Performance of a State-of-Art Packaged Heat Pump for Residential Space Conditioning and Hot Water

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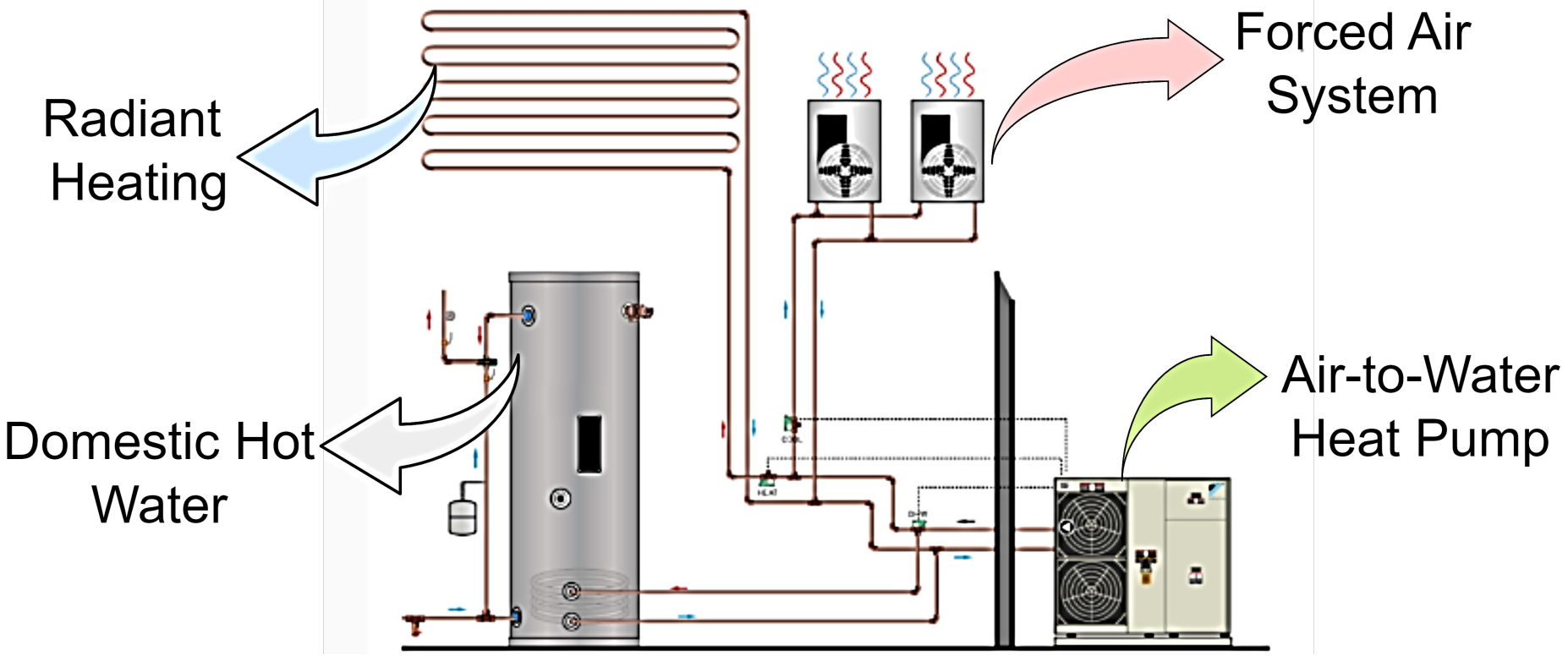
- Matt Blaylock and Thao Strong from Stone Mountain Technologies Inc.

Outline

- **What are combination (“Combi”) heat pump**
  - ✓ Types of combination heat pumps
  - ✓ Benefits of combination heat pumps
- **What is the proposed hybrid combi heat pump?**
  - ✓ Motivation
  - ✓ Prototype system
- **How did the prototype hybrid heat pump perform?**
  - ✓ Preliminary laboratory result
  - ✓ Conclusion
  - ✓ Future Work

What are combination (“Combi”) Heat Pumps

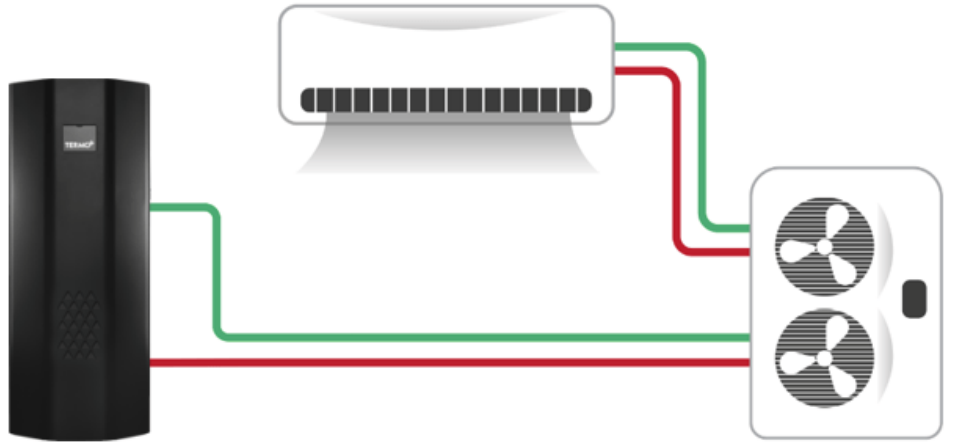


“Combi” heat pumps are systems with the capability to provide space conditioning (heating or cooling) with domestic hot water (DHW)

Types of “Combi” Heat Pumps

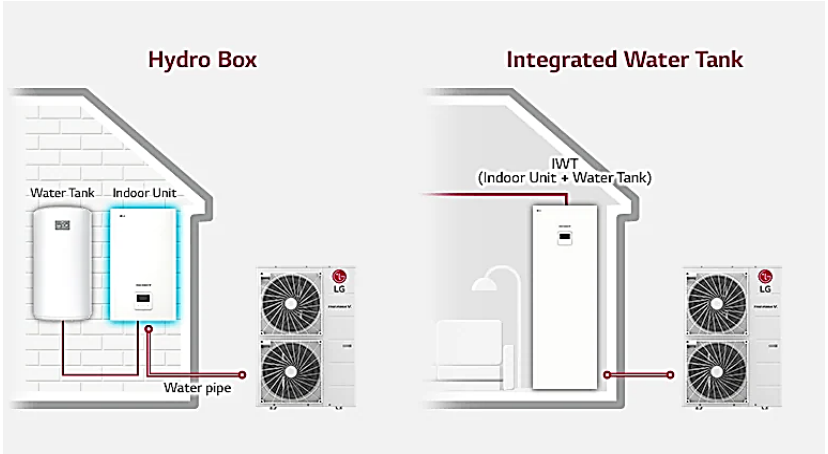
Electric Heat Pump

- Air-to-water heat pump
- Upcoming in North America and common in Europe
- Low-GWP (R744, R32, R290)
- Heating and cooling COP up 4.5



“Combi”

- Replaces both the furnace/boiler and high-GWP air-conditioner for **space conditioning** (heating + Cooling) and gas-fired **DHW** for single or multi-family homes
- Provide DHW >140˚F
- Heat recovery capability @ cooing season



Source: https://www.lg.com/global/business/heating-R32-hydrosplit

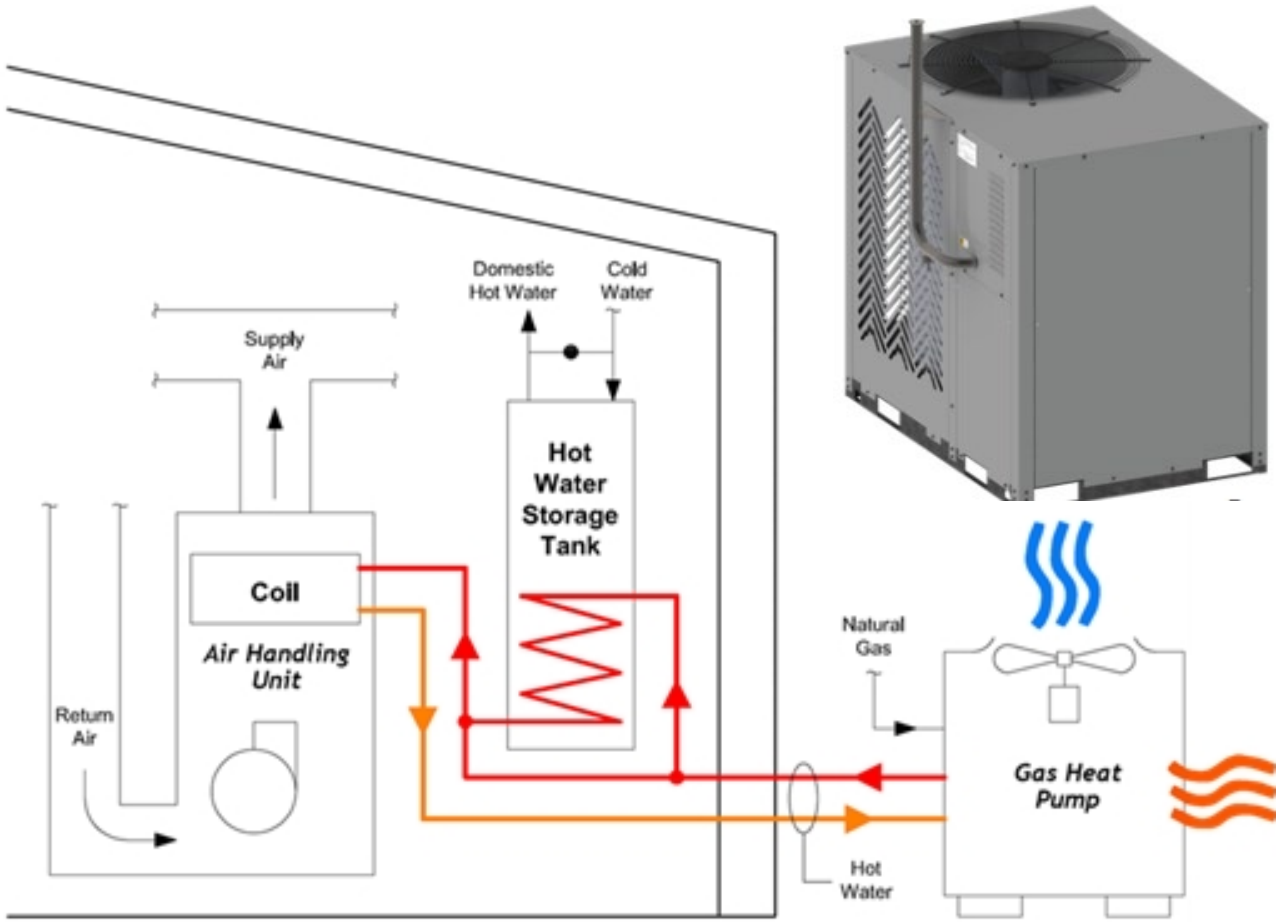
Types of “Combi” Heat Pumps

Gas Absorption Heat Pump

- Air-to-water heat pump
- Zero-GWP
- 140% AFUE (sCOP)
- Improved Cold-climate performance
- Refrigerant and combustion outdoors

“Combi”

- Replaces both the furnace/boiler and high-GWP air-conditioner for **space heating only** (gas-fired **DHW** for single or multi-family homes
- Provide DHW >140˚F
- Could be integrated with radiant and forced air system



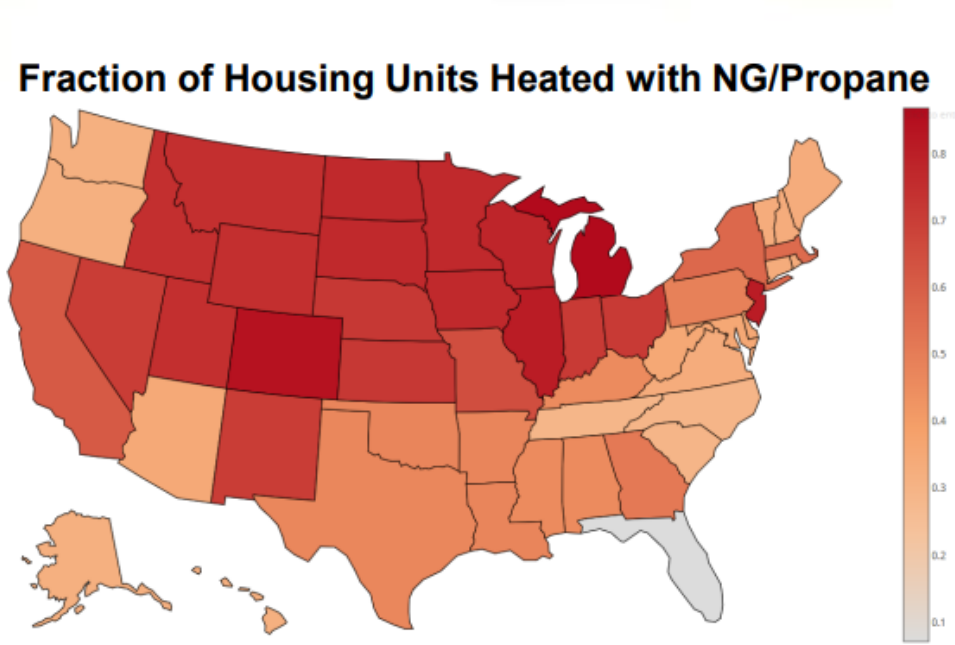
Benefits of “Combi” Heat Pumps

- **Uses only one outdoor unit for space condition and water heating**
  - ✓ Installing and commissioning a single system can be less costly, quicker, and involves less coordination
  - ✓ Avoids the cost of duplicative controls and forced-air system
- **Compact systems reduce costs in space-constrained buildings**
  - ✓ Retrofit decarbonization for multifamily buildings is challenging and costly because of tight space limitations
- **Enables lower-cost retrofit options**
  - ✓ No costly rework of all distribution systems and terminal unit
- **Modular system reduces design and installation costs.**
  - ✓ Engineering design and labor typically account for more than half of the first costs
  - ✓ Hydronic systems, the design, installation, and commissioning of the balance of plant (BOP) components can be especially burdensome

Motivation for hybrid “Combi” System

- **Gas-Fired Space and Water Heating**
  - ✓~57% of U.S. homes
  - ✓~85% of those homes use central furnaces, and less than half have 90% AFUE or better
  - ✓Only 5% of gas storage water heaters are >0.67 UEF
  - ✓For example, 28% of Chicago’s GHGs are from home heating

- **Greater deployment of high-efficiency products limited by:**
  - ✓Equipment cost
  - ✓Low, stable utility costs diminish economics
  - ✓Declining loads – New build and improved standards
  - ✓Occupancy



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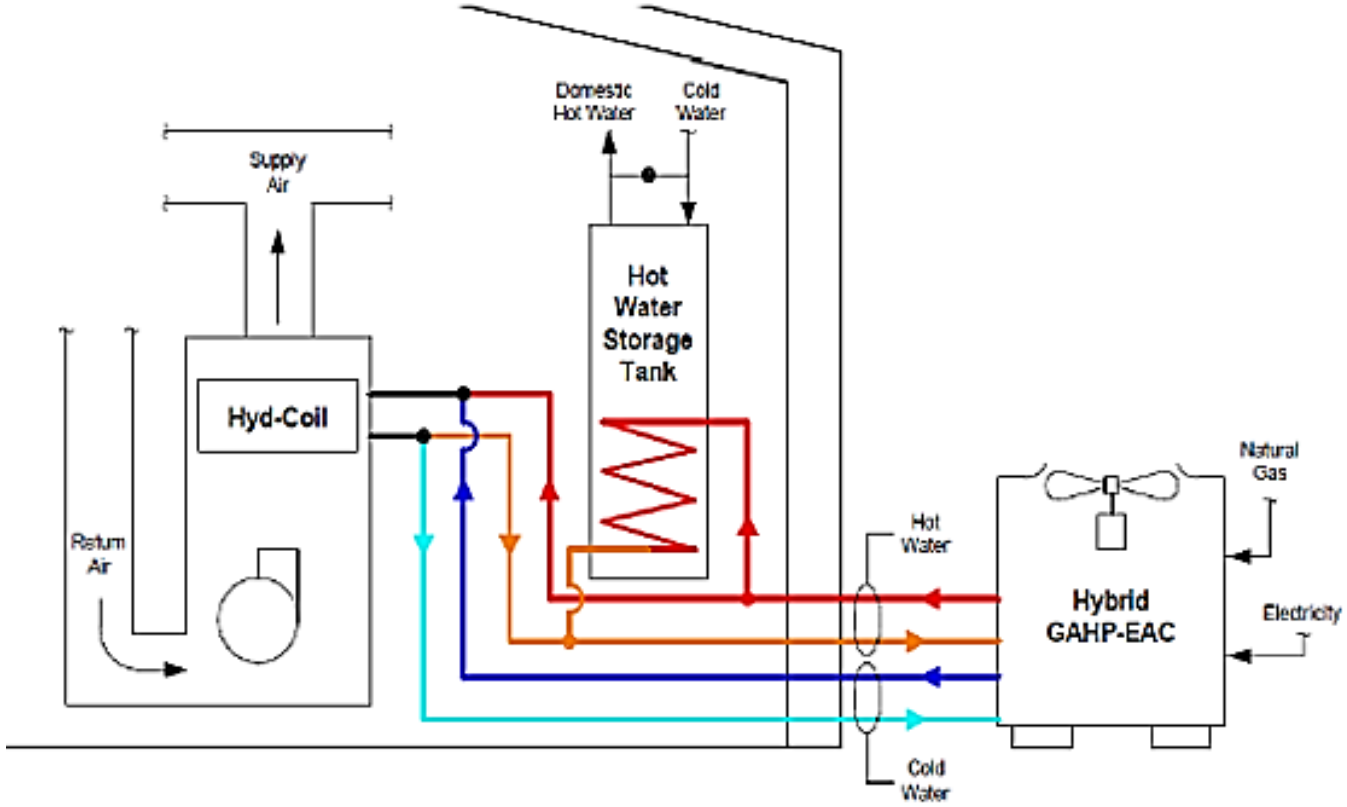
Current GAHP’s are high-capacity and highly efficient heating heat pumps with limited cooling capability at low efficiency.

Hybrid “Combi” System

Hybrid “Combi” System

- Single outdoor packaged outdoor unit
  - ✓ Solving the “two boxes” issue, requiring only one outdoor HVAC equipment and a single air handling unit indoors.
  - ✓ Air-to-water heat pump
  - ✓ Gas Absorption Heat Pump + Elec. Air Conditioner
- Heating with gas-fired heat pump
- Cooling with vapor compression cycle
- Increase marketability of GAHP



Hybrid Combi” heat pumps integrates gas absorption heat pump (GAHP) + Elec. air conditioner (EAC) to provide complete space conditioning and domestic hot water load with a single packaged outdoor unit

Prototype

The Prototype Unit Includes:

- ✓ 40 kBTU/hr single-effect gas absorption heat pump
- ✓ 1.9 RT R-410a refrigerant 2-stage compressor
- ✓ A single outdoor coil for both heating and cooling

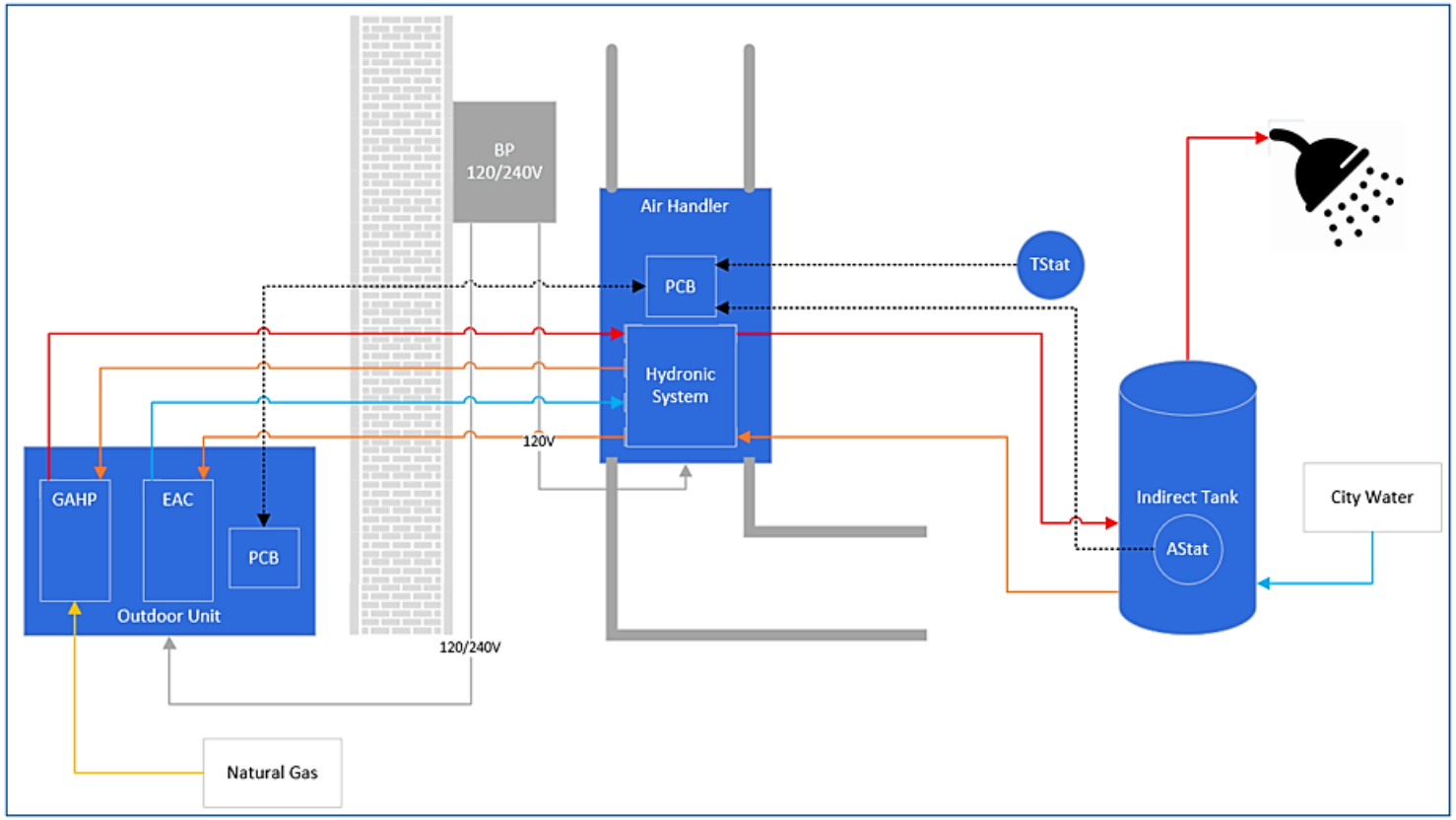
The Prototype Unit Includes:

- ✓ Specially-designed Water-to-air forced air handling unit
  - ✓ Two Pumps
  - ✓ Three-way valves
- ✓ 80-gal indirect storage water heater

Laboratory Evaluation

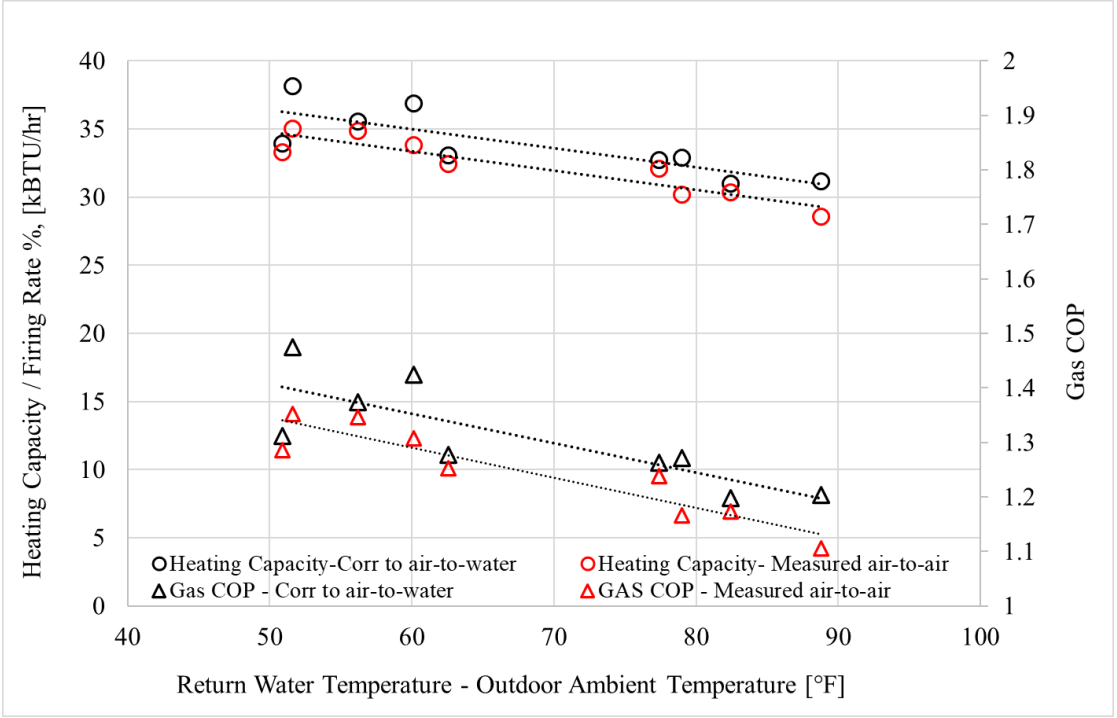
Evaluation

- Steady-state standardized testing
  - ✓ANSI Z21.40.4 for space heating
  - ✓ANRI 210/240 for space cooling
- Simulated use testing – Load base
  - ✓Space + Water Heating
  - ✓Space Cooling + Water Heating



Preliminary Results – Steady-State Heating

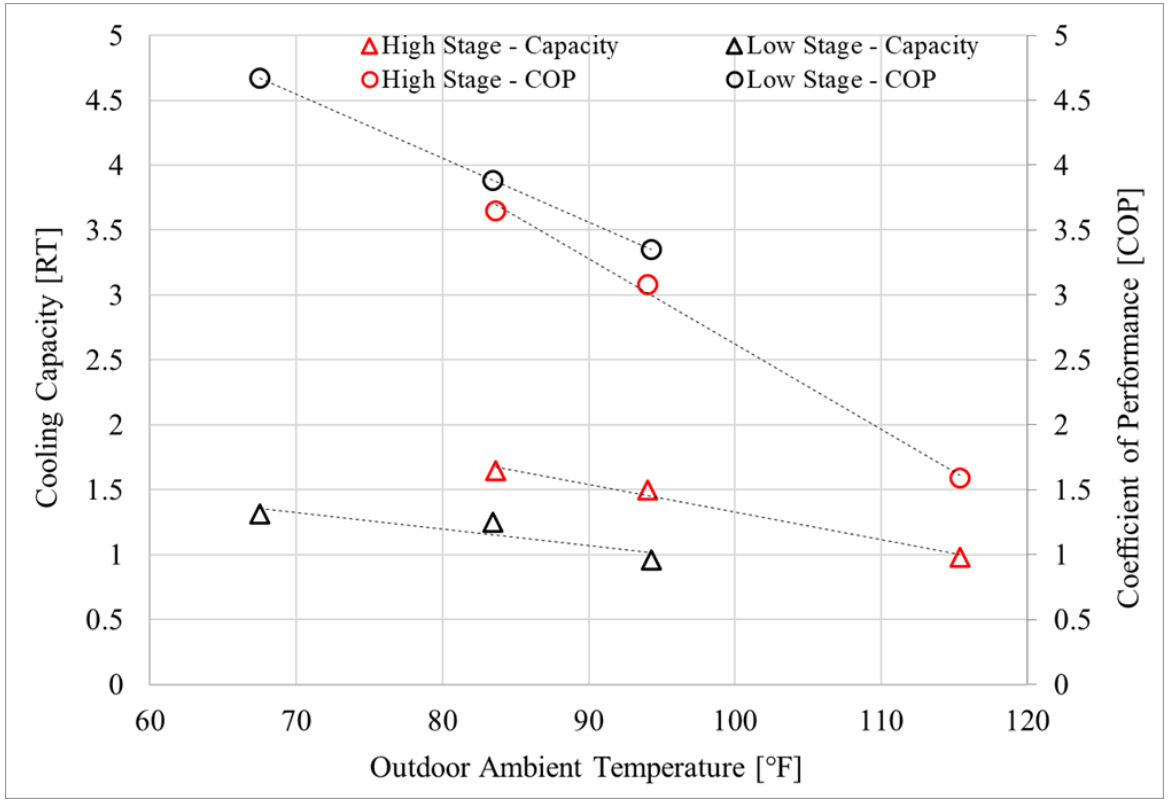
- Steady-State seasonal performance:
  - ✓AFUE (sCOP): 121.6% (Air-to-water)
  - ✓AFUE (sCOP): 118.9% (Air-to-air)
  - ✓Capacity: 38.6 kBTU/hr @ 47 ˚F
  - ✓Low-NOx system - <14 ng/J
- Performance Variation:
  - ✓With air-to-water, slightly reduced performance and capacity due to higher return water temperature.



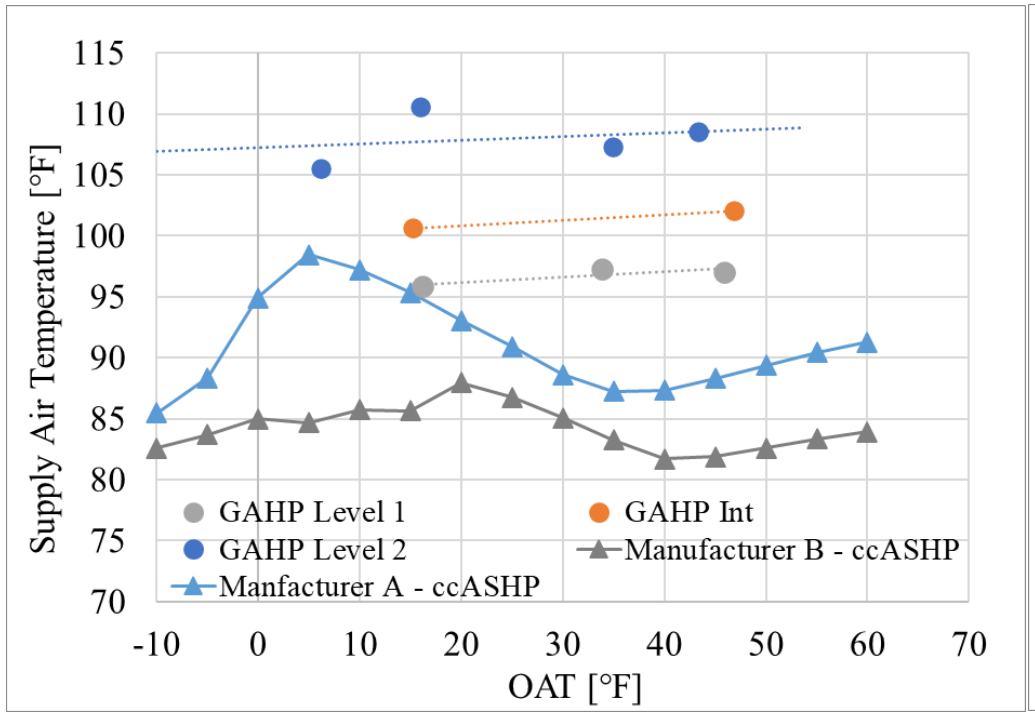
Modulation Level	O_2 %	CO_2 %	CO Air Free (ppm)	NO_x (ng/J)
Level 1	4.6±0.3	9.2±0.3	11.5 ±12.7	7.8
Intermediate	5.2±0.3	8.9±0.3	32±12.8	7.3
Level 2	5.3±0.3	8.8±0.3	101±12.6	7.8

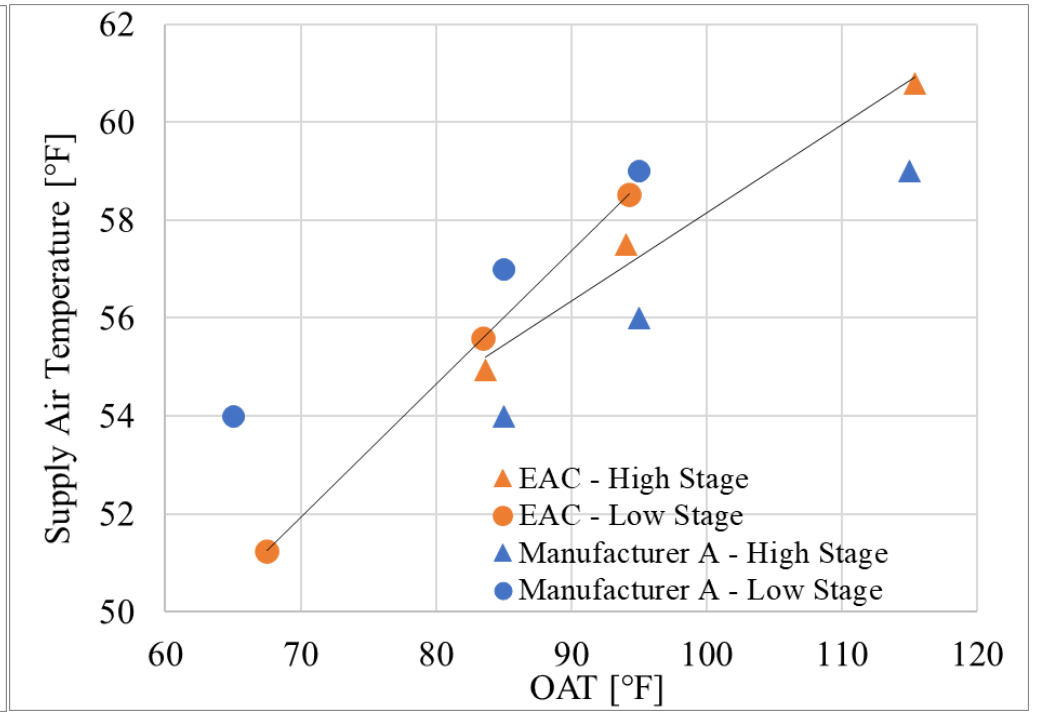
Preliminary Results – Steady-State Cooling

- Steady-State seasonal performance:
  - ✓SEER: 12
  - ✓Capacity: 1.6 RT @ 82°F – Designed for mild cooling load region



Air Handling Unit Performance



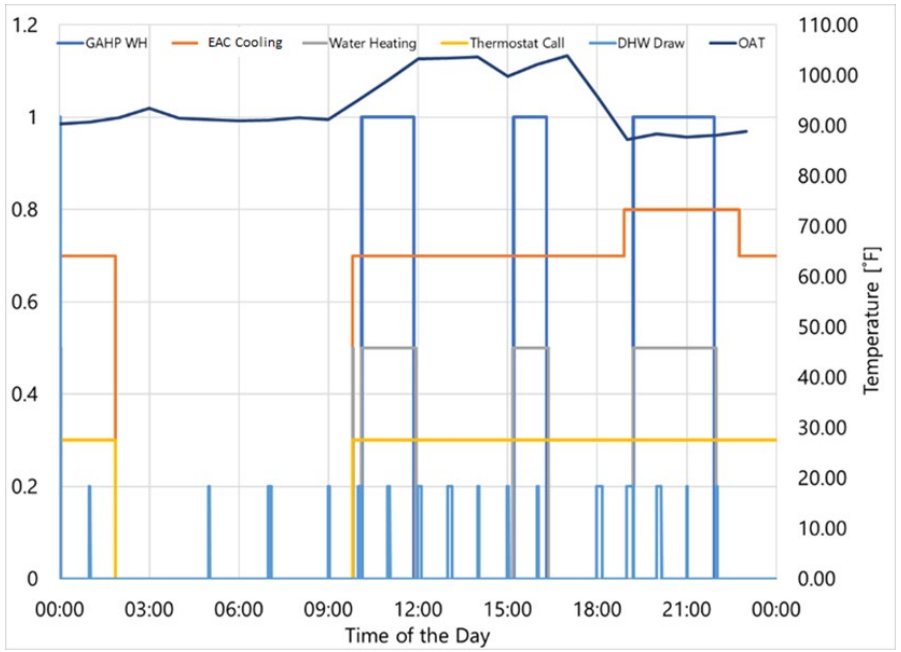


Our AHU's supply air performance for water-air configuration compared to a direct-expansion heat pump AHU for space heating and cooling

Preliminary Results – Simulated Testing Cooling Season

Simulated Space Cooling and Water Heating Load

- ✓Operates at COP of 2.56 (Cooling, electric) and 1.3 (Water Heating, gas) @ 92 ˚F ambient
- ✓8% performance degradation between rating and system.

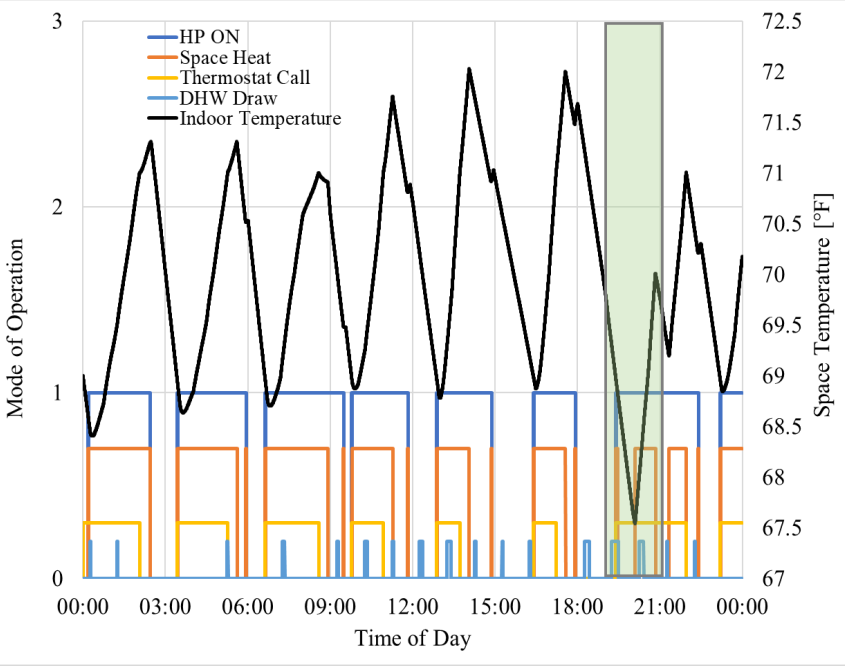


	Space Cooling	Water Heating
Gas [kBtu]	-	32
Cooling Supplied - @EAC [kBtu]	205.1	-
Heating Supplied - @ DHW [kBtu]	-	48.1
GAHP/EAC Electric Load [kWh]	16.3	0.7
AHU/Pump Electric Load [kWh]	5.5	0.8
COP_{gas}		1.5
COP_{total}	2.56	1.3
Standby-by Electric usage [kWh]	0.36	
Water Drawn [Gal]	-	86.3
Average OAT [°F]	92.2	

Preliminary Results – Simulated Testing Heating Season

Simulated Space Heating and Water Heating Load

- ✓Operates at COP_{gas} of 1.19 (Combined) @ 39.3 ˚F ambient
- ✓COP_{gas} of 1.21 (Space heating) and 1.1 (Water heating) @ 39.3 ˚F ambient
- ✓13% performance degradation between rating and system. Similar to a furnace



	Space Heating	Water Heating
Gas [kBtu]	177	44.8
Heating Supplied [kBtu]	231	53.2
GAHP Electric Load [kWh]	2.24	0.59
AHU/Pump Electric Load [kWh]	2.79	0.37
COP_{gas}	1.21	1.1
Standby-by Electric usage [kWh]	0.623	
Water Drawn [Gal]	-	92
Average OAT [°F]	39.3	

Conclusion

- **We evaluated a hybrid "Combi" heat pump under a series of laboratory evaluations to map the performance for residential space conditioning and water heating**
  - ✓Showed the viability of integrating a GAHP with elec. Air condition system with R410a
  - ✓The standard testing performance: AFUE 121.6% (Heating) and 12 SEER (Cooling)
  - ✓The hybrid prototype operated at more than 100% efficiency under combi operation

- **Future Work:**
  - ✓Control optimization
  - ✓More simulated use to testing to map the performance further
  - ✓Design and implementation of heat recovery (desuperheater) during the cooling season


Thank You!