OCTOBER 8 & 9 DOWNEY, CA

ET Summit Fall 2018

COMMERCIAL + RESIDENTIAL BUILDINGS

Gas-fueled Absorption Heat Pump
Commercial Water-Heaters

On the way to commercialization

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Agenda

1. What is & why the gas-fueled Absorption cycle?
2. Application Focus: Restaurant Water-Heating
3. Application Focus: Commercial Laundry Water Pre-Heat
4. General progress towards commercialization
5. How Utilities Can Prepare
6. Q&A

Heat Pump Types

Comparing Various Types of Heat Pumps	GAHP Gas Absorption Heat Pump	GEHP Gas-Engine Heat Pump	EHP Electric Heat Pump
Thermodynamic Cycle	Gas Absorption	Vapor Compression	Vapor Compression
What Drives the Compressor Stage?	Heat	Recip. Engine - mechanical	Electro. Motor - mechanical
Input Fuel	NG, LPG, Oil, BioFuel	NG, LPG, Oil, BioFuel	Electricity
Refrigerants	NH_3 / H_2O	R410A, R134A, CO_2	R410A, R134A, CO_2
GWP	*zero*	*1300, 1725, 1.0*	*1300, 1725, 1.0*
Backup (resistance) Heater (water-heating appl)	rare	needed if it gets cold	needed if it gets cold
Typical Heating COPs (@120°F supply)			
Ambient Temperature 47°F *Equipment*	*1.45*	*1.30*	*3.50*
Ambient Temperature 47°F Primary Energy	**1.32**	**1.18**	**1.01**
Ambient Temperature 17°F *Equipment*	*1.30*	*1.15*	*2.30*
Ambient Temperature 17°F Primary Energy	**1.18**	**1.05**	**0.66**

PEF - Electricity (US avg)	*3.15*
PEF - Natural Gas	*0.91*
COPs at the standard rating point (47°F)	

GAHP

GEHP

EHP

What is a Gas-fueled Absorption Heat Pump?

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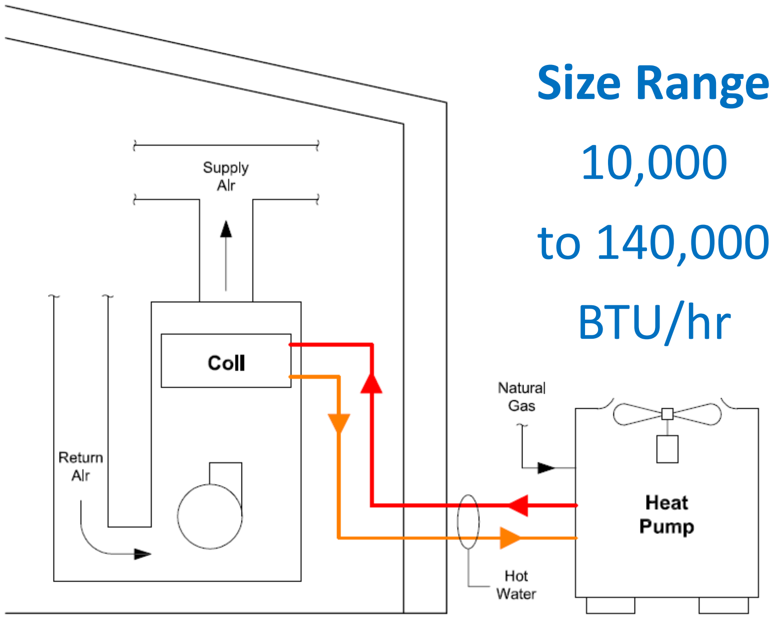
- **Warm Comfort:** useable in all heating system types
- **All Climates**: **excels in cool/cold weather**
- **All Fuels:** natural gas, propane, fuel-oil, bio-fuels
- **Very High Fuel Efficiency**: 1.45 (COP)
- **Natural Refrigerant** (GWP = 0)



Size Range

10,000

to 140,000

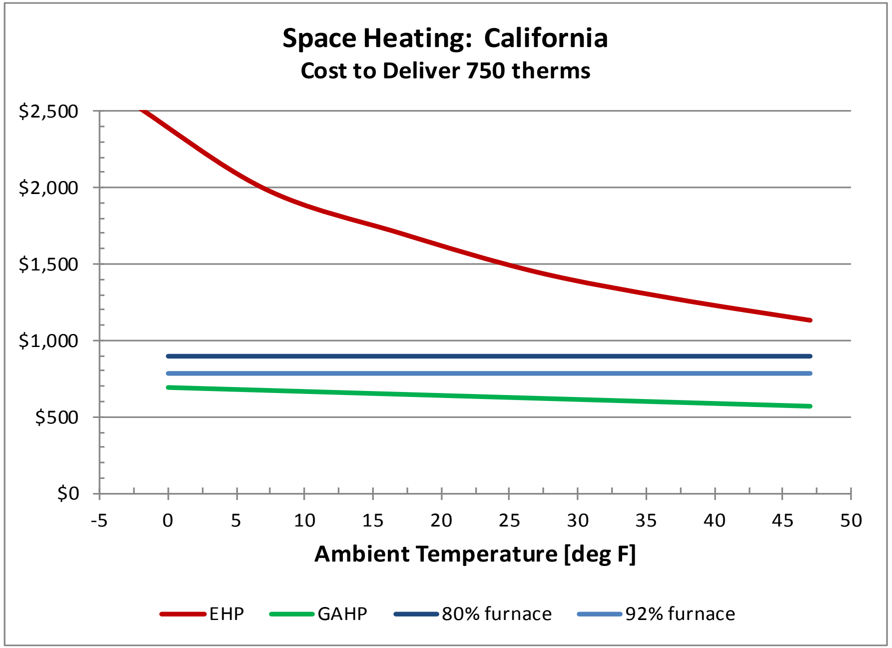
BTU/hr

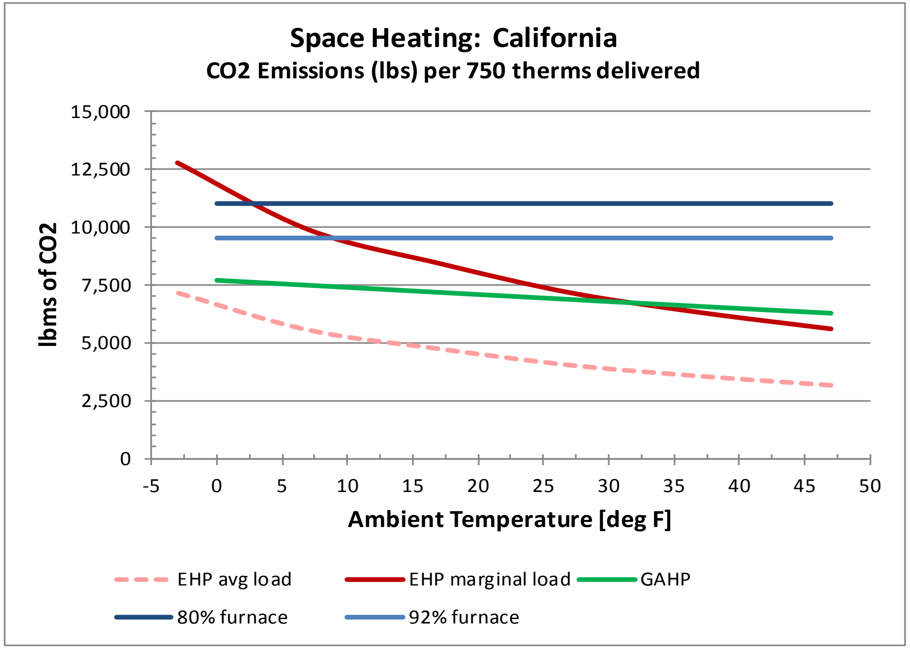
Many Uses:

- ✓ *Residential Space-heating*
- ✓ *Residential Water-heating*
- ✓ *Commercial Water-heating*
- ✓ *Commercial Space-heating*
- ✓ *Pool Heating*

30-50% energy & cost reduction

Reduces Heating Cost & Emissions by 30-50%





EHP = Standard 8 HSPF Electric Heat Pump

NG Rate: $0.80 / therm
Elec Rate: $0.14 / kWh

Emissions Data: eGRID 2016
CA Electrical Grid: 0.528 lb. / kWh (total average)
0.943 lb. / kWh (non-baseload)

Focus: Restaurant Water-heating

Gas Absorption Heat Pumps for Restaurant Hot Water + Free Cooling

- Full-service restaurant DHW loads dwarf all other food-service type buildings in gas usage.
- Often have waste heat that can be recovered (from cooking equipment, people, etc.), or just need to be cooled from weather.
- GAHP output ratio (heat to cool, ~2.25 : 1). DHW is the dominant load. Thus, GAHPs will always need to run, year-round.
- Free Cooling function is optional (switch on whenever it is needed) costs nothing.

Application Overview

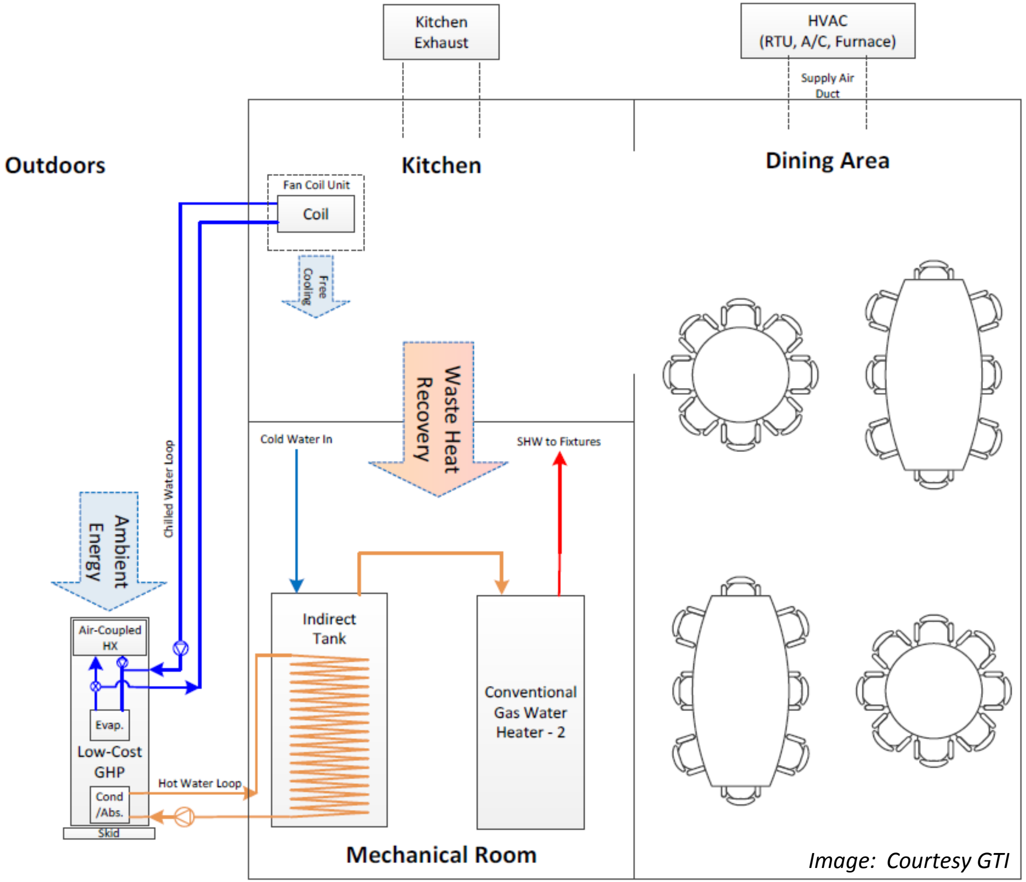


Image: Courtesy GTI

Focus: ***Restaurant Water-heating***

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Specifications
("80K")

	Specification	Notes
Heating Output	80,000 BTU/hr	Gas input: 55,000 BTU/hr
Cooling Output	2.5 tons (with heating load)	Optional inside cooling, Or draw heat from ambient (outside) air
Venting	n/a	All combustion outdoors
Gas piping	1/2" OD	
Electrical Input	375W / therm	Per therm of delivered heat, 220 VAC single phase
COP gas (heat)	1.45 at 47°F and 100°F return to heat pump	COP is mainly a function of water temperatures (in, out), ambient temp, and cycle times.
Global Warming Potential	0.00	Refrigerant pair: H_20 / NH_3 (charge = 0.2 kg /kW heating capacity; about 10 lbs)
DHW Capacity:	2,200 GPD	Running 16 hours non-stop with 70°F temp rise. However, GAHP will serve as baseload with a "peaker"
Renewable Energy	1/3 of output	Heat drawn from ambient air

Focus: Restaurant Water-heating

California

- 88,000 restaurants
- Full-service locations consume 230 million therms per year for DHW (more than twice that of all other food services combined)
- 90% use gas to heat DHW; 85% use storage tanks – the majority are 80% fuel efficient

Potential Market Impact

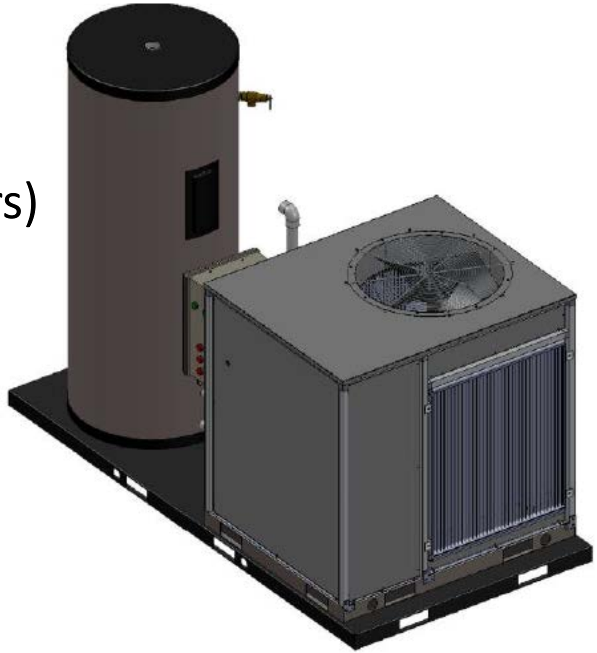
Data: Courtesy GTI

Focus: Restaurant Water-heating

CEC Project for Restaurant Field-Tests

- 2 demonstration sites (southern Calif.)
  - proves concept in live environment
  - gain insights on controls, installation, etc.
- Primary Market Research (contractors and end-users)
- Completion Scheduled: Q4-2019

Market Introduction Target: 2020-21



Commercialization Plan

Focus: ***Restaurant Water-heating***

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CEC Test

- Baseload/peak-load strategy enables maximum run-time; best economics
- Creates proactive replacement sales opportunity
- Load profile will determine economically preferred choice (e.g. 80 vs 140 kBTU)

		Standard	Condensing	GAHP 140K	GAHP 80K
Customer	Equipment Price	**$ 9,400**	**$ 12,700**	**$ 7,400**	**$ 5,300**
	Installation	$ 1,250	$ 1,500	$ 11,200	$ 11,200
	Installed Cost	**$ 10,650**	**$ 14,200**	**$ 18,600**	**$ 16,500**
Annual Energy Cost Savings					
vs. Standard			$ 800	$ 3,100	$ 2,500
vs. Condensing				$ 2,300	$ 1,700
Simple Payback (years)					
vs. Standard			**4.4**	**2.6**	**2.3**
vs. Condensing				**2.0**	**1.4**

Key Assumptions:

* Full-service restaurant using 2,500 GPD DHW (temp rise = 70F°)
* Cost of NG: $0.80 / therm. Cost of Electricity: $0.12/ kWh
* Standard Scenario: (2) AO Smith Masterfit (199kBTU, 100gal storage, 80% AFUE)
* Condensing Scenario: (2) AO Smith Cyclone Mxi (199kBTU, 100gal storage, 95% AFUE)
* GAHP Scenario: (1) GAHP (140 kBTU + 100gal tank, 1.25 COP, 85% load fraction) -- OR --
GAHP Scenario: (1) GAHP (80 kBTU + 100gal tank, 1.35 COP, 66% load fraction)
-- AND -- (1) AO Smith Masterfit (199kBTU, 100gal storage, 80% AFUE, 15% or 34% load fraction)
* Electrical Savings from Cooling included in GAHP ($1,460 of the Fuel Savings). Parasitic power included.
* NO INCENTIVES

Economics

Focus: *Commercial Laundry*

- Large commercial laundry serving multiple area hospitals, nursing homes, etc. Owns, cleans, and delivers the sheets, linens, uniforms, robes and more for each facility.
- Located in Johnson City, Tennessee. One of 55 sites in a company that processes 630 million pounds of laundry annually.
- Part of a national company providing general healthcare facility services to 1,300 locations.
- Entire facility uses ~50,000 GPD water
- Specific GAHP test project is to pre-heat 10,000 to 20,000 GPD of hot water currently served by a steam boiler. Installed March 2018

Project Overview

Focus: ***Commercial Laundry***

Nominal 80% natural gas fired boiler (20+ years old; 21mmBTU)

Steam Heated Tank

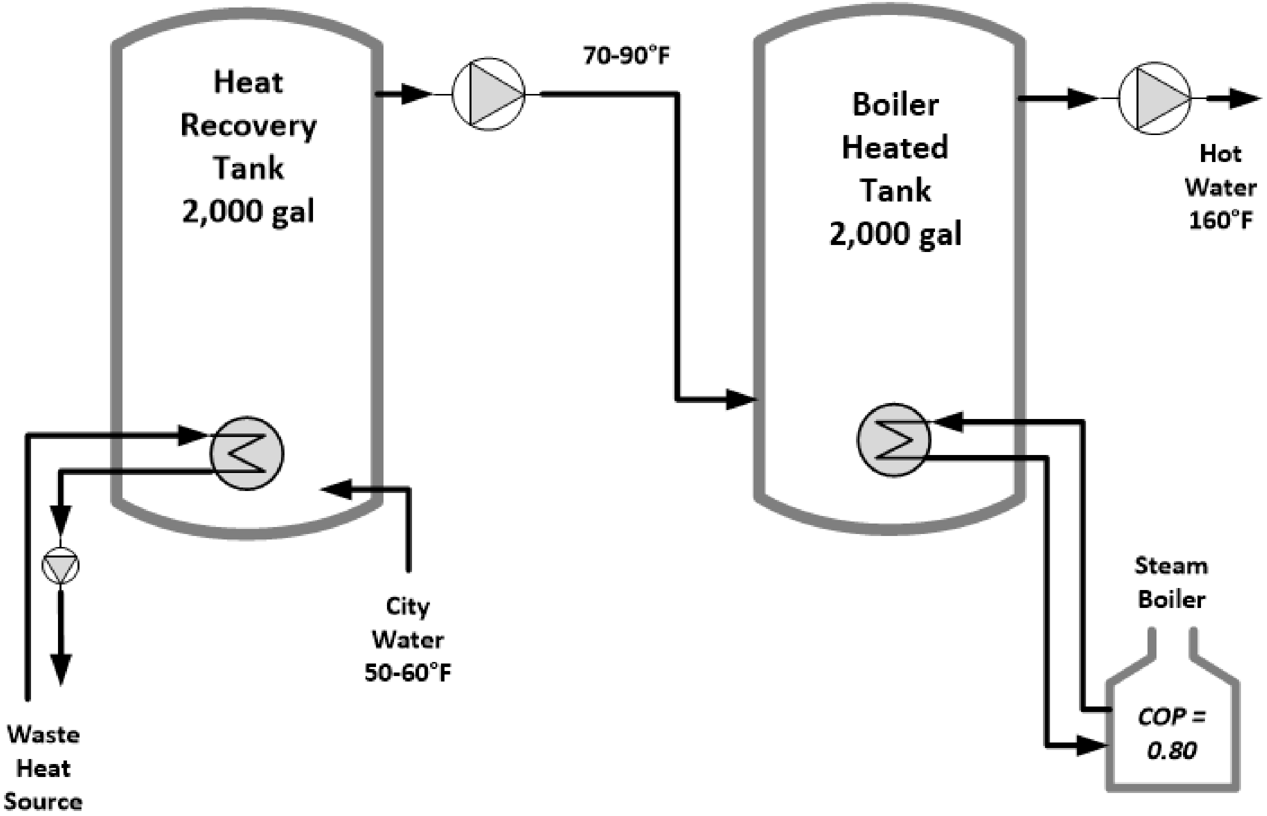
Heat Recovery Tank

Current Configuration

Focus: Commercial Laundry

Current Configuration

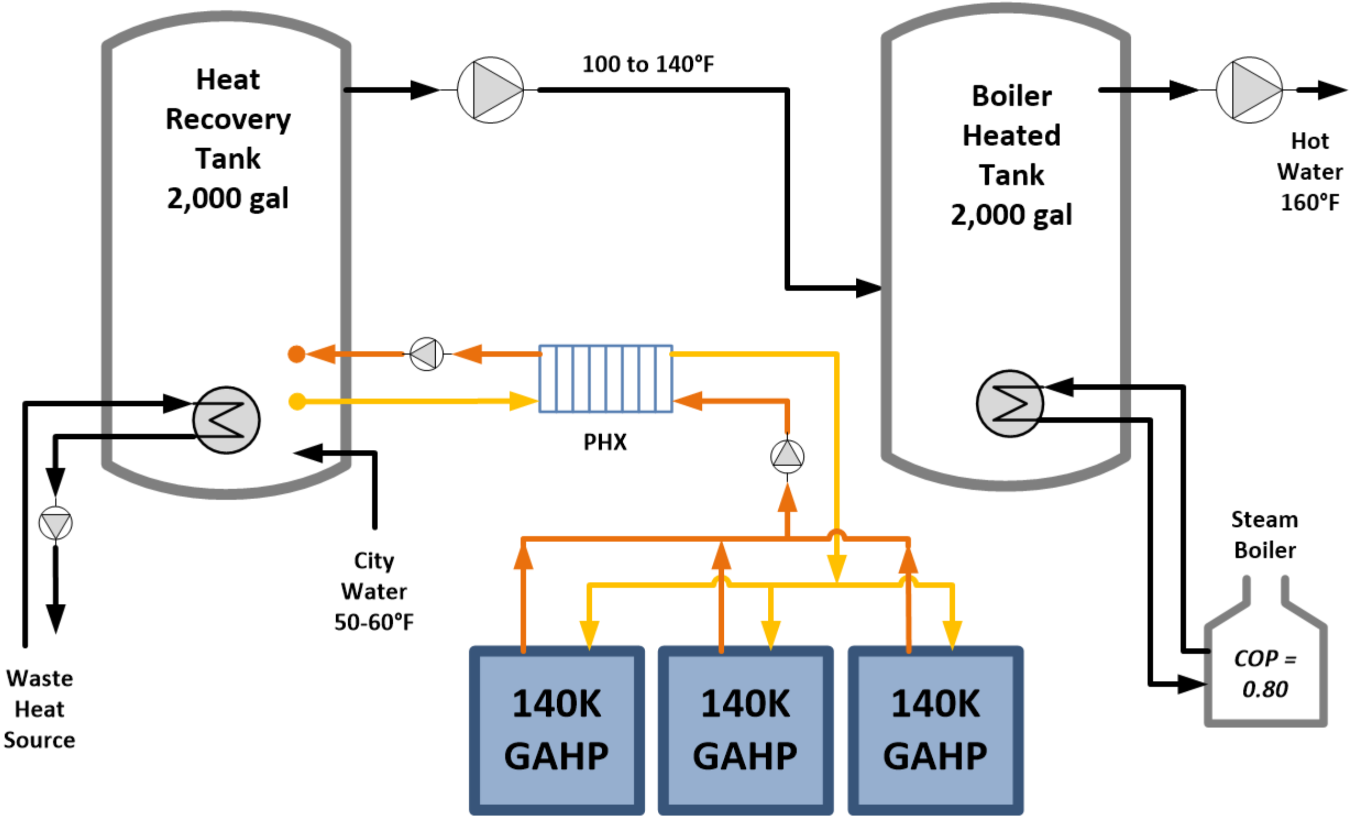
- Waste heat recovered from laundry process
- Steam-boiler driven (COP= 0.80)
- 16,000 gallons per day avg (per flow-metering)
- 6 days/week, 16 hrs/day
- Annual Heat: 43,800 Th
- Annual NG: 54,700 Th
- Annual NG Cost: $50K



Focus: Commercial Laundry

Ideal Configuration

- Multiple 140 kBTU GAHPs (optimized for max baseload coverage and max runtime)
- Boiler covers peaks and backup (significant increase in equipment life)
- Minimal impact on existing configuration

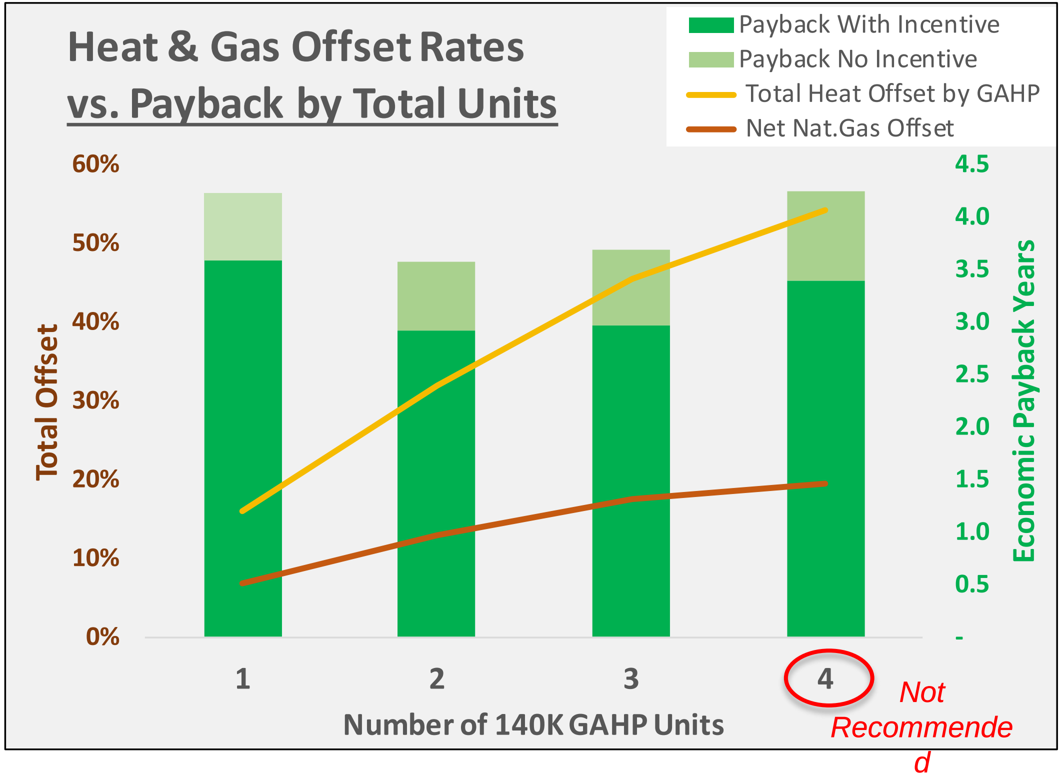


Focus: *Commercial Laundry*

Optimizing Economics

- Payback: 3.7 – 4.2 years (no incentives) or 2.9 – 3.6 years (50¢ / Yr1-therm incentive)
- IRRs (10-year) 20-25% (before incentives)
- Ideal economic picture illustrates flatter load profile (i.e. larger tank)
- Optimal system size is 3 units (45% heat load offset)

Best Strategy: Select largest number of units consistent with load profile, thermal storage, & available cash.



Focus: *Commercial Laundry*

Project Summary

- Field test installed 2018; data available in 2019
- Positive expected project economics, short payback periods
- Tight-margin operations motivate customers to save $$
- Often straight-forward technical application of GAHP technology
- Large consumers of domestic hot water with minimal progress in heating technology efficiency

Commercialization Strategy

Thermal Compressor

HVAC & WH OEMS

End Use Products

- ✓ OEMs as Partners, not competitors
- ✓ Leverages existing brand & marketing power
- ✓ Least-cost, Fastest-to-market, Lowest-risk Pathway

Development Status

- ✓ SMTI Initial Investment (Dec. 2017; multi-million, strategic)
- ✓ Two major products to launch within next 18-24 months (residential furnaces and residential water-heaters)
- ✓ Business model can start with modest volumes.
- ✓ Volume in all market segments benefits all other products
- ✓ Expanding staff and reach with key focus on initial products (commercial hot water is important)

Two Fundamental Questions That Need Answers

Before a Decision to Launch Brand New Product:

1) Will it work,
   at what cost?

2) Who will buy it,
   at what price?

What Can Gas Utilities Do Now?

- Develop incentive scenarios (hypothetical Ok)
- Contribute toward specific product development projects and field demonstrations

- Gas-fueled Absorption Heat Pumps have many building-heat applications
- 30-50% savings in energy and operating costs – generally strong economics
- Significant carbon and other emissions reductions
- Realistic path to market and large scale based on low-cost mfg platform
- Advanced product development now underway
- Gas utilities should begin preparations now

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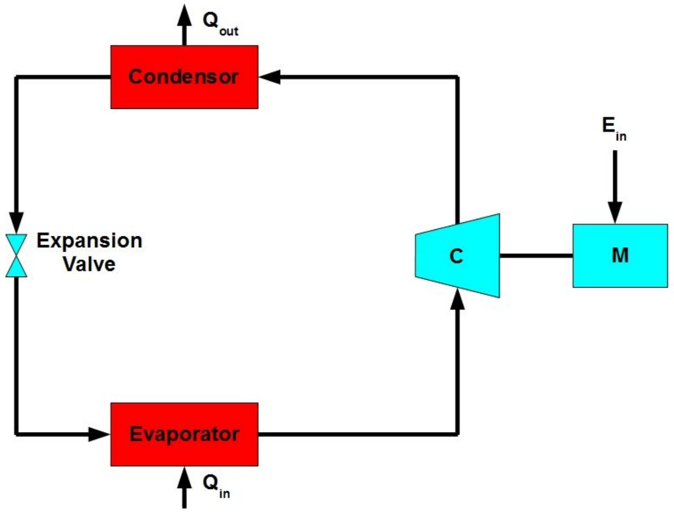
Attic Slides

How Does It Work?

Vapor Compression Cycle



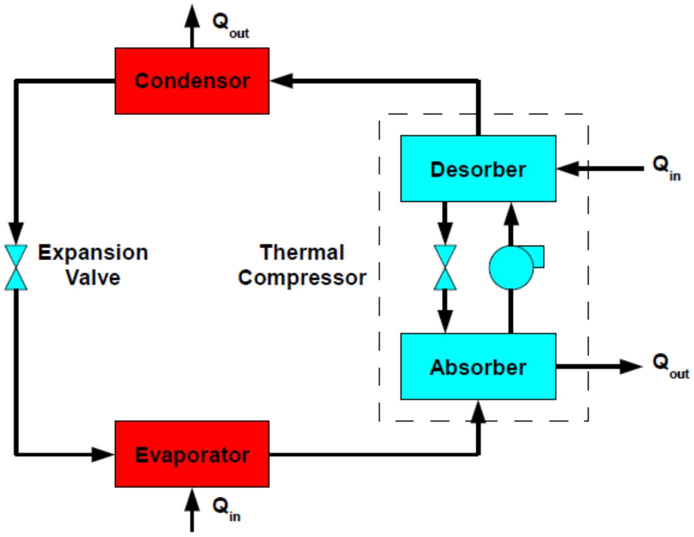
$COP_h = Q_{cond} / E_{in} = 3.0\text{-}4.0$

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

$COP_{PE} = COP_E \times (0.91 / 3.15)$

$0.91 = PEF_{NG}$ $3.15 = PEF_E$ *(US avg)*

Gas Absorption Cycle

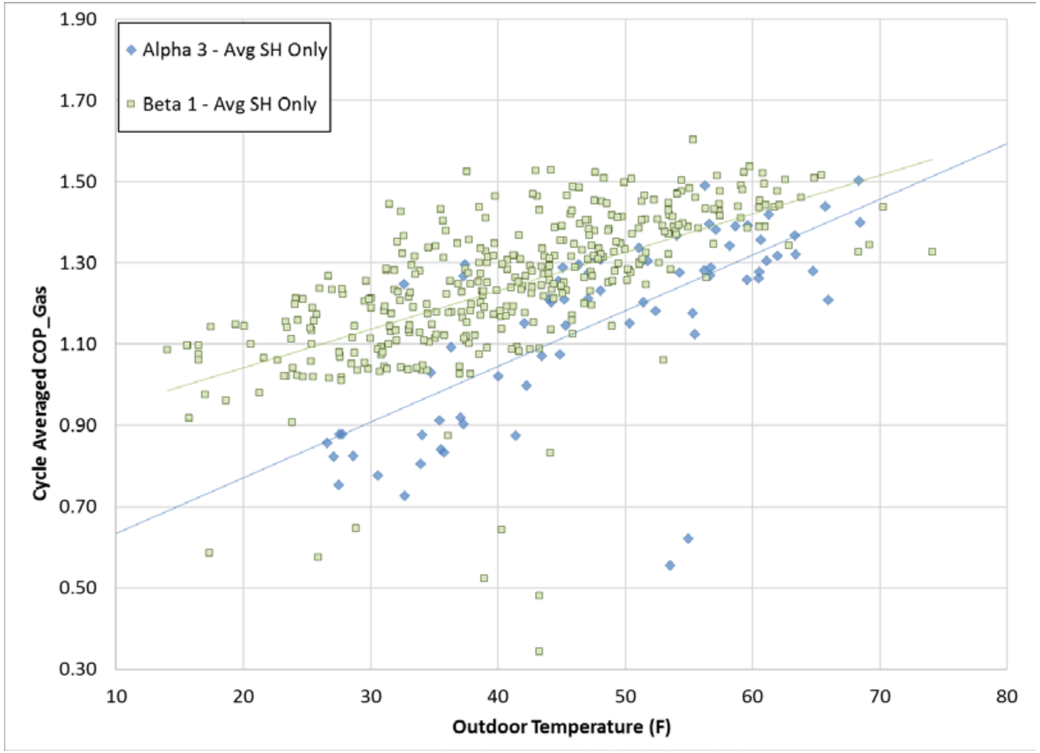


$COP_h = (Q_{cond} + Q_{abs}) / Q_{in} = 1.4\text{-}2.0$

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

Past Performance Testing

- GTI confirmed performance on successive generations of 80K GAHPs (2016-18)
- Additional 80K units (4th gen) in the field 2018-20. Incorporating lessons learned from previous generations and exploring new uses (beyond residential space-heating).



Data from GAHP Combi Sites highlighting improvements in 1st to 2nd generation prototypes (now on 4th gen)

Courtesy GTI

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.

Focus: Restaurant Water-heating

CEC Test Scenario

Standard

AOS
Master-fit
199kBTU, 100gal, 80% TE

Condensing

AOS
Cyclone Mxi
199 kBTU, 100gal, 95% TE

GAHP 140K

SMTI
Gas Absorption HP + Indirect Tank
140 kBTU, 140% AFUE (assumed TE 125%)

+

AOS
Master-fit
100gal, 80% TE

GAHP 80K

SMTI
Gas Absorption HP + Indirect Tank
80 kBTU, 140% AFUE (assumed TE 135%)

+

AOS
Master-fit
100gal, 80% TE

Economic Modeling Scenarios

Other Gas-Fueled Absorption Products

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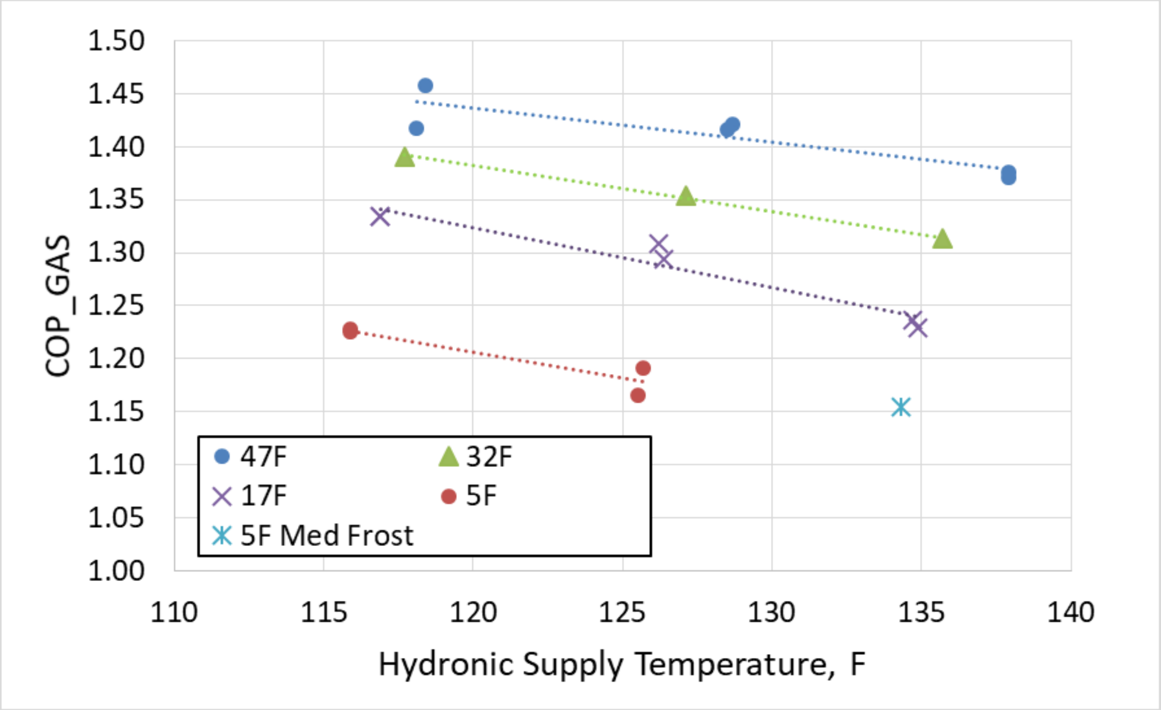
- **Residential Space-heating (furnaces)**
  - $2.7 million project with DOE & major OEM partner
  - Final ready-for-market design & testing
  - Primary market research on contractors & consumers

- **Residential Water-heating (storage water-heaters)**
  - CEC / GTI project with major OEM partner
  - In-home field-tests of advanced design WHs
  - Primary market research on contractors & consumers

- **NZE / Low-load Homes (wall-hung unit)**
  - Engie (France) contract to design 20kBTU unit (tested by GTI)
  - Outdoor mounting provides combi (space & water heat)
  - Also applicable to N. American markets

Focus: Commercial Laundry

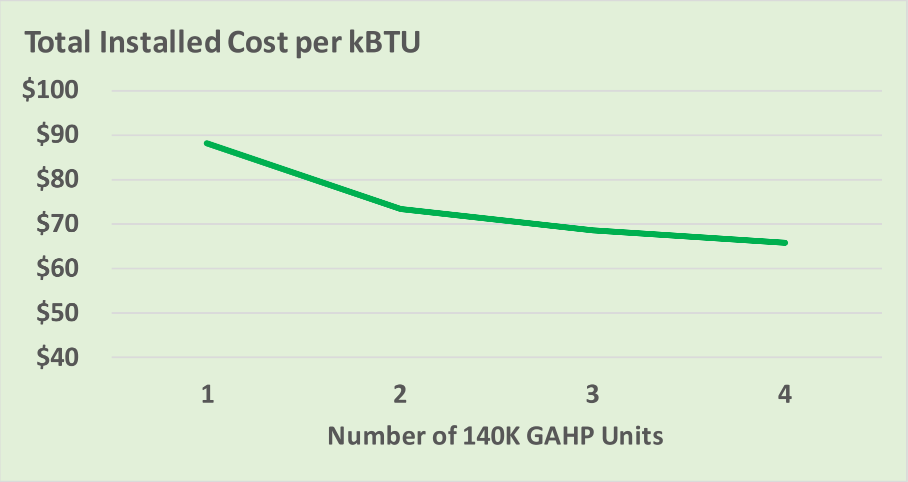


Performance: vs. Supply & Ambient

Focus: *Commercial Laundry*

Economic Assumptions

- Operations: 5,000 hours / year
- Average COP_{GAS} : 1.40 – 1.25 (depends on # of units)
- A single 140 kBTU unit
    - ❖ Delivers 7,000 therms / year
    - ❖ Offsets 3,700 therms / year (against 80%)
    - ❖ Parasitic Electricity: 304 W / $therm_{OUTPUT}$
- Cost of Natural Gas: $0.904 / therm (TN)
- Cost of Electricity: $0.100 / kWh (TN)



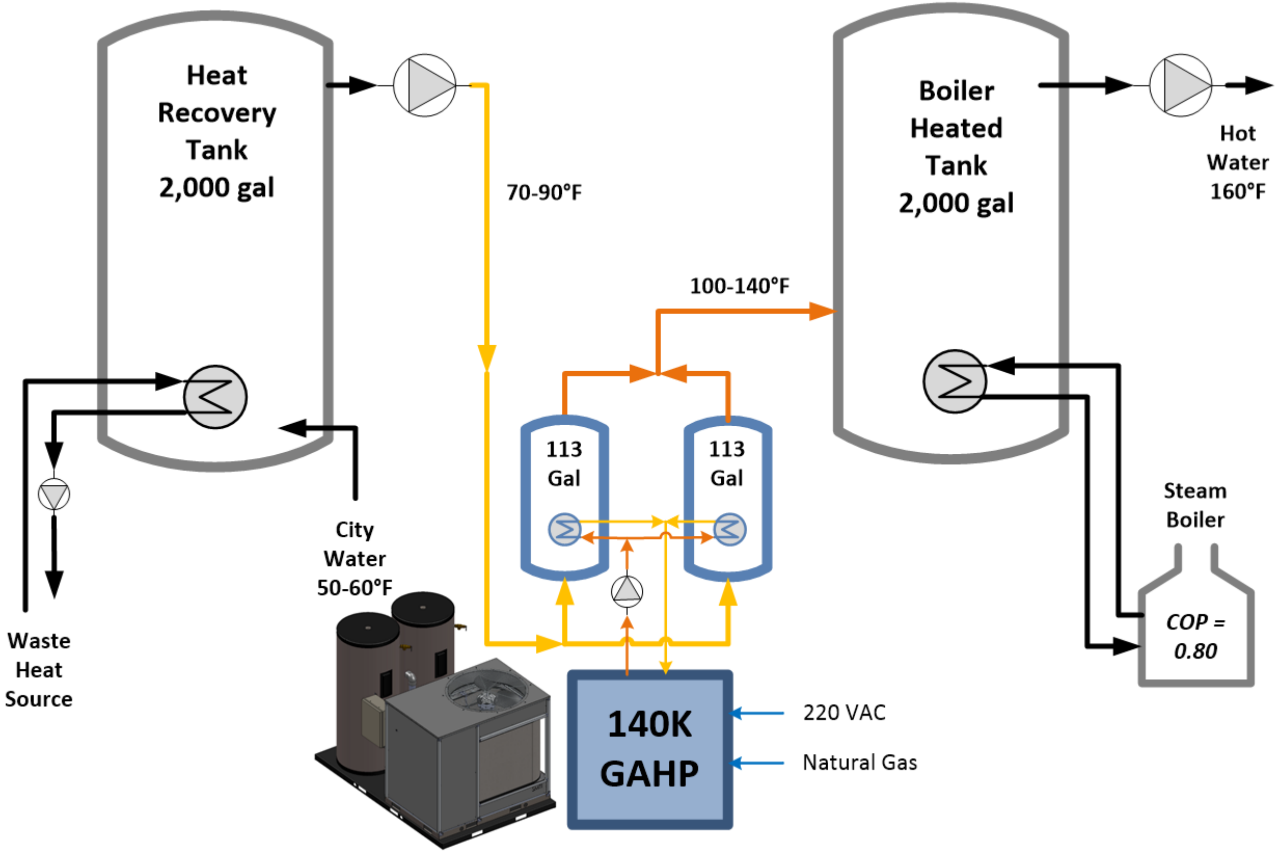
Expected Economic Outcomes

- Net Energy Cost Savings: $3,200 / unit / year (TN)
- Increased life of existing boiler equipment

Focus: ***Commercial Laundry***

Test Configuration

- Single 140 kBTU GAHP (for baseload – max run time)
- Boiler covers balance (85% of current duty)
- Temporary nature of the test dictated intermediate tanks to exchange heat
- New heat exchangers (in small tanks) not ideally sized



HVAC Mfr'g: Go-to-Market Steps

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5-10 years

Technology Design & First Prototypes *(SMTI R&D)*

Bread Board ➤ Basic Engineering ➤ First Proto ➤ Lab Tests ➤ 1st Field Testing ➤ Reliability Run Tests

…….Market Research…….

12-24 months

Product Development: DFM / Joint Prototype

Joint Engineering ➤ * T.C. Design * BOS Design ➤ * T.C. Proto * BOS Proto ➤ Joint Proto ➤ Lab & Field Tests

…….Market Research…….

9-18 months

Prepare for Production

Refine / Finalize Design ➤ Final Proto ➤ Field Tests / Reliability Run Tests ➤ Production Design ➤ Buy Capital Equipment ➤ Production Test Runs

Launch!