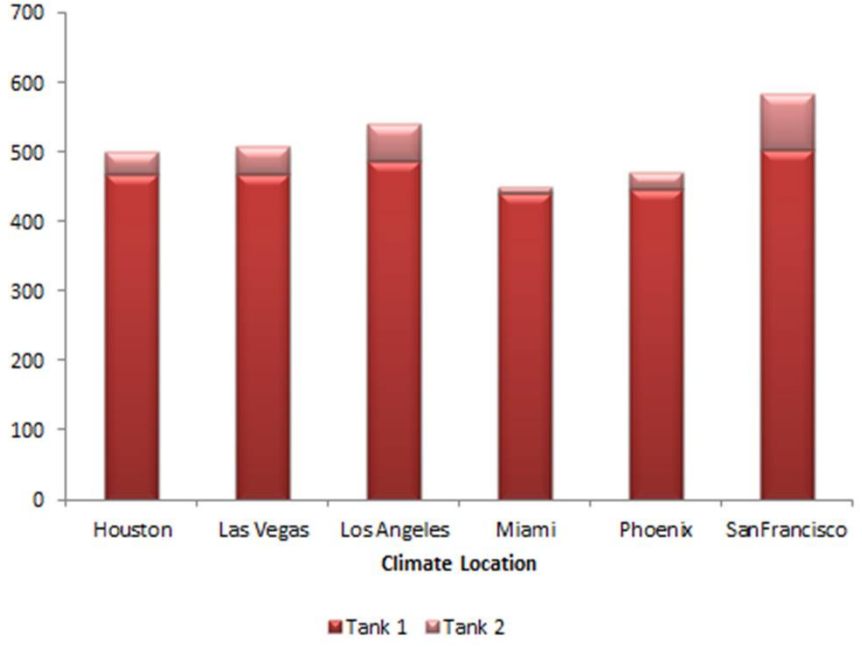
Commercial Water Heater Modeling

- 6 cities in the Southern and South Central climate zones investigated
- Full service restaurant (FSR) using **2080** gallons per day
- On average, the 140K GAHP configuration offered an annual gas savings of 35%

140K GAHP Configuration



Conventional High Efficiency Configuration



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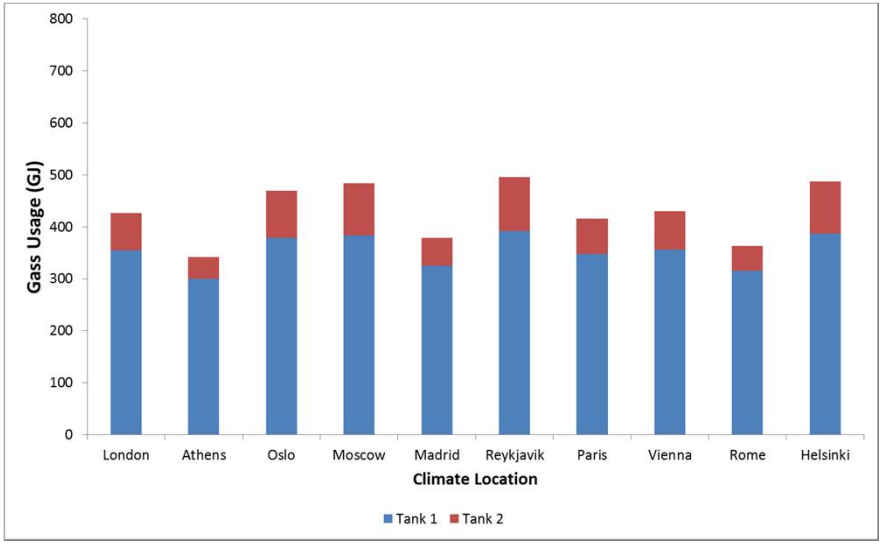
Commercial Water Heater Modeling

- 10 cities in the European Union (EU) investigated
- FSR using 2080 gallons per day
- The 140K GAHP configuration offered an average annual gas savings of 31.1%

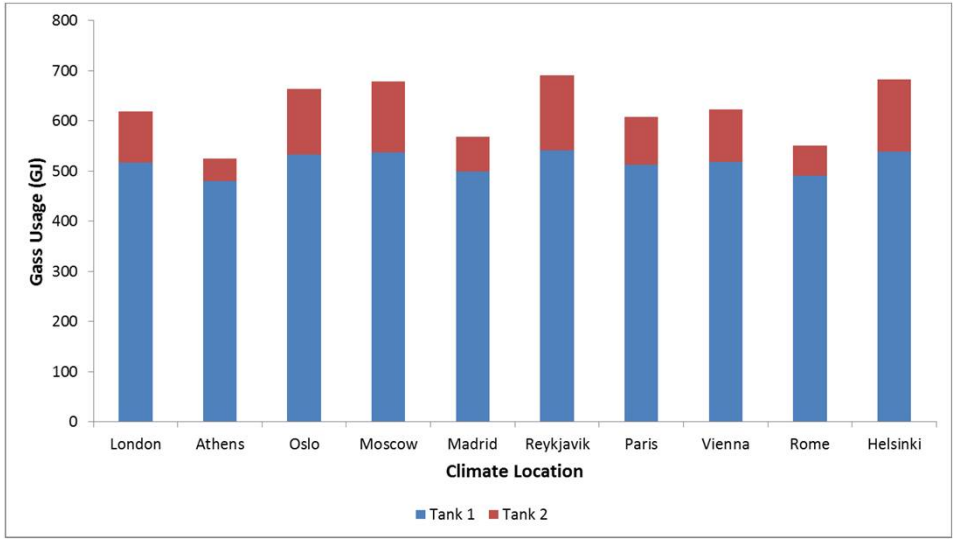
Yearly Average Ambient Temperature, °F				
London	Athens	Oslo	Moscow	Madrid
53	64	42	41	58
Reykjavik	Paris	Vienna	Rome	Helsinki
40	54	51	62	40

(Portland, OR yearly average is 55°F)

140K GAHP Configuration



Conventional High Efficiency Configuration

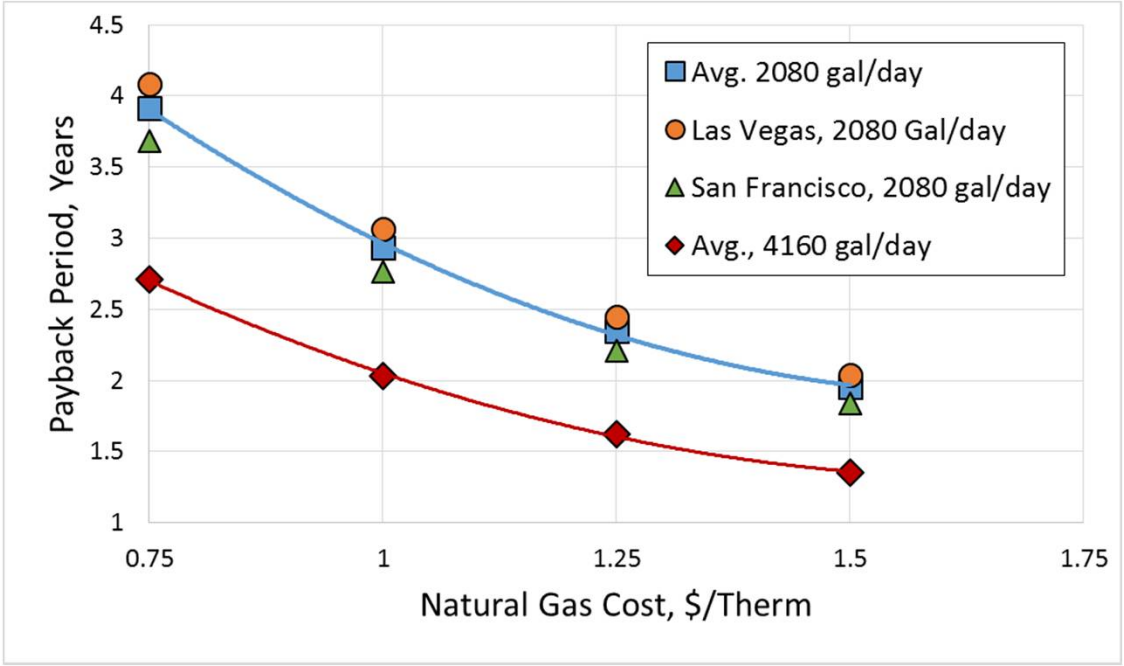


*Sharma, V., Shen, B., Keinath, C., Garrabrant, M., Geoghegan, P., "European Regional Climate Zone Modeling of a Commercial Absorption Heat Pump Water Heater," 12th *IEA Heat Pump Conference,* May 15-18, 2017

Commercial Water Heater Modeling

- 6 U.S. cities studied by Geoghegan *et al.* (2016) at 2080 gpd
- 4160 gpd SMTI modeling

	Capital Cost
Conventional High Efficiency System	$11,500
140K GAHP System	$16,500

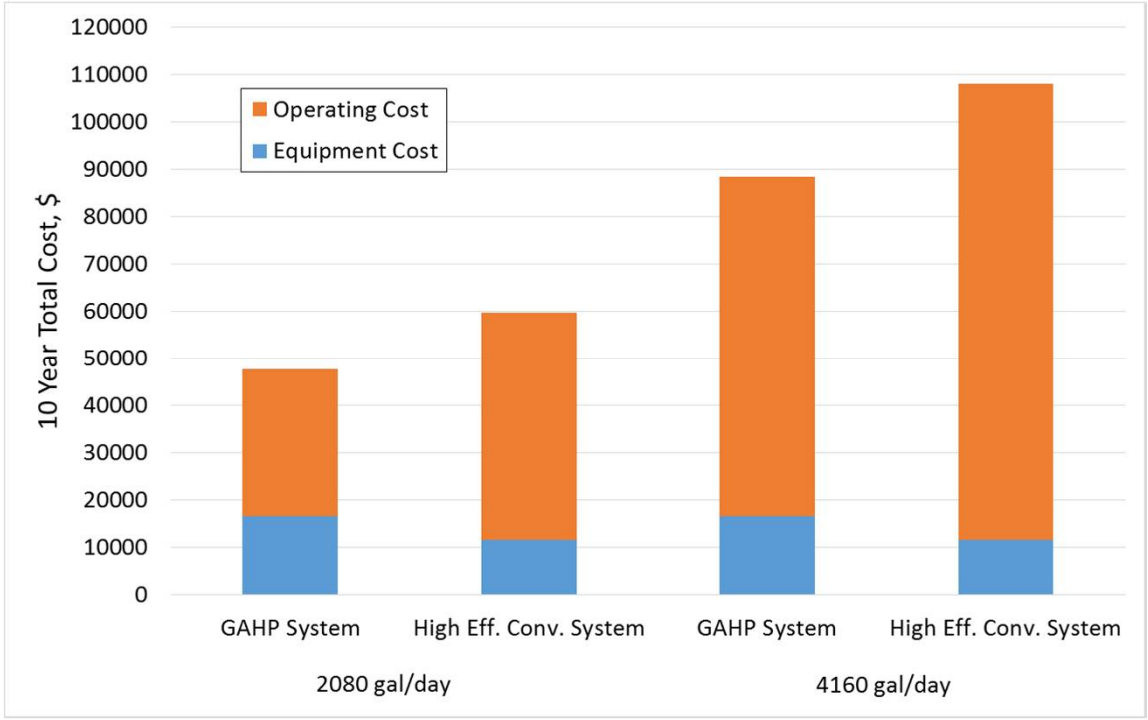


Commercial Water Heater Modeling

- 10 Year total cost for avg of 6 U.S. cities studied by Geoghegan *et al.* (2016)
- Savings of $12,000 for 2080 gpd
- Savings of $19,600 for 4160 gpd

	Capital Cost
Conventional High Efficiency System	$11,500
140K GAHP System	$16,500

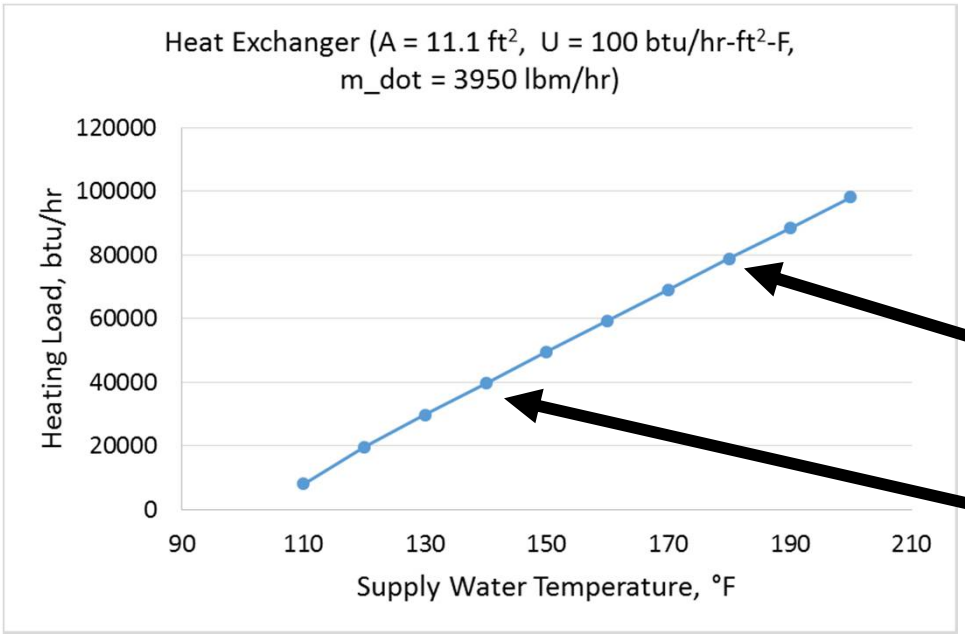
Natural gas cost of $1.00/therm assumed



Impact of Indirect Storage Tank

Impact of Indirect Storage Tanks on GAHPs

- Indirect heat exchangers are undersized
  - Heat exchangers are sized for hydronic supply temperatures of 160-180°F (increased LMTD to limit UA)
  - GAHPs need to operate at lower supply temperatures to take advantage of higher COPs

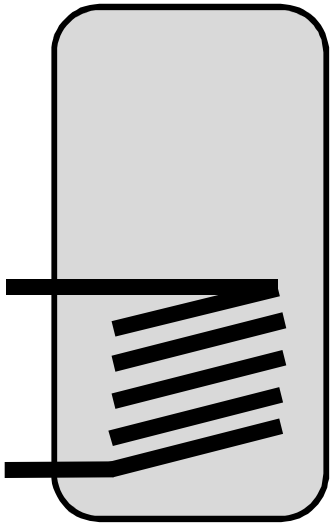


For same coil and conditions

80K btu/hr at 180°F hyd in

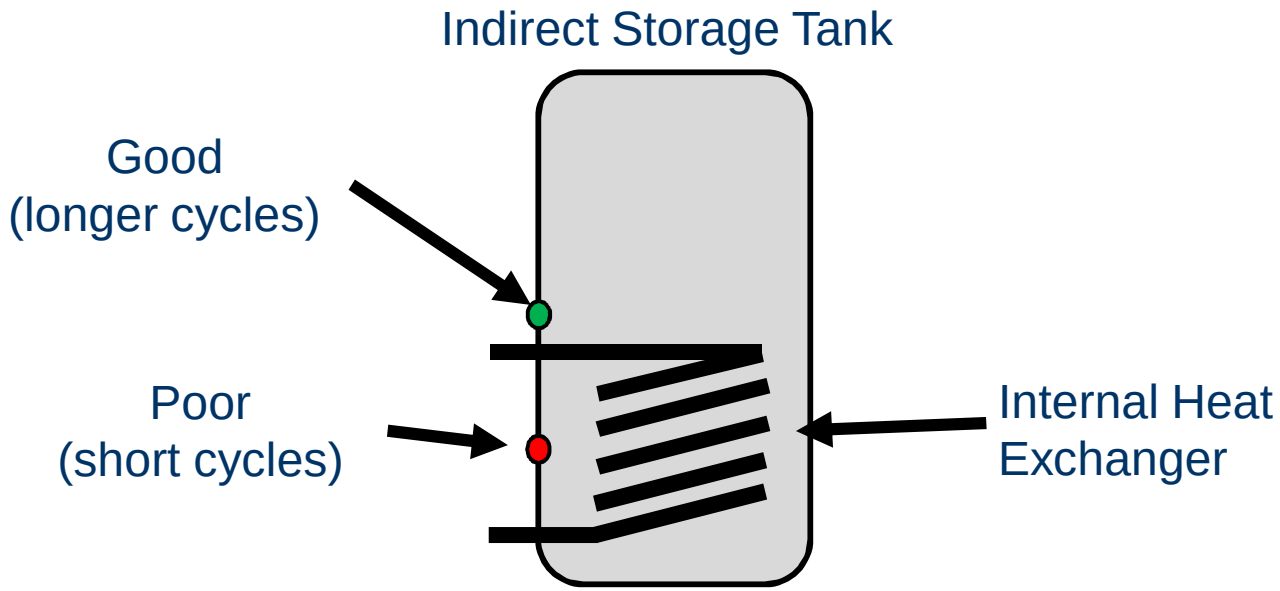
40K btu/hr at 140°F hyd in

Indirect Storage Tank



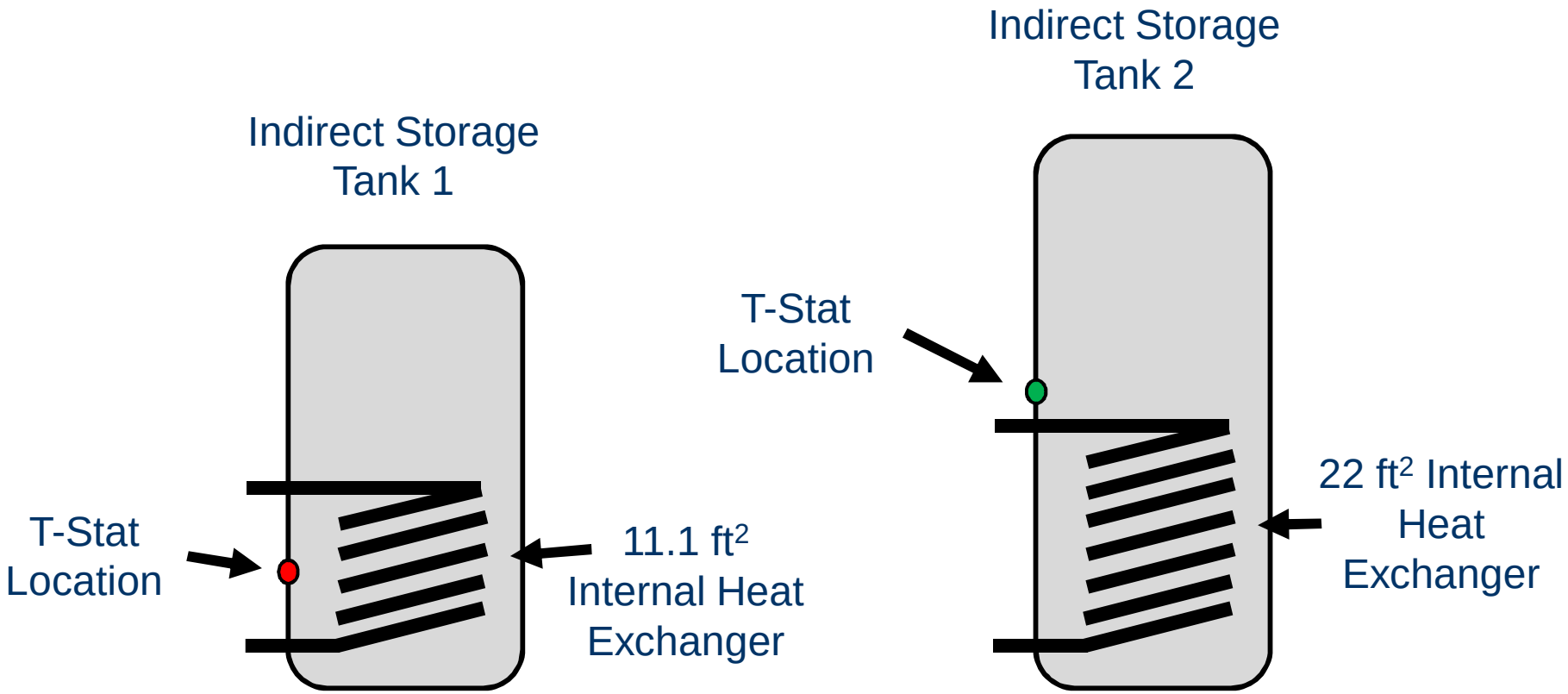
Impact of Indirect Storage Tanks on GAHPs

- Thermostat Location
  - T-stats located at the mid internal coil location result in frequent cycling of the heating system
  - GAHPs should be operated for longer cycles to limit the impact of reduced performance during the start-up period



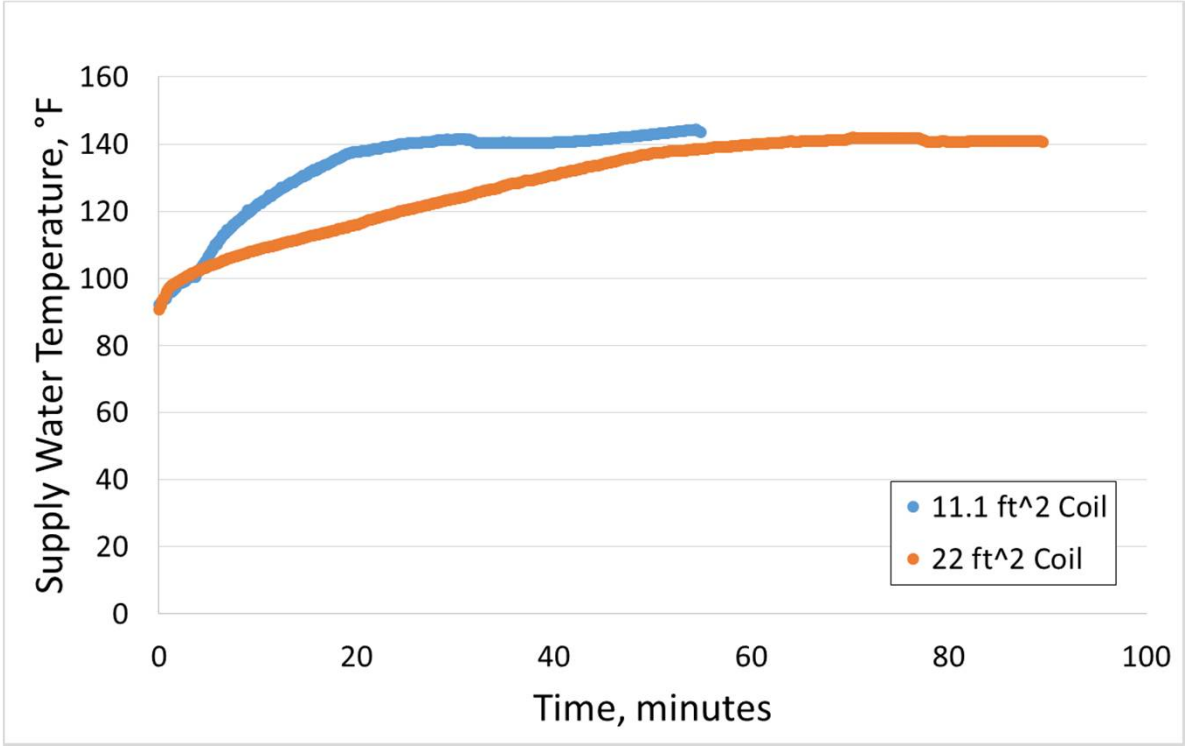
GAHP Tank Heating Investigation

- Tank 1 (45 Gallon) coil is 28.3 feet long, surface area of 11.1 ft^2
- Tank 2 (113 Gallon) coil is 67.3 feet long, surface area of 22 ft^2



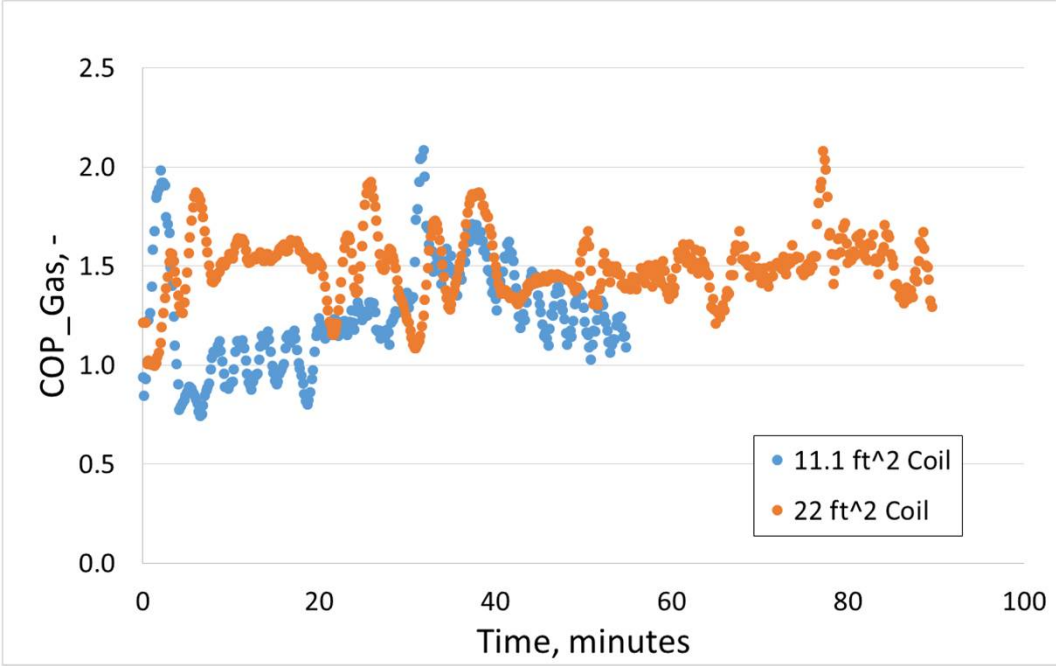
GAHP Tank Heating Investigation

- Supply Water Temperature Set-point of 140°F
- Once SP achieved, GAHP firing rate starts to reduce
- Larger HX Coil Allows Operation at Lower Supply Temperatures



GAHP Tank Heating Investigation

- Tank 1 Average COP of 1.25
- Tank 2 Average COP of 1.50



GAHP Storage Tank Design

- 80K GAHP matched coil – surface area of ~50 ft^2
- 140K GAHP matched coil – surface area of ~85 ft^2

- Heat exchange and surface area enhancement must be balanced with pressure loss

- Potential for scaling reduced with lower driving temperatures

Guidelines for tank design coupled to GAHP

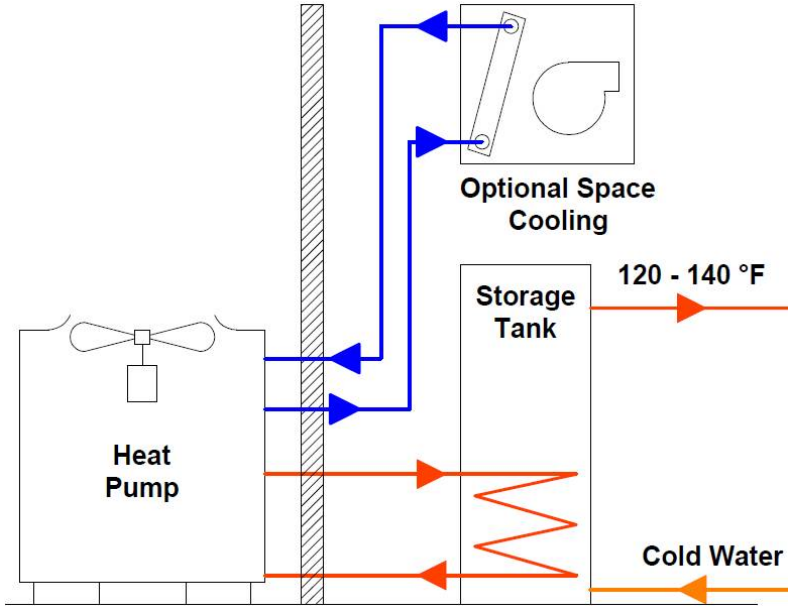
- Thermostat location above the hydronic coil to limit cycling (ideally close to the mid-point of the tank)
- Tank/coil size selected relative to GAHP capacity so that minimum acceptable runtimes are achieved
- Maximum GAHP firing rate is a function of the internal heat exchanger size (needs to be considered when sizing the coil)

Summary

- Commercial GAHP water heaters have the potential to significantly reduce energy use and operating cost
- Reasonable paybacks expected compared to condensing storage (<4 years)
- Success tied to indirect hot water storage tank design
- Appropriately sized tanks/internal coils not readily available

Next Steps in 2017

- Commercial water heating field test in Tennessee
- Two full service restaurant field tests in Los Angeles, California (Water heating and kitchen cooling)



Next Steps in 2017

- 3-6 Residential combi field tests (pending)
- Six residential water heater field tests in Los Angeles, California
- 5 kW Residential Combi Prototype
- Beta engine waste heat driven chiller for military and disaster relief applications

Acknowledgments

- Oak Ridge National Lab & US DOE
- A.O. Smith
- NEEA
- Gas Technology Institute

Thank You!

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