

4C: Design and Development of Low-Cost GHPs for Residential “Combi” Systems

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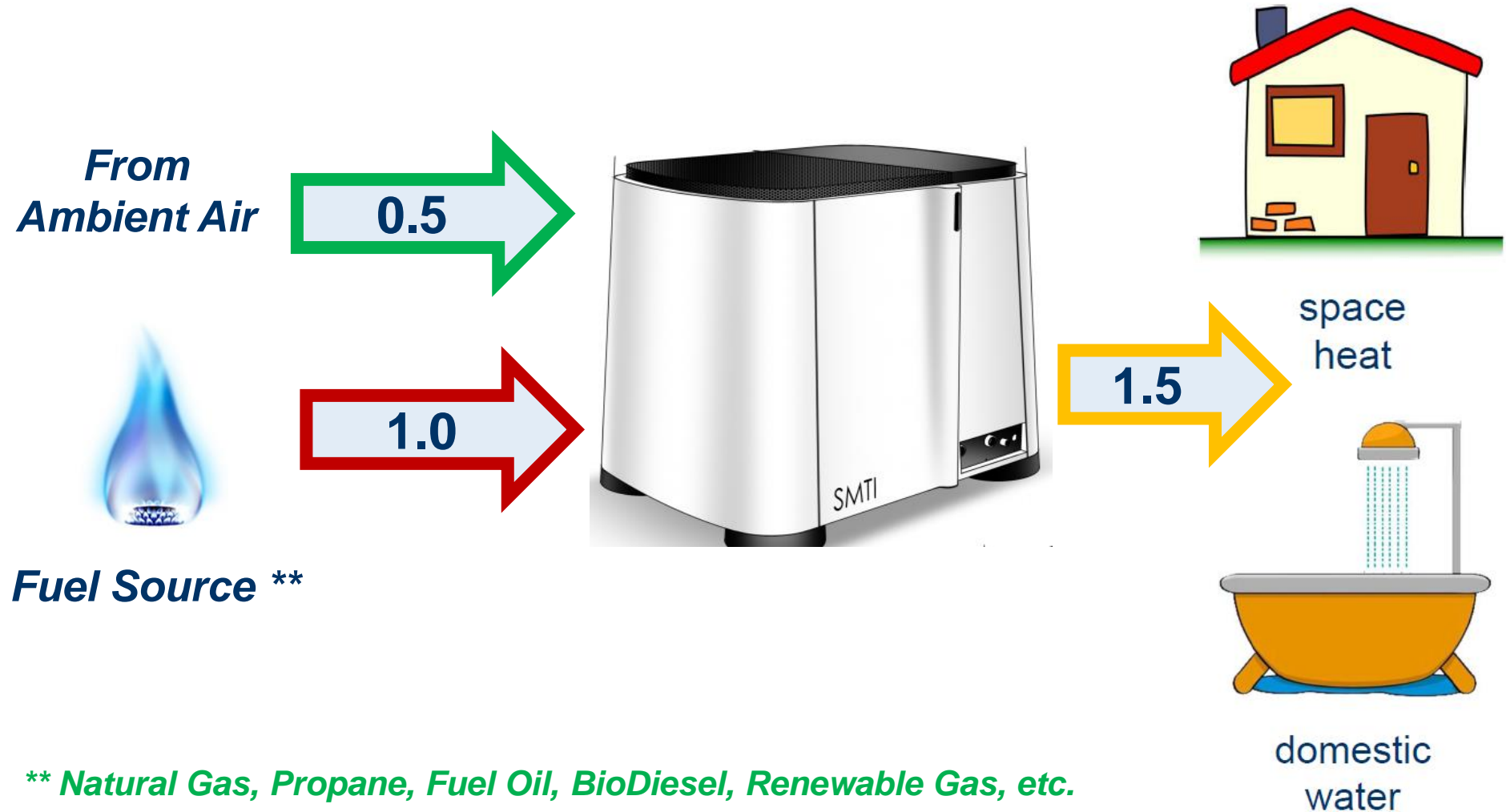
March, 2019



Outline

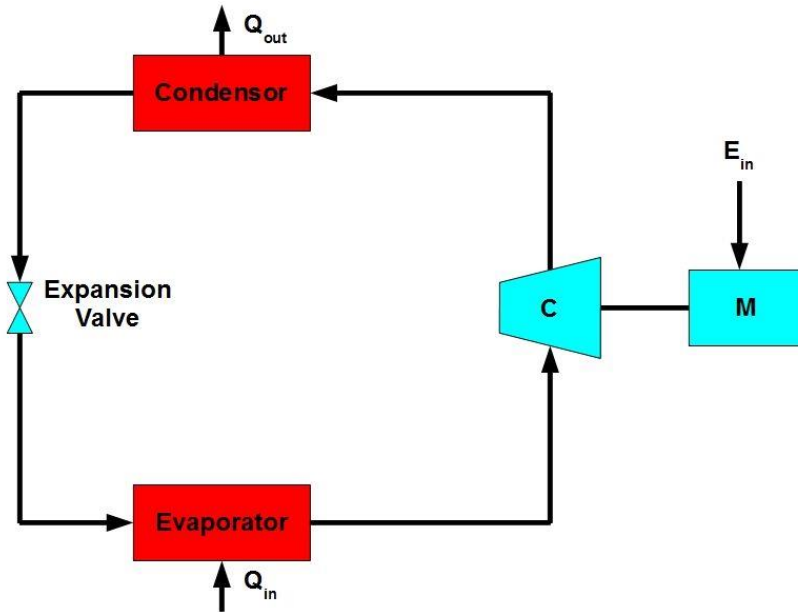
- Technology Review
- Low Cost GAHP system
- Combi installations to date

Gas-Fired Absorption Heat Pump



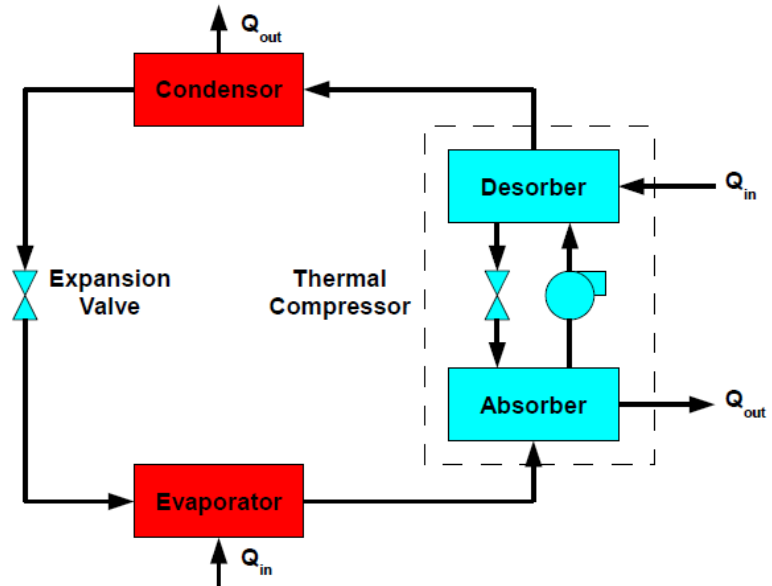
** *Natural Gas, Propane, Fuel Oil, BioDiesel, Renewable Gas, etc.*

How Does It Work?



$$\text{COP}_h = Q_{\text{cond}}/E_{\text{in}} = 3.0\text{-}4.0$$

$$Q_{\text{heat}} = \sim 1.1 \times Q_{\text{cooling}}$$



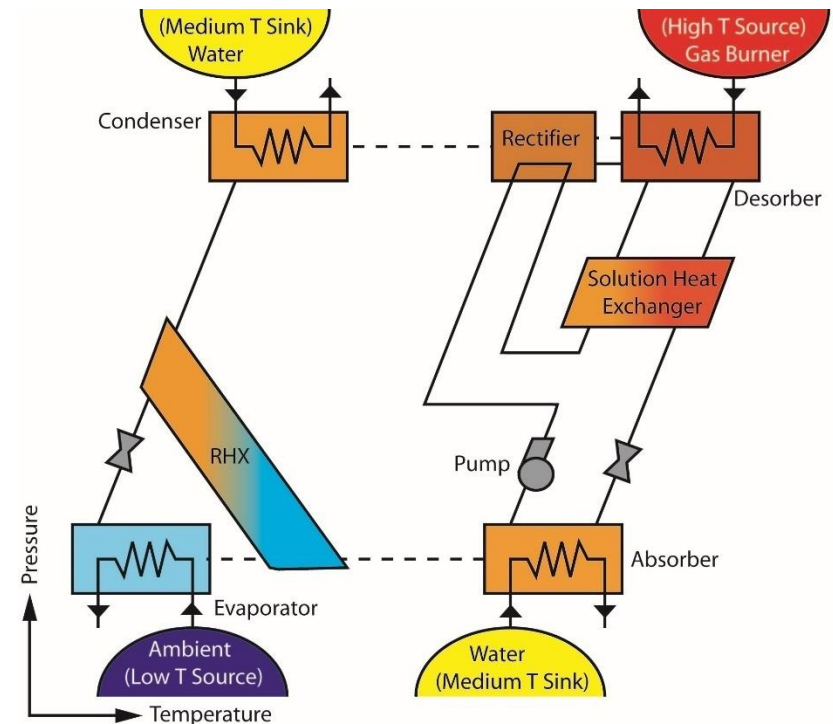
$$\text{COP}_h = (Q_{\text{cond}} + Q_{\text{abs}})/Q_{\text{in}} = 1.4\text{-}2.0$$

$$Q_{\text{heat}} = (Q_{\text{cond}} + Q_{\text{abs}}) \sim 2.5 \text{ times } Q_{\text{evap}}$$

Capacity & COP Remain High at Low Ambient Temperatures

Single-effect GAHP used by SMTI

- Absorption system consists of heat exchangers
 - Absorber, Condenser, Desorber, Evaporator, Rectifier, Refrigerant Heat Exchanger, and Solution Heat Exchanger
- Solution pump
- Expansion devices
 - Refrigerant and WS let downs



Low Cost Design Approach

- **Simple Cycle** – Single-effect GAHP optimized for cost and reliability
- **Commonality of raw material, processes** – Heat exchangers use same low cost materials, geometries and fabrication methods
- **Scalability** – Heat exchanger designs scalable for demonstrated heating system range of 3 kW up to 43 kW
- Projected **40-50%** of current cost of similarly sized commercially available GAX GAHP
- Cost-effective method of achieving significant CO2 emission reductions for space/water heating in cold climates, while retaining customer use of low cost fuel

SMTI Gas Absorption Heat Pumps

$$\text{COP}_{\text{HHV}} = 1.45 \text{ at } 47/120^{\circ}\text{F}$$

- 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
- **GWP = 0**



Patents Pending

Family of GAHP Models

10 kBth



20 kBth



80 kBth



140 kBth



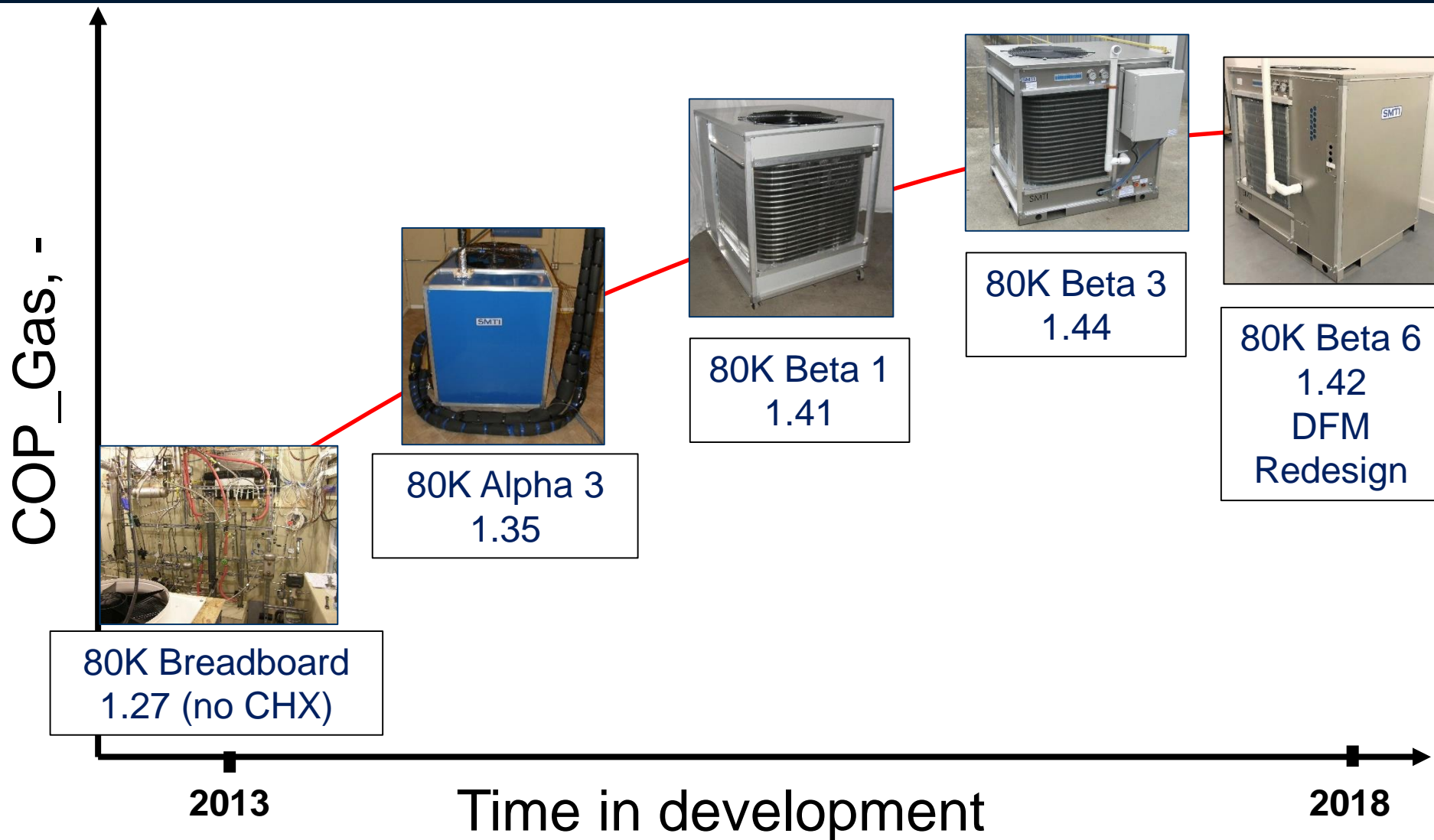
← Anything In-Between →



U.S. DEPARTMENT OF ENERGY



80K GAHP Development Timeline



GAHP Combi-installations

Forced-Air Space Heating

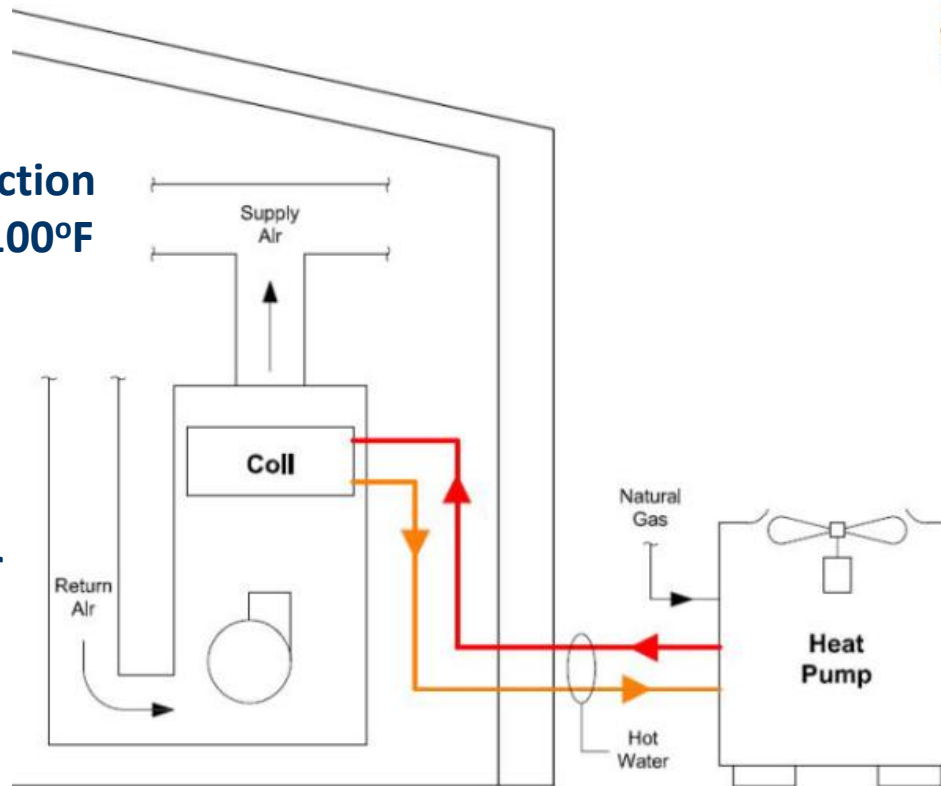
Heating Dominated Climate Zones: 4000+ HDD

Ultimate Comfort Solution



Supply Air Function of Ambient, >100°F

Modulating or Multi-Speed Air-handler

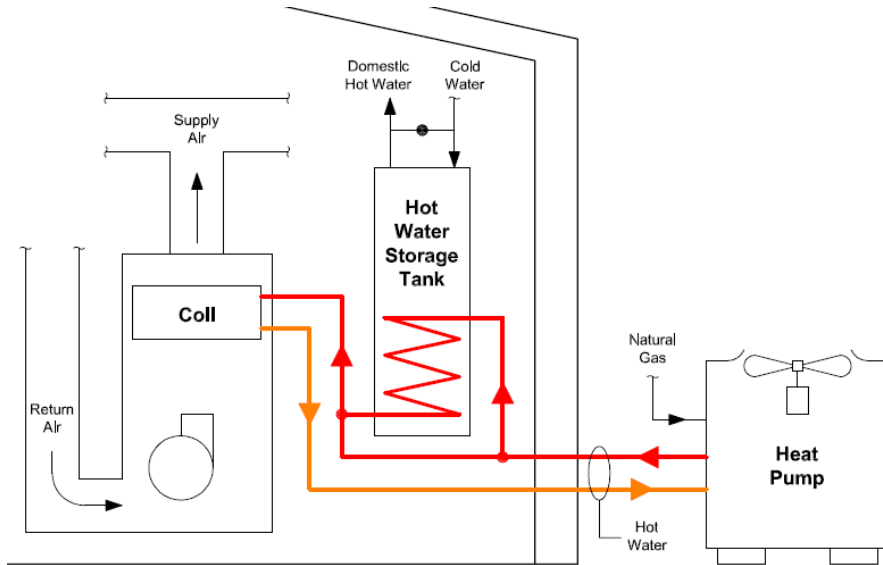


4:1 Modulating Heat Pump with Ambient Set-Back

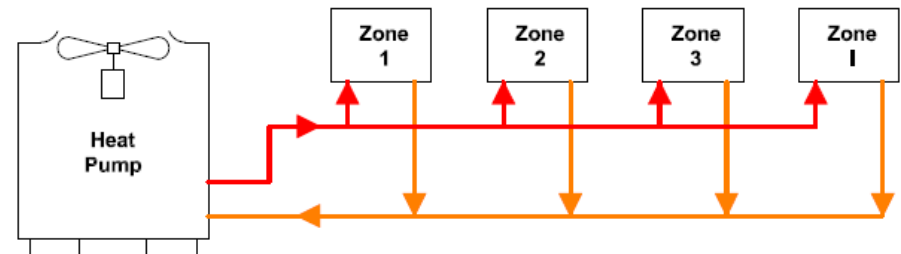
Outdoor Location for Safety

Residential Space Heating

Heating Dominated Climate Zones: 4000+ HDD



Combi



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

TN 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

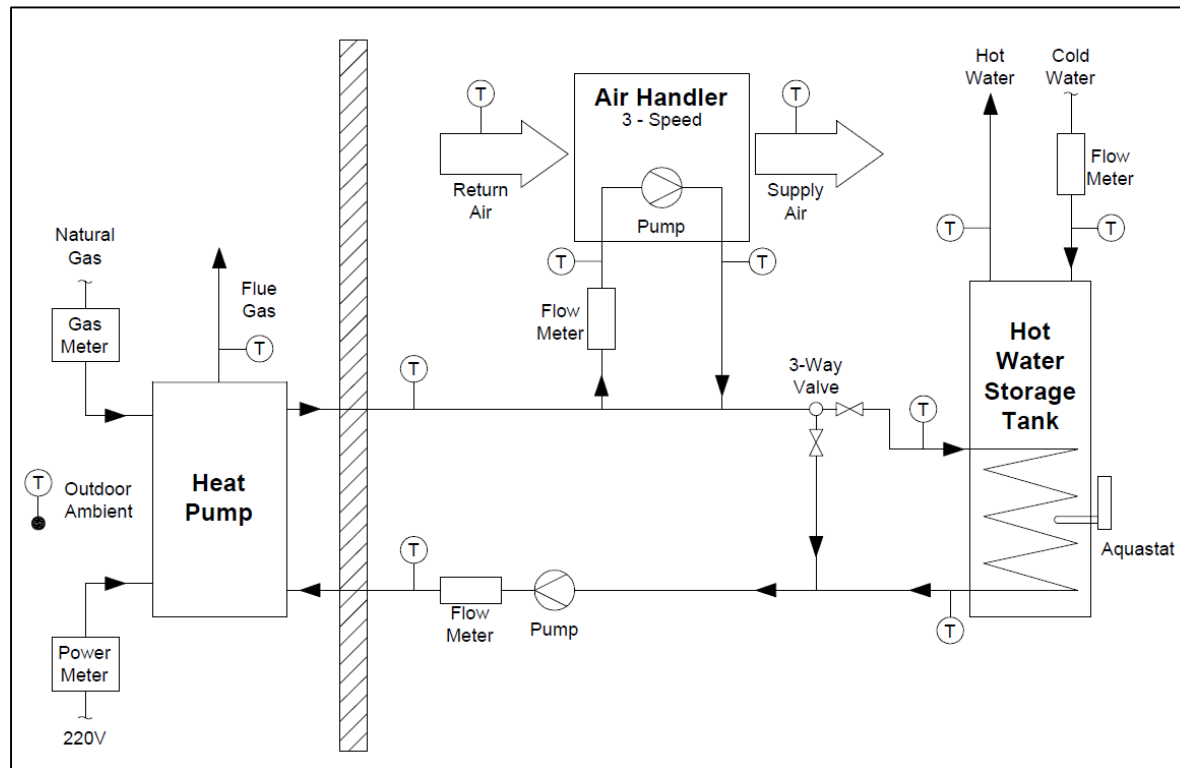
- GAHP Replaced
 - 80,000 Btu/hr 90% Furnace
 - 50 gal Electric Water Heater

- March, 2016 Installation
- M&V by GTI



TN Residential Combi Demonstration

- All SMTI Controls
- Programmable Thermostat with 3 Heating Mode Settings
- Heating Mode Determines Fan Speed: High/Med/Low
- AHU with on/off hydronic pump based on demand
- Flow to DHW tank controlled by 3-way valve



TN Residential Combi Demonstration

Alpha 80K
GAHP

March 2016 to
October 2016



Main Loop Circulating Pump



Beta 80K
GAHP

November
2016 to
Present



Hydronic Air Handler with
Internal Pump



Indirect DHW
Tank (Tank #2)

TN Residential Combi Demonstration

Summary of Test to Date:

Time in operation: 3 years

Hours in operation: 4000 hours

Lessons learned from installation and test:

- Importance of storage tank and indirect coil sizing
- Impact of long plumbing lengths of hydronic loop
 - Thermal mass impacts water heating efficiency in Summer
- Over/undershoot controls approach to space heating
 - Allow for longer runtimes necessary to maximize system performance
- Significant benefit to integrating space and water heating runs
 - Potential to eliminate water heat only runs in space heating months

WI Residential Combi Demonstration #1

- Single family home in Western WI
- GAHP unit provides space and domestic hot water heating
- 2,700 sqft conditioned space
- 4 Occupants

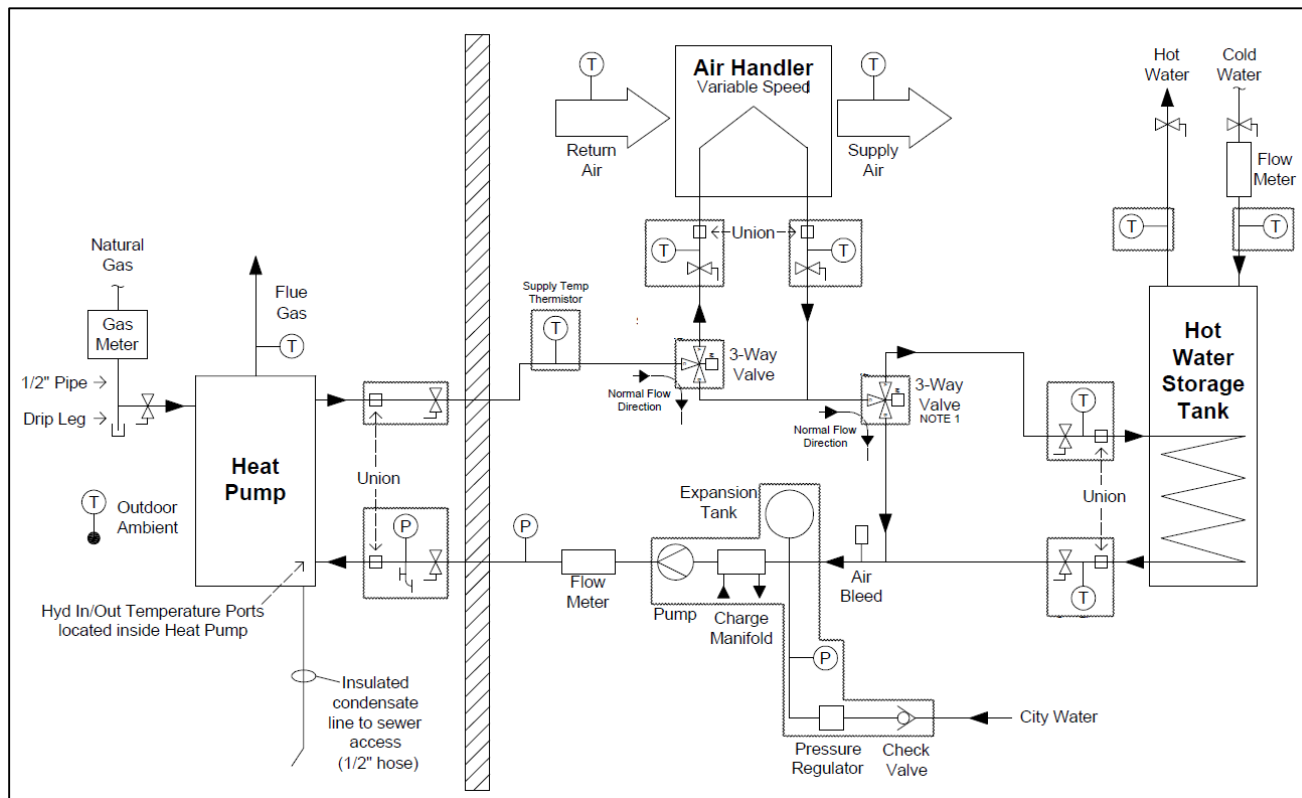
- GAHP Replaced
 - 100,000 Btu/hr 90% Furnace
 - 60 gal Standard Gas Water Heater

- February, 2018 Installation
- M&V by GTI



WI Residential Combi Demonstration #1

- **SMTI PLC Controls interfaced with OEM partner Air-Handler and thermostat control**
- Programmable Thermostat
- **Thermostat Determines Fan Speed: Continuously Variable**
- **Flow to AHU controlled by 3-way valve**
- **Flow to DHW tank controlled by 3-way valve**



WI Residential Combi Demonstration #1



Beta 3 80K
GAHP
February 2018
to Present



Indirect DHW Tank



Hydronic A-Coil and
Furnace (Blower)



Main Loop Circulating Pump and
3-way valves

WI Residential Combi Demonstration #1

Summary of test to date:

Time in operation: 1 years

Hours in operation: 2950+ hours

Lessons learned from installation to date:

- Impact of limited space for hydronic plumbing
 - High pressure drop due to higher use of elbows
 - Pros-cons of ¾" PEX versus 1" PEX
- Importance of mode switching during a water heat recovery
 - Balancing water heat and setback recovery
- Significant benefit to integrating space and water heating runs
- System capable of operation throughout Polar Vortex (-25°F ambient)
 - Performance reduced to that of a condensing boiler
 - **Held indoor temperature above 67°F during two -25°F nights**

WI Residential Combi Demonstration #2

- Single family home in Western WI
- GAHP unit provides space and domestic hot water heating
- 2400 sqft
- 2.5 Occupants

- GAHP Replaced
 - 100,000 Btu/hr 90% Furnace
 - 40 gal Standard Gas Water Heater

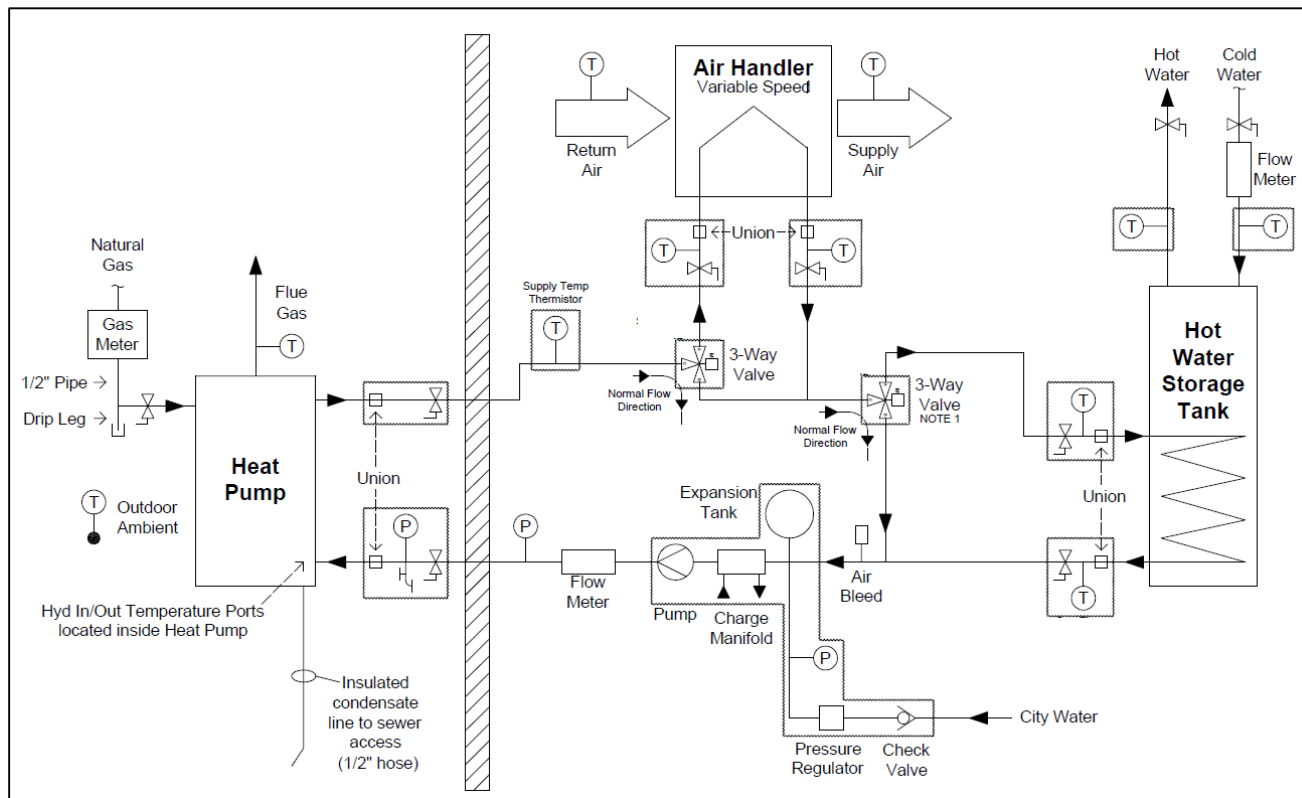
- December, 2019 Installation
- M&V by GTI



Work sponsored by US Department of Energy

WI Residential Combi Demonstration #2

- **OEM partner controls (GAHP and indoor equipment)**
- Programmable Thermostat
- Thermostat Determines Fan Speed: Continuously Variable
- Flow to AHU controlled by 3-way valve
- Flow to DHW tank controlled by 3-way valve



WI Residential Combi Demonstration #2

Main Loop
Circulating Pump



Beta 6 80K GAHP
Dec. 2018 to Present



Hydronic Air Handler



Indirect DHW Tank &
Standard Gas WH

Summary

- SMTI GAHP Design
 - Target Low Cost Design for GAHP technology
 - Mass Producible
 - Scalable
- 3 Combi-field tests ongoing
 - 1 in Northeast TN
 - 2 in Western Wisconsin
- Variations in controls and loop design
- Ongoing monitoring and evaluation in collaboration with GTI

- Additional installations and evaluations to come

Acknowledgments

- Gas Technology Institute
- US Department of Energy
- NEEA

Thank You!

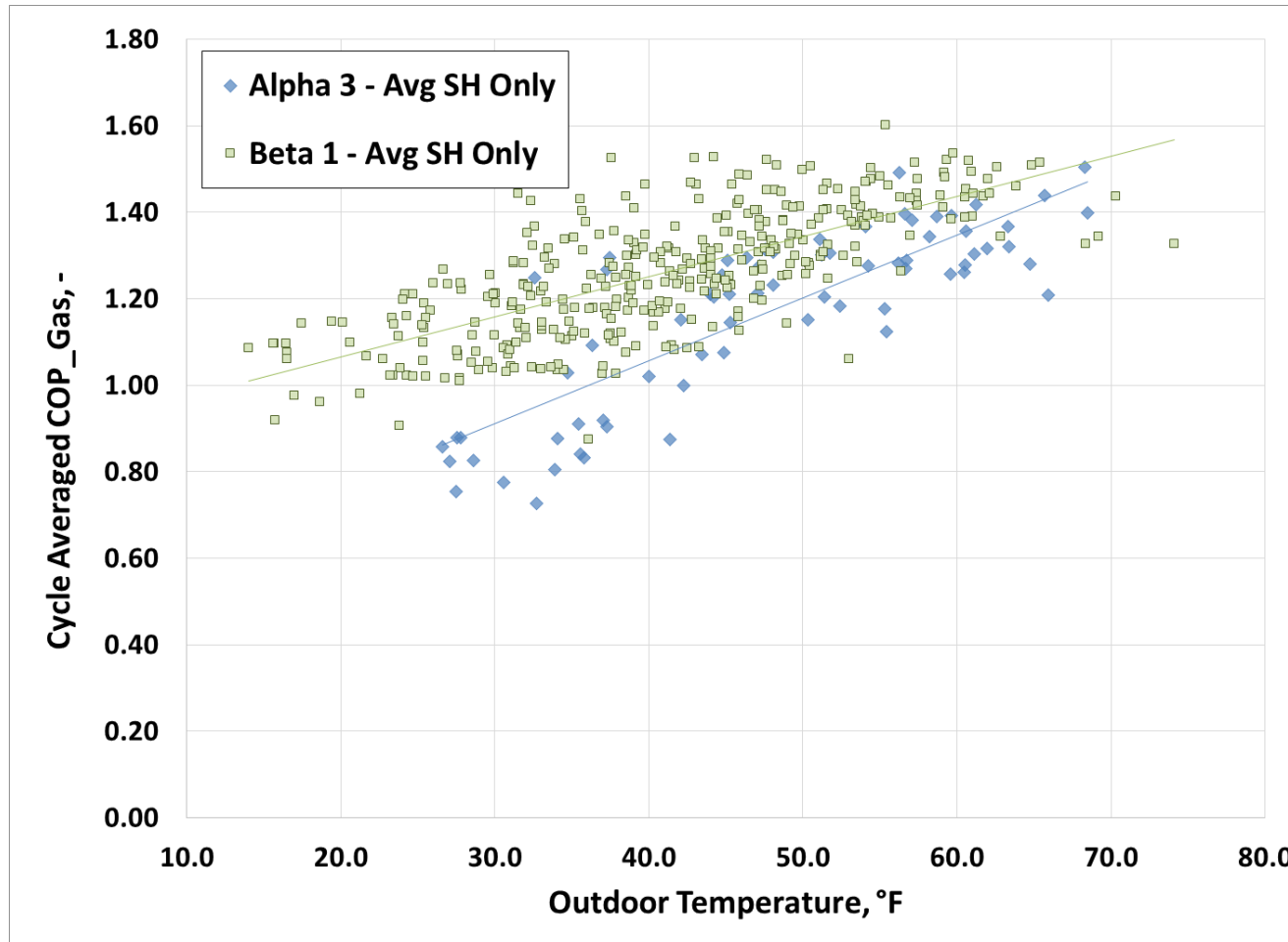
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Residential Combi Field Test

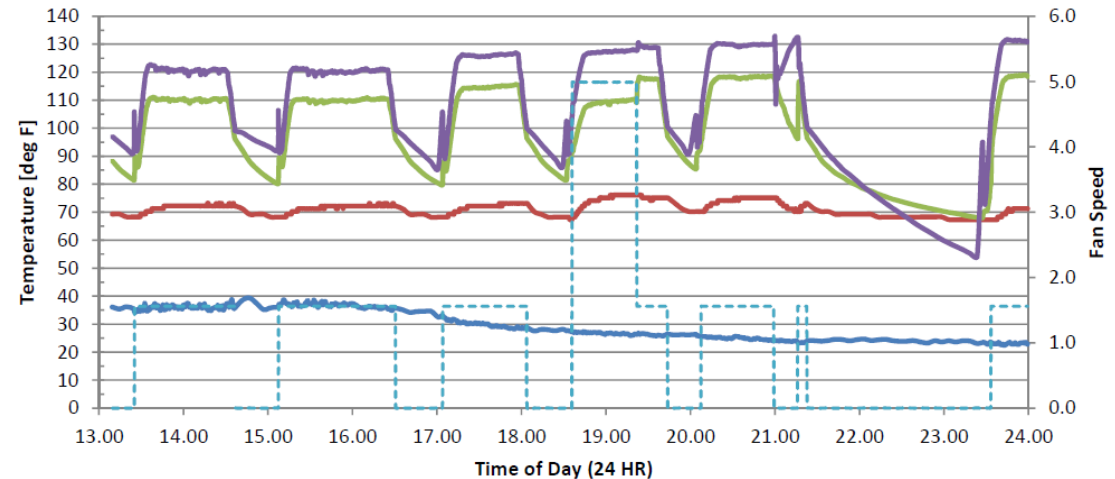
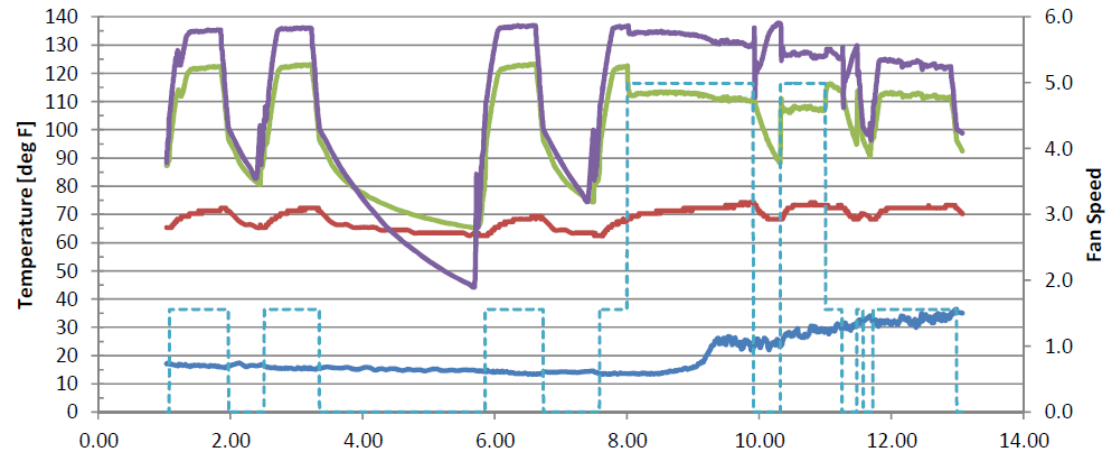


Data courtesy of GTI

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



— Outdoor — Indoor — Supply Air — Hyd Supply - - - Fan Speed

Residential Combi: Data Snap Shot

