Residential Combi-Space/Water Heating Gas Absorption Heat Pump System:

Field Evaluation and Lessons Learned

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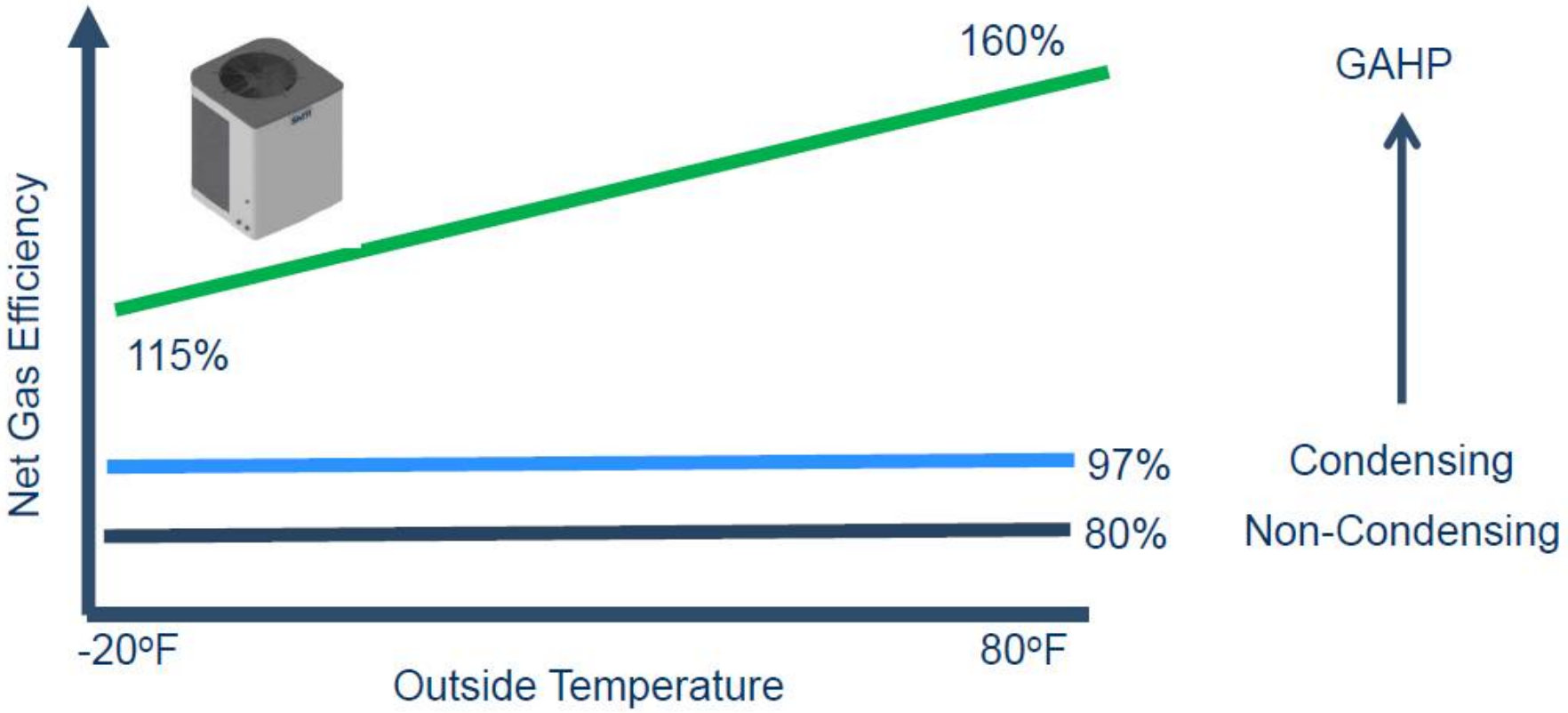
Topics of Discussion

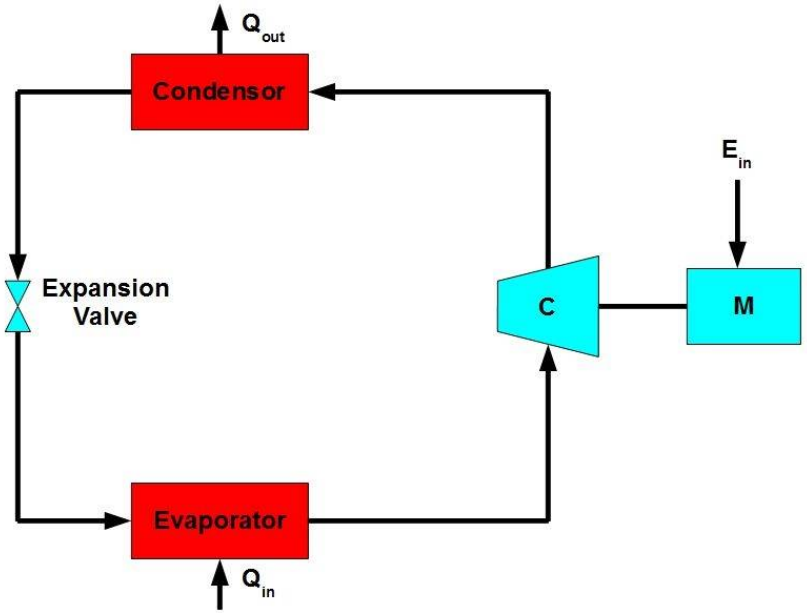
- GAHP Technology Background
- GAHP Combi Demonstration
  - Preliminary Results
- Lessons Learned and Next Steps

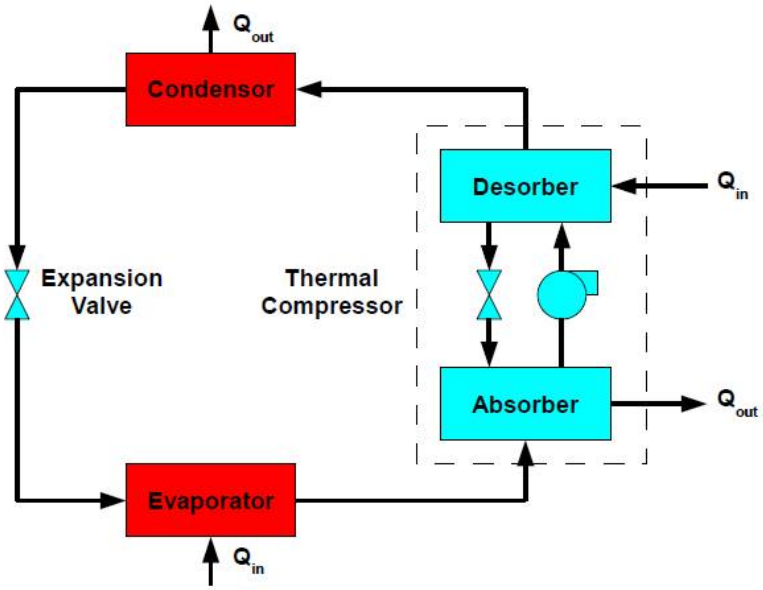
GAHPs: Efficiency Leap for Heating



- Work well at low outside temperatures (back-up not required)

How Does It Work?





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

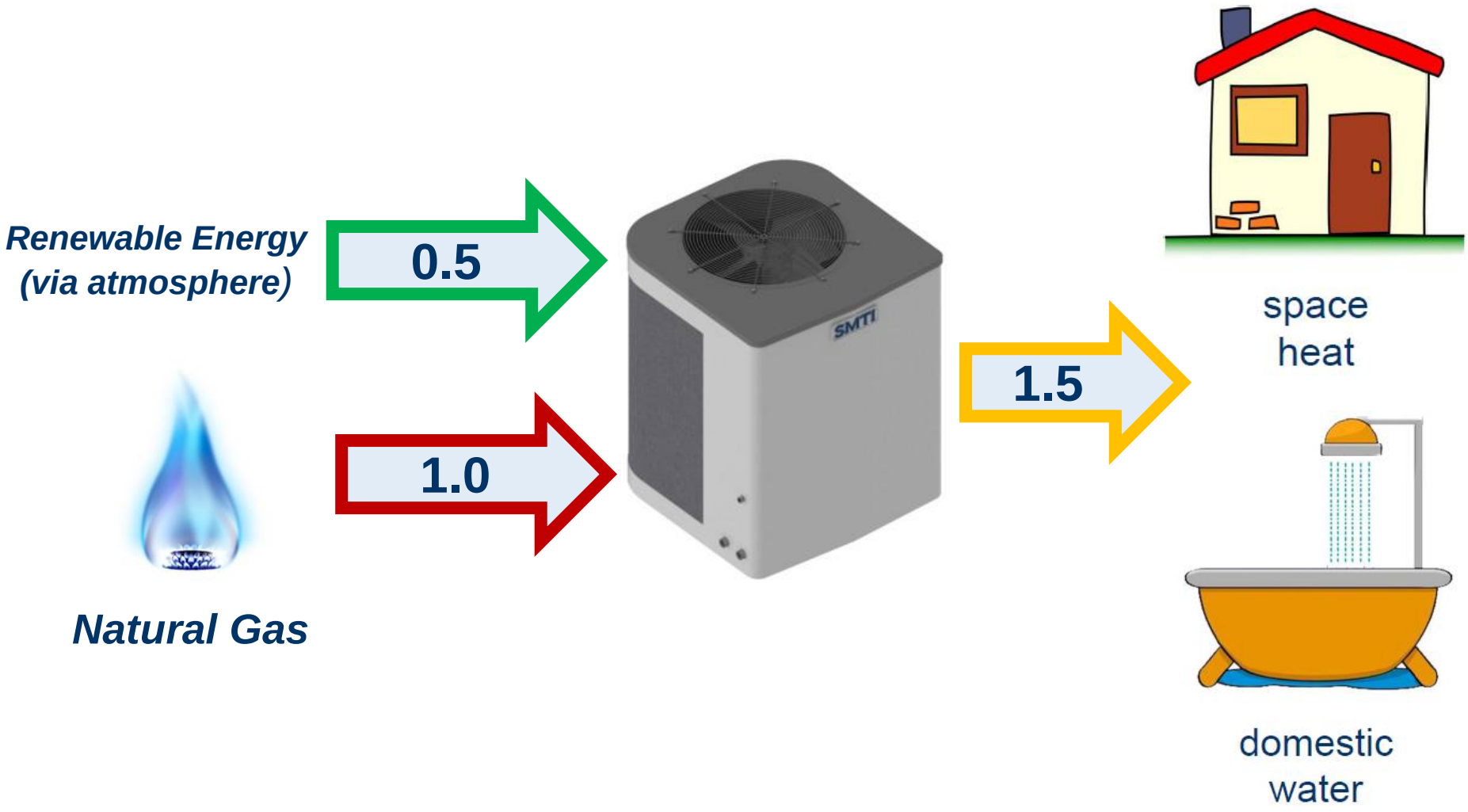
Qheat = ~1.1 x Qcooling

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

Qheat = (Qcond + Qabs) ~ 2.5 times Qevap

Capacity & COP Remain High at Low Ambient Temperatures

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

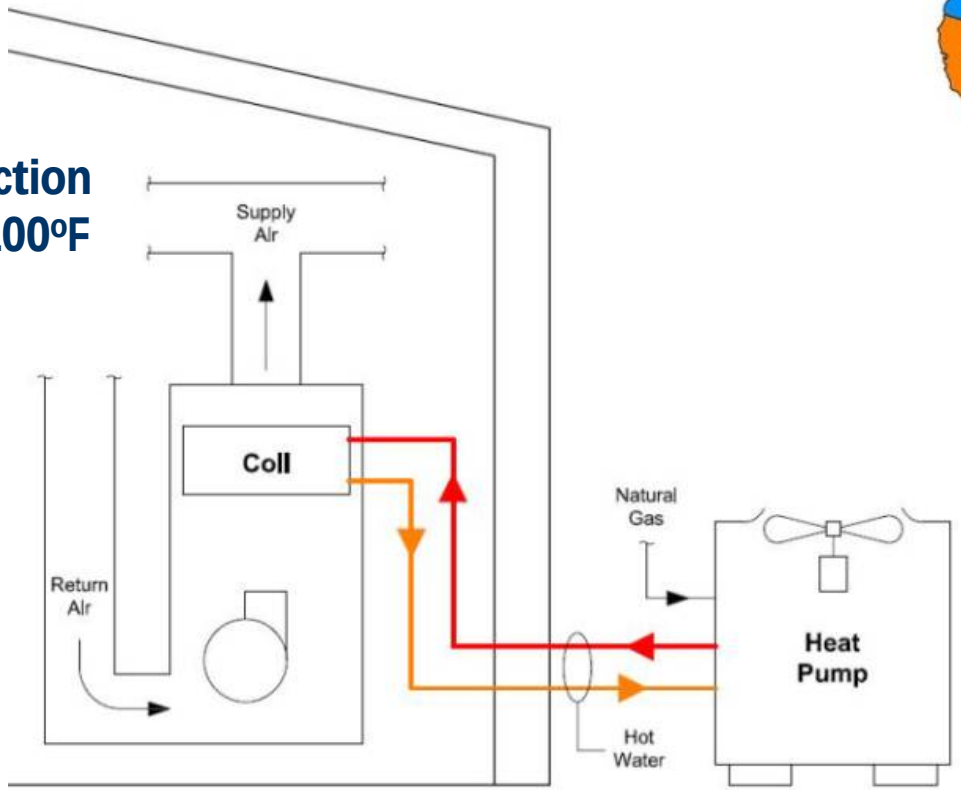
- 10,000 to 140,000 Bth Heating Output Models
- 20° F Hydronic Differential
- Outdoor Installation (no venting)
- SCAQMD NOx Compliant

Forced-Air Space Heating

Heating Dominated Climate Zones: 4000+ HDD

Ultimate Comfort Solution

Supply Air Function of Ambient, >100°F



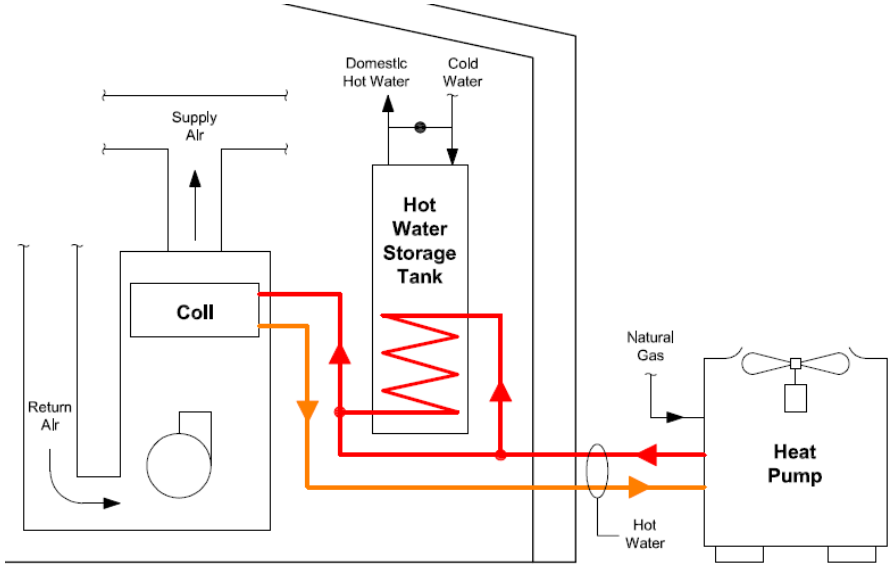
Modulating or Multi-Speed Air-handler

4:1 Modulating Heat Pump with Ambient Set-Back

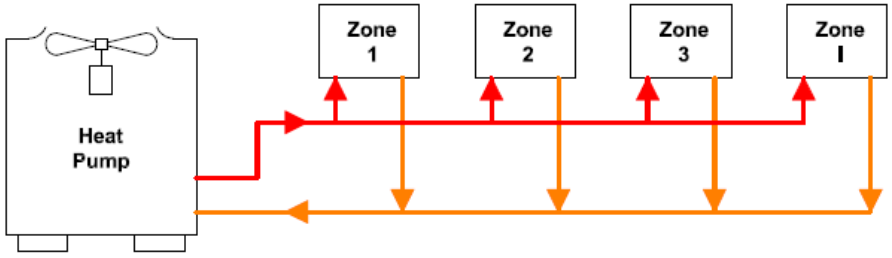
Outdoor Location for Safety

Residential Space Heating

Heating Dominated Climate Zones: 4000+ HDD

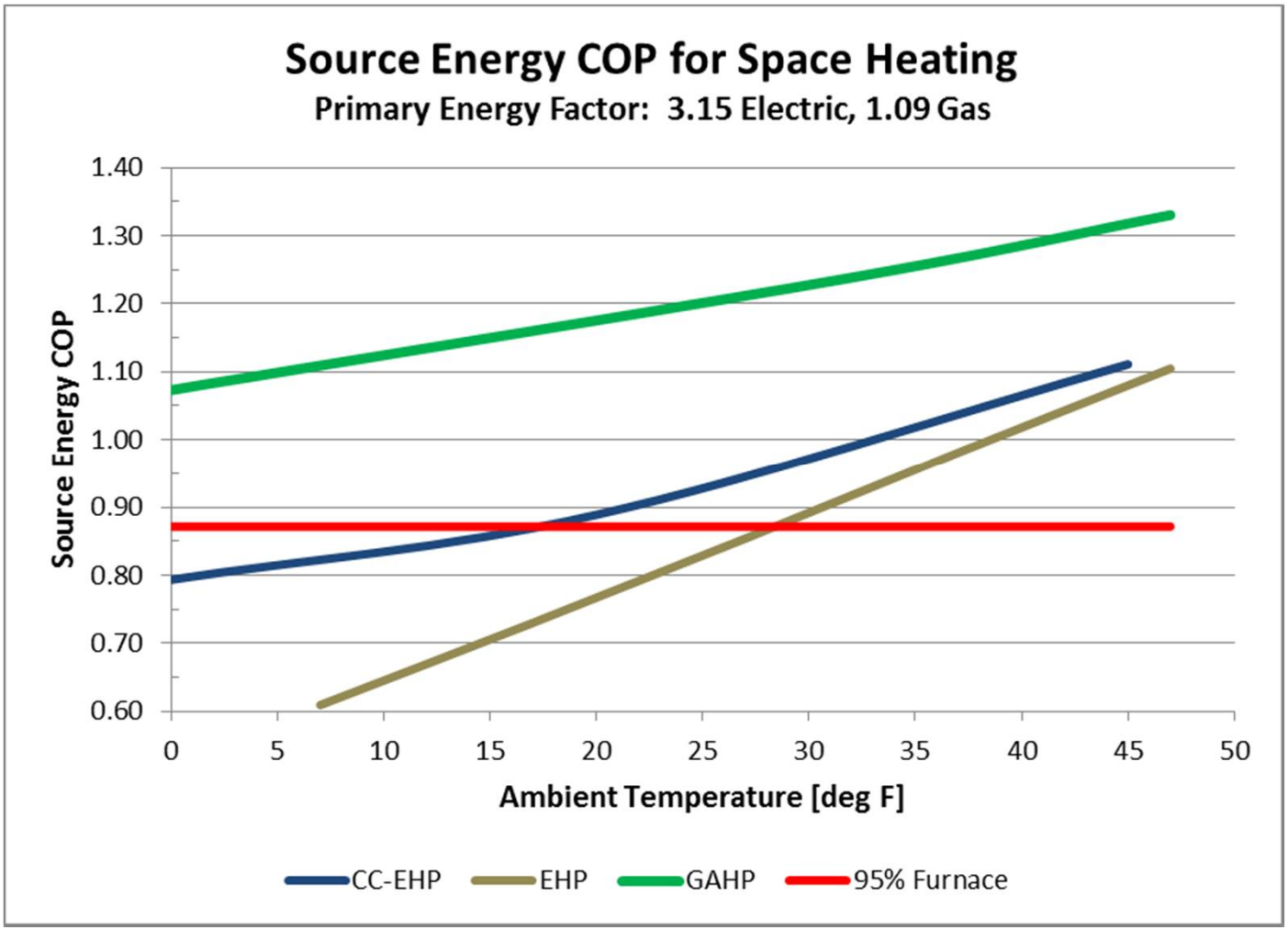


Combi

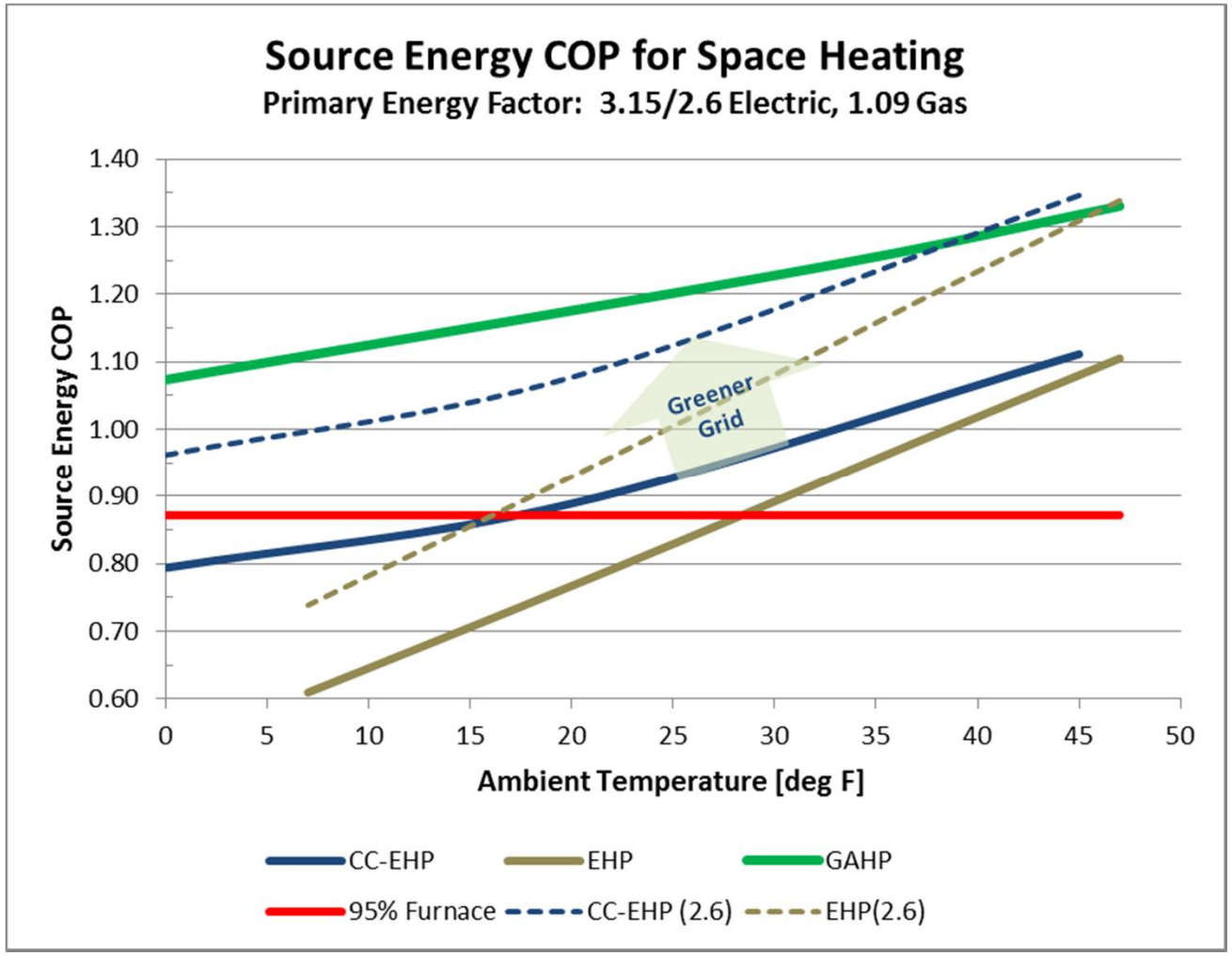


Hydronic Zoned
(radiant, 'mini-split', etc)
(can also be Combi)

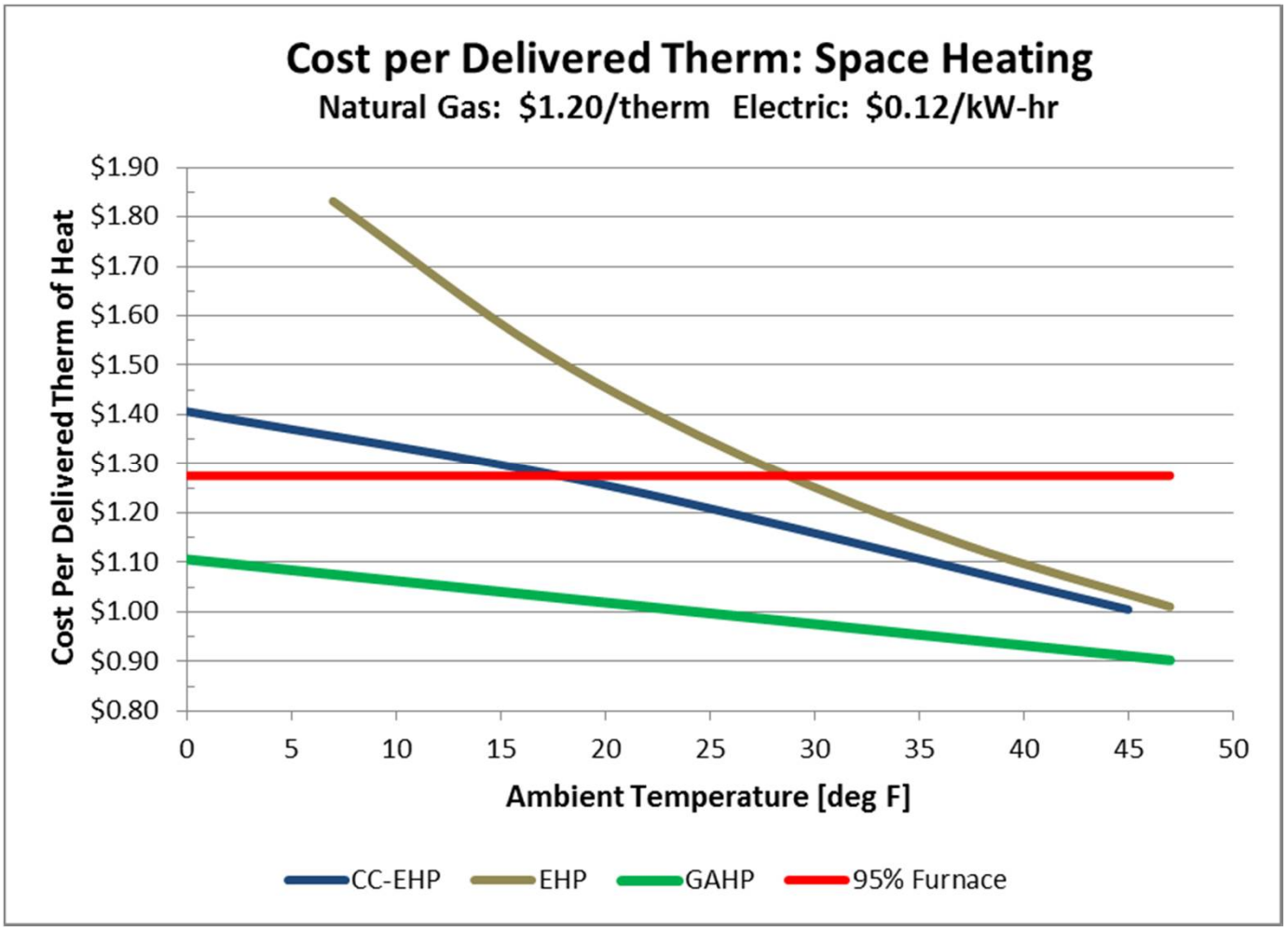
Source Energy and CO_2 Advantage



Source Energy and CO_2 Advantage



Cost Per Delivered Therm of Heat



GAHP Development Status

10,000 btu/hr

Field Testing

80,000 btu/hr

Field Testing

140,000 btu/hr

Lab Testing

gti

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SMTI Gas Absorption Heat Pumps - AFUE

AFUE for Region IV: 139%

80,000 Btu/hr “Beta 2” Prototype

Rating Point	Actual Ambient Temperature (°F, dry bulb)	Actual Ambient Humidity (°F, dew point)	Actual Hydronic Return Temperature (°F)	Firing Rate (Btu/hr)	Output (Btu/hr)	COP_Gas	Measured Power Draw (W)
1	45.1	31.1	95.5	14313	20233	1.41	309.0
2	32.8	30.8	95.2	13728	18609	1.36	315.7
3	14.7	2.3	94.8	15232	19322	1.27	335.1
4	14.8	12.2	95.3	34317	46601	1.36	438.7
5	33.0	28.3	94.9	55537	77778	1.40	591.9
6	14.4	12.2	94.6	55737	74875	1.34	611.9
7	4.9	3.4	94.4	56871	72339	1.27	604.7

Data courtesy of GTI
ANSI Z21.40.4 Performance Testing & Rating Gas-Fired Air-Conditioning and Heat Pump Appliances

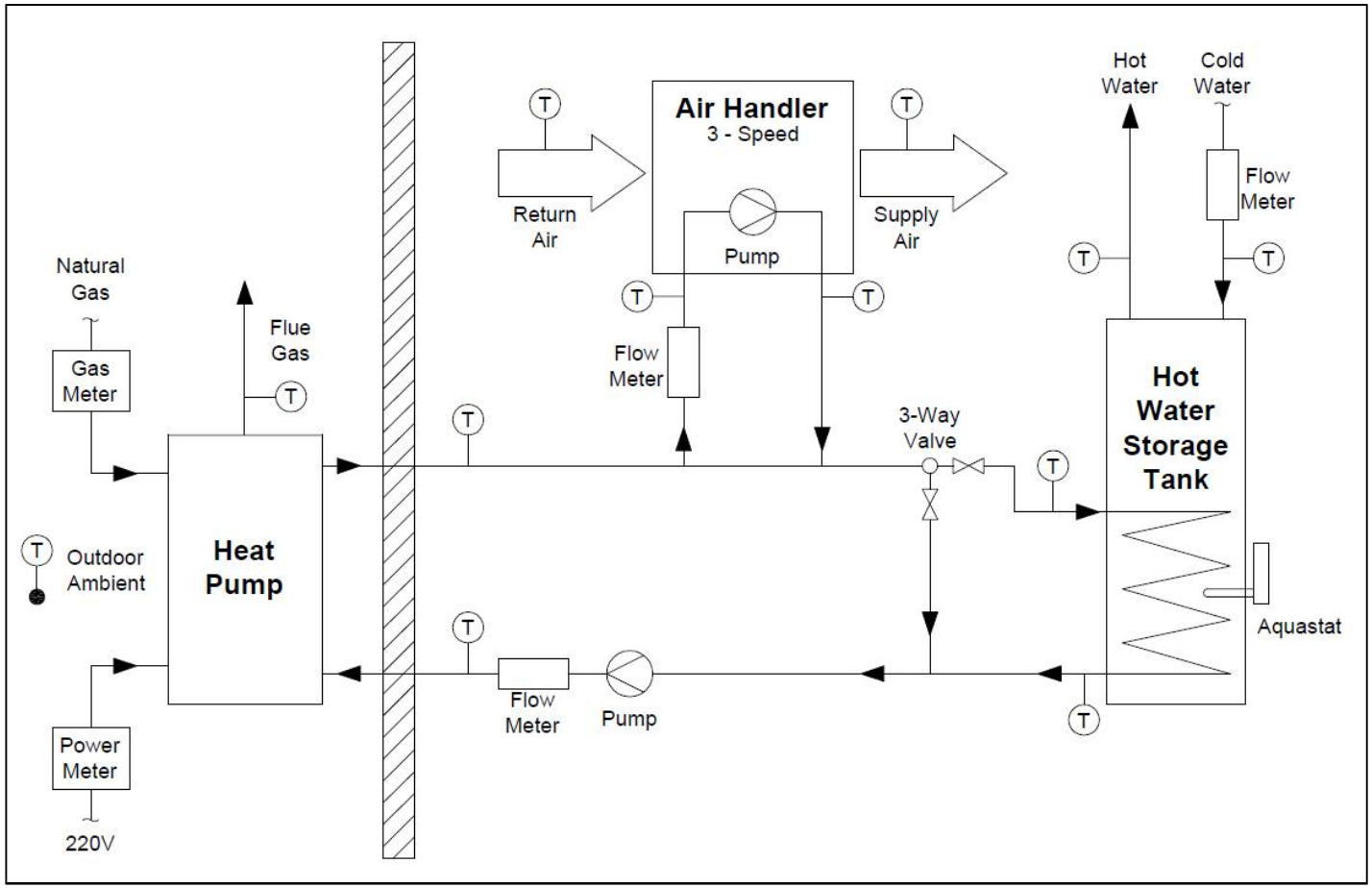
Residential Combi Demonstration

- Single family home in Northeast TN
- GAHP unit provides space and domestic hot water heating
- 2,200 sqft, built 1947
- 3.5 Occupants

- GAHP Replaced
  - 80,000 Btu/hr 90% Furnace
  - 50 gal Electric Water Heater

- March, 2016 Installation
- M&V by GTI

Residential Combi Demonstration



Programmable Thermostat with 3 Heating Mode Settings
Heating Mode Determines Fan Speed: High/Med/Low

Residential Combi Demonstration

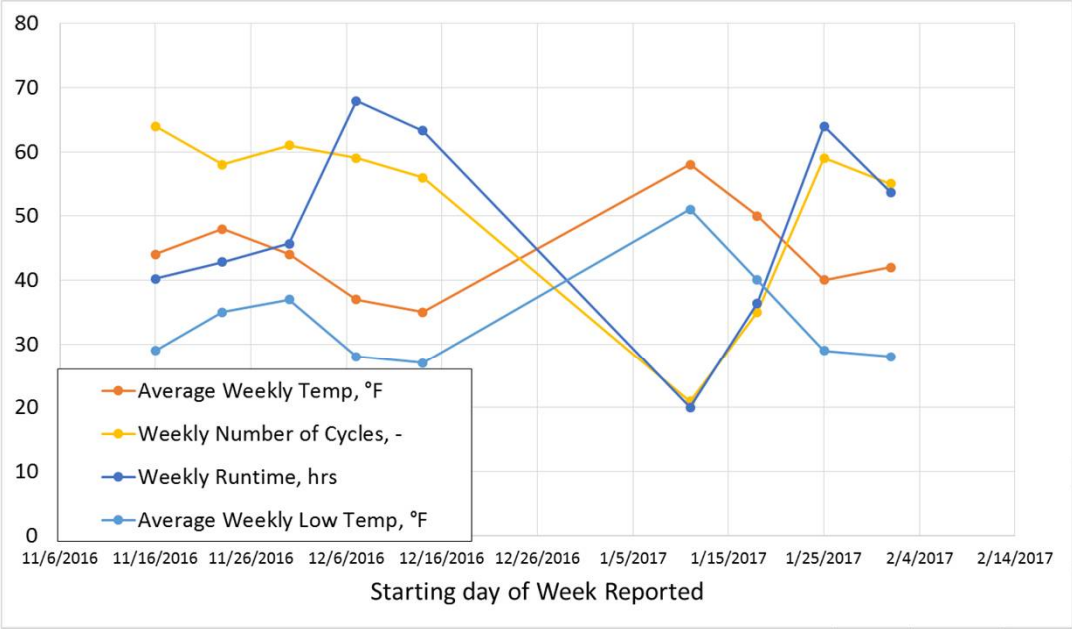
Alpha 80K GAHP

Installed from March 2016 through October 2016

Beta 80K GAHP

Installed from November 2016 to present

2016/2017 Heating Season to Date

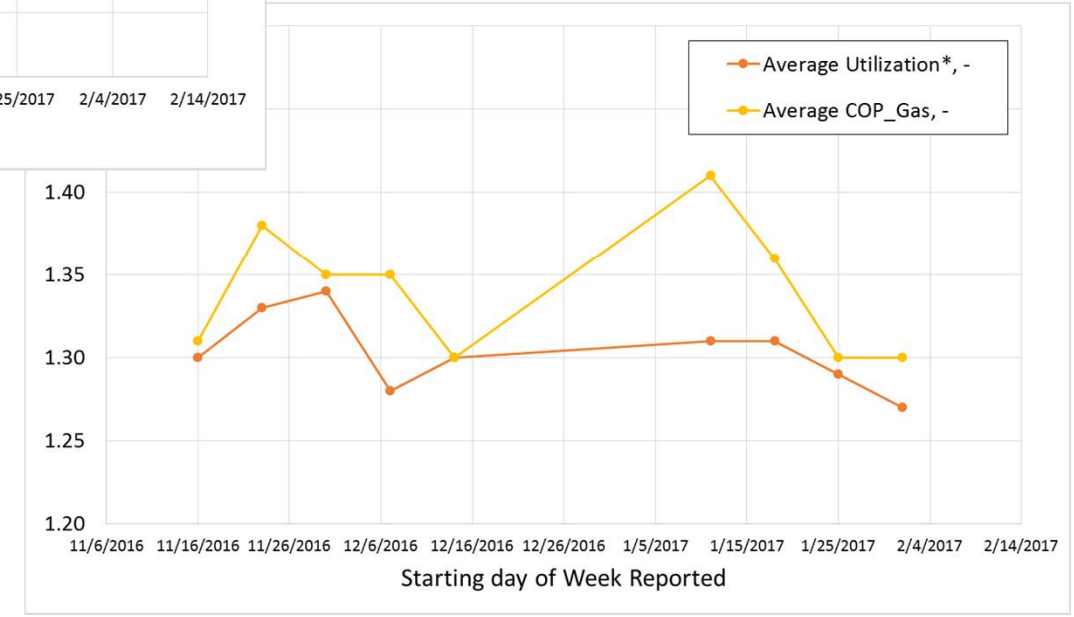


- 373 gallons of DHW drawn on average per week - 54 gallons per day for household (3.5 occupants)

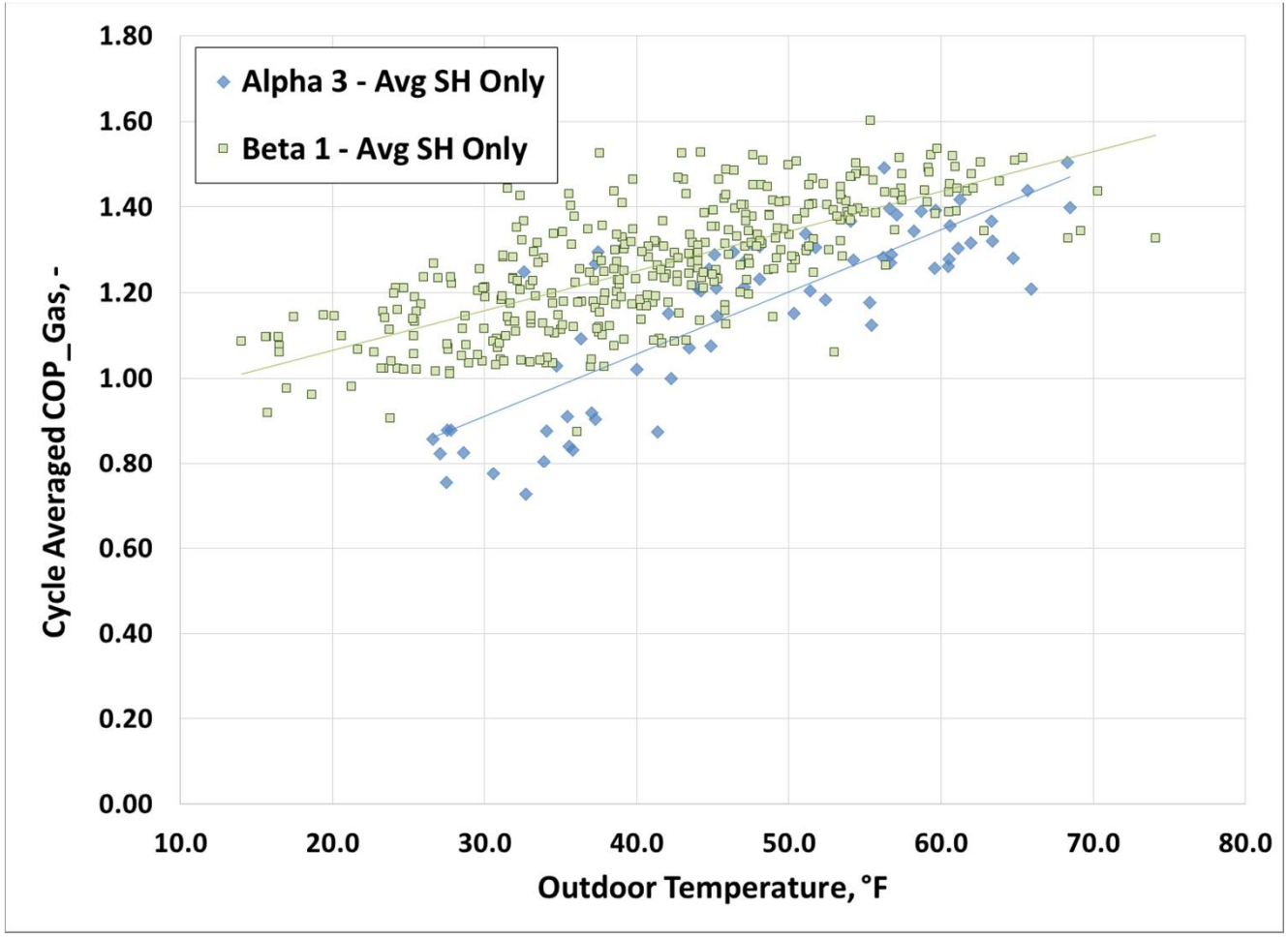
GOP_Gas = (GAHP_output)/(Input)

*Utilization defined as (GAHP_output)/(Gas + Electricity Input)

Note: Unit serviced from 12/21/2016 to 1/10/2017



Residential Combi Field Test

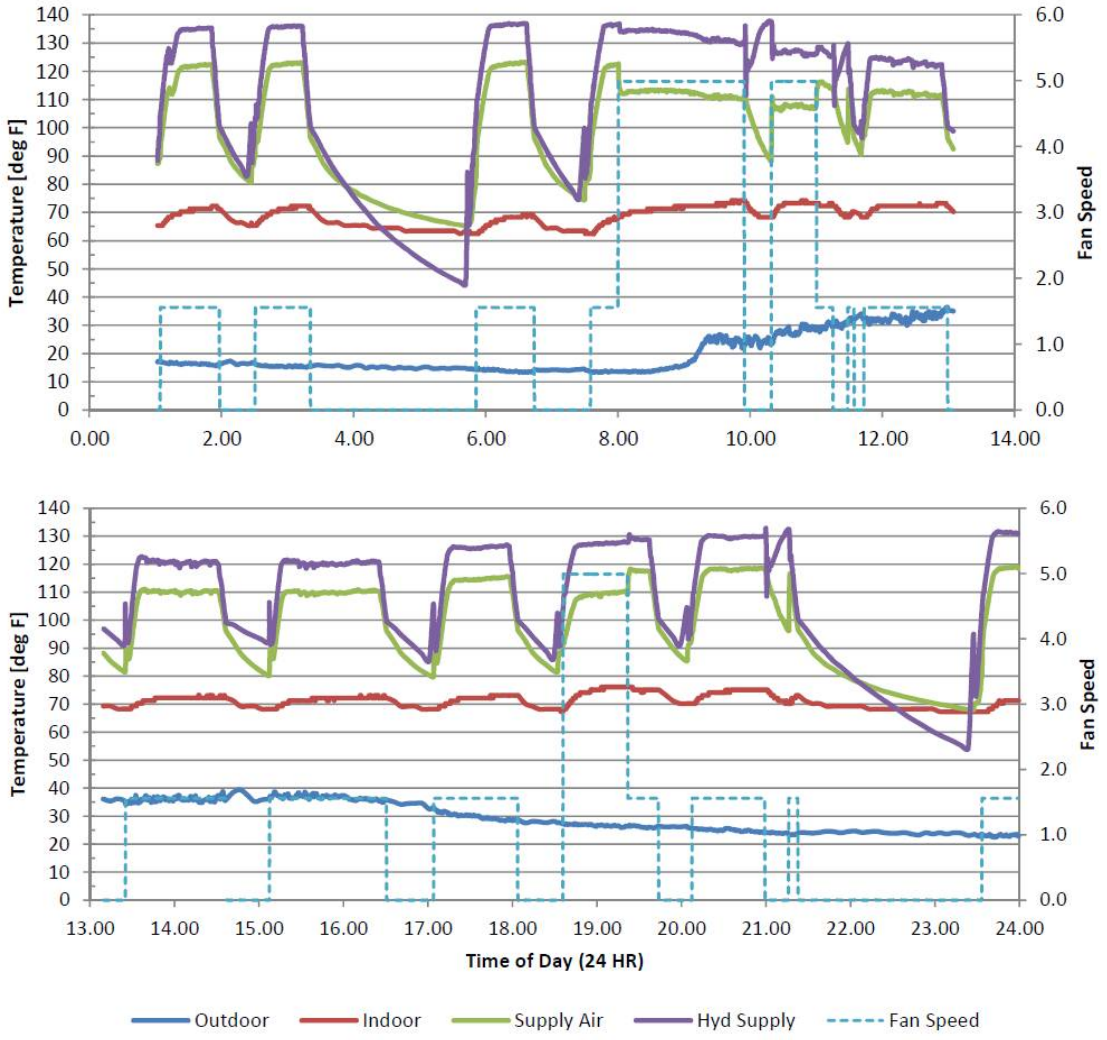


Data courtesy of GTI

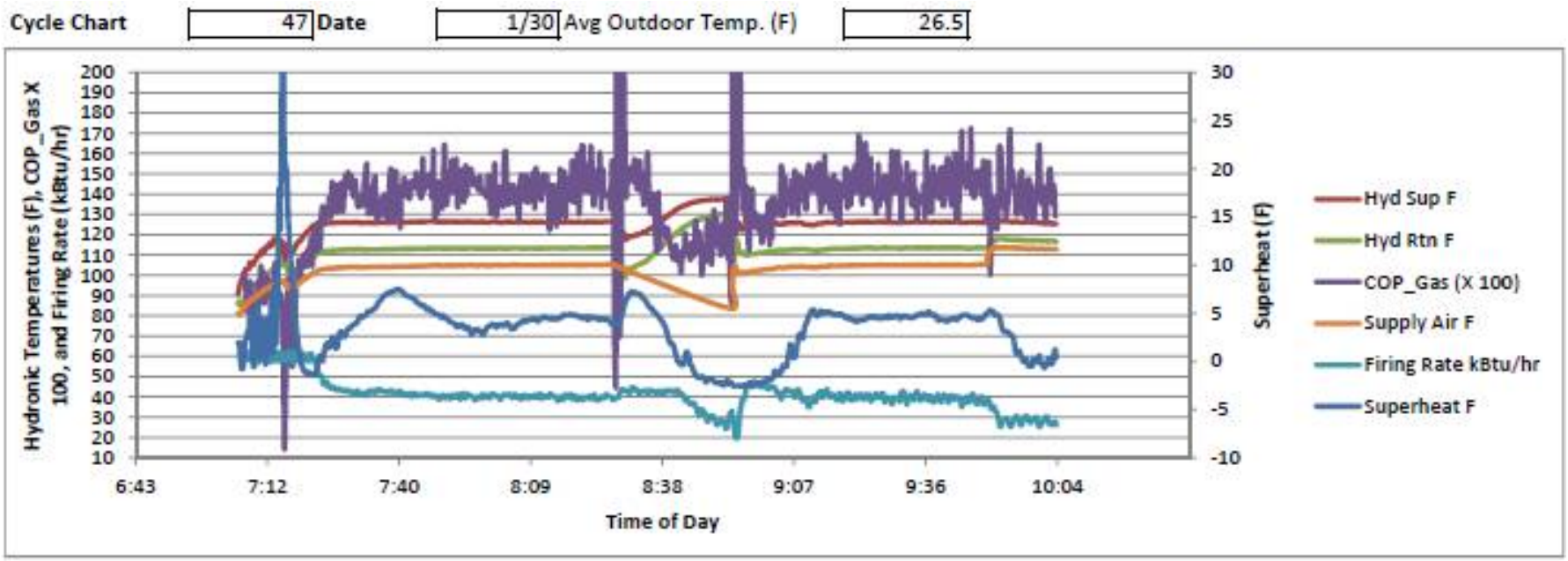
Residential Combi: Data Snap Shot

24 hour operating period (December 10, 2016)

- GAHP able to heat home quickly after nighttime set-back switch
- Supply air temps above 105°F (above 110°F for all but 1 run)
- Potential to reduce ambient setback curve
- 10 total cycles



Residential Combi: Data Snap Shot



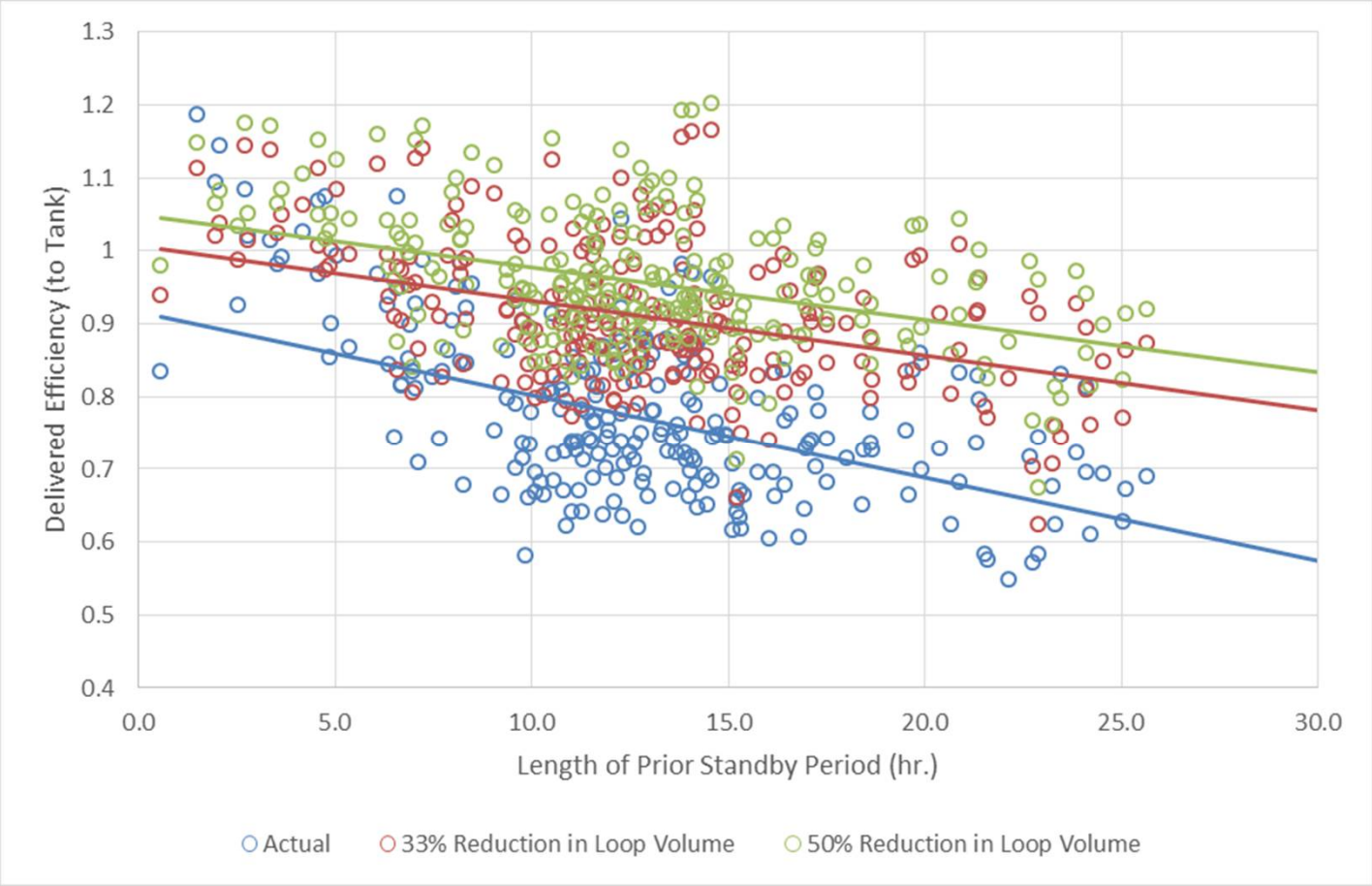
Data courtesy of GTI

Lessons Learned – Hydronic Loop

Minimize Hydronic Loop Volume

- Field test loop volume is large (~15 gallons)
- High Cycling Losses (energy used to heat loop volume but not fully utilized)
- Most significant during summer, with water heating only
- Switching from 1” ID tube to 0.75” ID tube reduces charge volume by 42%
- Balance hydronic loop volume and required pump power

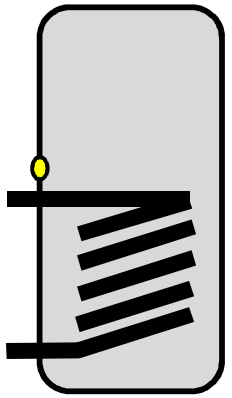
Lessons Learned – Hydronic Loop Volume



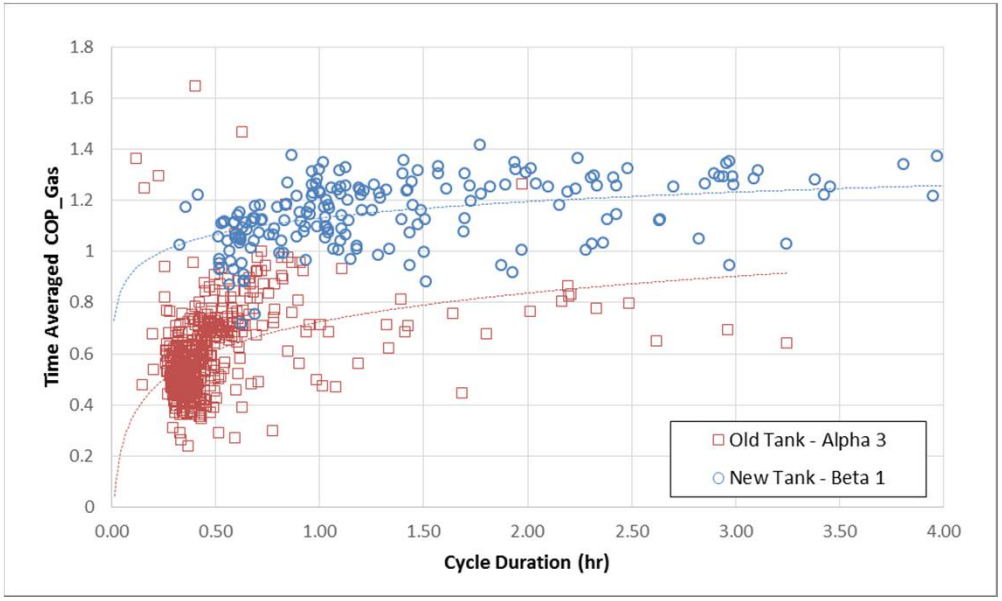
Water Heater Only Cycles, Data Courtesy of GTI

Lessons Learned – Storage Tank

Size/Performance of Indirect Coil Critical



- **First Tank:** 45 gallon, internal coil 11.1 ft^2, T-stat located low in tank
  - Short cycles (6-8 gallons heated), high hydronic temperatures required
  - More energy to heat hydronic loop than to heat water in tank!
- **Second Tank:** 80 gallon, internal coil 18 ft^2, T-stat above coil
  - Longer cycles (18-25 gallons heated), lower hydronic temperatures required



Lessons Learned - AHU

Air-Handler Capacity & Modulation Must Match GAHP

- 5 speed Hydronic AHU (limited to 3 speeds by T-stat)
- Low Speed: Provides heating capacity >4:1
  - Unless hydronic supply temperature low → low supply air temps
- Increased cycling of the GAHP, lower avg cycle COPs

- Modulating Blower Preferred
- Lowest Speed Must Result in 4:1 Modulation
  Will allow for longer cycles at lower speeds

Developments: AHU under development at SMTI using ECM blower

Lessons Learned –System Controls

- Thermostat Settings
- On/Off Timing of AHU/Pump/GAHP
- Ambient Set-Back Curve
- Space & Water Heating Modes

Summary

GAHPs offer significant potential for energy and cost savings with an AFUE of 139% (Region IV)

HOWEVER,

This savings can only be maximized when auxiliary systems are designed for operation with a GAHP

Next Steps in 2017

- 3-6 Residential combi field tests (pending)
- Two full service restaurant field tests in Los Angeles, California (Water heating and kitchen cooling)
- Commercial water heating field test in Tennessee
- 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

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- Special Thanks to Paul Glanville, GTI

Thank You!

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