140% AFUE is Coming

Introducing Thermal Heat Pumps

Jason LaFleur

EEBA
VIRTUAL HIGH PERFORMANCE HOME SUMMIT 2020
SEPT 29 - OCT 9 | ONLINE VIA WHOVA
EXTENDED

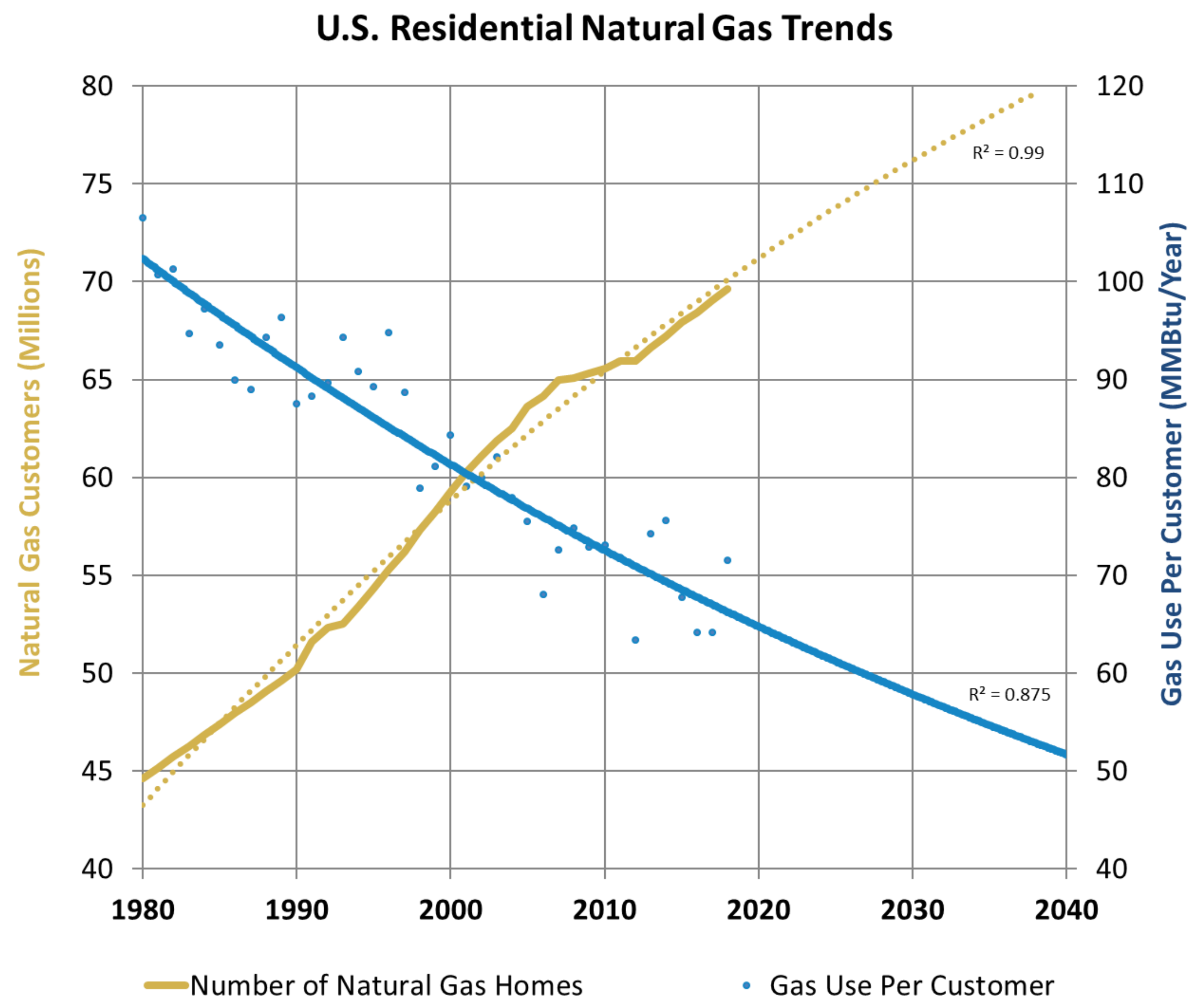
GTI: Turning Raw Technology into Practical Solutions

Jason LaFleur **jlafleur**@gti.energy

www.gti.energy

Photo: Dvele

Dvele + GTI automating all-electric Passive House modular homes with DOE support



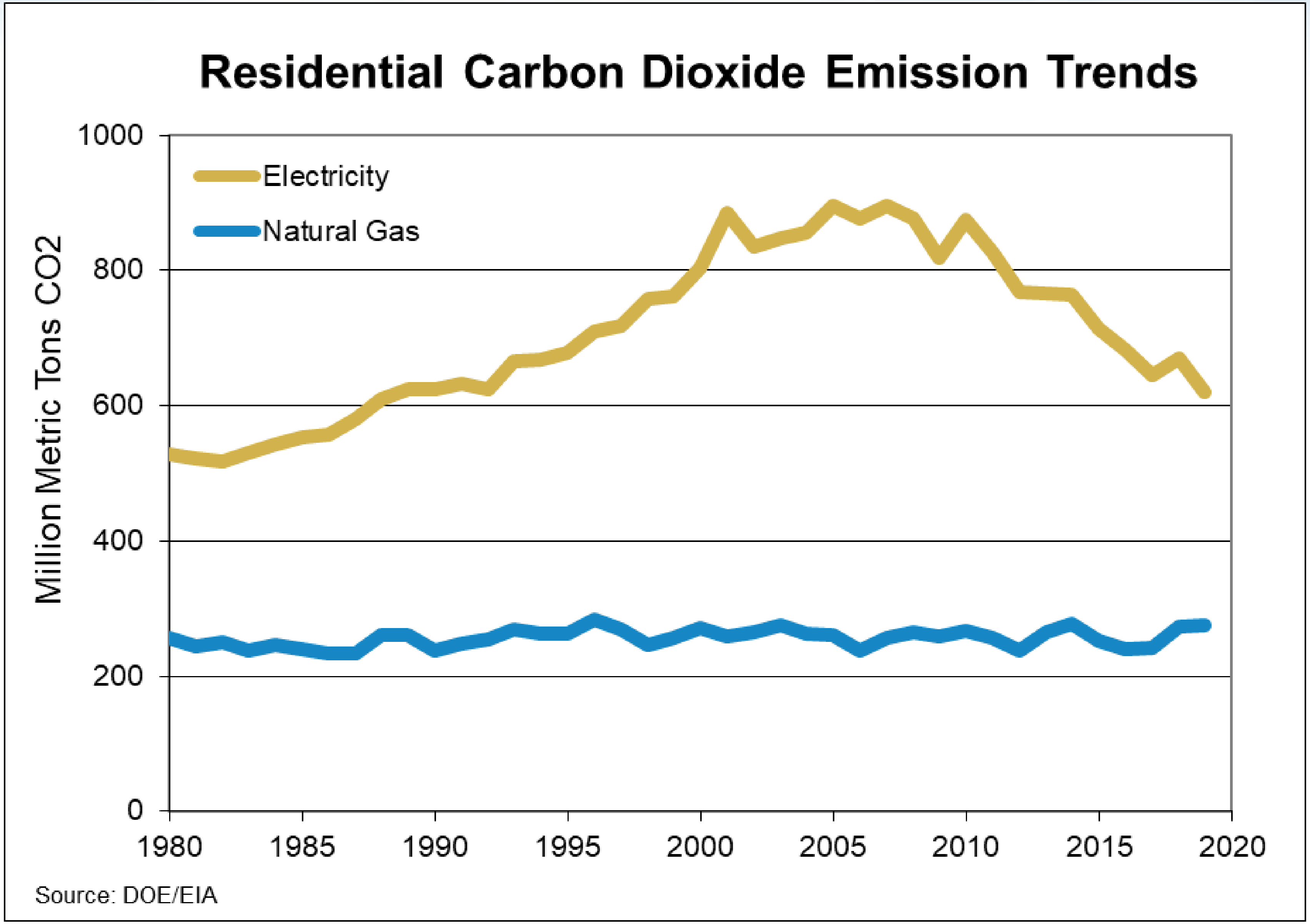
Source: DOE-EIA. Annual variations due manly to weather (e.g., annual heating degree days)

Thank You Builders!
Real Progress Made Since 1980

Your embrace of new technology has helped average U.S. natural gas home use trend downward for four decades.

25 million more homes (+55%) using natural gas since 1980 with **no change in total demand**. About 26% decline per home since 1980.

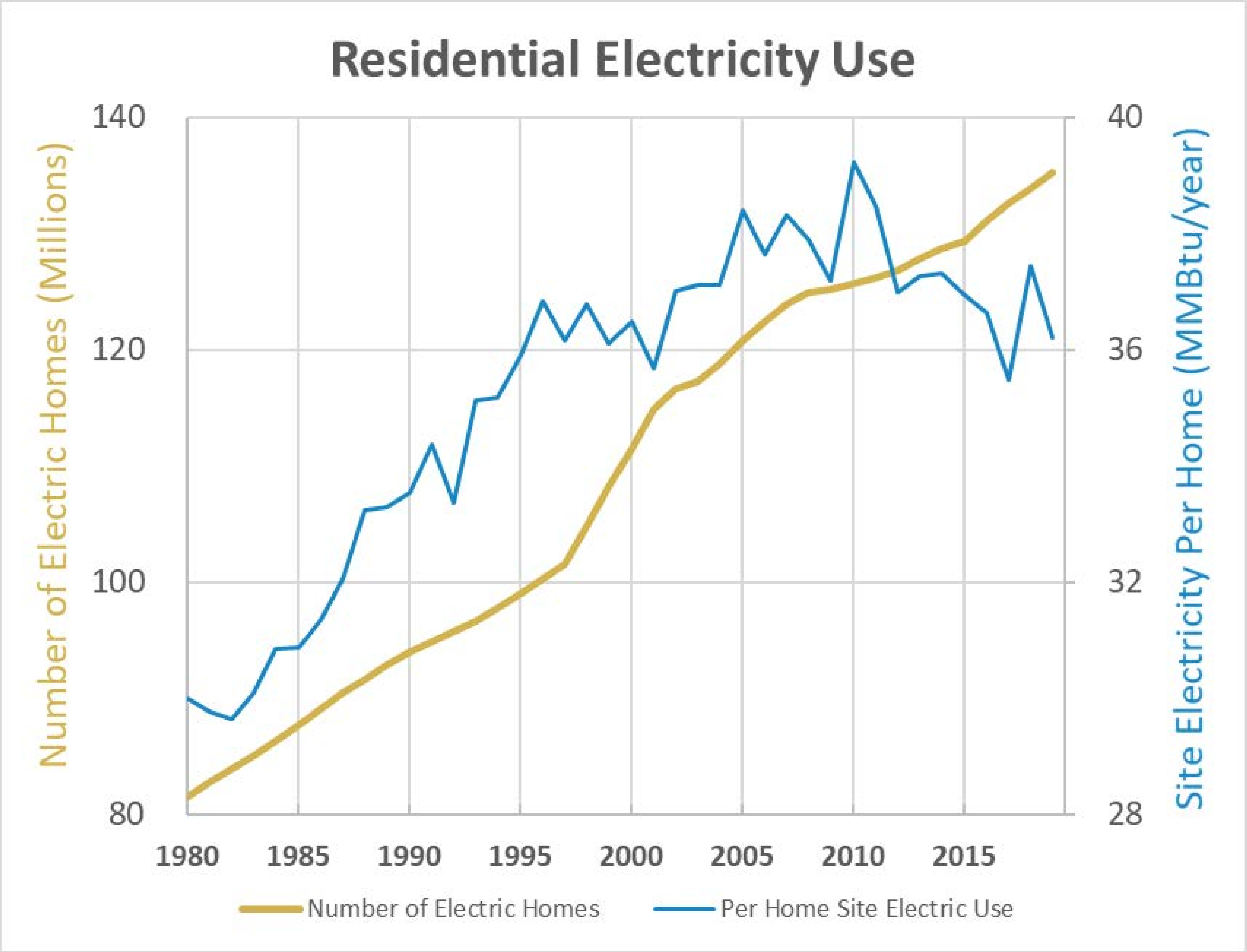
Further penetration of high-efficiency natural gas equipment and home weatherization can build on this trend.



Electric grid emissions are critical.

After growing since 1980, residential electricity GHG emissions showing significant decrease (including coal displaced). Still above 1980 levels.

No net change in CO_2 emissions with a 55% increase in the number of gas homes (+25 million) since 1980.



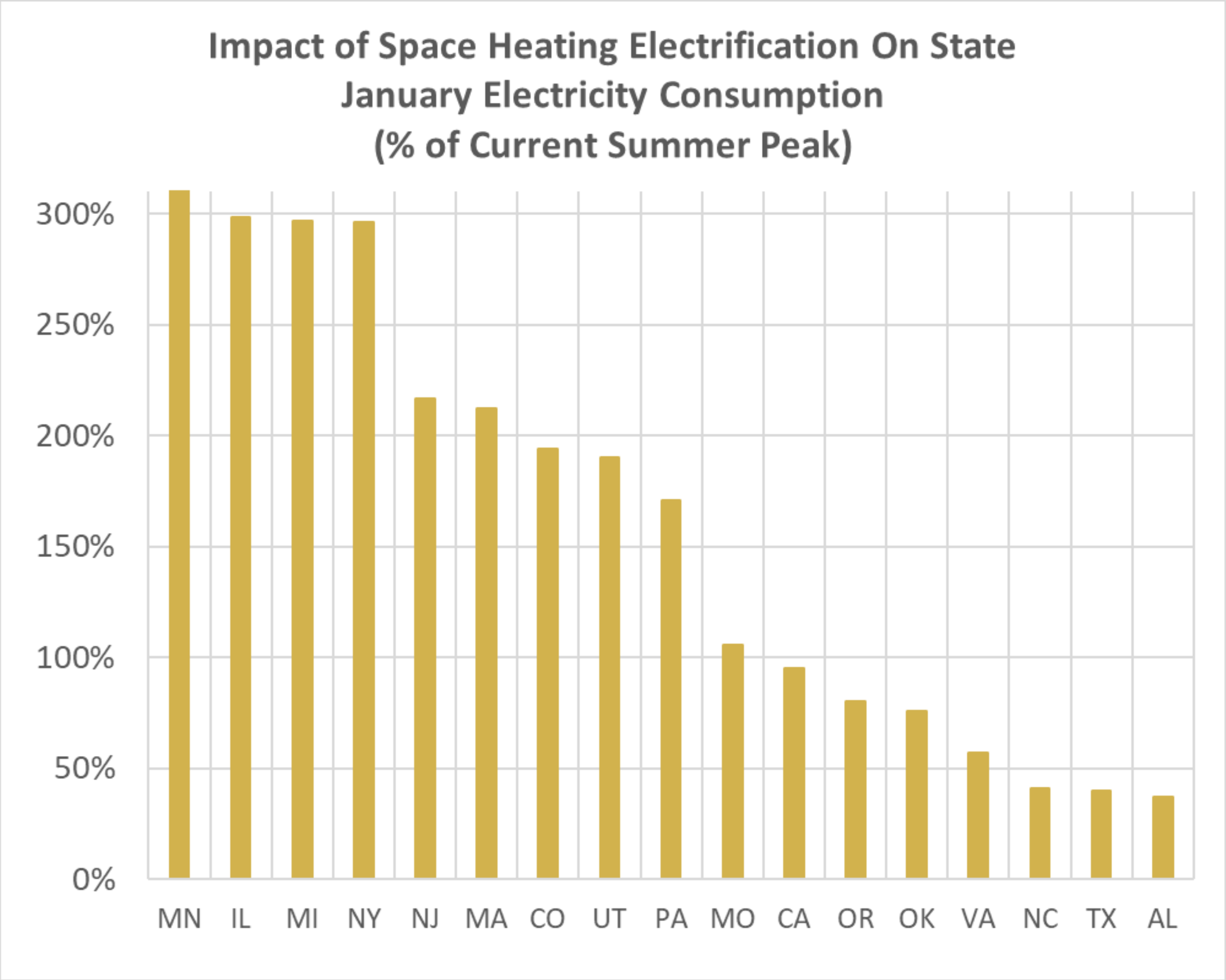
Since 1980, average per home annual consumption of electricity has increased 20%.

Growth in per home electricity use has leveled off over past 20 years.

BUT:
Impacts of EV charging?

Source: DOE Energy Information Administration; US Census

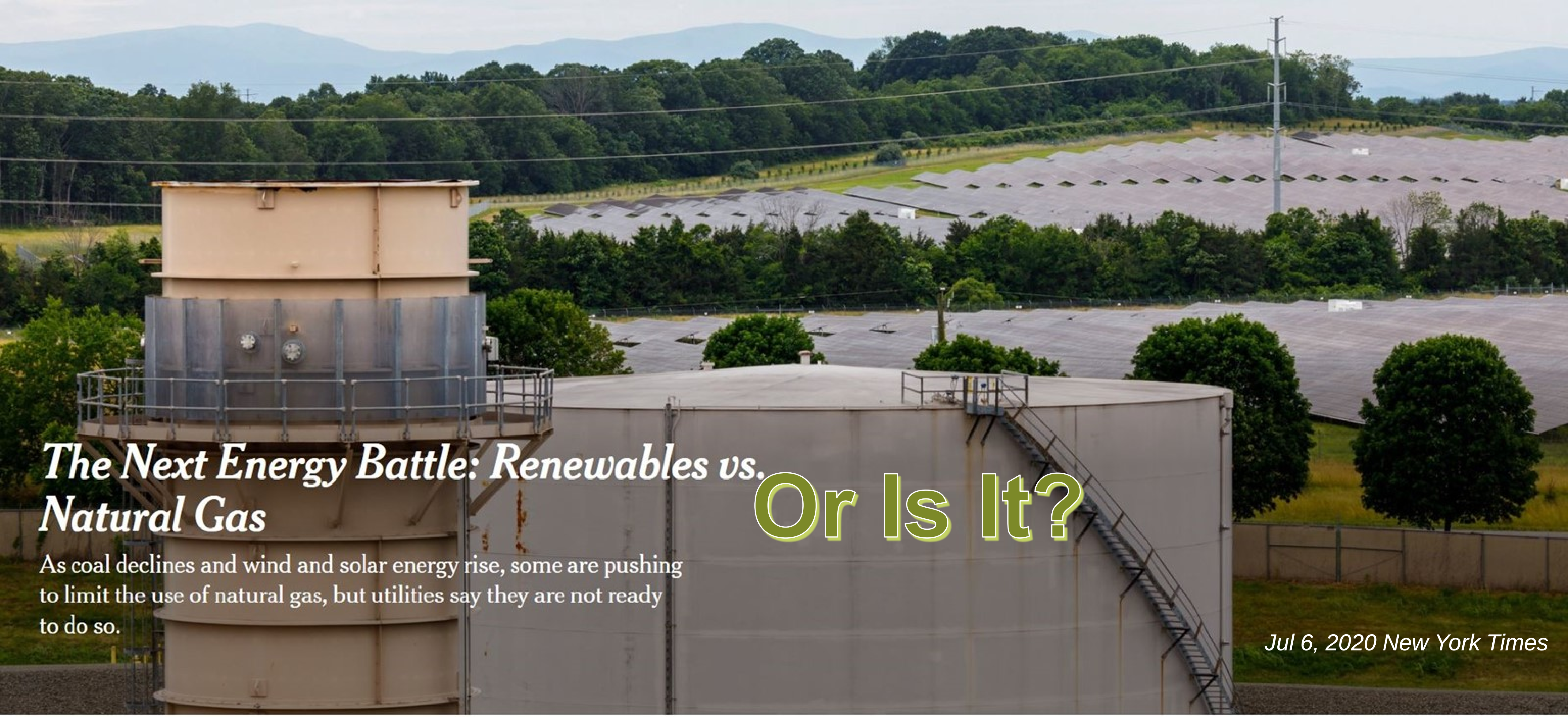
Large Increases In Peak Winter Electricity Use



Source: Analysis of DOE Energy Information Administration data

Switching from gas heating to electric heating would (on average) increase peak residential month electricity use by 150% in these 18 states.

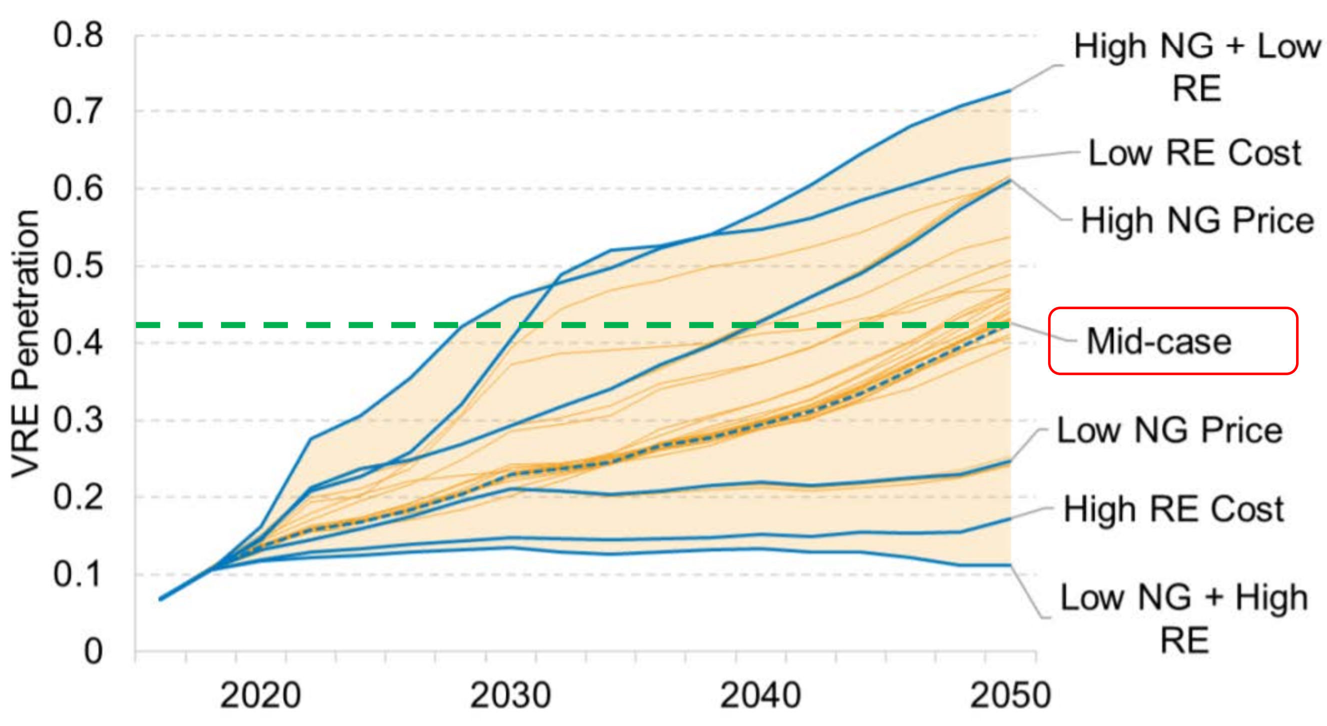
What if the grid isn't ready?



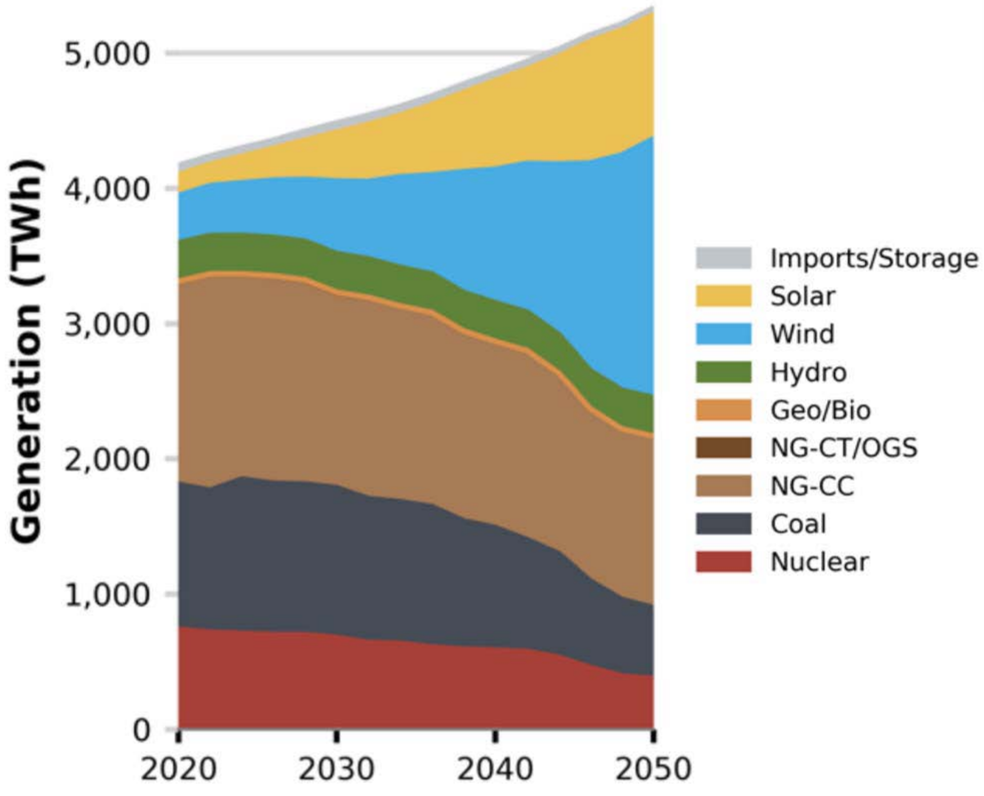
Power sources at Dominion Energy in Remington, Va., include natural gas, a diesel backup tank and solar panels in the field. Ting Shen for The New York Times

NREL projections on electric grid generation

Variable Renewable (VRE) Growth Across Scenarios



Mid-case: total generation sources



Answer to the Ultimate Question of Life, the Universe, and Everything: 42

GTI envisions a carbon-managed future in which integrated energy systems leverage low-carbon fuels, gases and infrastructure to limit global temperature rise.

By deploying hydrogen, carbon-neutral fuels and chemicals in ways that build on existing infrastructure and systems, we can reduce costs, lower risk and provide pathways to economy-wide deep decarbonization that supports growing economies worldwide.

Residential Natural Gas Pathways to Lower Greenhouse Gas

Near-Term (25-50+%)

Expanded use of high-efficiency gas equipment

Hybrid natural gas furnace/ boilers and electric heat pump systems

Building envelope improvement

Next-Gen (40-60+%)

Natural gas heat pumps for space & water heating

Micro CHP systems

Deep building retrofits

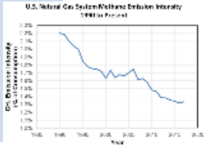
Renewables (Added 10-30%)

Renewable gas blends (bio-methane, hydrogen)

Solar thermal & geothermal /natural gas space & water heating

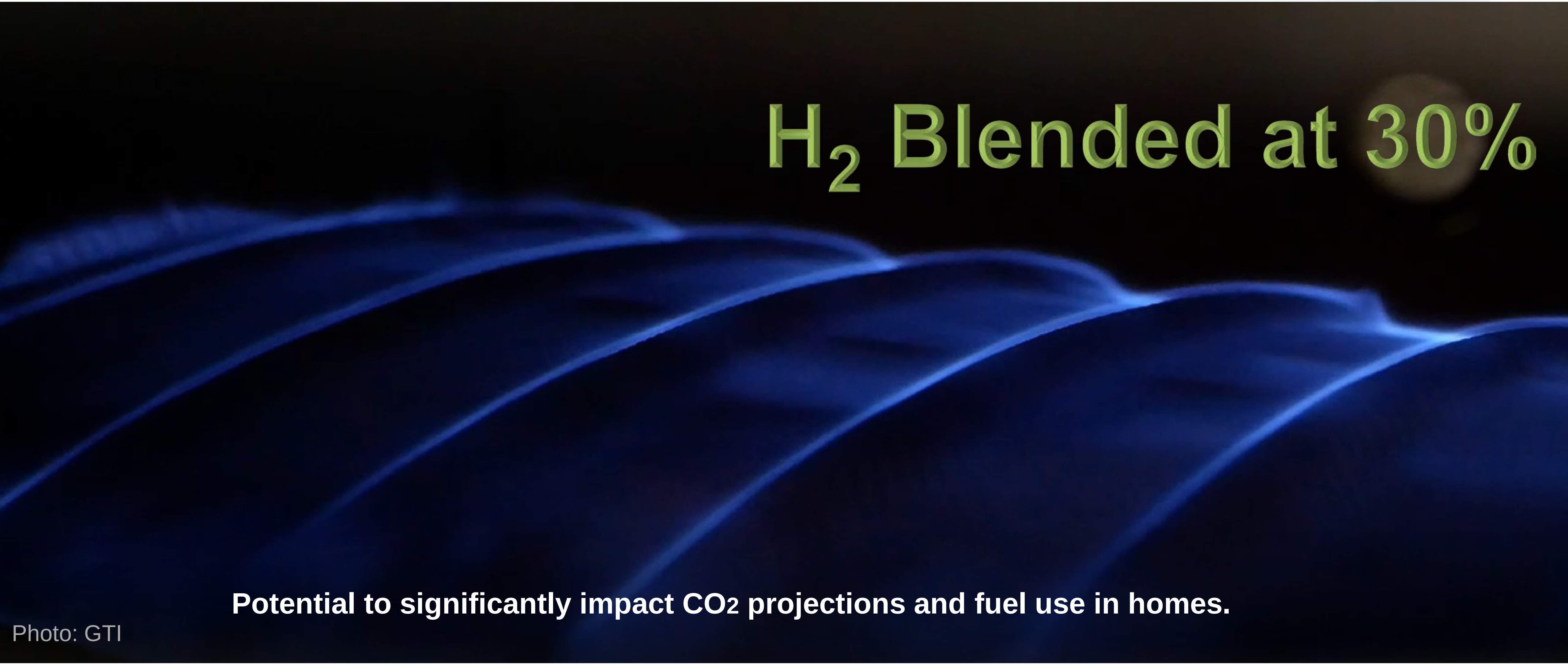
Lower Methane Emissions (5-10%)

Reducing full-cycle natural gas methane emissions



* Numbers indicate nominal GHG reduction potential

A Greener Gas Grid coming soon?



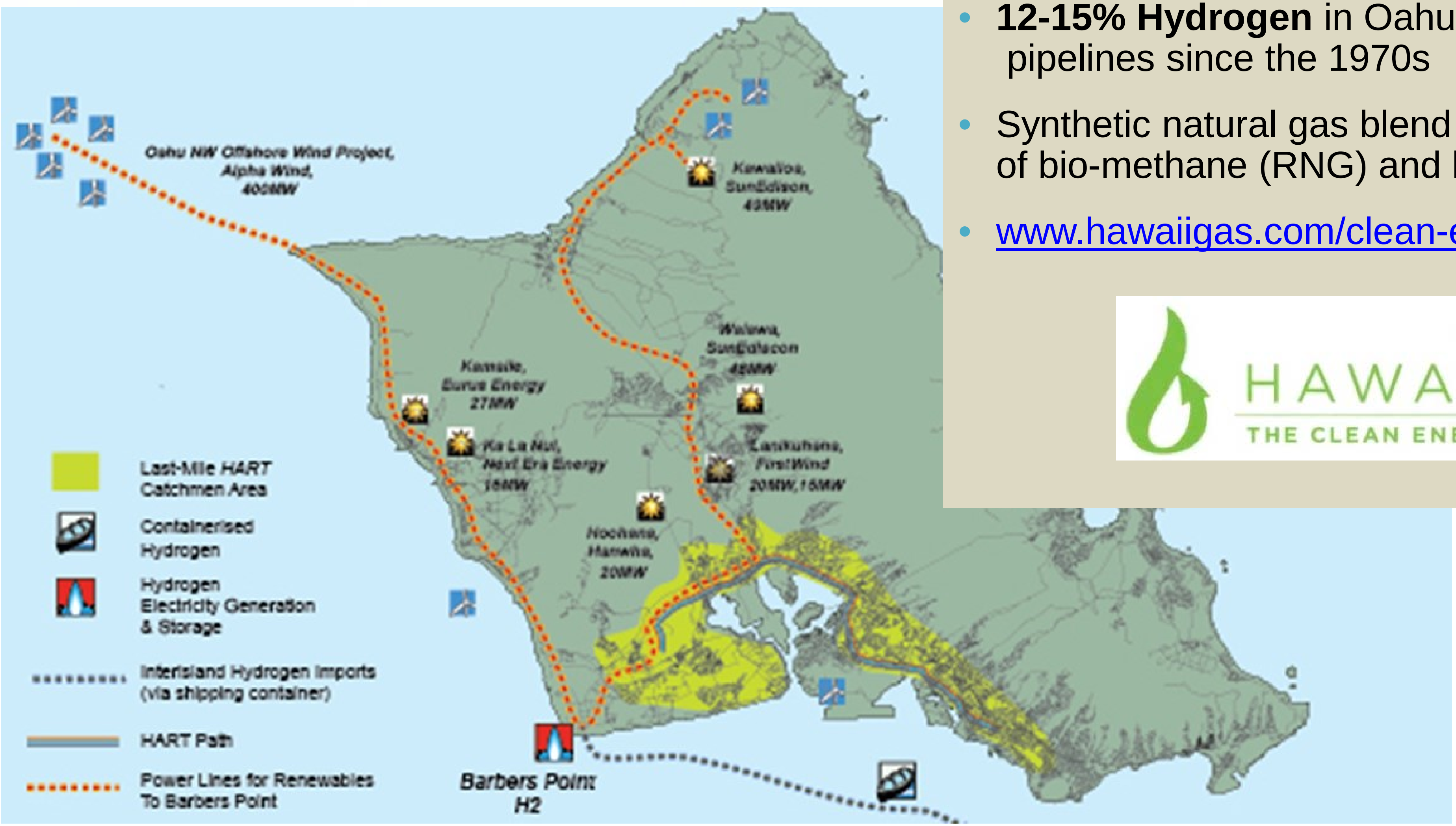
Potential to significantly impact CO_2 projections and fuel use in homes.

Photo: GTI

A Greener Gas Grid: Hydrogen is Happening

- **HyDeploy** (Cadent and NGN), UK – 20% blending of H_2 in Keele University natural gas distribution system
- **HYPOS** (German Government), Germany – 28 projects including 120 companies, including 100% H_2 network and home demonstrations
- **HyReady** (DNVGL, 11 partners), Europe – Guidelines for natural gas networks and operations for the injection of H_2, up to 100%
- **Magnum** Carbon-Free Gas Power Plant (Vattenfall), Netherlands – 440 MW CCGT fired on 100% H_2
- **GRHYD Demo Project** (Engie), France – 0.5 MW Electrolyzer, variable blending to 20%, 50 buses, 200 homes
- **H2@Scale** (DOE, GTI), Austin, TX – Cross-platform demonstration project including green hydrogen production, FCEV fueling, data center

Pipedream? Hawaii has a Hydrogen Economy



- **12-15% Hydrogen** in Oahu pipelines since the 1970s
- Synthetic natural gas blend of bio-methane (RNG) and hydrogen
- www.hawaiigas.com/clean-energy/hydrogen/

HAWAI'I GAS THE CLEAN ENERGY COMPANY

gti

https://www.renewableenergyworld.com/2015/10/07/hawaii-worlds-first-hydrogen-economy/

Low Carbon Resources Initiative

- New five-year partnership between GTI and EPRI, focusing on advancing technologies and large-scale deployment of:
  - Low-carbon electricity generation
  - Low-carbon chemical energy carriers -- such as clean hydrogen, bioenergy, and renewable natural gas
- Launched in August ‘20, with initial tasks of developing technology roadmaps and launching near-term projects

https://www.epri.com/lcri

gti

The Evolution of Gas Heating

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

New Efficiency Req’s, Ignition Controls

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

EnergyStar, Venting issues, Condensate, NOx

2010s to Present
Gas Sorption/Engine
Heat Pumps
120-140% AFUE
Cooling COP_{Gas} 0.5-1.2

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

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

Grid-Interactivity, Hydrogen-fueled, Natural Refrigerants, Energy Storage

Drivers/Issues

Image sources: FS Mechanical, Robur, Boostheat

Comparing True Efficiency… and a new product category

	Electric Resistance	Gas Standard	Elec Heat Pump	Gas Tankless	Thermal Heat Pump
Water Heater Technology					
Energy Factor	EF = 0.95	EF = 0.62	EF = 2.3	EF = 0.95	EF = 1.3
Site Efficiency	95%	62%	230%	95%	130%

Source: eGRID 2016 U.S. national site/source energy conversion for electricity of 2.79 and natural gas of 1.09

Case Study: The 2019 NAHB New American Remodel Home

2019 International Builder Show (IBS), Las Vegas, NV

- 1950’s ranch, gut rehab
- 4,950 sq ft
- Enhanced thermal barrier
- On-site water storage
- Infrared sauna
- Rooftop PV
- NGBS Emerald certified
- Designed for net zero

All space conditioning (heat/cooling) provided by natural gas-fired heat pumps.

- Ductless system
- Independent room control
- Stable fuel pricing

Photo: Studio G Architecture

Case Study: The 2019 NAHB New American Remodel Home

"The biggest thing here, which is the most different than a lot of the other homes, is the **gas heat pump HVAC system**.

The **efficiency to cost benefit** is one of the best investments clients can make, especially when you **pair it with solar** because you can really then start to offset a lot more of your costs."

- Michael Gardner, Studio G Architecture

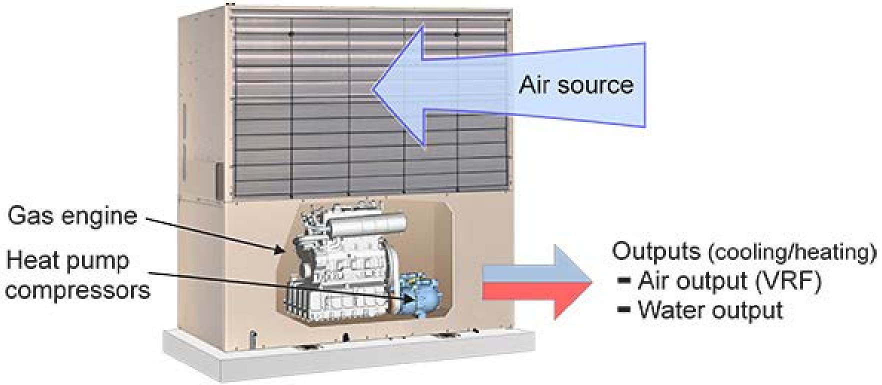
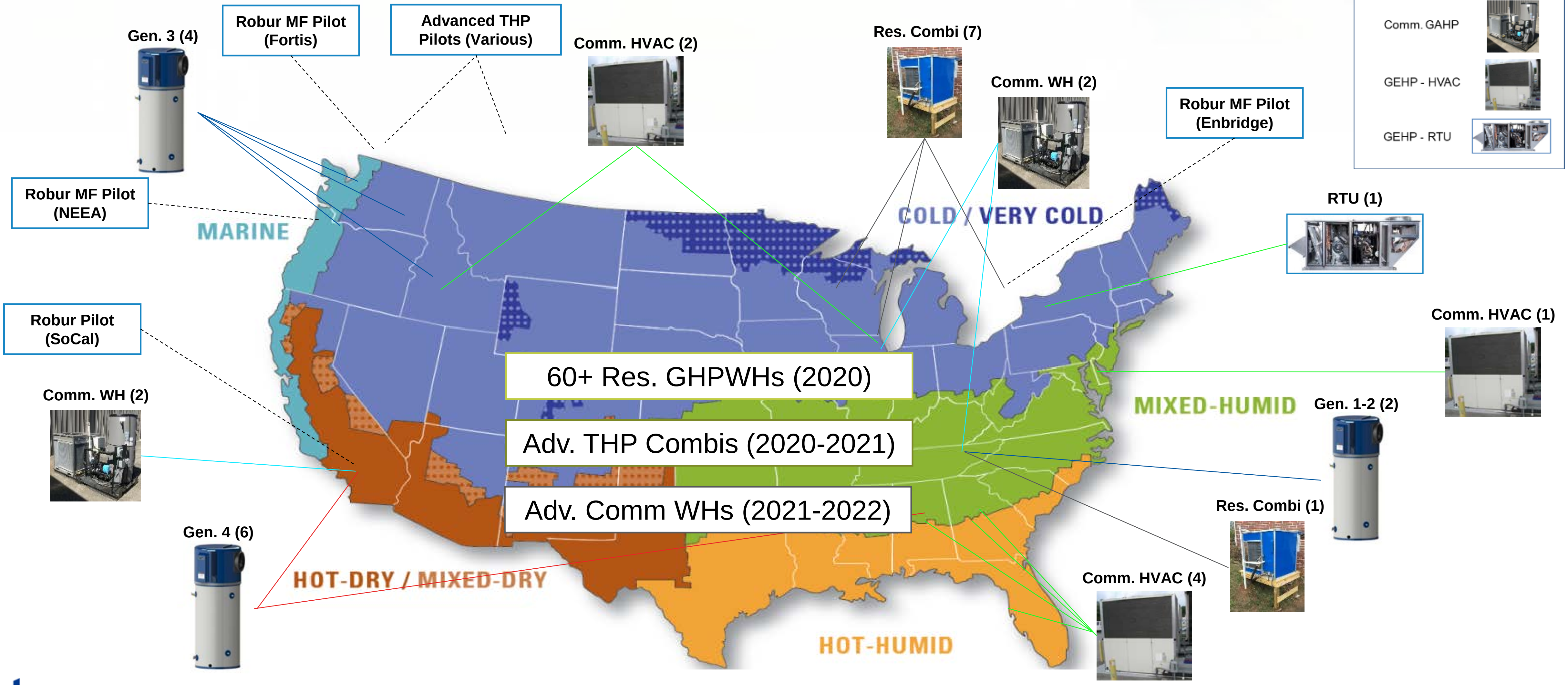


Photo: Next Luxury; space conditioning delivered through indoor VRF components

THPs – Demos & Deployment



Map reference: Baechler, M. et al. “Guide to Determining Climate Regions by County”, PNNL-17211, 2010.

New Gas Heat Pump Water-Heater Product

Key Features

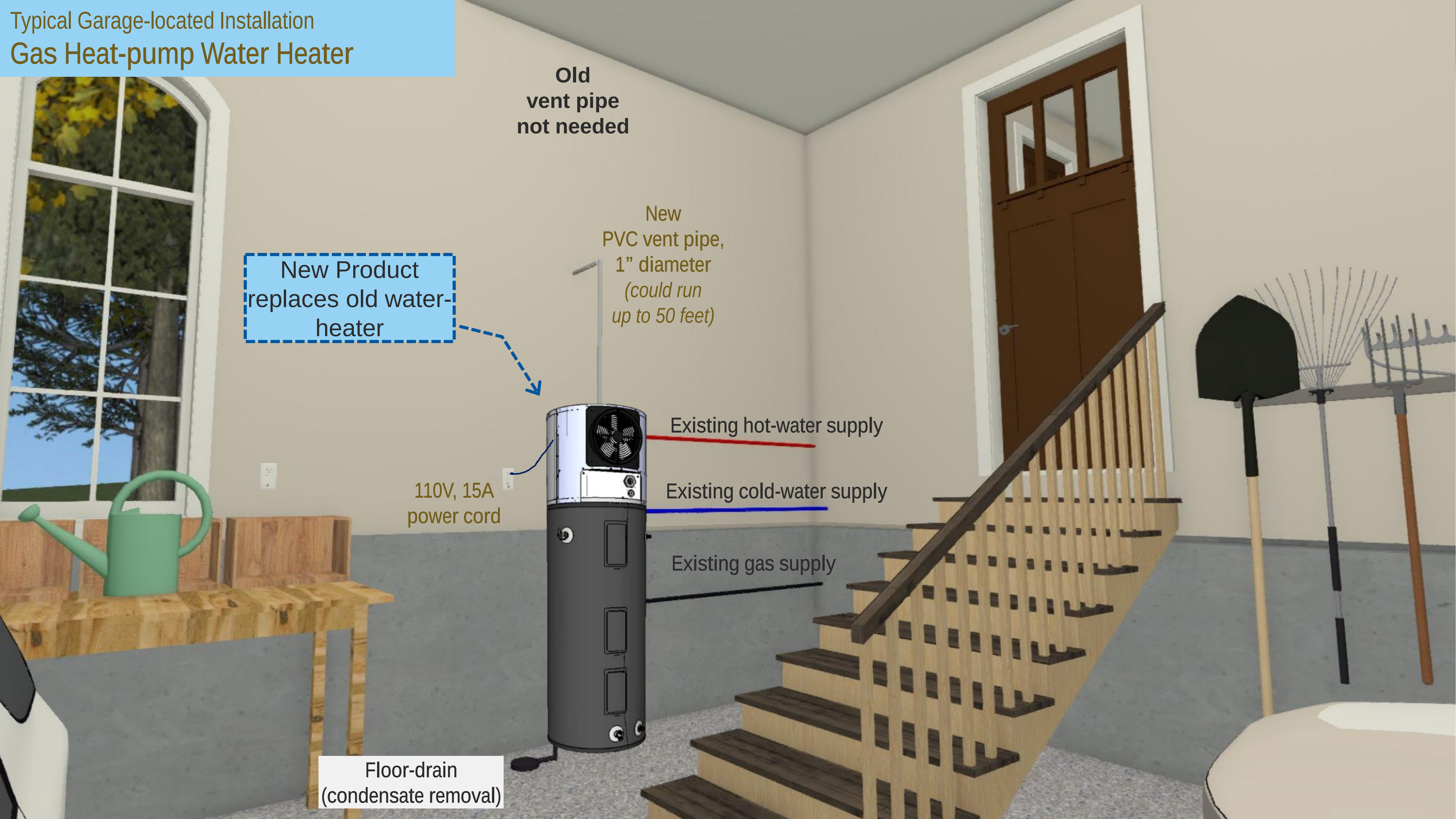
- Uses just 50% of the usual energy to heat water
- Performance verified by 3rd party labs
- Underlying technology: a Thermally-Driven Heat Pump (based on a long-used, safe, thermodynamic cycle that draws part some heat from the surrounding air, and is therefore a partially (1/3) renewable energy appliance)
- Product will be made by major water-heater manufacturers
- Maintenance Requirements: similar to a power-vent or condensing storage tank water-heater
- Will be available, in-stock at all major distributors
- Expect significant energy efficiency incentives from utilities

Typical Garage-located Installation

Traditional Tank-style Hot-Water Heater

Typical Garage-located Installation

Gas Heat-pump Water Heater



New Gas Heat-Pump Water-Heater Product **Specifications**

UEF (efficiency) Rating	**1.20**
Renewable Energy Content	1/3 total heat from ambient air
Tank Size	80 gallons, etc.
First Hour Draw	80 gallons (same as tank)
Fuel	Natural Gas or Propane
Fuel Line Size (minimum)	¼" or **½"** diameter gas pipe
Electrical Connection	110v/15a (non-dedicated circuit Ok)
Installation Location	Conditioned or Unconditioned space
Venting	**1" PVC** pipe (50 ft length possible)
Condensate Disposal	Typically to a floor drain
Dimensions	79"H x 24"W x 24"D; 370 lbs.
Recharge Time (cold inlet = 55°F) (from fully-drained up to 125°F) (from fully-drained up to 105°F (backup-element capacity)	 4.0 hours (complete tank) 2.5 hours (complete tank) 45 minutes to provide 10 gal at 105°F)

Milestones & Targets

- Multi-sponsor effort
- Targeting ~50 sites across 4-5 regions
- California (LA basin) essential market
- Field demonstration launches Q3 2021

ENBRIDGE · SoCalGas (A Sempra Energy utility) · spire · Southern Company · FORTIS BC · Research Foundation · neea · BRIO · Rinnai · CenterPoint Energy · gti

Project Objectives

Demonstrate commitment to GHWPH commercialization and launch

Evaluate product readiness across various climates and housing stocks with emphasis on reliability, efficacy, efficiency, installation experience, customer satisfaction and manufacturer/technology developer business capabilities

Support program development with savings, cost, and installation information needed to quickly develop and deploy programs upon product launch

Support timely product launch by communicating in situ performance information to manufacturer with a goal of product launch by 2022

Prime the market by providing hands-on experience to local distribution and installation companies

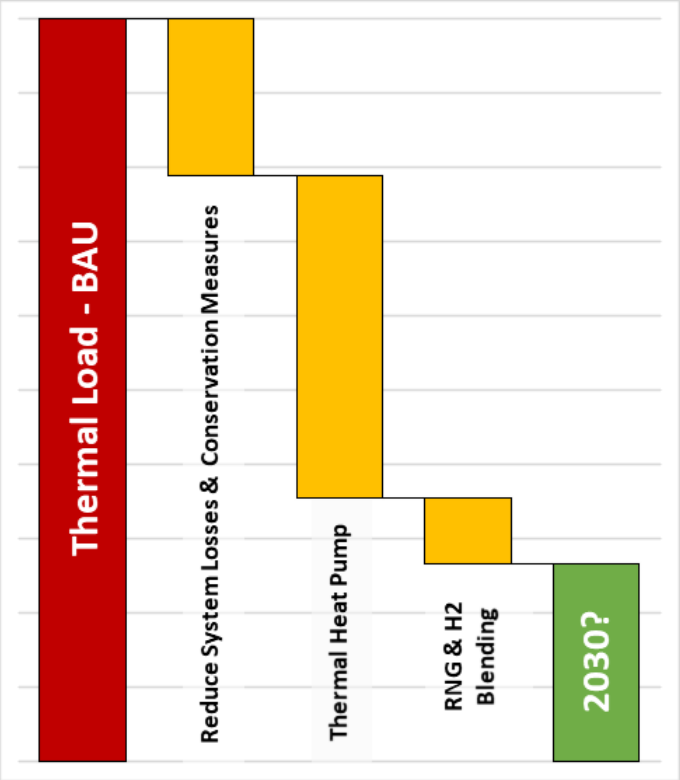
Characterize GHPWH's performance to generate performance curves/modules for rating software, standard metrics , and provide technical support towards certification.

Interested? Email msweeney@gti.energy

THPs – GHG Reduction Potential

- Primary advantage of THPs is >40% reduction in gas consumption over baseline
  - Studies indicate >1.20 UEF, >140% AFUE feasible*
  - Better retain capacity, efficiency in cold climates**
- Add'l benefits include, typically:
  - Combustion outdoors or sealed, no IAQ concern
  - Climate-friendly natural refrigerants (NH_3, CO_2)
  - Multi-function appliance w/ heat recovery
- Key piece in **thermal load decarbonization** puzzle
  - Address low-hanging fruit with system losses, conservation
  - THP partial/full retrofit (e.g. GAHP)
  - Low-carbon fuels (25% blend shown, higher blends are feasible)

Reducing GHG Impact (Example)

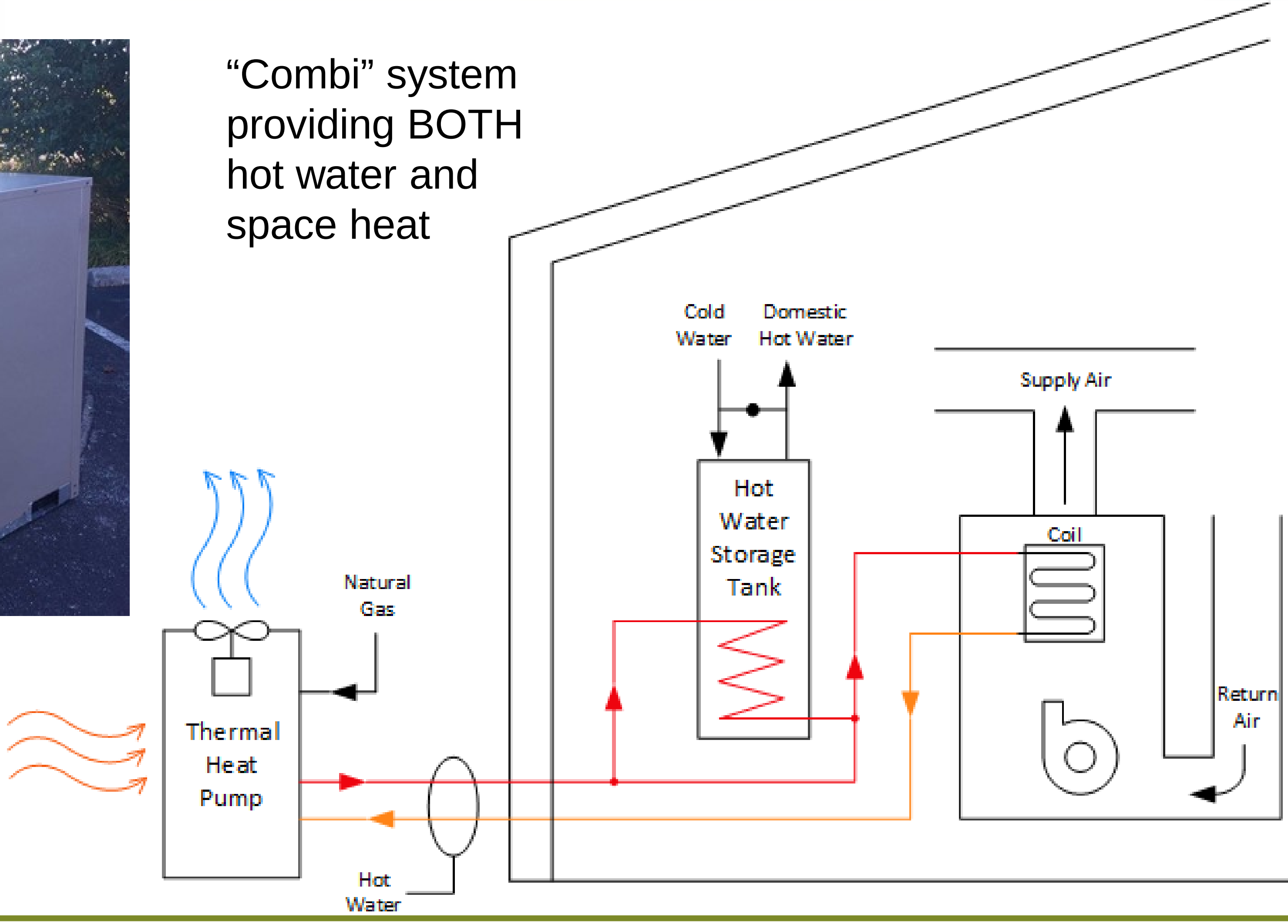


*Glanville, P. et al. *Integrated Gas-fired Heat Pump Water Heaters for Homes: Results of Field Demonstrations and System Modeling,* ASHRAE Transactions . 2020, Vol. 126 Issue 1, p325-332

** Glanville, P. et al. *Demonstration and Simulation of Gas Heat Pump-Driven Residential Combination Space and Water Heating System Performance,* ASHRAE Transactions . 2019, Vol. 125 Issue 1, p264-272

Space AND Water Heating with THPs

"Combi" system providing BOTH hot water and space heat



Inside a THP…


Photo: GTI

Photo courtesy SMTI

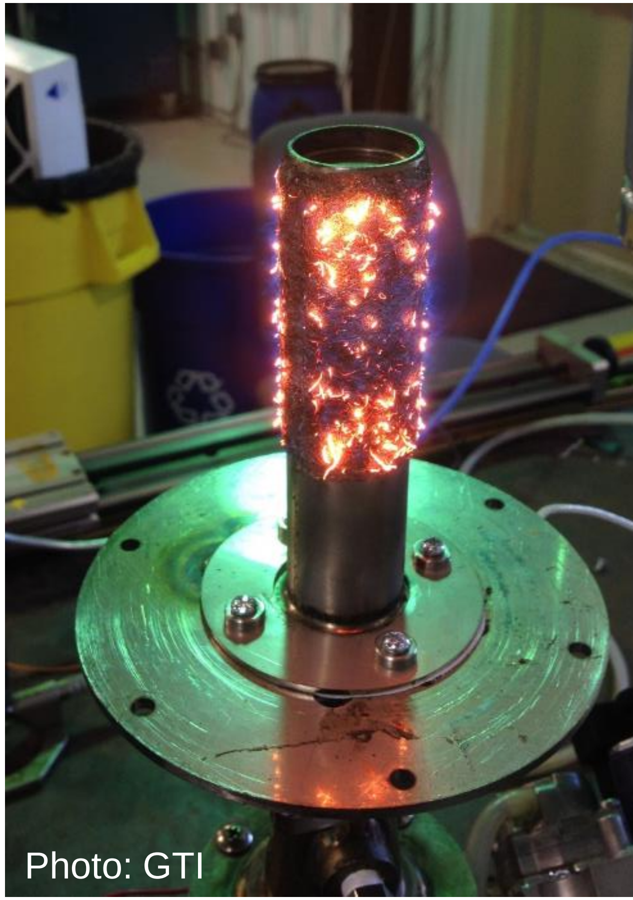


Photo: GTI

Vicot THP Unit, by HOMY

HOMY is responsible for **selling**, **commissioning** and supplying **after sales services** for a high efficiency **THP** system in Canada and USA

Natural Gas

Air Energy

VICOT THP UNIT

Floor heating

Radiator

DHW

Residential Integrated THP with Zoning

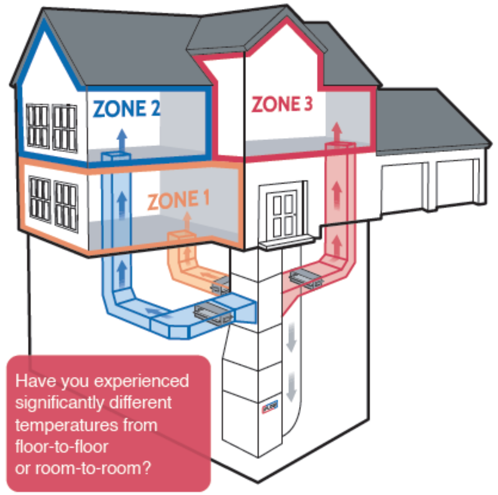
- In 2021 HOMY plans to launch **THP** for **~60-68 kBTU** (18-20kW) w/ **Hydronic AHU** as a packaged solution.
- Now offering ~220,000 BTU (65 kW) Vicot unit

- HOMY uses a sophisticated AHU matched with THP and benefiting from state of art IoT.

- HOMY provides **installation and after sales service** for the integrated system and **contractors training.**

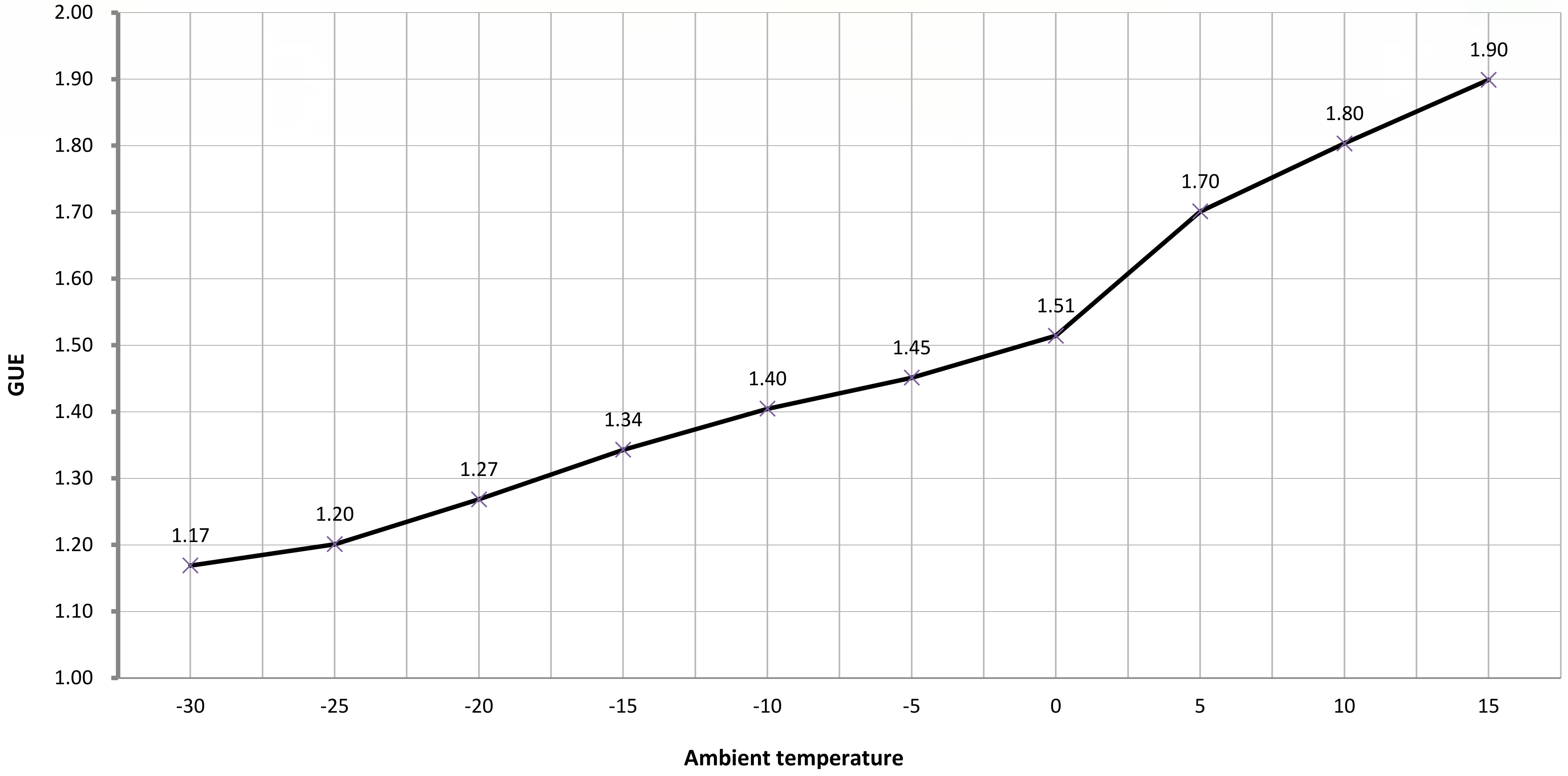
- **Integrated zoning** further lowers energy use while maximizing comfort

Ultimate Comfort with Zoning



Vicot Performance: Gas Utilization Efficiency

Working data and curve of ambient temperature and water temperature change – Vicot V65

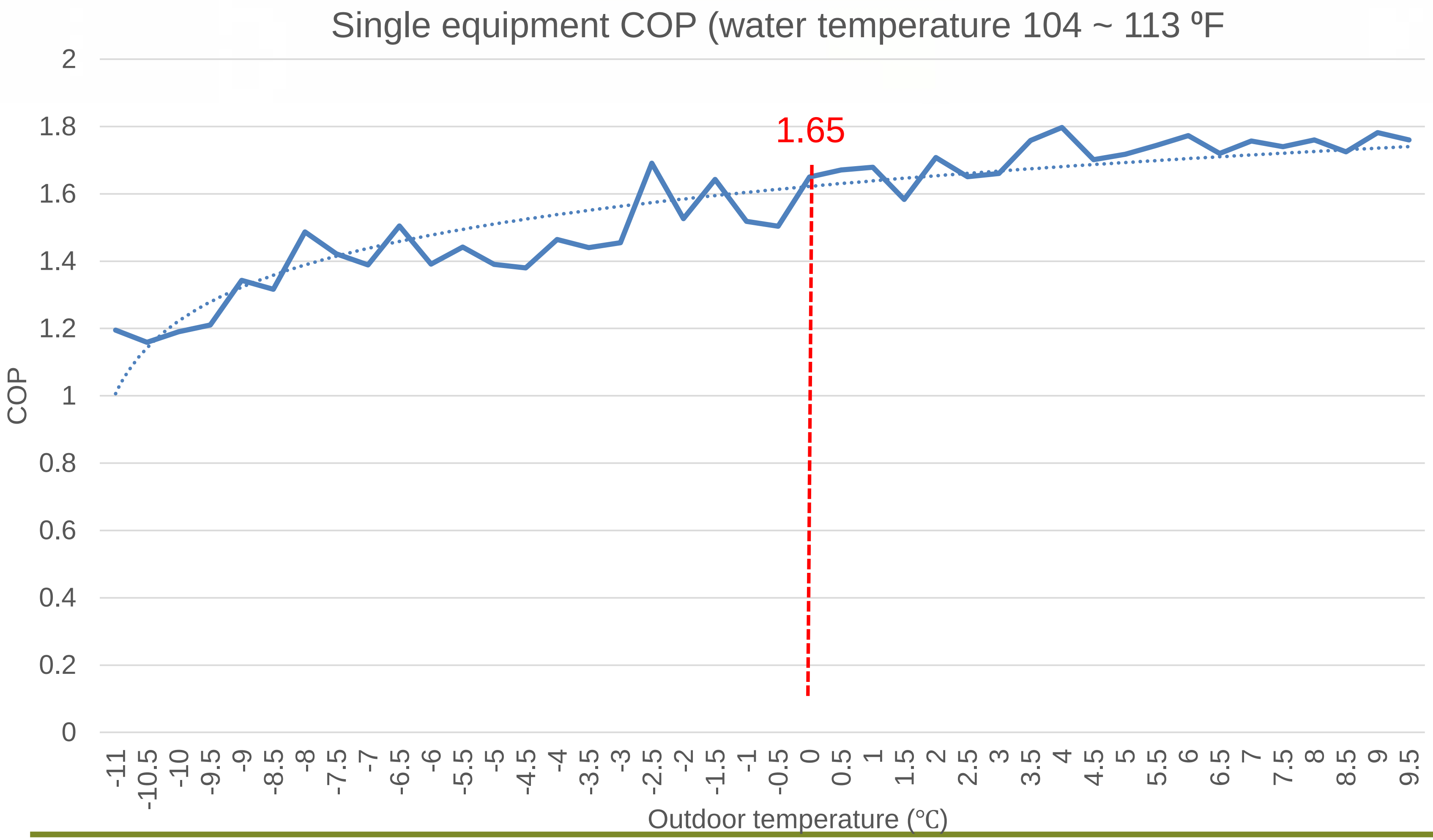


(ºC)

$$\frac{\text{Supplied energy}}{\text{Burned energy}}$$

Note: Manufacturer data

Vicot System COP



The COP increases as
the outdoor temperature rises.

2020-2021 Pilot

ENBRIDGE

Vicot 65 kW for Domestic Hot water heating in Multi-family Retrofit

Location:
Toronto, Ontario - Canada
Rental Apartment Building (MURB)
9-story, 51 apartment units

Pre-Retrofit system for DHW:
- 630 KBtu Boiler
- 3x 120 Gal Tank

HOMY BUILDING SOLUTIONS

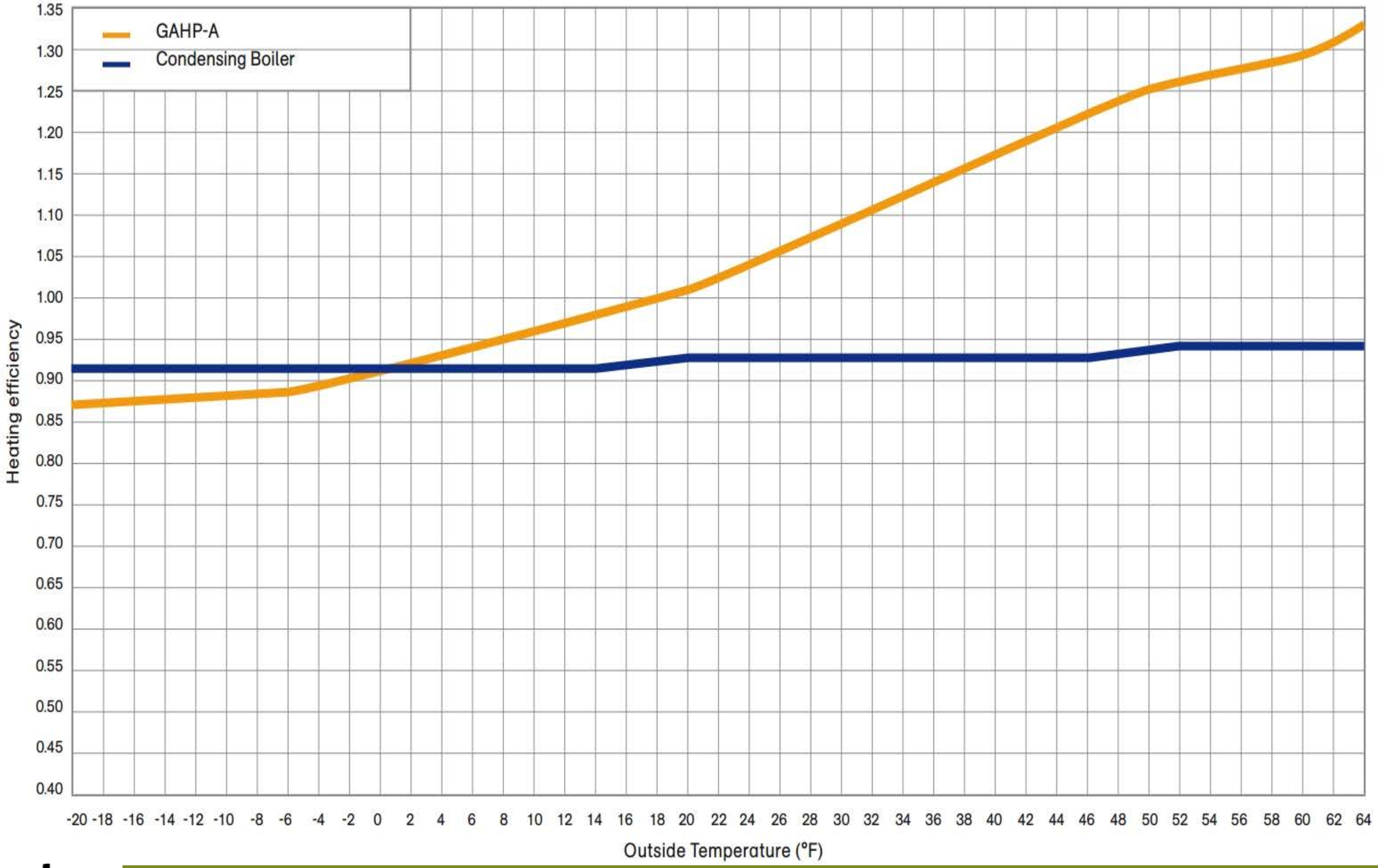
VICOT

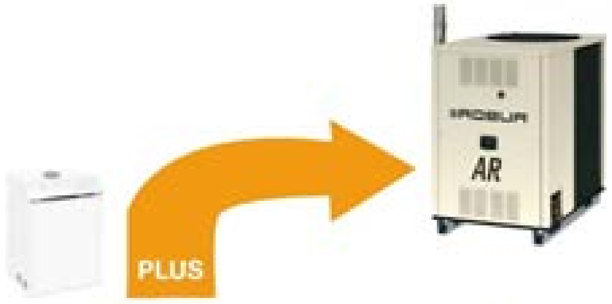
Robur Residential

WWW.ROBURCORP.COM

ROBUR
caring for the environment

ROBUR HEAT PUMP vs. CONDENSING BOLIER

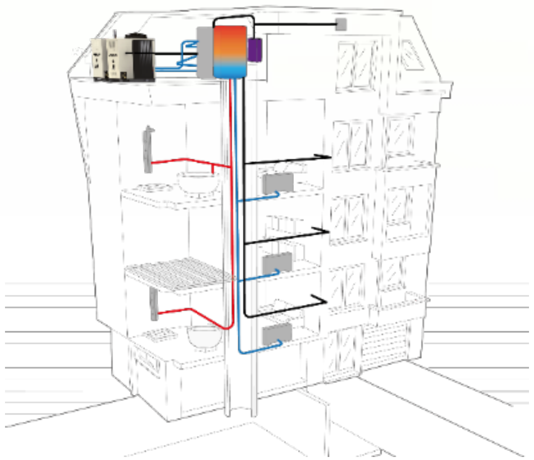
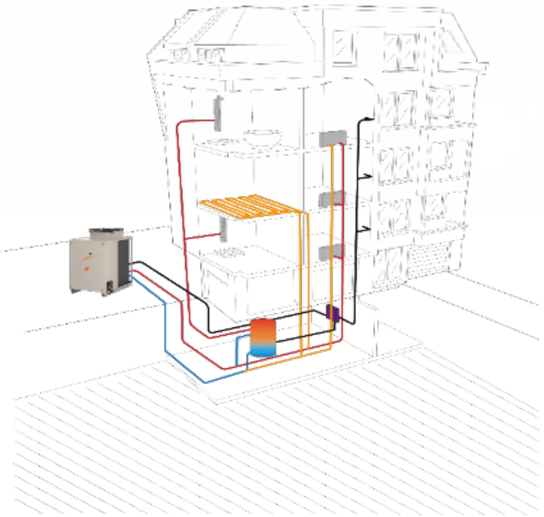




CONDENSING BOILER ADVANTAGES

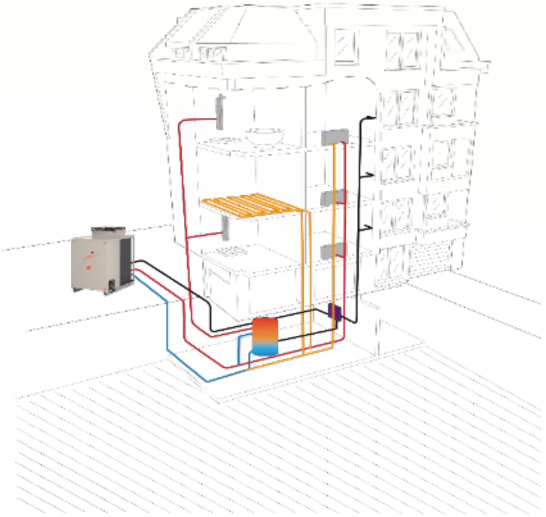
- •Environmentally friendly using natural gas
- •DHW supply
- •Only 1/10 of electricity consumption in comparison to electrical heat pumps
- •ideal integration into existing or new installations
- •High Reliability
- •Easy Maintenance
- •No use of Harmful Refrigerants

ROBUR caring for the environment

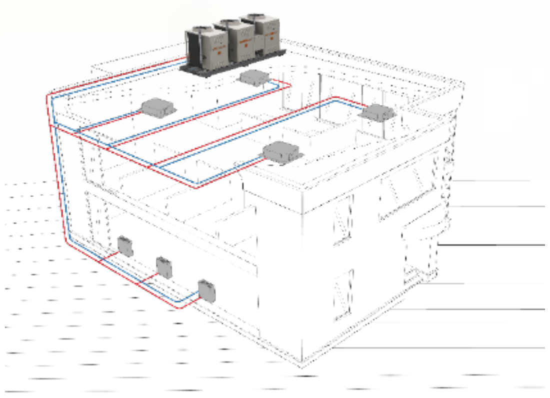
Cooling	Heating
	

- Reversible Cooling & Heating System
- Provides *126%* Heating Efficiency at Nominal Conditions
- Ambient Operating Temperatures : 120°F to -20°F
- Max Outlet Water Temp 140°F
- Min Outlet Water Temp 37.4°F

Heating / DHW



Heating



- Heating Only System
- Provides *129%* Heating Efficiency at Nominal Conditions
- Ambient Operating Temperatures : 113°F to -20°F
- Max Outlet Water Temp 140°F

Austin, TX Area

GAHP AR

Reversible Heat Pump

5T Cooling – 120,000 Btu/h Heating

ROBUR
caring for the environment

5T air handler using the chill water/ hot water coil. By using the Unico system air handler we were able to accomplish installation through a very tight attic. With approximately 120' of supply plenum in 38 outlets, the combination of both systems gives us efficiency and the performance were looking for, all the way over to the other side of the house in the master suite and other bedrooms and bathrooms. Approx. installed cost $25,000.

Robur K18 –Combi THP

- Modulating, condensing gas absorption heat pump, using renewable energy and natural gas for heating and Indirect domestic hot water production (combi).
- All-In-One Heating Solution
- 18kW – 61,400 BTU's
- Up to 150% Efficient
- Easy to Install
- Low Maintenance
- Ultra Quiet Operation
- Natural Refrigerant
- Custom Residential Applications

Photo: Robur

SMTI Combi THP Case Study

80,000 Btu/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*.

Validated designs through 2019 – 2020 winter

Field Demonstrations (4 retrofits / 3 existing)

- Prepare for product commercialization launch
- Understand experience installation issues + costs
- Improve the contractor experience

Photo: 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.
** 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.

Res Space Heat/Combi Next Steps: 2019-2020 Heating Season

	IL - Chicago	IL - Elmhurst	IL - Geneva	Canada
House Details	3 BR / 1 BA	4 BR / 2.5 BA	4BR / 2.5 BA	4 BR / 3.5 BA
Size	1300 sf	2500 sf	2900 sf	2400 sf
Occupancy	5 (3 kids)	4 (2 kids)	4 (2 kids)	4 (2 College kids)
Existing Water Heater	36 kBtu/h input 40 gal. storage	38 kBtu/h input 50 gal. storage	40 kBtu/h input 40 gal. storage	199 kBtu/h Navien tankless
Existing Space Heater	88 kBtu/h input Bryant Furnace	126 kBtu/h input Philco Furnace	100 kBtu/h input Lennox Furnace	80 kBtu/h input Trane Furnace
Heating design load at 0º F	96,000 BTU	65,000 BTU	66,000 BTU	60,000 BTU

Outdoor Unit – Moving the Outdoor THP Unit

Outdoor THP Unit

Photo: GTI

Photo: GTI

Indoors – Hydronic Air Handler

Horizontal install (parallel to existing furnace for pilot)


Photo: GTI

Vertical install


Photo: GTI

Indoors – Hydronic Controls

Simplify install with pre-assembled hydronic pumps and controls

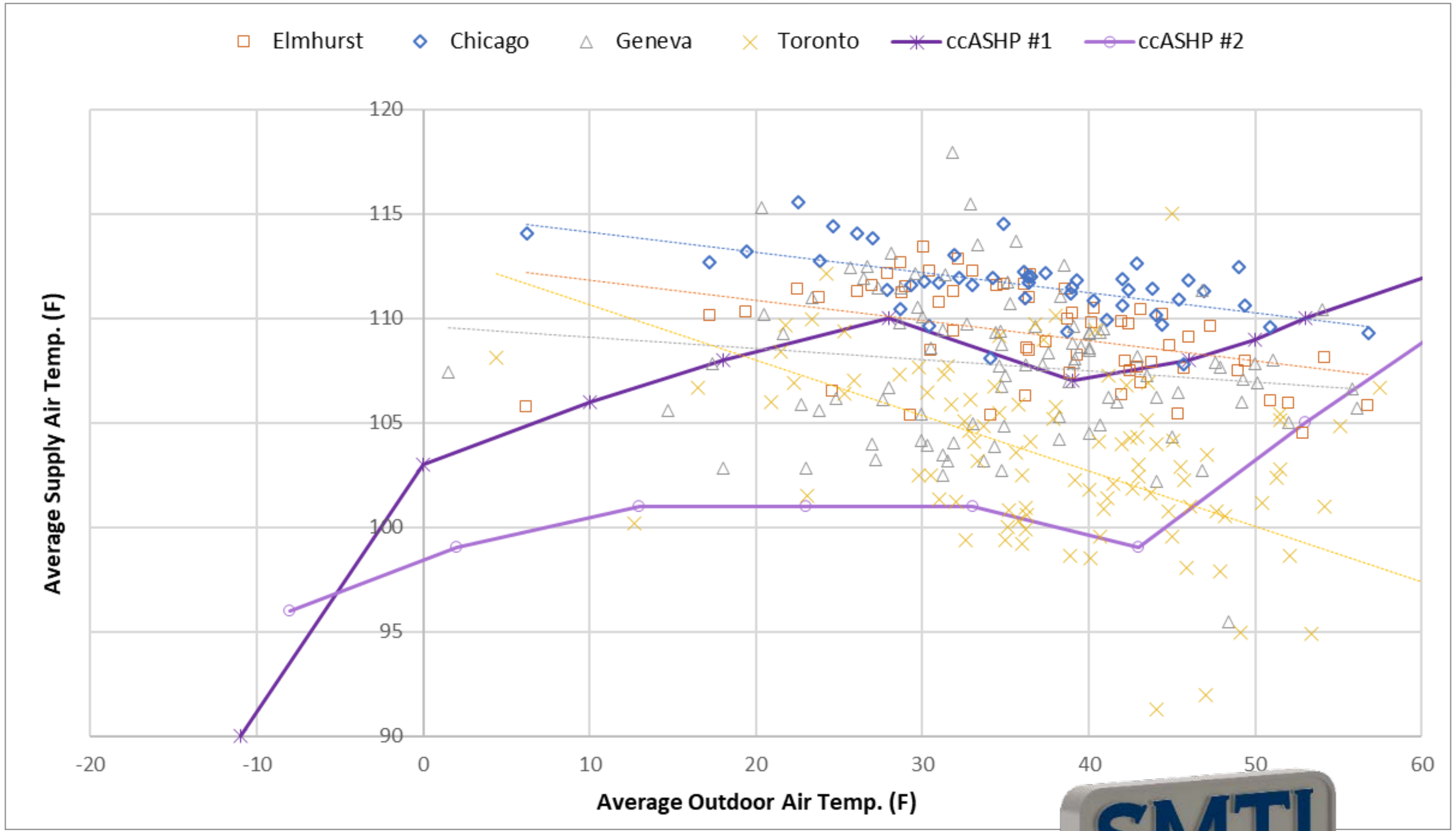
THP water heater

SMTI Case Study 2019-20 Results

Thermal Comfort:

- When operational, THPs were successful in maintaining thermal comfort
  - Delivered air temperatures at or above targets in most cases
  - Delivered DHW temperatures similarly on target

> In IL, WI, ON, and TN, eight THP "combi" space/water system demos yielded up to **45%** energy savings versus condensing furnace/standard water heater combined, including operation at -30ºF without backup heat[2].

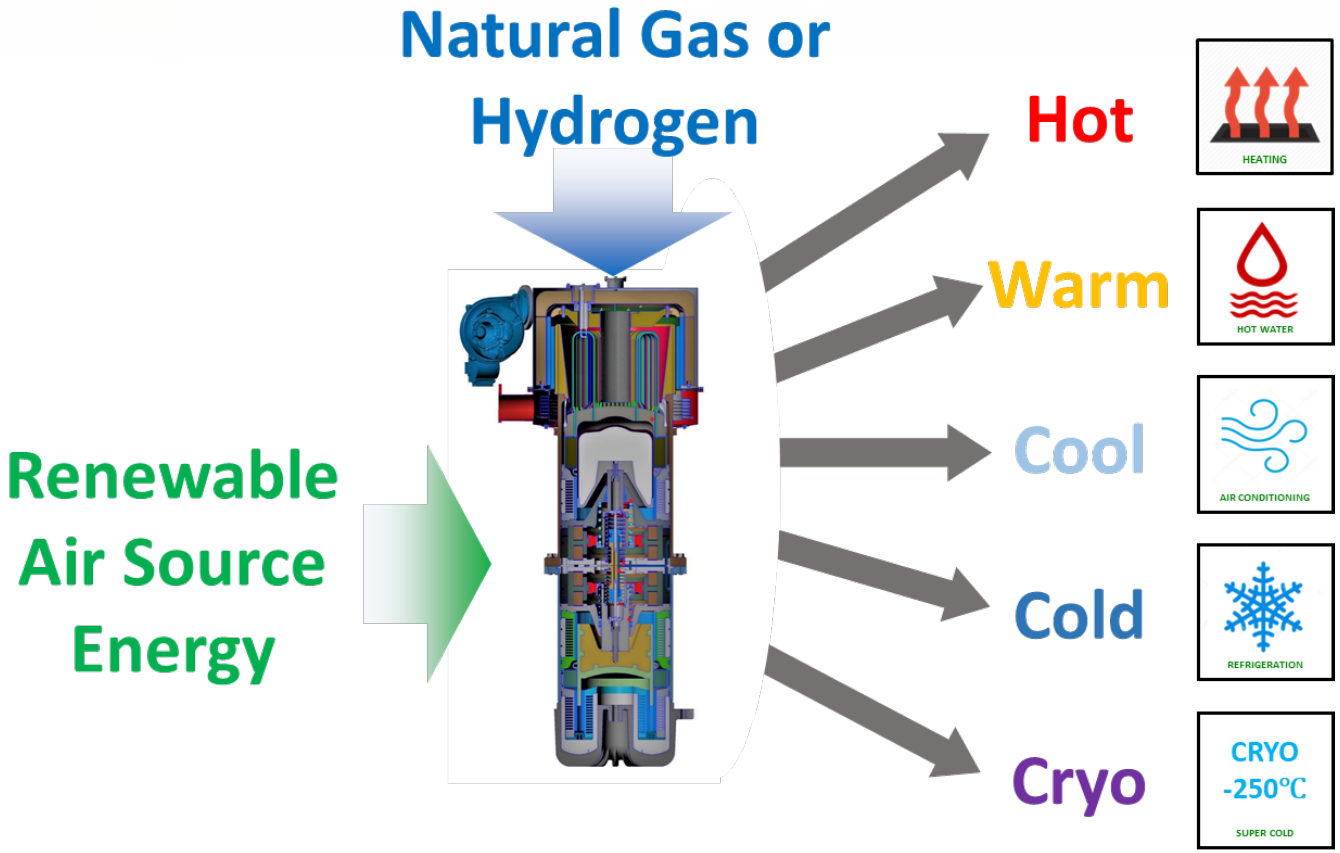


Glanville, P. et al. (2019) Demonstration and Simulation of Gas Heat Pump-Driven Residential Combination Space and Water Heating System Performance, ASHRAE Transactions; Vol. 125 264-272.;

Thermal Compression Highlight - Thermolift

- Potential for heating COP_{gas} = 2 at 47°F / cold climate heating COP_{gas} > 1.3 at -13°F, early data is promising*
- Simultaneous cooling (COP_{gas} = 1 target)
- 2018 prototype testing showed COP stable at part load and internal power generation feasible
- 3+ years of R&D with GTI on hot-side of cycle, **prototype GTI lab testing and Thermolift demos in 2019 planned**

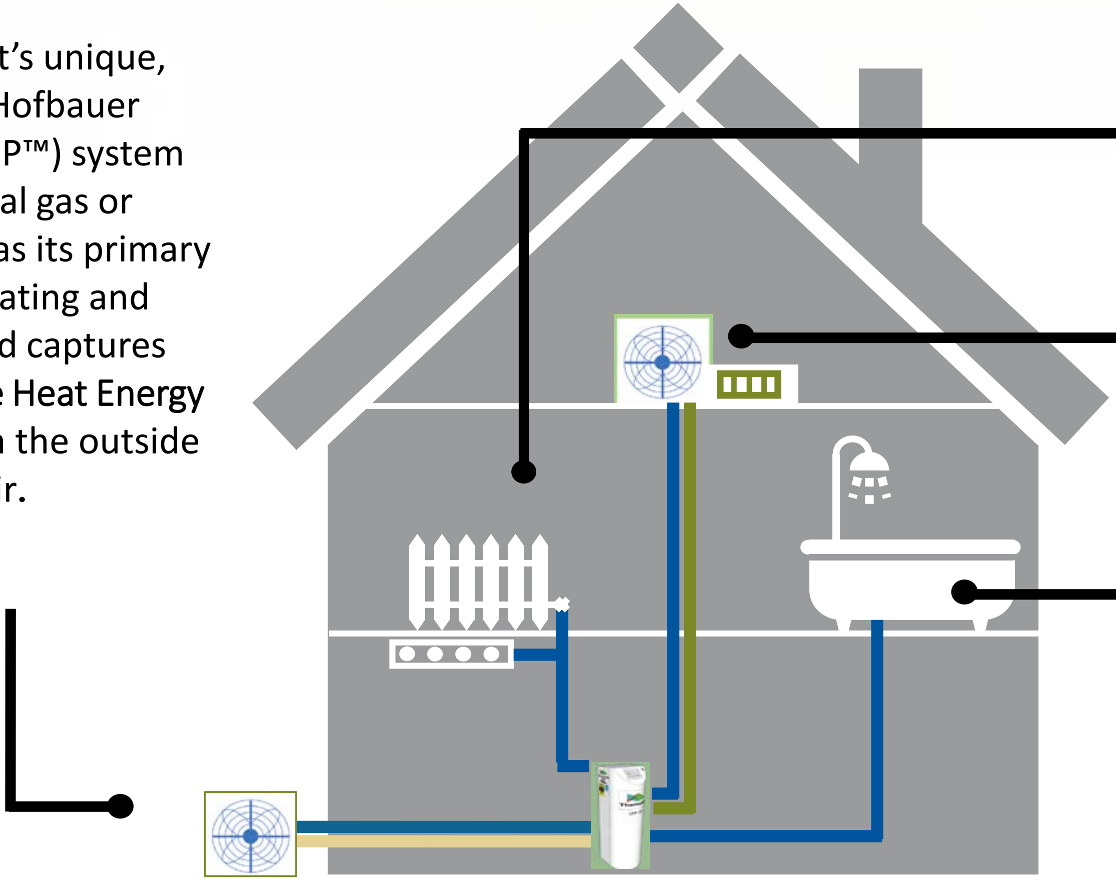
Image is Courtesy of Thermolift



*Source: ORNL, "Test Report of the Thermolift Natural Gas Fired Air-Conditioner and Cold-Climate Heat Pump", prepared by ORNL with support from Thermolift under contract DE-EE0006350.

Building Integration

ThermoLift's unique, patented Hofbauer Cycle (TCHP™) system uses natural gas or hydrogen as its primary fuel for heating and cooling and captures Renewable Heat Energy (RHE) from the outside ambient air.



1 The heat from the burner ***plus*** RHE from outside is sent to any radiator, air-handler, or underfloor heating system.

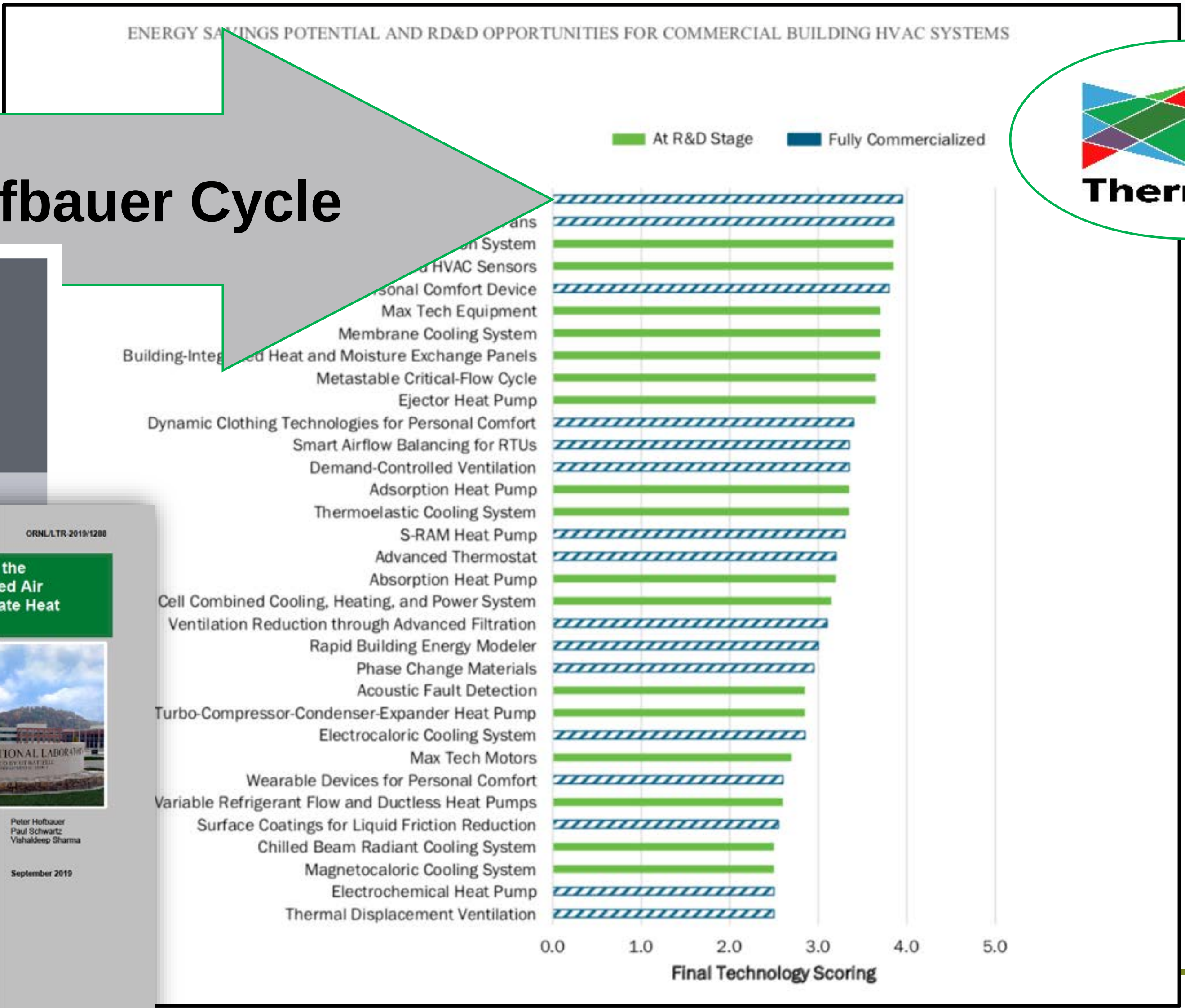
2 As an air conditioner, the system pulls heat out of the house and delivers it to hot water.

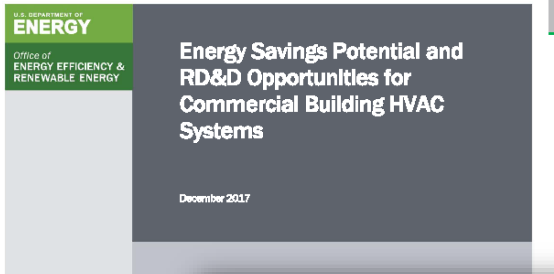
3 The same heat can be used for hot water delivery.

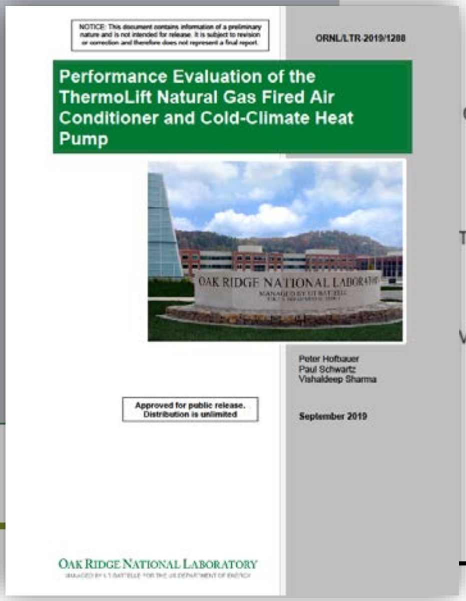
DOE Ranked HVAC Technologies

Based on global review of 300 technologies.

TCHP – Hofbauer Cycle



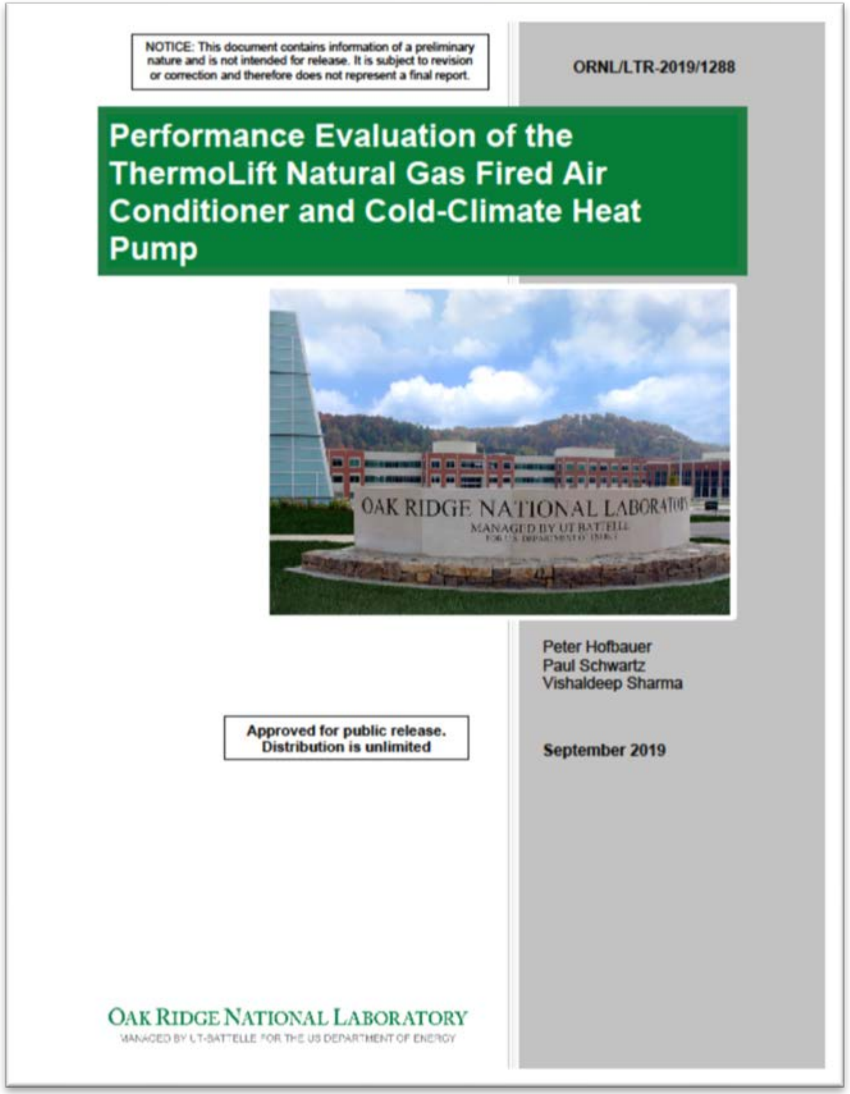




ThermoLift

***Exceeded** DOE Target COP's for Cold Climate Heat Pumps*

Exceeding State-of-the-Art


NOTICE: This document contains information of a preliminary nature and is not intended for release. It is subject to revision or correction and therefore does not represent a final report.

ORNL/LTR-2019/1288

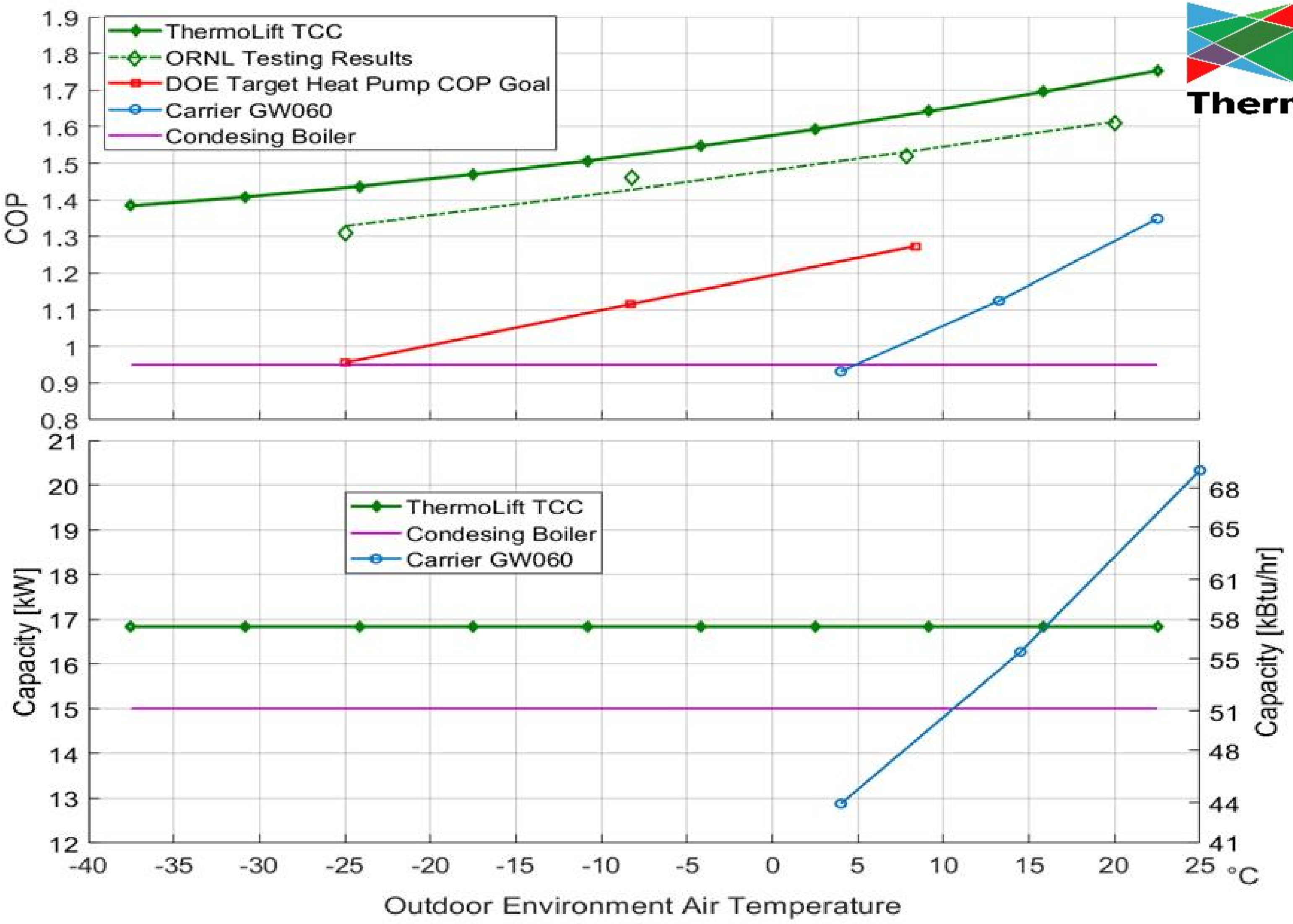
Performance Evaluation of the ThermoLift Natural Gas Fired Air Conditioner and Cold-Climate Heat Pump

Peter Hofbauer
Paul Schwartz
Vishaldeep Sharma

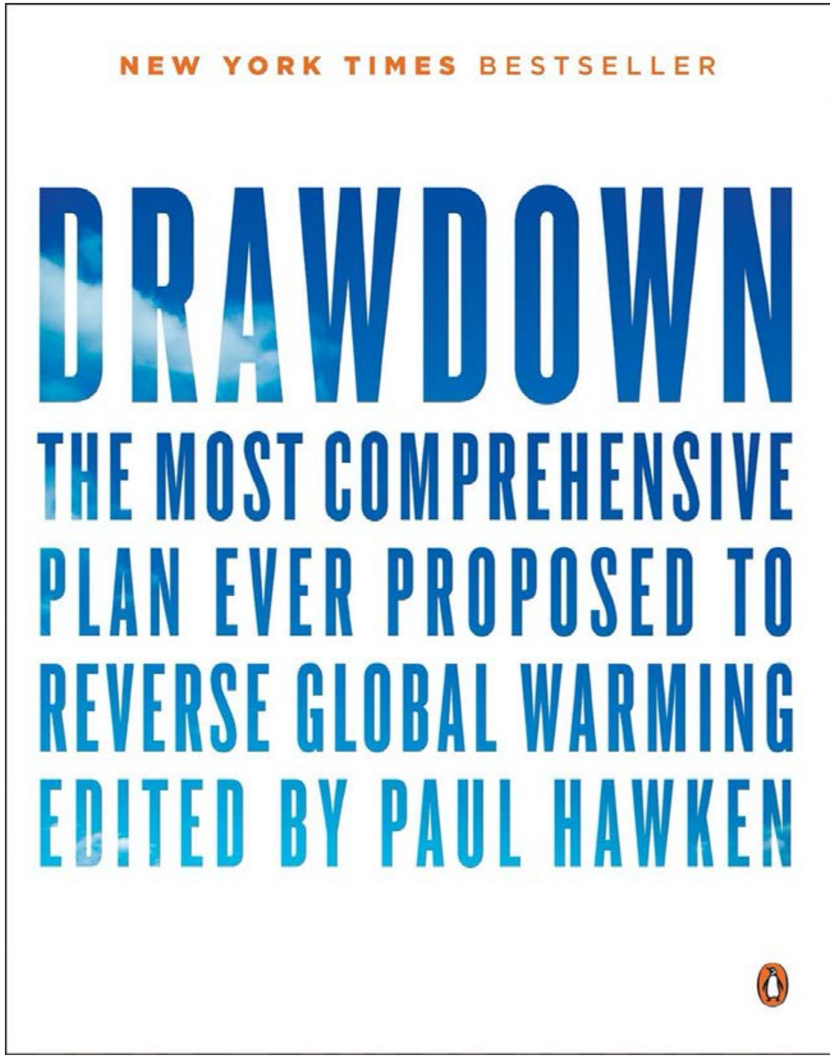
September 2019

Approved for public release. Distribution is unlimited

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE US DEPARTMENT OF ENERGY

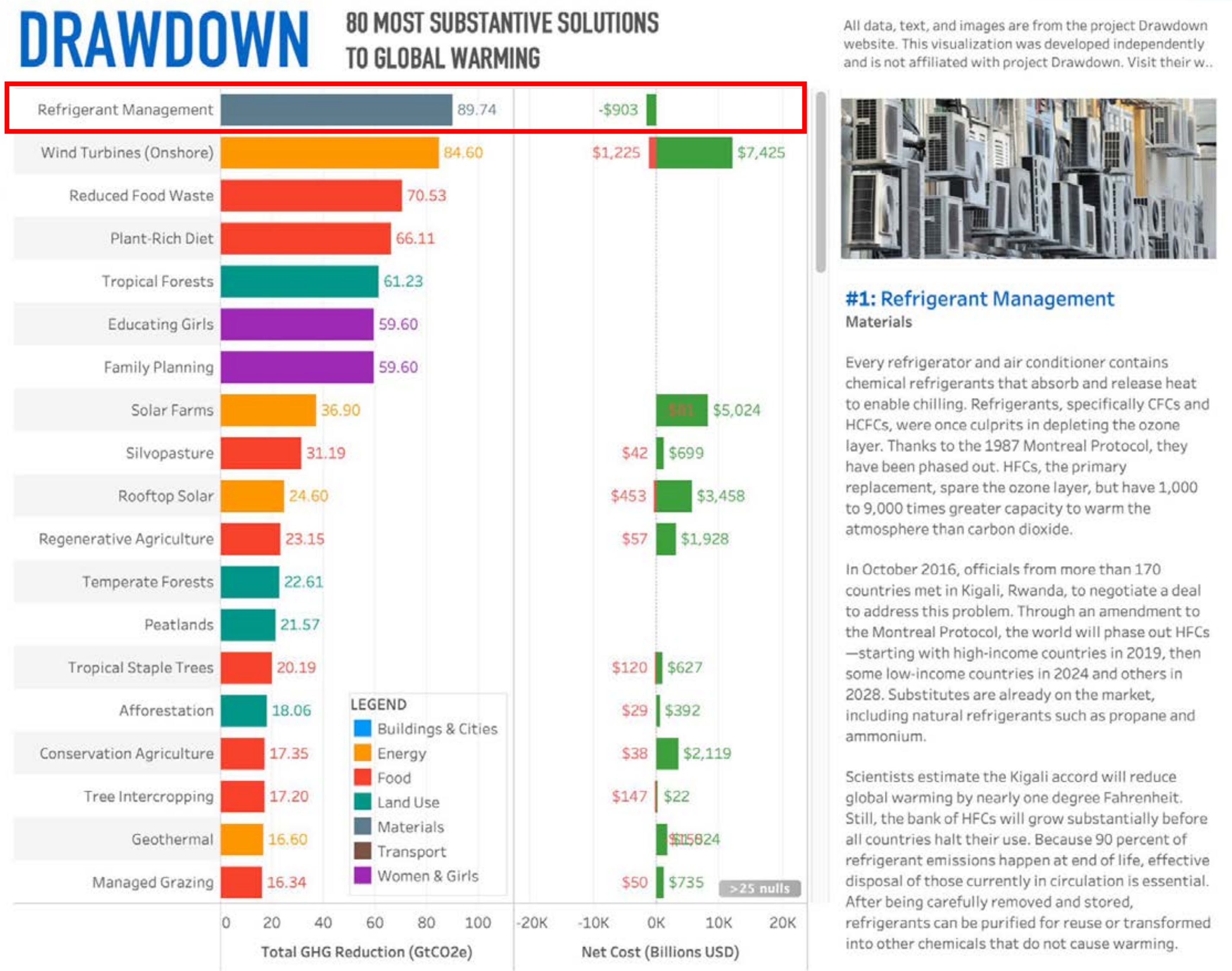


What is the top solution for global warming?



(Source: Drawdown – The Most Comprehensive Plan Ever Proposed to Reverse Global Warming, 2017)

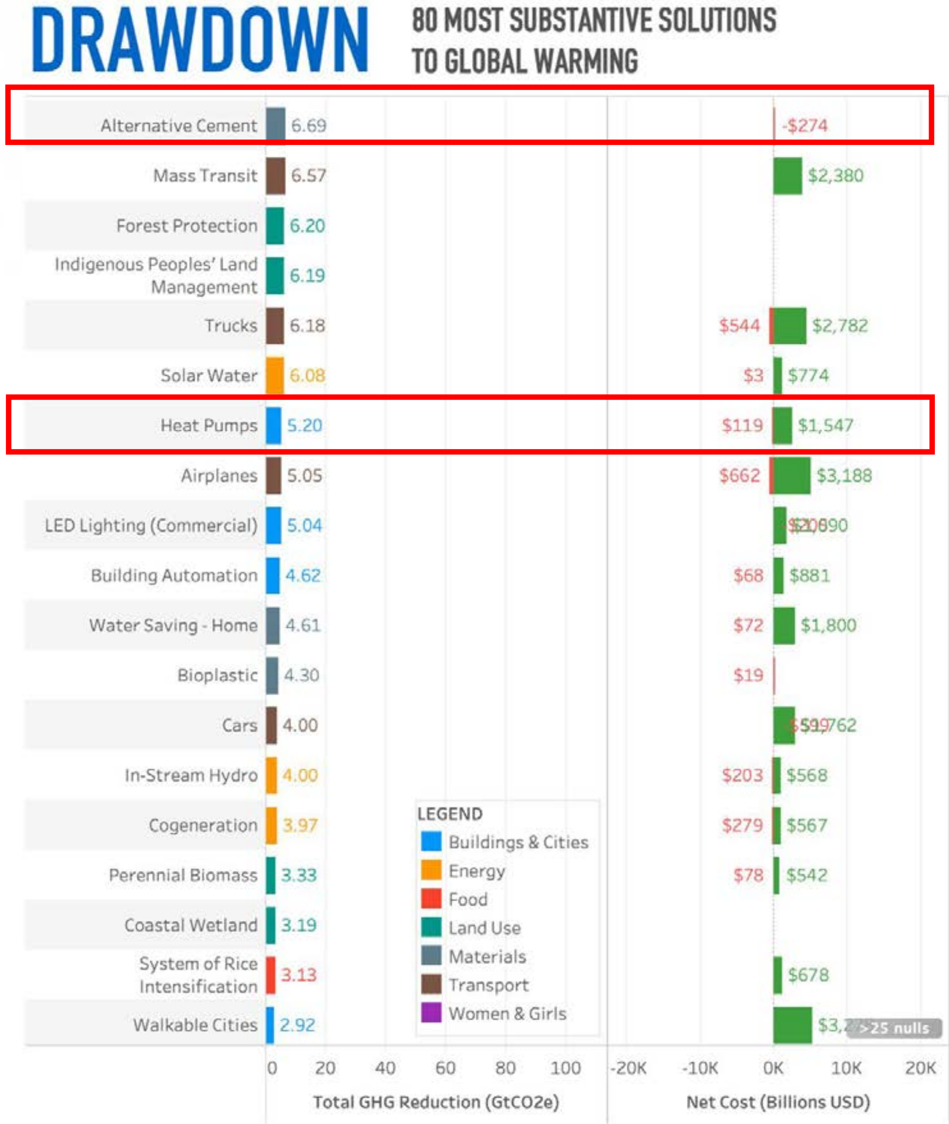
#1 – Refrigerant Management



(Source: Priopta Data Visualization of Drawdown, 2017)

(Data Source: Drawdown – The Most Comprehensive Plan Ever Proposed to Reverse Global Warming, 2017)

#36 – Alternative Cement; #42 – Heat Pumps



All data, text, and images are from the project Drawdown website. This visualization was developed independently and is not affiliated with project Drawdown. Visit their w..

#36: Alternative Cement

Materials

Cement is a vital source of strength in infrastructure, second only to water as one of the most used substances in the world. It is also a source of emissions, generating 5 to 6 percent annually.

To produce Portland cement, the most common form, a mixture of crushed limestone and aluminosilicate clay is roasted in a kiln. At high heat, limestone's calcium carbonate splits into calcium oxide (the desired lime content) and carbon dioxide (the waste). Decarbonizing limestone causes roughly 60 percent of cement's emissions. The rest result from energy use.

To reduce emissions from the decarbonization process, the crucial strategy is to change the composition of cement. Conventional clinker can be partially substituted for alternative materials that include volcanic ash, certain clays, finely ground limestone, ground bottle glass, and industrial waste products—namely blast furnace slag (from manufacturing iron) and fly ash (from burning coal). These materials leapfrog the most carbon-emitting, energy-intensive step in the cement production process.

The average global rate of clinker substitution could realistically reach 40 percent and avoid up to 440 million tons of carbon dioxide emissions annuall Standards and product scales will be key for

(Source: Priopta Data Visualization of Drawdown, 2017)

(Data Source: Drawdown – The Most Comprehensive Plan Ever Proposed to Reverse Global Warming, 2017)

Refrigerants (GWP20 vs GWP100)

Methane:

GWP100	28
GWP20	84

R-134a

GWP100	1,430
GWP20	3,830

R-410a

GWP100	2,088
GWP20	4,340

R-32

GWP100	675
GWP20	2,330

R-717 (ammonia)

GWP100	0
GWP20	0

Table 1: List of the most commonly used HFCs, HCFCs and low GWP alternatives. (IPCCC Fourth Assessment Report- 2007): Atmospheric lifetime and GWP20 and GWP100

Substance	Application	20 Year GWP	100 Year GWP	Atmospheric Lifetime
HCFC -22	Air-conditioning: most commonly used refrigerant	5,160	1,810	12
HCFC -141b	Insulation foam blowing	2,250	725	9.3
HCFC-142b	Insulation foam blowing	5,490	2,310	17.9
HFC-23	Low temperature refrigerant	12,000	14,800	
HFC-32	Blend component of refrigerants	2,330	675	4.9
HFC-125	Blend component of refrigerants	6,350	3,500	29
HFC-134a	Refrigerant in domestic refrigerators, mobile air-conditioning, stationary air-conditioning, blend component of refrigerants, foam blowing agent, aerosol propellant	3,830	1,430	14
HFC-143a	Blend component of refrigerants	5,890	4,470	52
HFC -152a	Blend component of refrigerants, foam blowing agent, possible future refrigerant	437	124	1.4
HFC-227ea	Refrigerant	5,310	3,220	
HFC-245fa	Foam blowing agent Possible future refrigerant	3,380	1030	7.6
HFC-365mfc	Foam blowing agent Possible future refrigerant	2,520	794	8.6
HFC-404a	Refrigerant blend: a leading alternative to HCFC-22 in air-conditioning	6010	3922	34.2
HFC-410 a	Refrigerant blend: a leading alternative to HCFC-22 in air-conditioning, transport refrigeration	4340	2088	
HFC-407c	Refrigerant blend: a leading retrofit alternative to HCFC-22 in air-conditioning, transport refrigeration	4115	1774	
CO2	Refrigerant, foam blowing agent	1	1	
Hydrocarbons	Refrigerant, foam blowing agent	<3	<3	
Ammonia	Refrigerant	0	0	

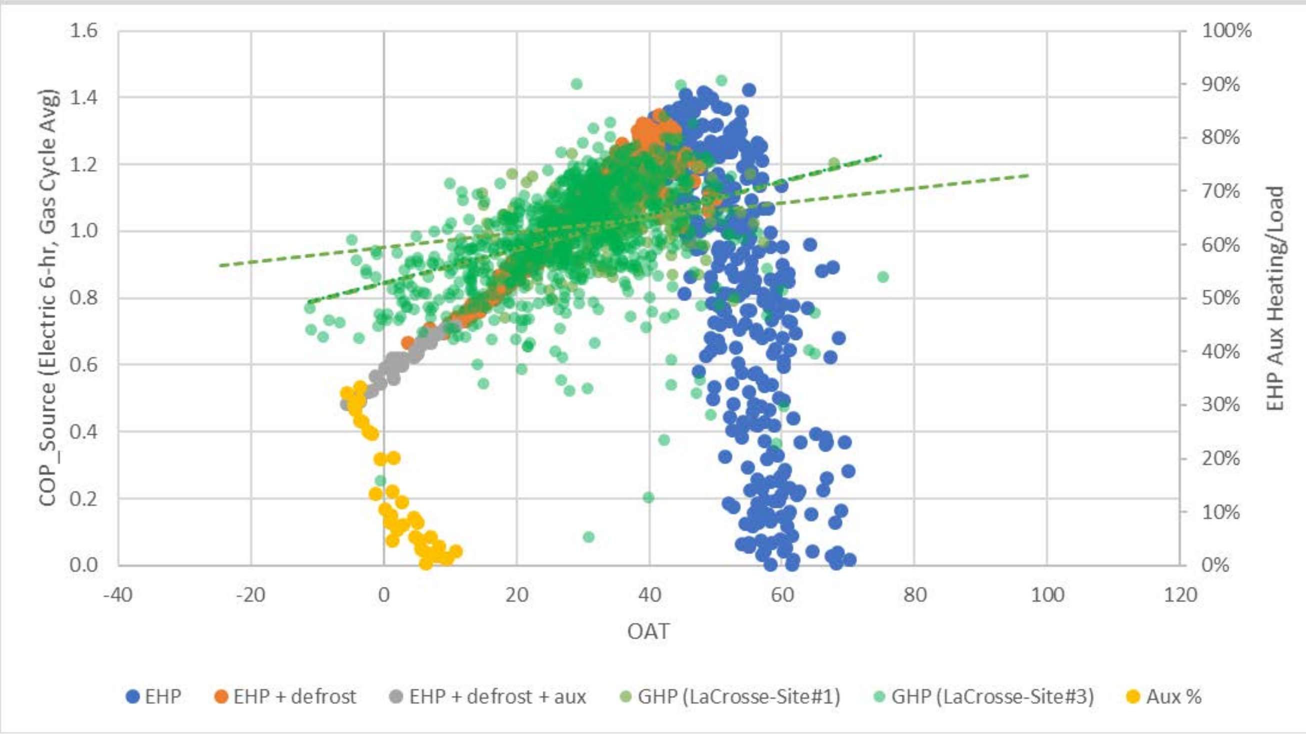
The lifetime of HFCs ranges from 1.4 years (HFC-152a) to 52 years (HFC-143a), the average lifetime is 21.7 years. The average GWP of these HFCs, calculated over 20 years is 4582, and 2362 over 100 years. [viii]

Source: The Benefits of Basing Policies on the 20 Year GWP of HFCs, Montreal Protocol Conference, 2011

Comparing THP w/ Air Source Heat Pumps

Key Differences from Electric ASHP:

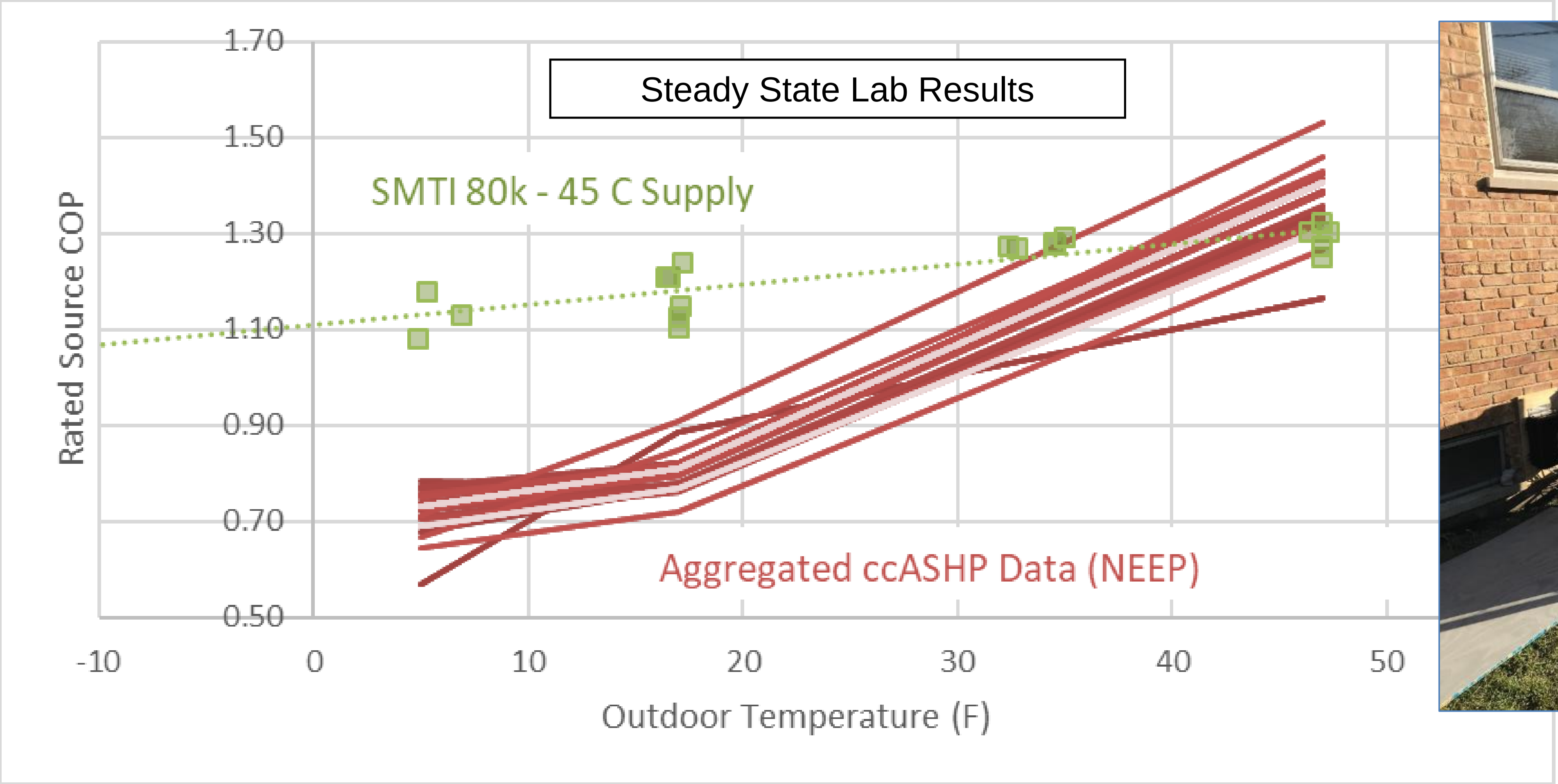
- Capacity and efficiency less impacted by outdoor temperatures
  - Delivered air temperature not impacted by outdoor temperature
- Can supply DHW and Space Heating loads simultaneously (combi)
- No backup/auxiliary heating needed



Cycling / Transient Performance for THP and ccASHP
[Source: GTI]

* Figure source: Schoenbauer, B., Kessler, N., and Kushler, M., Cold Climate Air Source Heat Pump, Report prepared for the Minnesota Department of Commerce under Contract #86417, 11/1/2017.
** "Site basis" includes assumed source energy factors of 1.09 for natural gas and 2.79 for electricity, 2016 US National Average

Field Study Comparison to NEEP Certified ccASHP

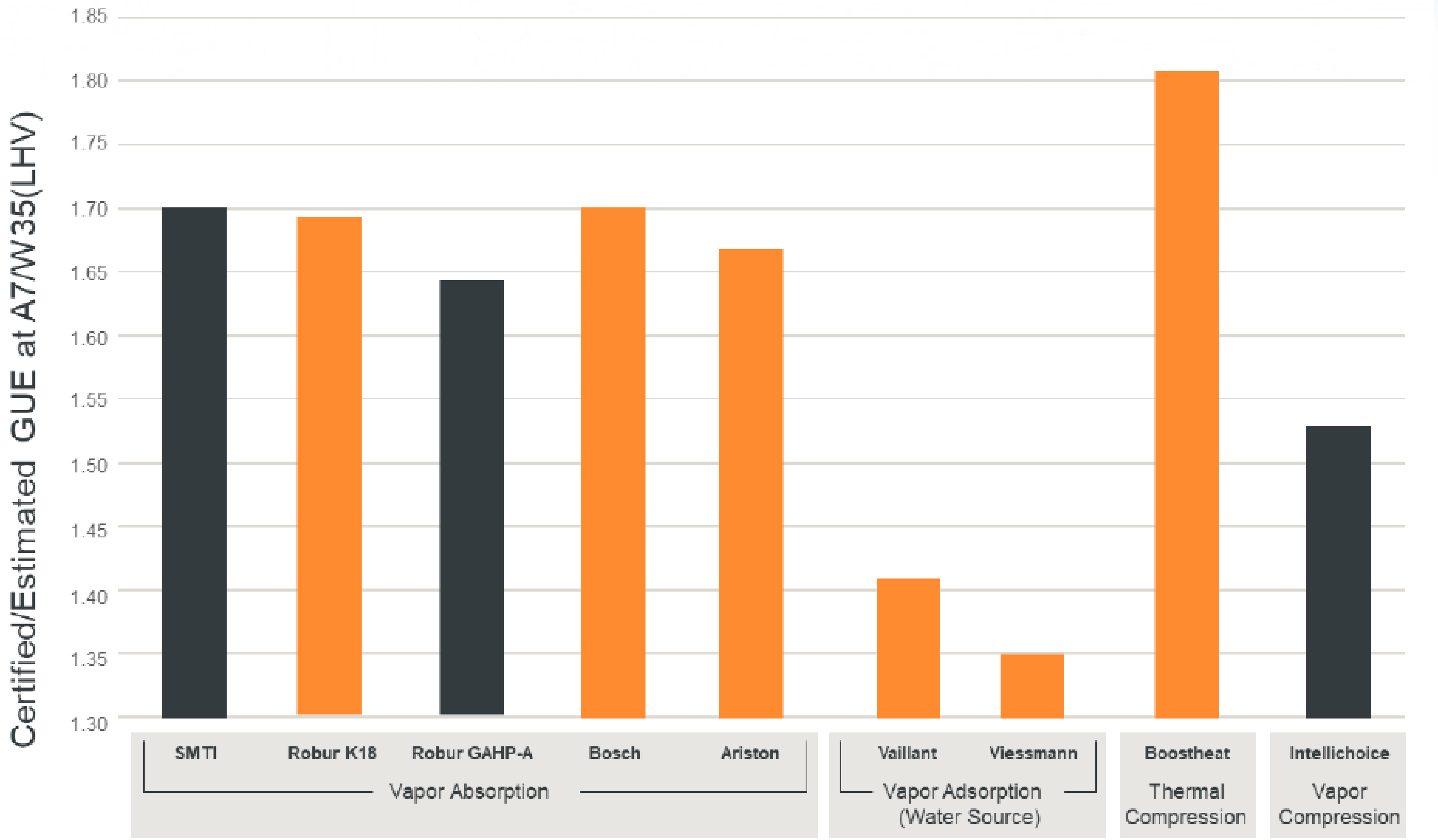


Using eGRID 2016 U.S. national site/source energy conversion for electricity of 2.79 and natural gas of 1.09

What about costs?

Source: Gas Heat Pump Technology and Market Roadmap

Many THPs with Potential (most combi)



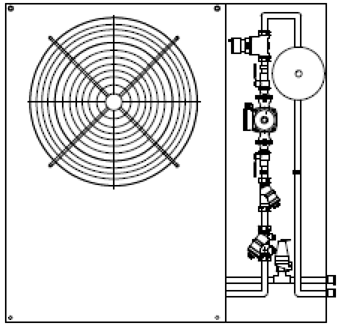
THPs Coming to market

Not purely coincidental that over the last year…

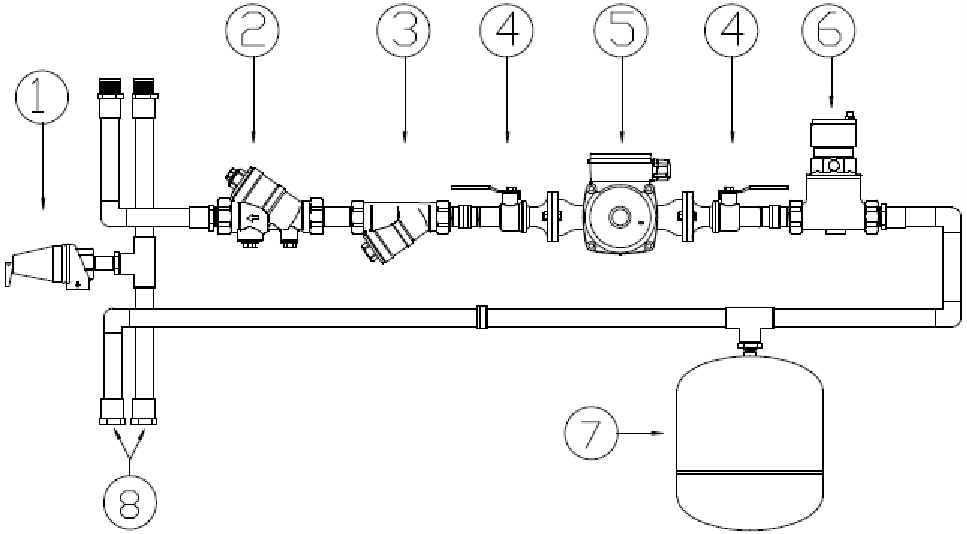
- Government agencies have announced funding calls specifically for THP R&D
- SMTI and their manufacturing partners have openly discussed residential product introductions in 1-2 years, multiple ongoing demos in US/Canada
- ROBUR caring for the environment is planning to introduce its residential-sized THP in the US/Canada
- ThermoLift is planning an expanded demonstration campaign in MN, NY, Canada
- SaltX Technology is spinning off its THP division, with interest in N. America
- BOOSTHEAT has sent products from France to US and Canada for testing
- YANMAR and BLUE MOUNTAIN ENERGY / AISIN have indicated increased interest in their products
- HOMY BUILDING SOLUTIONS introduced the VICOT THP in North America, demo in Canada

gti

Easing THP Installation – Hydronic Packages



TOP VIEW



1. 45 PSI PRESSURE RELIEF VALVE
2. CIRUIT SETTER - 12 GPM
3. Y-STRAINER
4. 1-1/4" FLANGED SHUT-OFF
5. CIRCULATOR PUMP
6. AIR SEPARATOR
7. EXPANSION TANK
8. 1-1/4" FIP CONNECTION

Photo: Robur

Photo: GTI

gti

What about O&M?

Outdoor System

- Ammonia refrigerants have safety concerns
- Refrigerant solution pumps
- Handling condensate

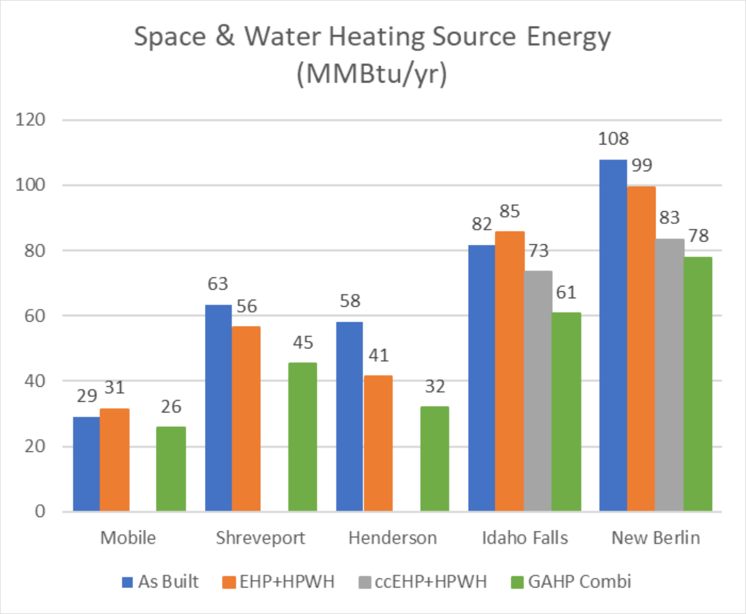
Indoor System

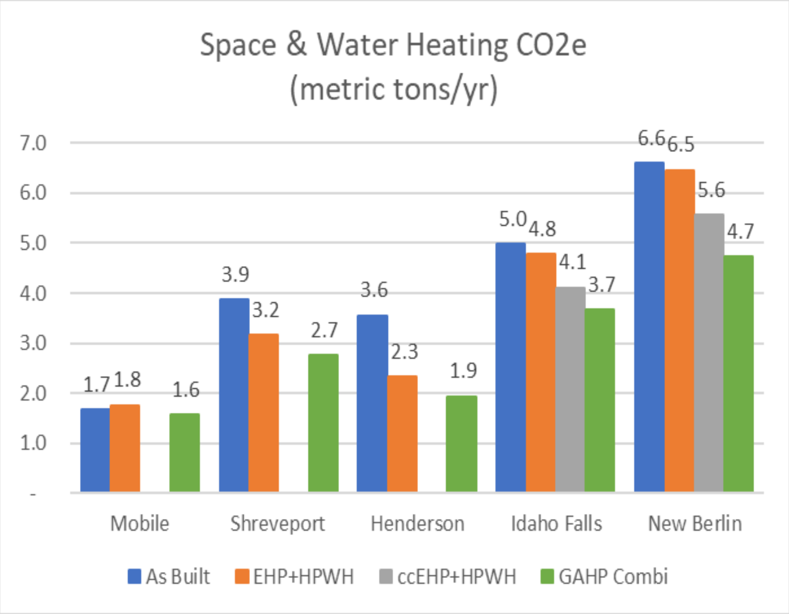
- Similar to other hydronic heating or solar thermal
- Water/glycol mix
- Air filter replacement

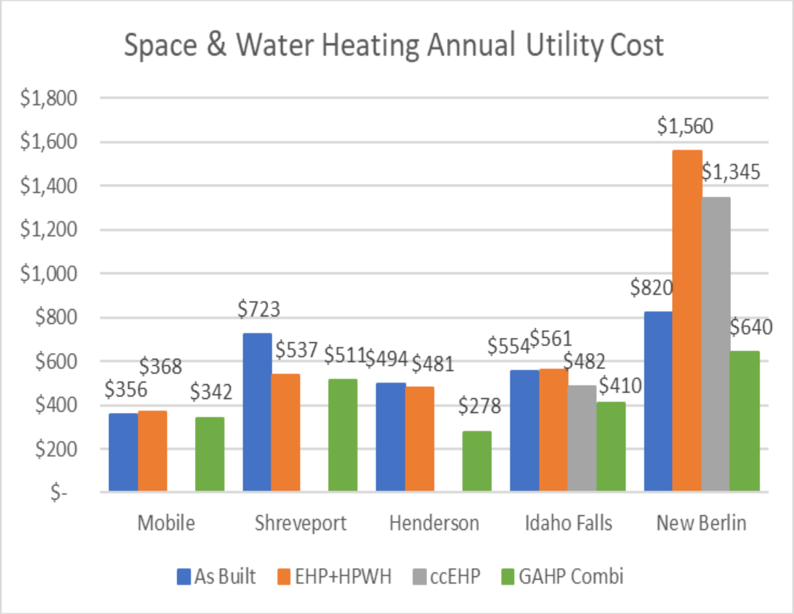
Gas Heat Pump Combis

- SMTI GHP Combi modeled in five builders’ homes
- Gas heat pump combi shows an advantage over both gas furnaces and electric heat pump technologies in all climates
  - Including cold-climate air-source heat pump (modeled for ID and WI)


Photo: GTI







gti

Thermal Heat Pump Summary

- THPs are a new product class, with many options coming to market

Forced Hot Air

Level	AFUE
CEE Tier 1	≥ 92%*
CEE Tier 2	≥ 95%*
CEE Tier 3	≥ 97%*
Advanced Tier	≥ 110%**

Boiler (Hydronic)

Level	AFUE	Other Requirements
CEE Tier 1	≥ 90%*	Thermal Load Management^
CEE Tier 2	≥ 95%*	Thermal Load Management^
Advanced Tier	≥ 110%**	Thermal Load Management^

Preliminary

- THPs offer a deep decarbonization alternative to full electrification
  - Emissions competitive, particularly in cold climates or a greener gas grid
  - Operating and installation costs competitive
  - Natural refrigerants
  - Combustion typically located outdoors, eliminating impact of IAQ risks

gti

THANK YOU

Jason LaFleur, GTI
Sr. Program Manager, Emerging Technologies
jlafleur@gti.energy
847.768.0765

Thank you to THP Partners for sharing information:

Rinnai	www.rinnai.com
Homy	www.homybuild.ca
Robur	www.roburcorp.com
SMTI	www.stonemountaintechnologies.com
Thermolift	www.tm-lift.com

Join the conversation:

#2020EEBAVirtualSummit #eeba #goeeba

Save the dates for next year!

SEPT 14 – 16 2021
Denver, CO