Results from the Demonstration of GHP "Combi" Systems in the Upper Midwest

Paul Glanville, PE
Gas Technology Institute

Presented at 2019 ACEEE Hot Water Forum
Nashville, TN
March 13th, 2019

Agenda

- Project Motivation
- GHP Combi System
- Preliminary Results & Analysis
- Conclusions

Motivation

In Chicago, it's still cold!

> "Polar Vortex" has hit the upper Midwest again
  - -23 F recorded at O'hare, after long period below 0 F
  - Frequency impacted by climate change*

> Most homes heated with gas furnaces/boilers (87%)
  - 46% of housing units built before WWII
  - Despite oversize, most could not keep up during Vortex

> If 28% of Chicago's GHGs are from residences, need to address emissions from home heating

Lake Michigan on Jan. 31st, 2019

*As reported by the Guardian ; Image Source: Chicago Tribune, Data sources: City of Chicago Greenhouse Gas Inventory Report, 2015, 2010-2012 US Census American Community Survey

Motivation

Of the ~57% of U.S. homes with gas-fired heating/DHW:

> For 85% of those with central furnaces, less than half have 90% AFUE or better

> Only 5% of 4MM gas storage water heaters are 0.67 UEF or better (EnergyStar)

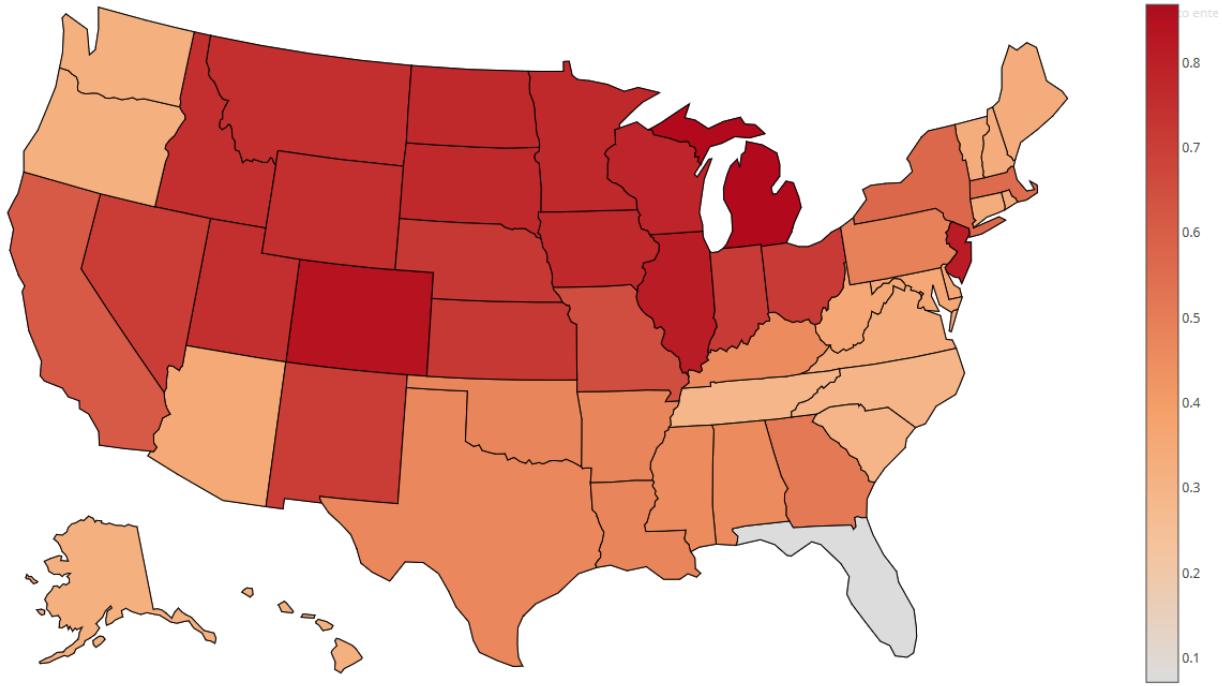
> In Canada, 65% of homes have gas-fired heating/DHW

Greater deployment of high-efficiency products limited by:

> Low, stable utility costs diminish economics

> Declining loads (relative & absolute), migration, occupancy

Fraction of Housing Units Heated with NG/Propane



Data sources: US DOE EIA RECS 2009/2015, EnergyStar, and DOE SNOPR 2016. Technical Support Document: Residential Furnaces, prepared for the DOE by Navigant Consulting, Inc. and Lawrence Berkeley National Laboratory., NRCan.

Motivation

Residential GHPs, available overseas, have many advantages:

> Best-in-class operating efficiency (primary basis)

> Good part-load performance and in cold climates

> Typically do not require backup heating and can continue operation during defrost

> Opportunities for peak load management

> Commonly use natural refrigerants/working fluids with low/no GWP/ODP

> NOx and GHG emissions are decreased by half or greater and combustion ‘sealed’ or occurs outdoors (IAQ & venting)

Image Source: Boostheat, Robur, Viessmann

Gas Heat Pump Combi

Prior research on combi systems reveals following themes for system design and controls to integrate space heating with DHW:

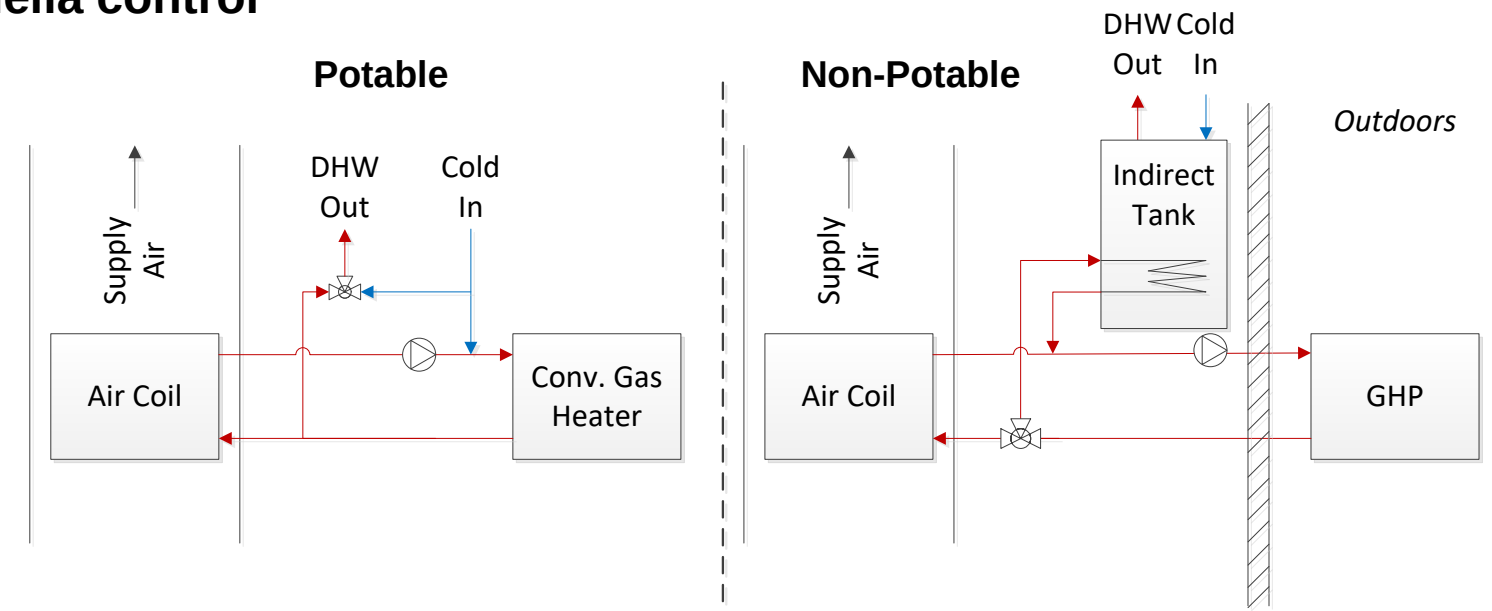
> Majority are **field-engineered**, some installed without proper controls/sizing to assure condensing equipment have sufficiently cool T_{return}

> For **DHW priority**, system must also be sized to minimize loss of thermal comfort when loads are simultaneous.

> For potable systems, proper care for **Legionella control**

Considerations to drive combi systems with an **Gas Heat Pump (GHP)**:

- Non-potable system has "higher mass", lower turndown ratio
- Capacity affected by operating conditions
- Greater motivation for packaged systems



Gas Heat Pump Combi

Previously described the development* and initial demonstration** of a low-cost GAHP for whole-house combi heating and light commercial:

> Base tech. is gas-fired single-effect ammonia water absorption cycle and design to be **easily manufactured design** to assure low-cost (30%-50% of existing GHPs)

> Absorption cycle development by startup, tech. support from research institute and OEMs

> Nominal 80 kBtu/h (23 kW) output with 4:1 output modulation, no aux./backup heat, Ultra-low NOx emissions, defrost capable, projected 140% AFUE (Region IV) and 3-5 yr. payback*

Lab Testing (2015-2016)

1st Pilot (2016-Present)

2nd Pilot (2017-Present)

Add'l Pilots (2018-Present)

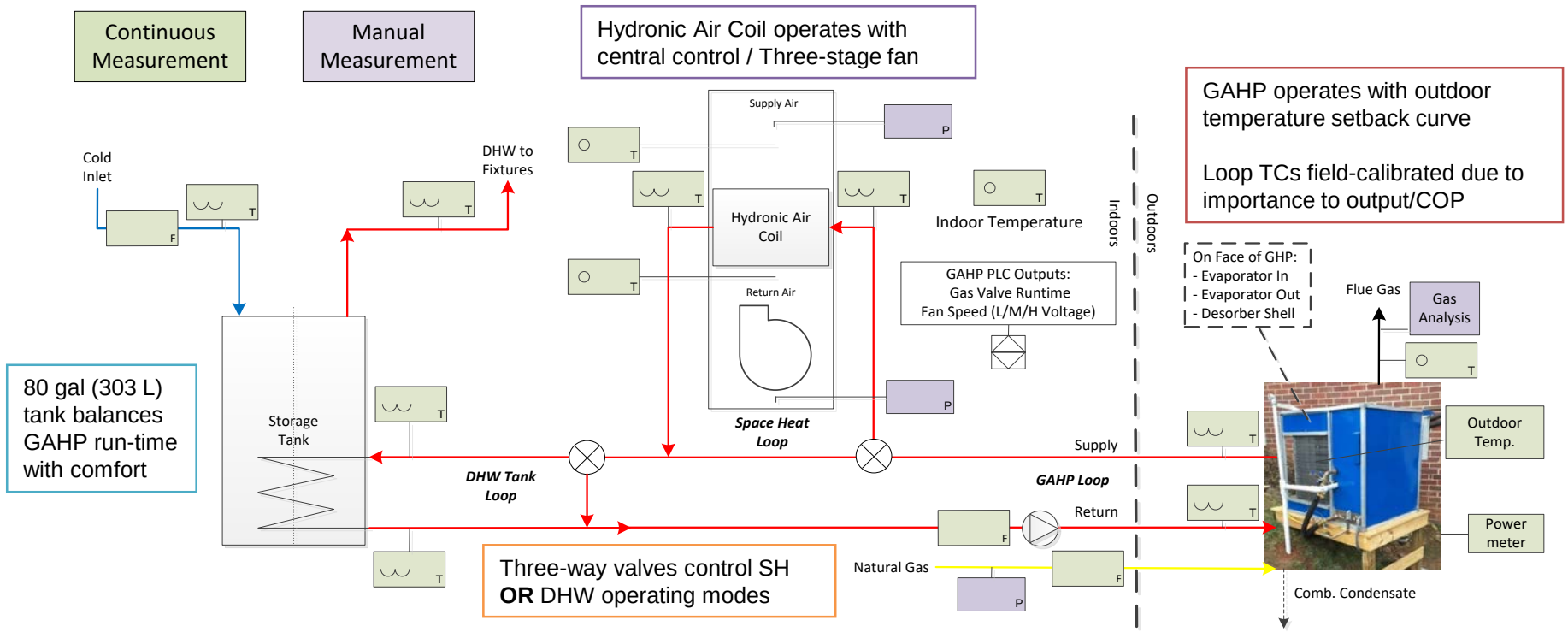
*Glanville, P, Keinath, C., and Garrabrant, M. (2017) *Development and Evaluation of a Low-Cost Gas Absorption Heat Pump*, Proceedings of the ASHRAE Winter Conference, Las Vegas, NV.

** Glanville, P., Suchorabski, D., Keinath, C., and Garrabrant, M. (2018), *Laboratory and Field Evaluation of a Gas Heat Pump-Driven Residential Combination Space and Water Heating System*, Proceedings of the ASHRAE Winter Conference, Chicago, IL.

Gas Heat Pump Combi - Site

For all four sites, team uses similar data collection platform for combination space/water heating system

- Focus on 2nd pilot, at split level 2,700 sf (251 m2) house with four occupants in Western WI (Climate Zone 6A)
- GAHP combi system replaces 93% AFUE / 100 kBtu/h (29.3 kW) two-stage furnace and 60 gal (227 L) 40 kBtu/h (11.7 kW) input water heater

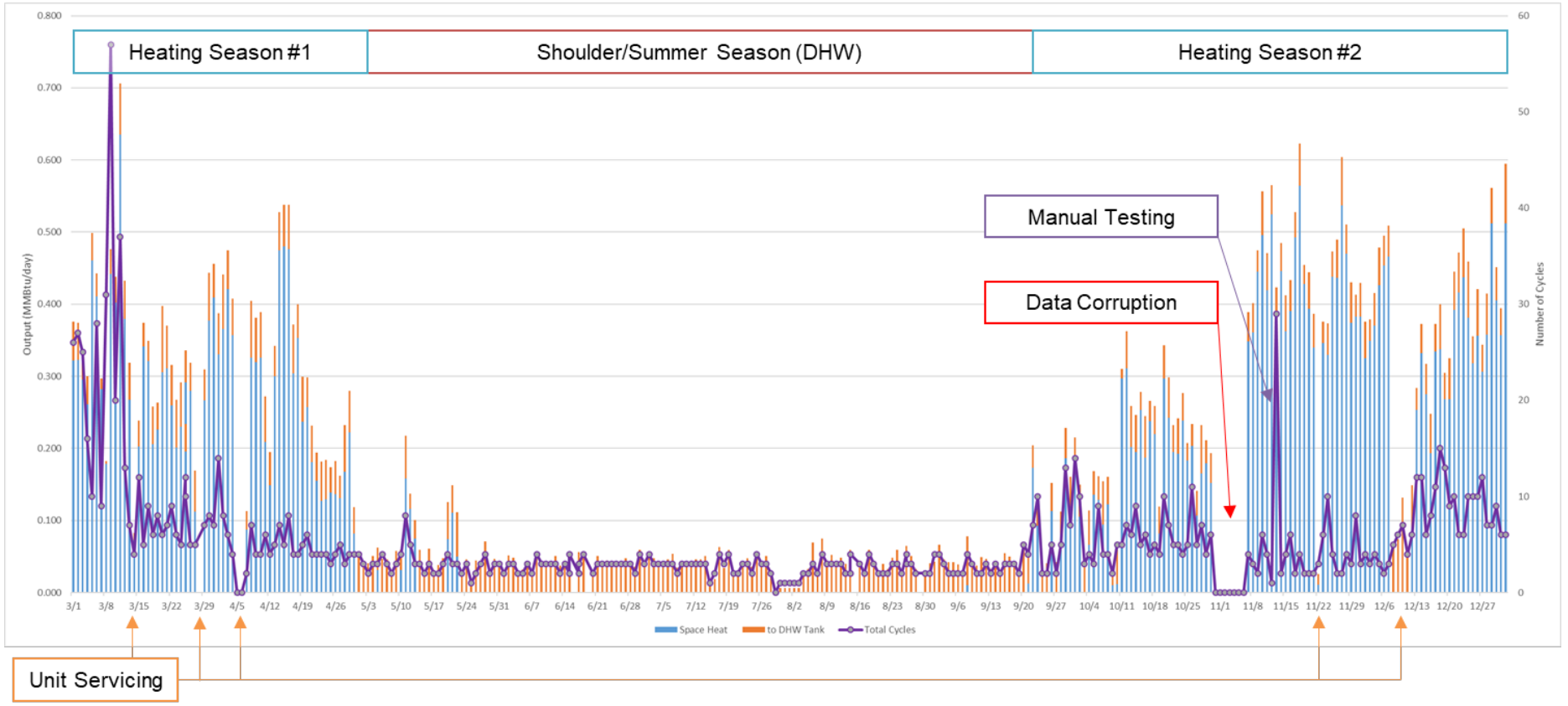


Gas Heat Pump Combi - Site

Multiple sites shown for illustration

GHP Combi – Preliminary Results

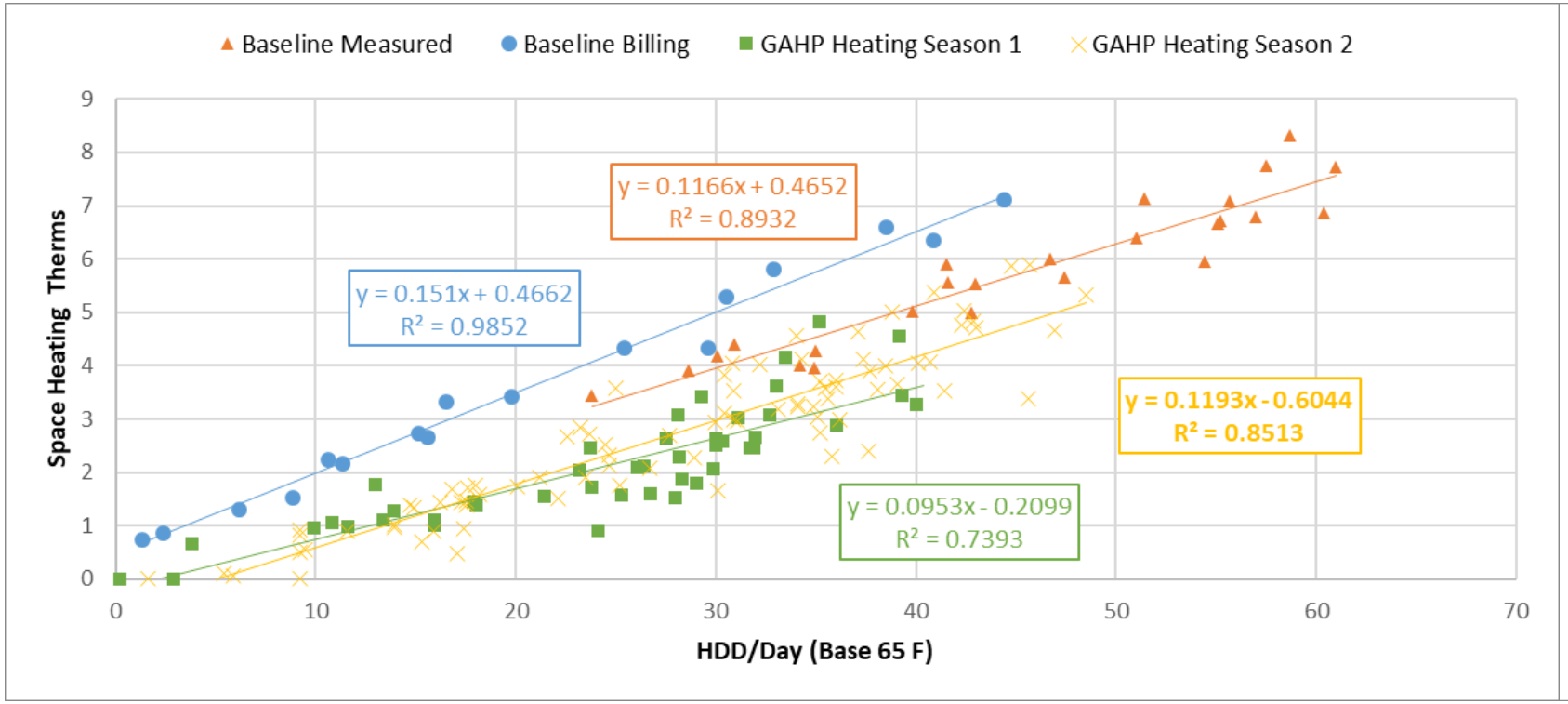
At 2nd Pilot Site: Brief baseline at beginning of 2017-18 heating season, followed by system commissioning in February ’18. > 1,500 operating cycles and > 1,970 operating hours

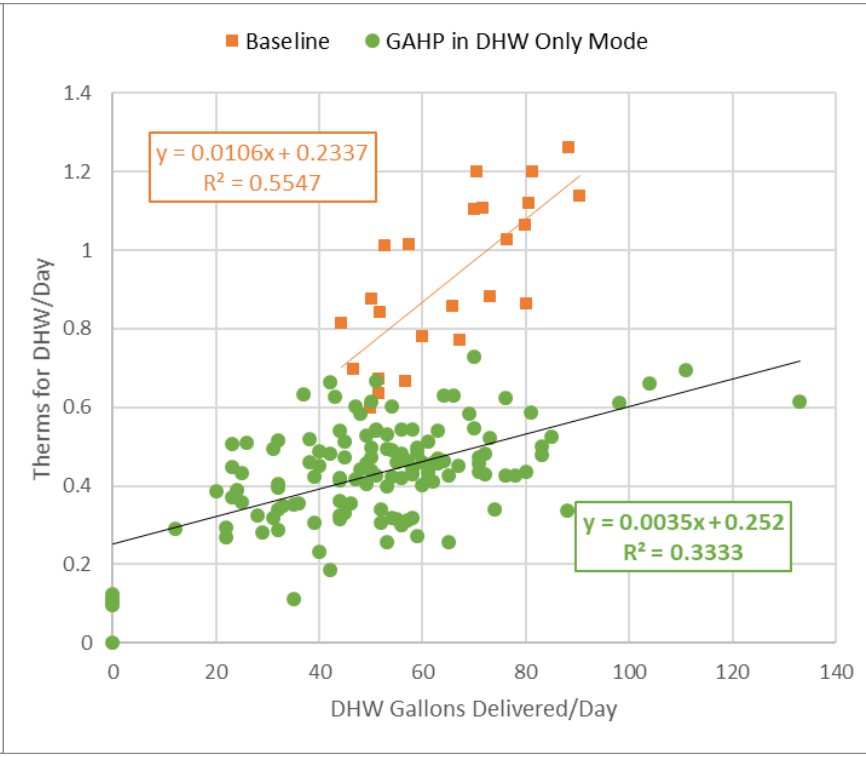


GHP Combi – Preliminary Results

Space Heating: Used HDD approach and extrapolate to TMY3 data (Oct-Apr), 32%-46% therm savings

DHW/Combined: Focusing on extended DHW-only Summer, 50% therm savings for 75 gal (284 L) per day (avg); 35%-45% therm savings estimated, when combined*





*Assumes 75 gal (284 L) per day DHW, extrapolated energy use for space heating, and in combined SH/DHW mode includes average pre/post cycling energy penalty.

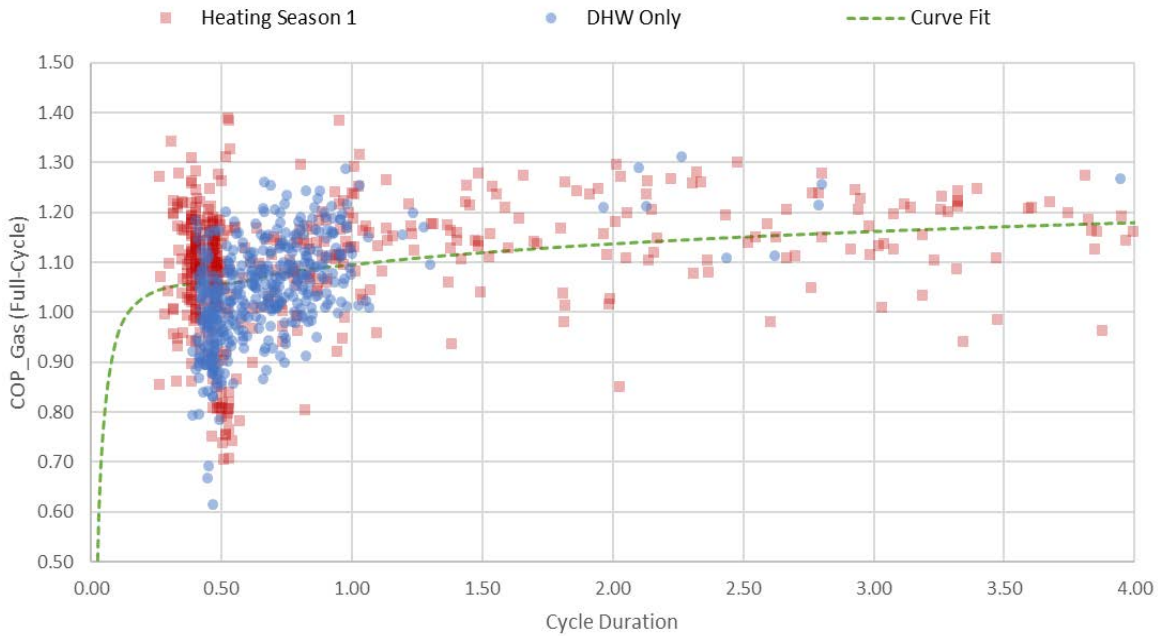
GHP Combi – Preliminary Results

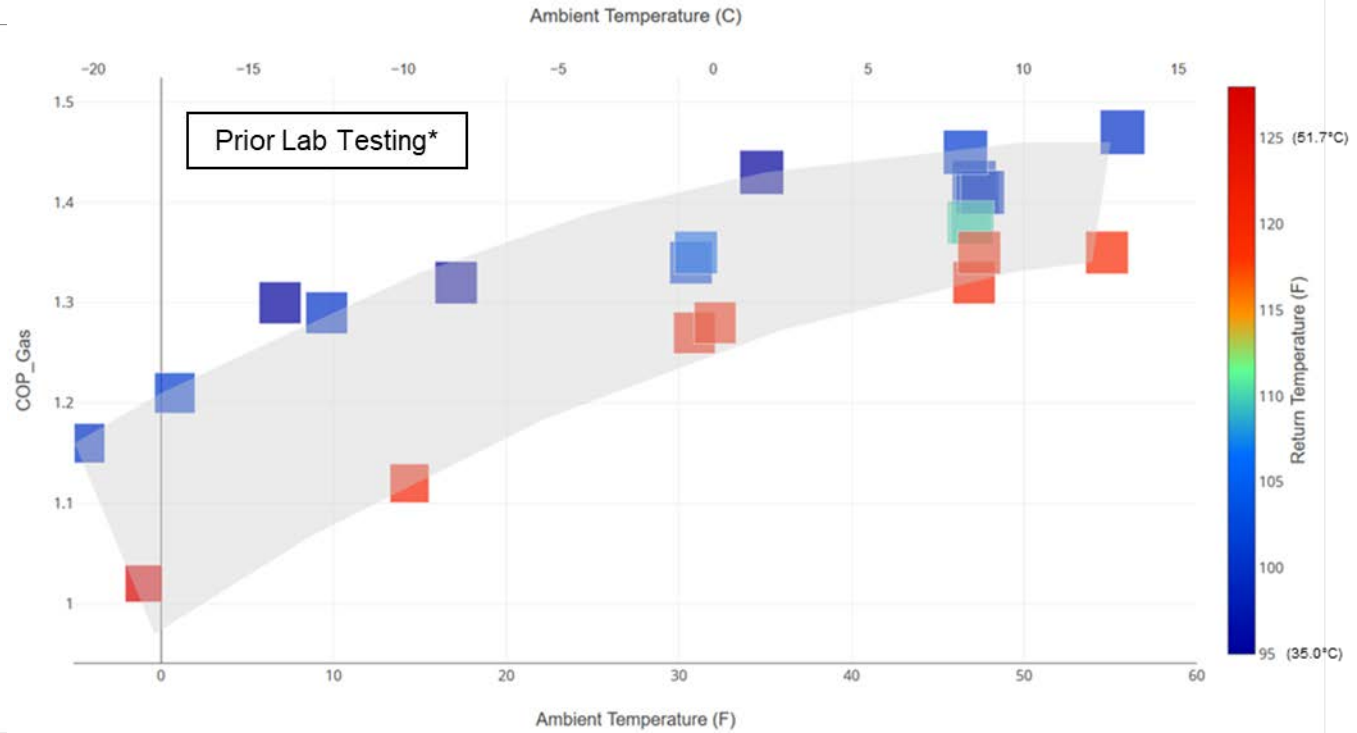
> With snowiest/coldest April on record for 2018, efficiency is lower

- Though GAHP steady state efficiency in-line with prior lab testing (below)

> Significant effort to limit short-cycling, full-cycle efficiency below potential for < 1.0 hr on-time

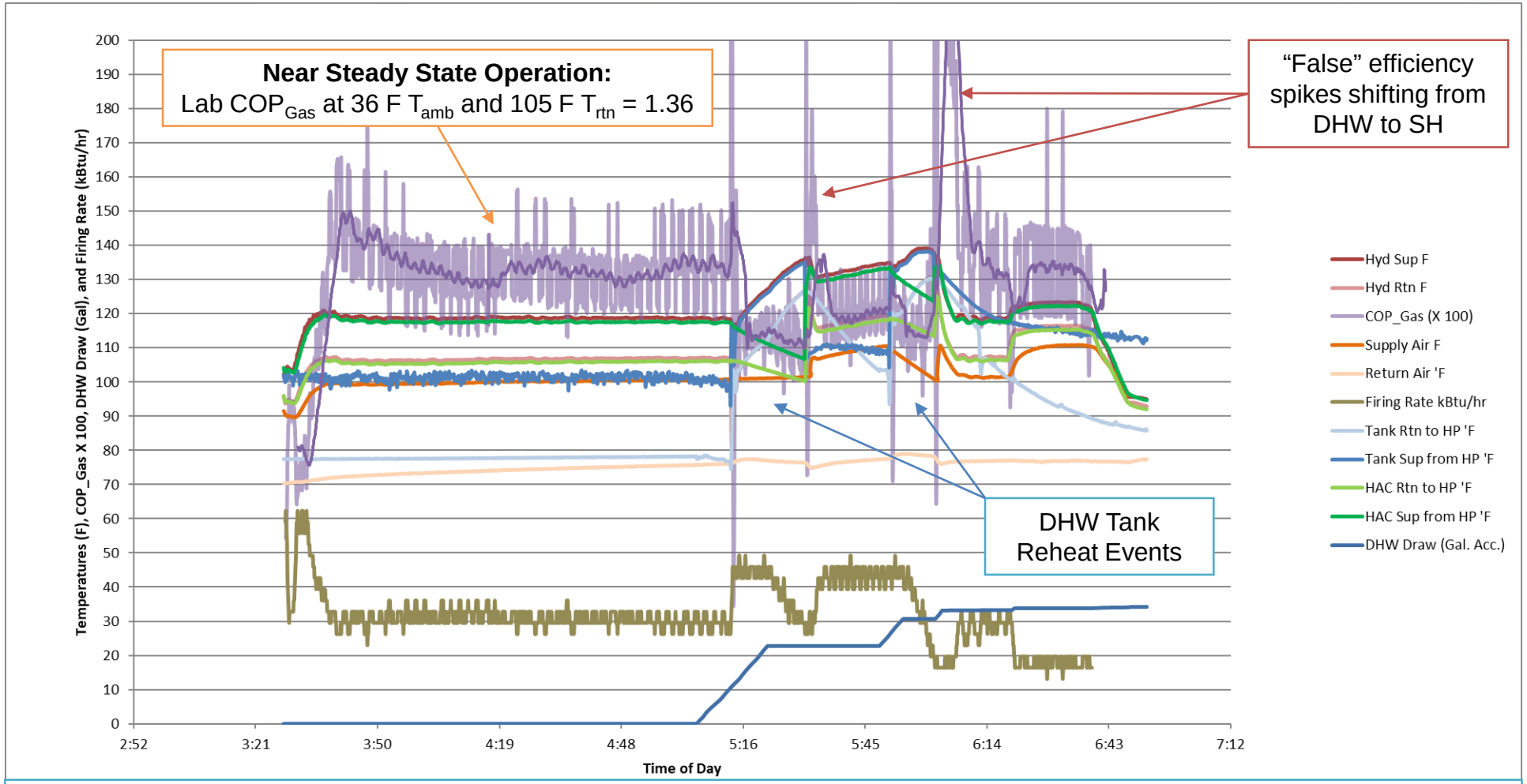
- Results in slight, unexpected tilt for DHW-operation in warmer summer





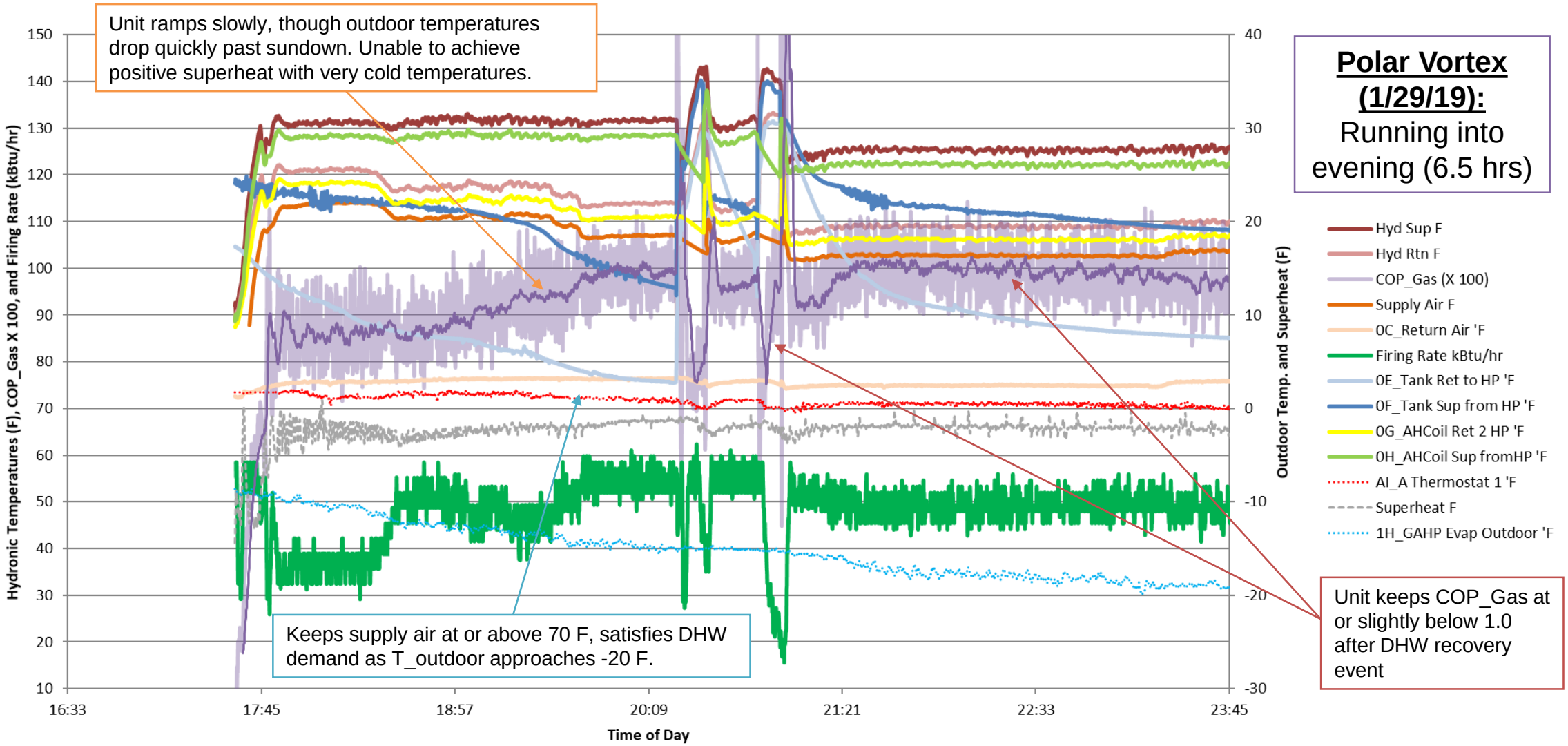
* Glanville, P., Suchorabski, D., Keinath, C., and Garrabrant, M. (2018), *Laboratory and Field Evaluation of a Gas Heat Pump-Driven Residential Combination Space and Water Heating System*, Proceedings of the ASHRAE Winter Conference, Chicago, IL.

GHP Combi – Preliminary Results



Focus on System Dynamics: On-cycle on 10/16; avg. outdoor T = 36 F (2 C)

GHP Combi – Preliminary Results

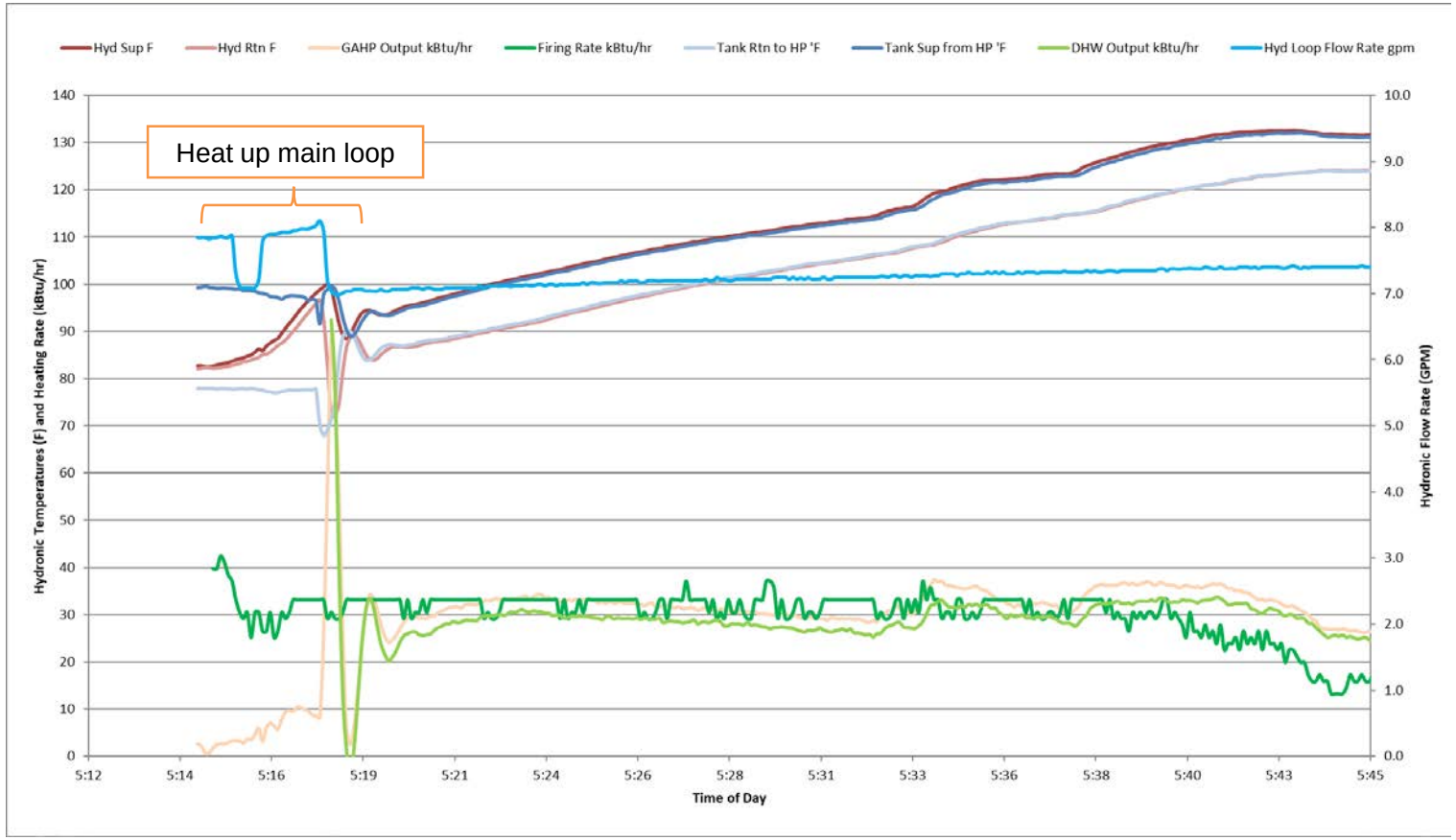


GHP Combi – Preliminary Results

Maximizing Runtime:

In shoulder season and when operating in DHW-only mode, long runtimes are critical

- System modulation is important, HVAC controls and loop/tank volume also
- Greater runtime per cycle limits this energy "tax"
- Typical DHW-only cycle (7/20), shows first 2 min. of 47 min. cycle for 'heat up', 2% of energy delivered
- For typical DHW-only week*, ~90% of GAHP output delivered to tank, ~81% delivered as DHW



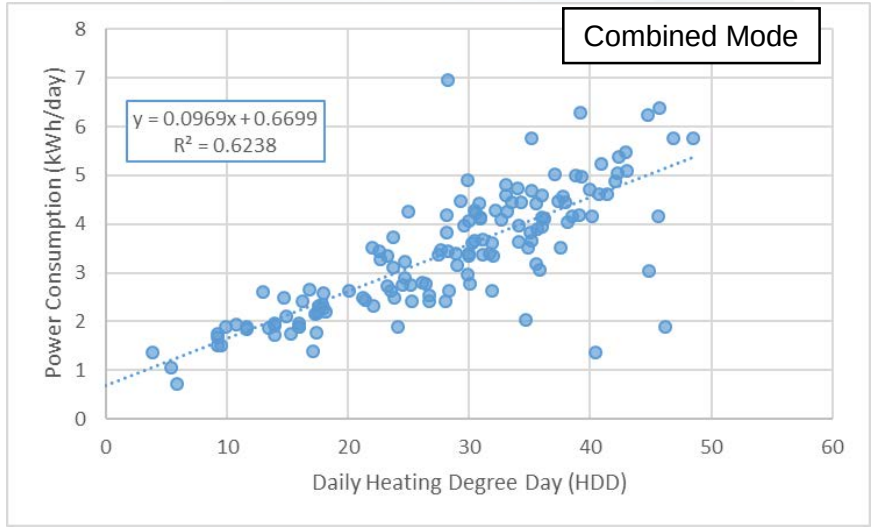
* Based on operation in July 2018

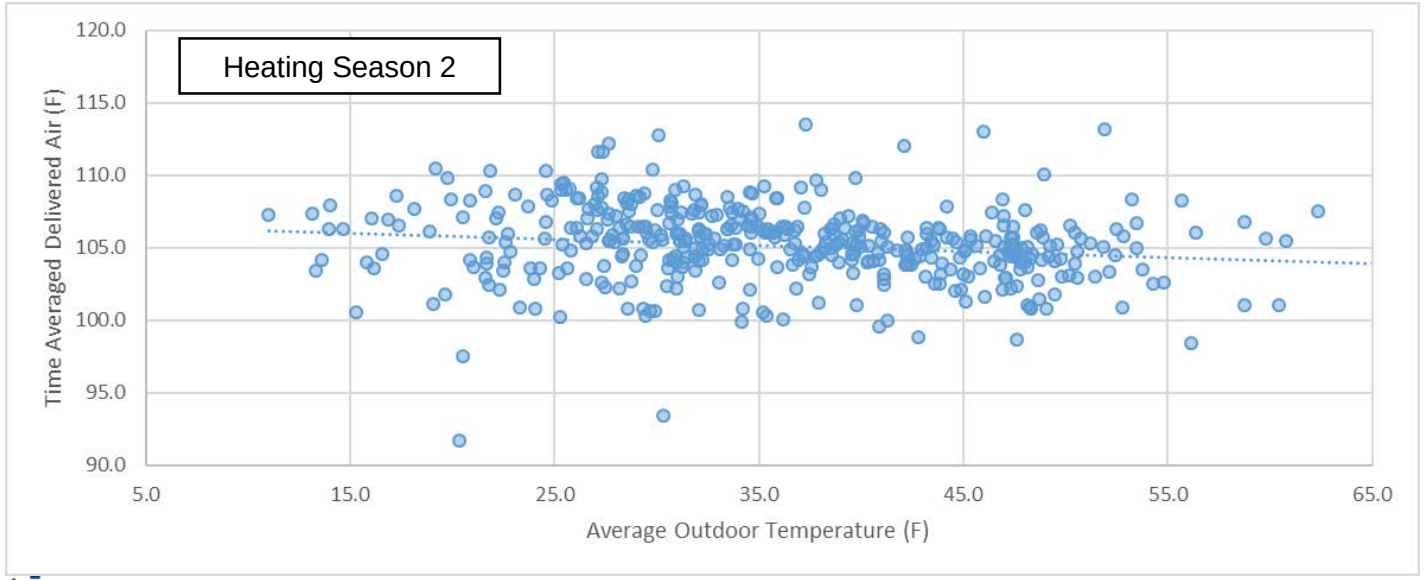
GHP Combi – Preliminary Results

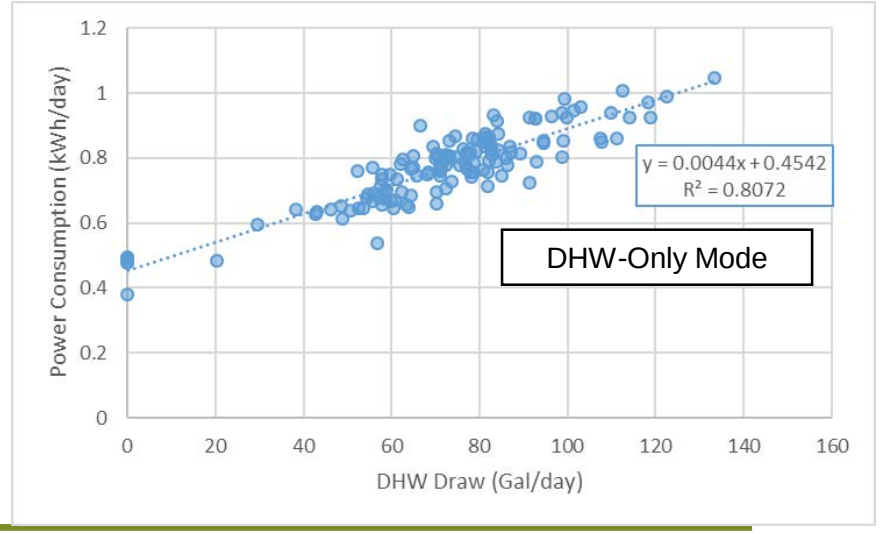
Power Consumption:

- GAHP unit modulates power consuming components (evaporator fan, solution pump) with overall system modulation
- Using TMY extrapolation, GAHP system would consume: 817 kWh/heating season (with DHW)

Thermal Comfort: Qualitatively (host feedback) and quantitatively, the GAHP is providing thermal comfort for DHW/space heating







GHP Combi – Preliminary Results

Defrost: Hot gas bypass with GHP allows the unit to continue operation (at a reduced COP) providing heat to the conditioned space during defrost period without supplement inputs or drawing heat from conditioned space

Defrost Lab. Test (0 F / -18 C)

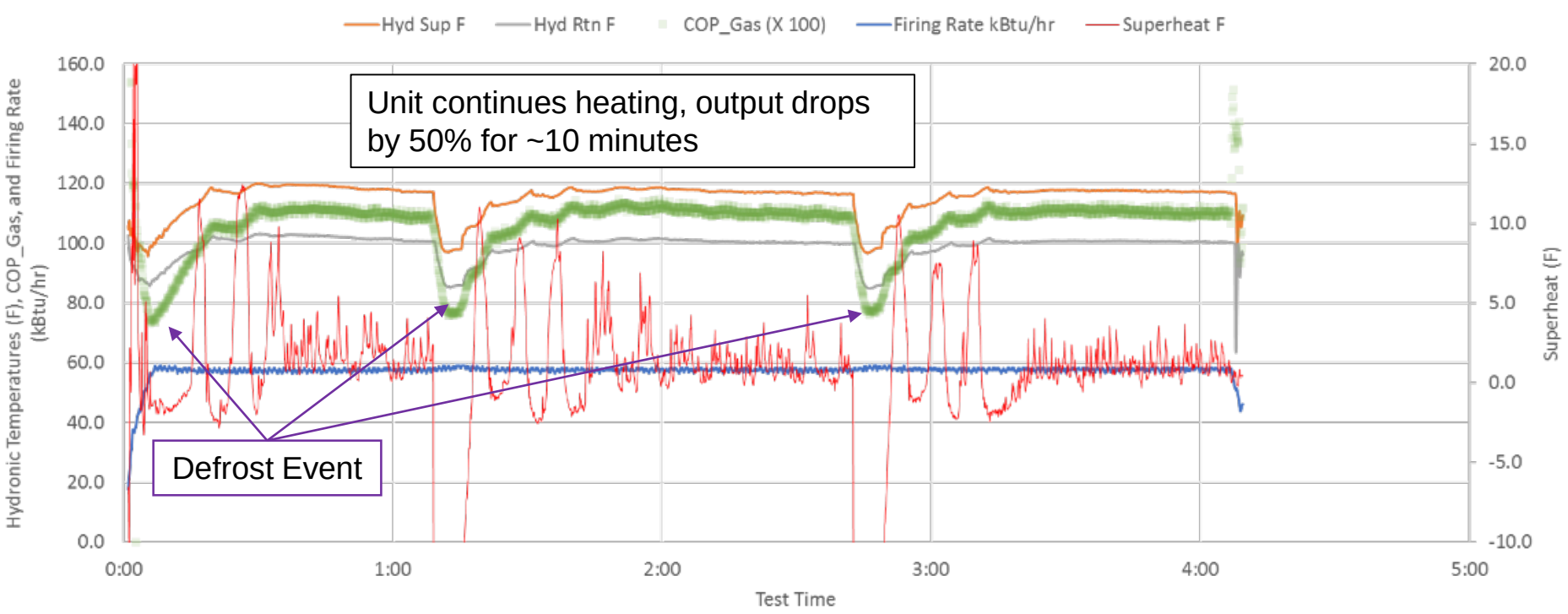


Image source: Local Installation Contractor

Conclusions – Next Steps

Conclusions

- GHP technologies are important solution towards goal of reducing GHG emissions from US/Canadian Homes
- Energy savings with comfort feasible with GAHP combi systems, even in cold climates
  - Important to design/control system to minimize short-cycling

Next Steps

- Continue demonstration/analysis at multiple sites over next 12 months, incl. integration with improved system components
- Summarize challenges/opportunities to reduce installation cost
- Continue supporting add'l applications of low-cost GHP tech.

Image source: Local Installation Contractor

Questions?

Further information:

pglanville@gti.energy

RD&D Discussed Supported by:

Gas Technology Institute

1700 S Mount Prospect Rd,
Des Plaines, IL 60018, USA

www.gastechnology.org

@gastechnology

http://www.stonemountaintechnologies.com/