27th WORLD GAS CONFERENCE | JUNE 25-29 | WASHINGTON DC | 2018 | IGU

Review of Research, Development, and Deployment of Gas Heat Pumps in North America

Paul Glanville, R&D Manager

Gas Technology Institute

HOST ASSOCIATION

AGA American Gas Association

PROUDLY SUPPORTED BY

ENBRIDGE gti

HOST PARTNERS

Chevron ExxonMobil

PRINCIPAL SPONSORS

CHENIERE TELLURIAN

Gas Heat Pumps in North America

Primary Takeaways

- Gas Heat Pumps (GHP) are an important emerging technology in the U.S. and Canada for homes and businesses
- GHPs today and tomorrow can:
  - Deliver best-in-class **GHG reductions**
  - Be integral to **cost-effective** Net/Near-Zero Energy Buildings
  - **Improve comfort** over other heat pumps, esp. in cold climates
  - Readily utilize **natural refrigerants**
- Many efforts to improve cost-effectiveness of mature GHPs, while pushing envelope on performance and efficiency

Gas Heating: Challenges and Opportunities

Direct use of gas in buildings is widespread and prevalent:

USA: 27% / 7.8 quads (8.2 EJ) of NG consumed in bldgs., add'l 7.7 quads (8.1 EJ) for electricity in buildings → 54% of US consumption (15 TCF)

- 84% of gas in buildings for heating and domestic hot water (DHW), 57% of homes have gas heating/DHW

Canada: 45.3% of total gas used by buildings, 1.2 quads (1.3 EJ)

- 64% of gas in buildings for heating and domestic hot water (DHW), 50% of homes have gas heating and 65% for DHW, 80% of business have gas heat/DHW

Image source: NY Daily News

Gas Heating: Challenges and Opportunities

GHP Threats/Opportunities

Efficiency: "Condensing Efficiency" is standard now or soon for most of NA, raising minimums.

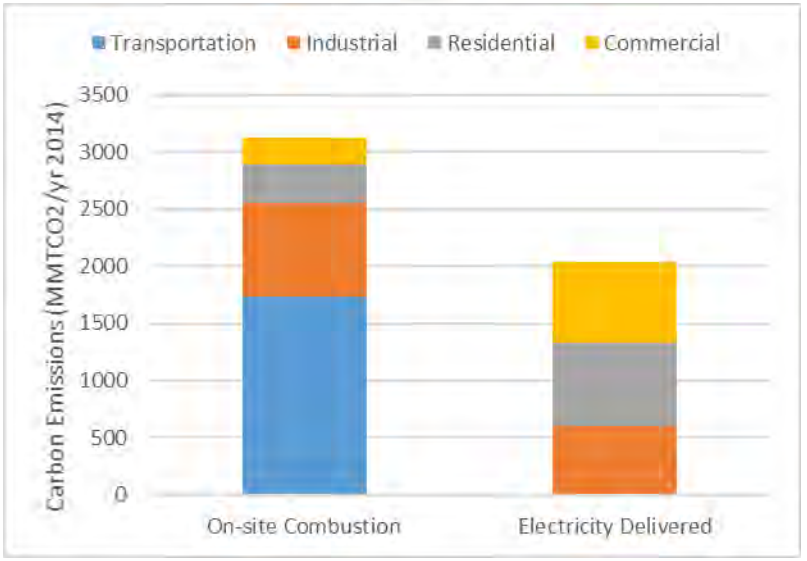
- GHPs ready as next efficiency level, with good part-load performance

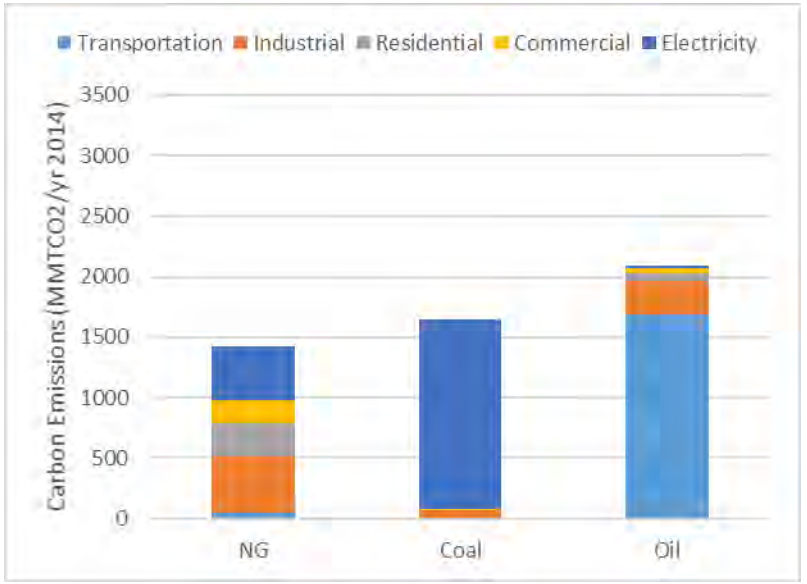
Emissions: GHG and conventional (e.g. NOx) emission & combustion safety requirements.

- GHPs are low-emission with outdoor installation and use natural refrigerants

Net-Zero/Electrification: Is gas incompatible with Net-Zero goals & electrification policies?

- GHPs can drive "mixed fuel" ZNE buildings, with better cost-effectiveness and comfort





2014 CO_2 Emissions in U.S. By Sector/Fuel

Gas Heat Pumps: History and Technical Potential

1970s-1980s
Non-condensing Furnace/Boiler
65-83% AFUE

New Efficiency Req's, Ignition Controls

1990s-2000s
Condensing Furnace/Boiler
90-98% AFUE

EnergyStar, Venting issues, Condensate, NOx

2000s to Present
Gas Sorption/Engine Heat Pumps
120-140% AFUE
Cooling COP_{Gas} 0.5-1.2

GHG, ZNE, Electrification, Peak Electric Demand, First cost, reliability

Future
Advanced Gas Heat Pumps
>140% AFUE,
Cooling COP_{Gas} > 1.5

?????

Drivers, Issues

*Image sources: FS Mechanical, Robur, Thermolift

Gas Heat Pumps: History and Technical Potential

GHP = Carbon Solution

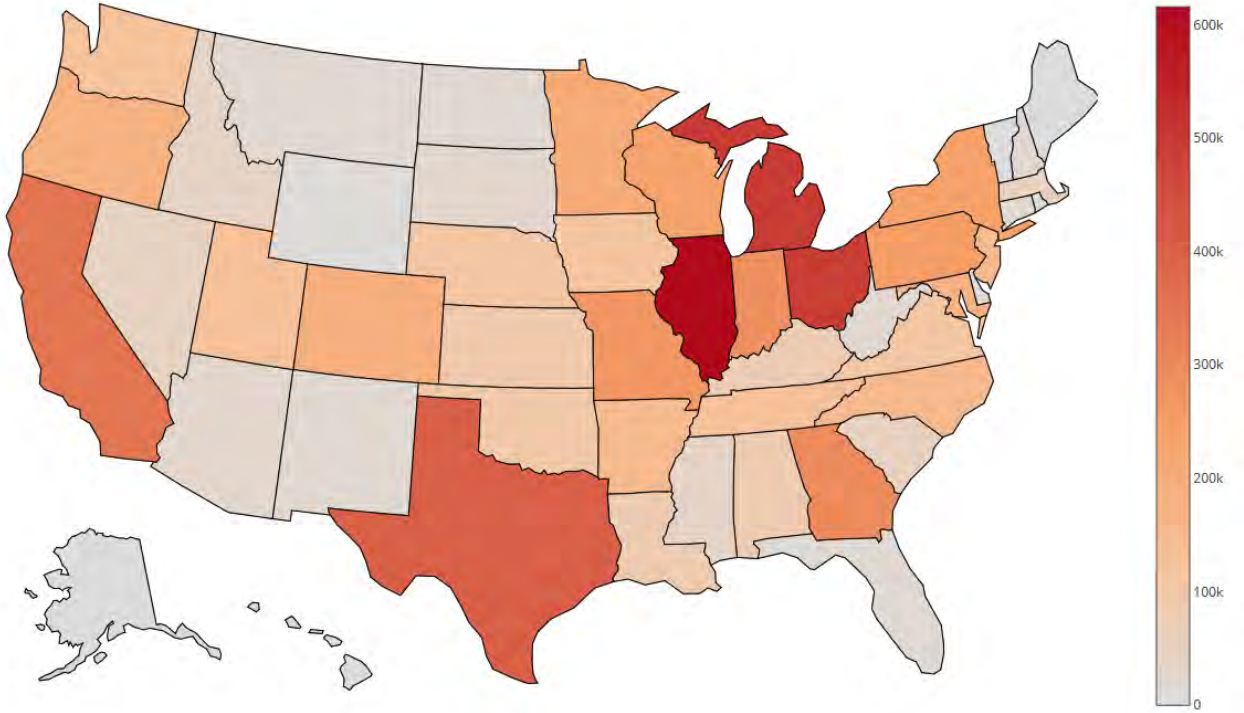
Modest deployment shows big potential for GHG reduction

- Regional variation reflects climate, population, existing equipment

Complete penetration of GAbHPs in U.S. homes over 10 yrs.*:

- 682 MMTCO2 avoided
- $226B operating cost savings
- Pop. weighted savings of $4,200 per household

Next-generation GHPs has even greater potential

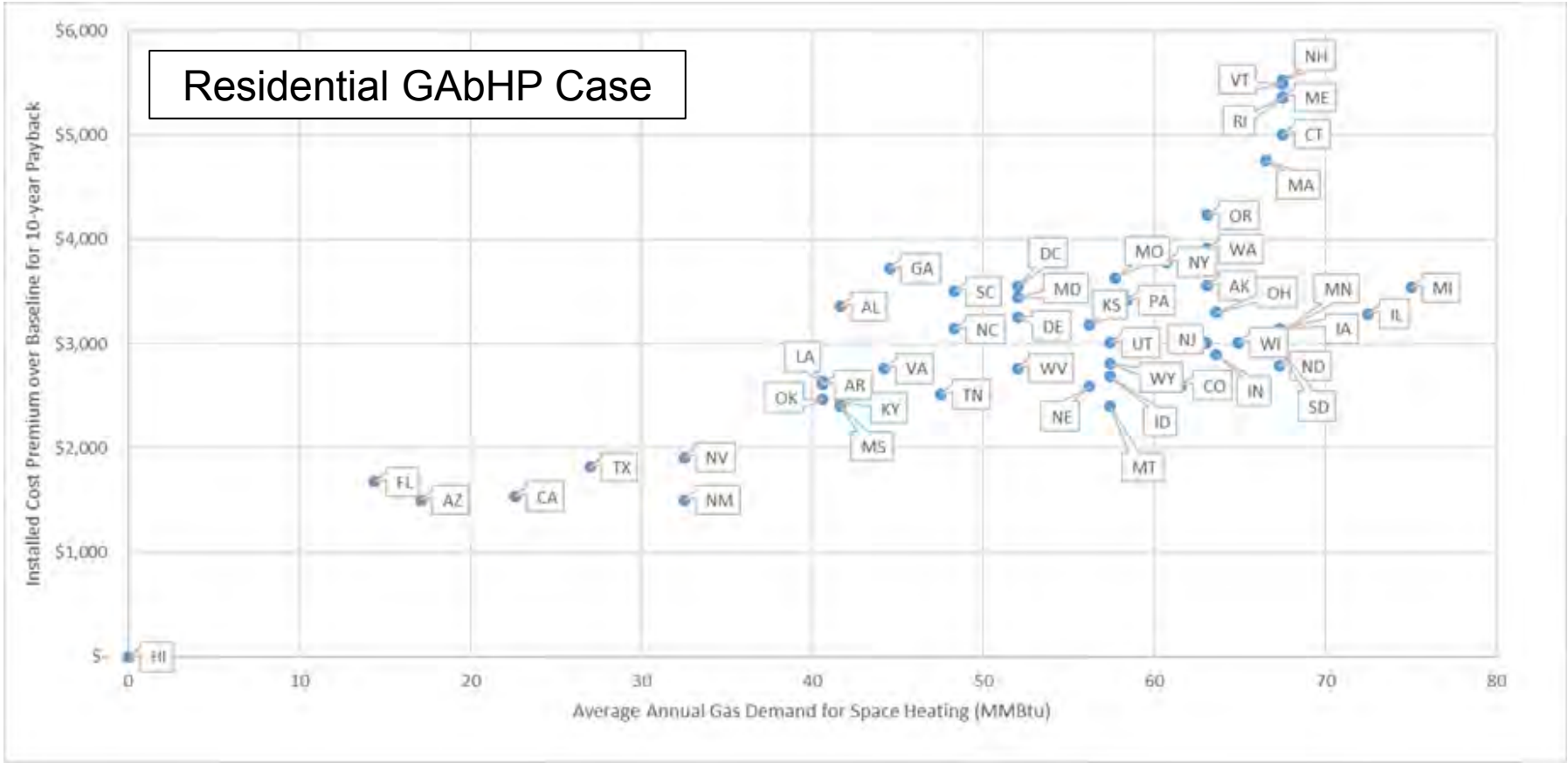


Statewide Annual GHG Emission Reduction (Metric Ton CO_2) for 10% Replacement of Gas Furnaces with GAbHPs

*Neglects new construction, fuel-switching, electricity consumption and assumes 2017 utility pricing, space heating and DHW operation only, accounts for condensing/non-condensing equipment populations

Gas Heat Pumps: History and Technical Potential

GHPs can be cost effective

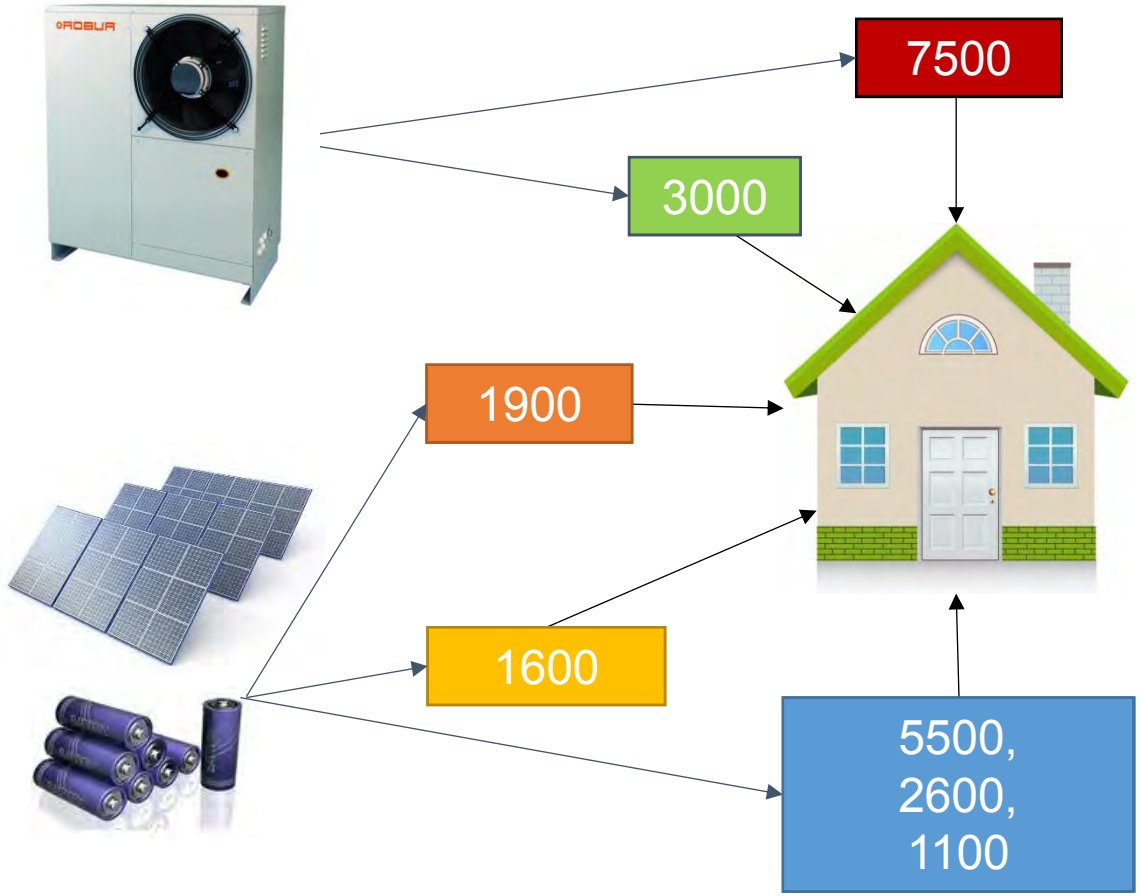


Installed Cost Premium Allowable for a 10-year Simple Payback

*Neglects new construction, fuel-switching, electricity consumption and assumes 2017 utility pricing, space heating and DHW operation only, accounts for condensing/non-condensing equipment populations

Gas Heat Pumps: History and Technical Potential

GHPs can support Net-Zero Energy/Carbon Goals



Annual GHG Emissions (lb/yr)

IECC 2012 Code Compliant Chicago House

Condensing Gas Furnace = 92% AFUE

Standard Gas Water Heater = 0.62 UEF

High-Eff. A/C = 18 SEER

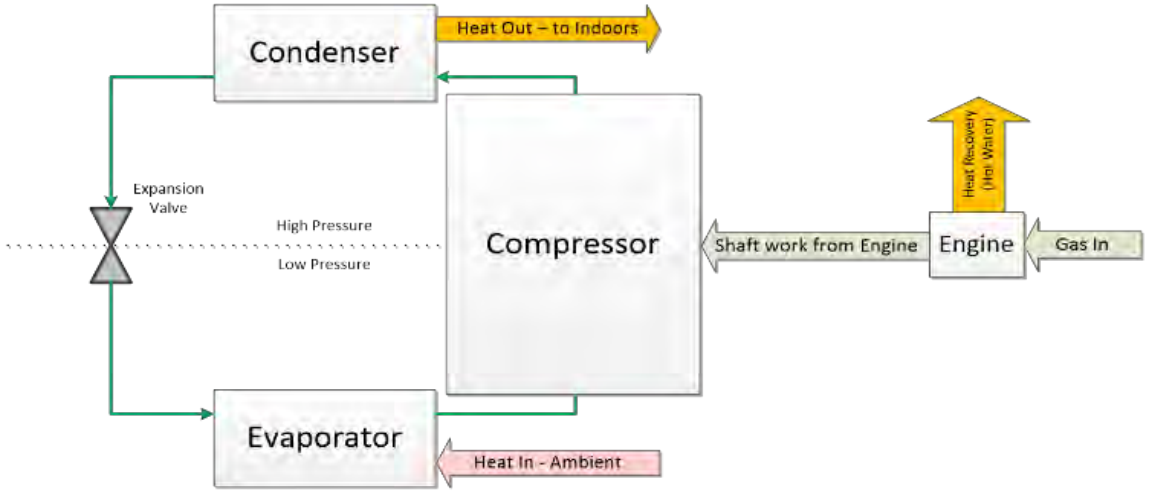
Code Compliant Lighting

Code Compliant Plug Loads, Appliances

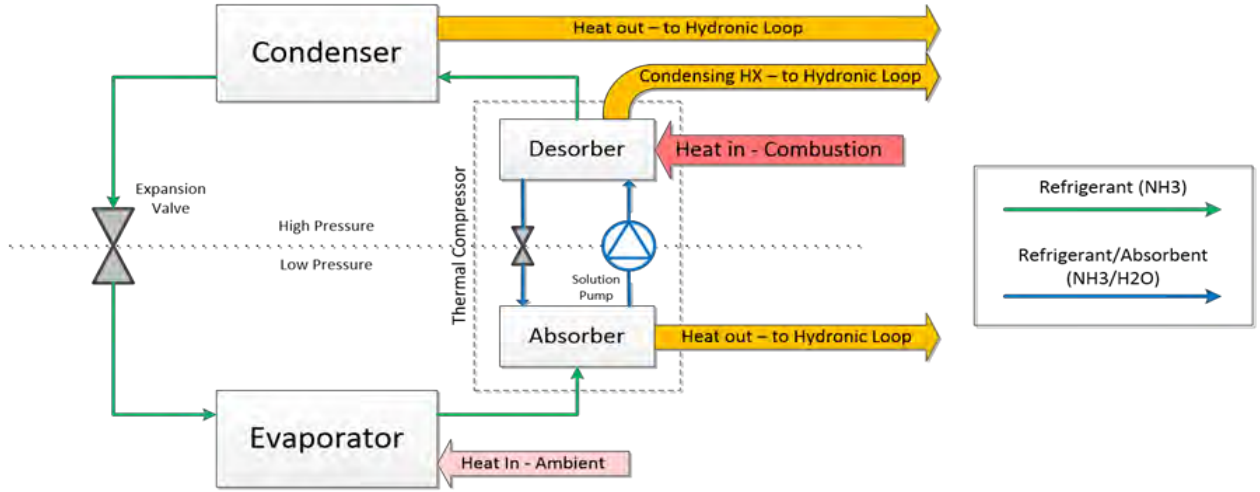
Data Source: Glanville, P., Kerr, R., Keinath, C., and Garrabrant, M., (2016), *The Role of Gas Heat Pumps in Zero Net Energy Buildings*, Proceedings of ACEEE Summer Study on Energy Efficiency in Buildings, Asilomar, CA.

Gas Heat Pump Primer

- **Gas Engine Heat Pumps (GEHPs):** Mature, strong market in Asia with 100,000s of units in operation. Generally focus on peak electricity demand reduction with A/C mode.
- **Gas Absorption Heat Pumps (GAHPs):** Building on significant RD&D efforts in 80s/90s, primarily for heating applications in EU/Asia. Recent push for residential-sized products as “beyond condensing”.



Simplified GEHP Cycle

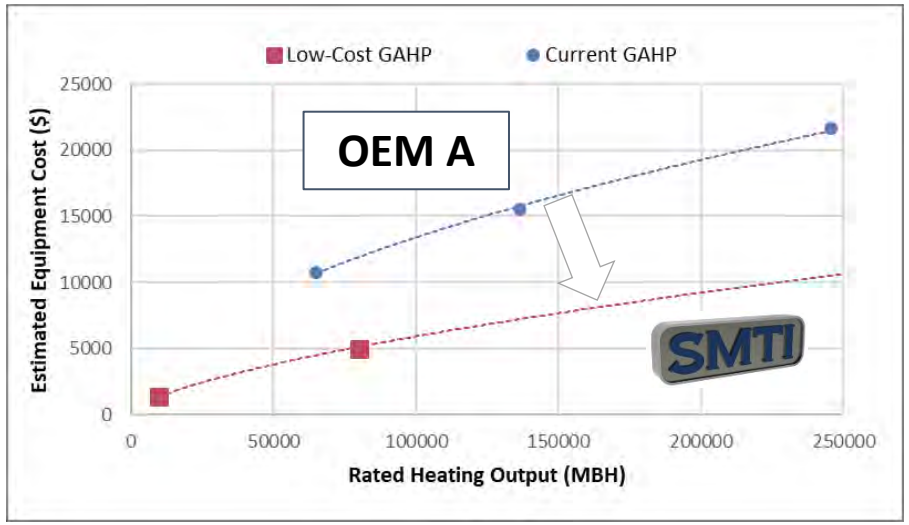


Simplified SE GAHP Cycle – NH3/H2O

- **Emerging GHPs:** Adsorption, external combustion engine, ejector, other exotic cycles

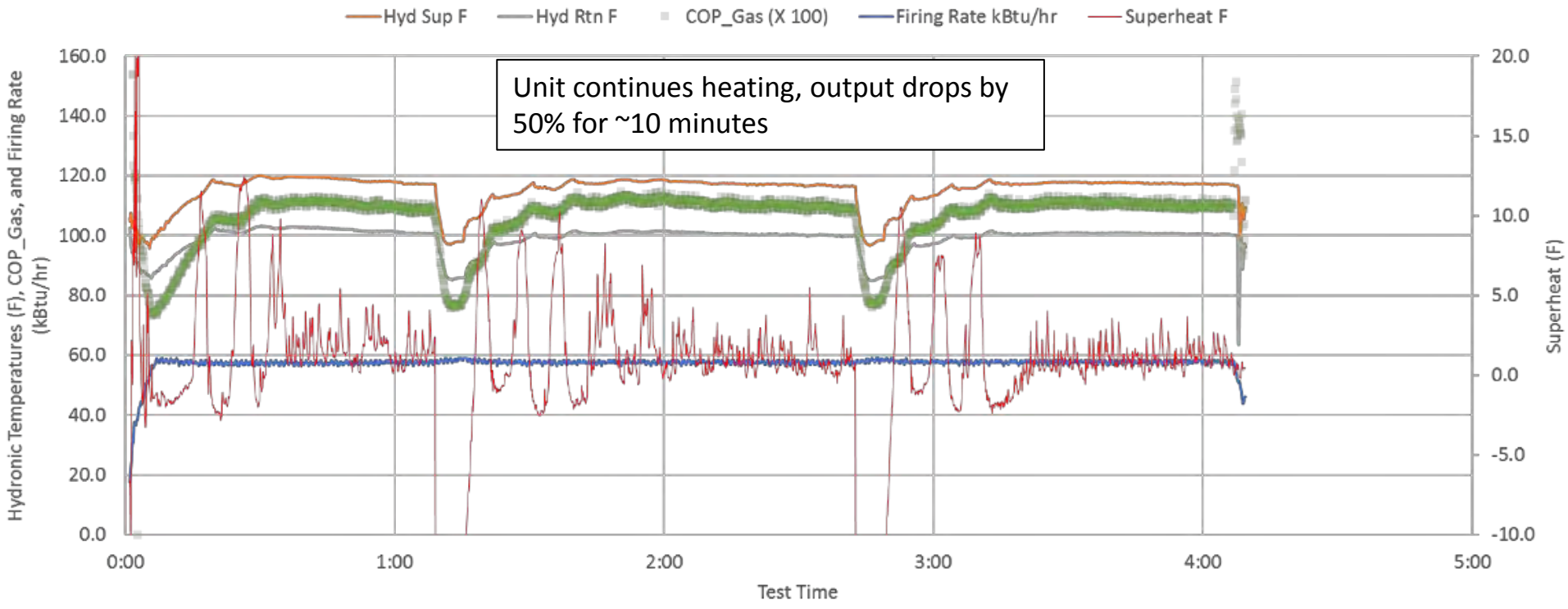
GHP Spotlight: Low-Cost GAbHPs

- SMTI started in 2008 to bring low-cost GAHPs to the market, driving down equipment costs with up-front value engineering and use of easily manufactured HX designs.
- GTI, with strong support from gas industry helped move Gas HPWH and GAHP combi system from proof-of-concept to field demonstration, ~10,000 hours accumulated
  - Best-in-class efficiency, with 1.2-1.3 UEF and 140% AFUE projected



GHP Spotlight: Low-Cost GAbHPs

Improved Thermal Comfort: GAbHPs in lab/field testing show whole-house heating with 45% savings, 4:1 modulation, no aux./backup, down to -25°C.



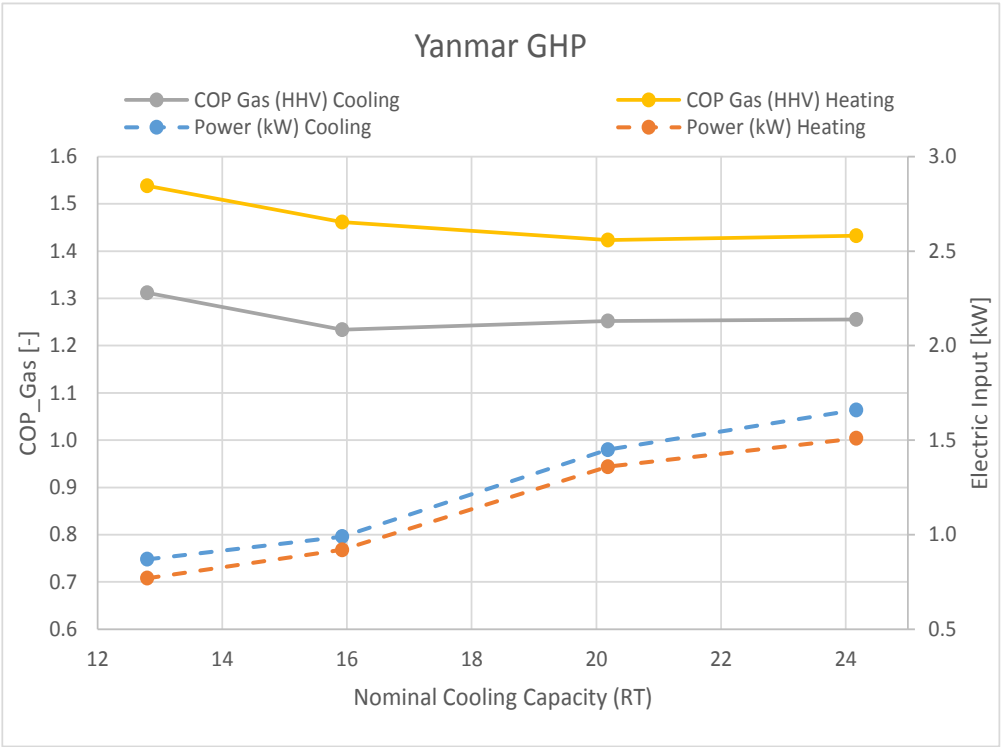
Combi Unit Defrosting in Field

Source: AC Docs

GHP Spotlight: GEHPs in Commercial HVAC

- GTI has supported long history of developing GEHPs for buildings, recently proving economics through pilots
- Cold climate performance of 15-ton NextAire™ showed:
  - Capacity reduced by 5% at lowest test temperature (5F); Heating efficiency: 1.20 to 1.30 COP at full load (47F).
  - Efficiency reduced when colder and at part load; VRF air handler design can improve efficiency by up to 20%
- Additional studies on residential-sized GEHP, Yanmar GEHP, and Side-by-side Field Trial of GEHP/EHP at DoD Facility

Yanmar GEHP has high performance with its recent generation products



GHP Spotlight: The Next Generation

Other GHP Tech. Developments:

- Vapor Adsorption GHPs (GAdHPs) can leverage simple design, working fluids to yield **low-cost GHPs** at small/mid-scale.
- Similarly, Ejector GHPs (GEjHPs) can deliver cost-effective, A/C in **solar/waste heat-driven** applications.
- External Combustion Engine (ECE) GHPs have **significant potential** for outperforming all GHPs discussed in heating/cooling, including high/low temp. operation

Image Source: boostHEAT

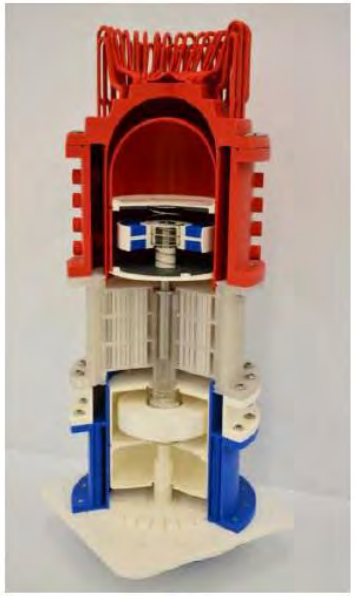
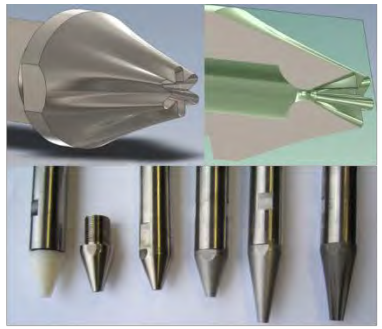


Image Source: Thermolift



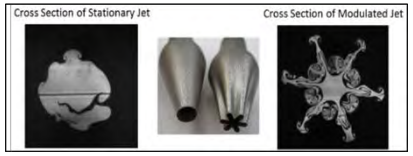


Image Source: MRTS

Thank you!

For more information:

paul.glanville@gastechnology.org

Gas Technology Institute

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

www.gastechnology.org