

Pre-Commercial Scale Up of a Gas Absorption Heat Pump



Stone Mountain Technologies, Inc., IR-Trane, Gas Technology Institute

Michael Garrabrant, President & CEO

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Project Summary

Timeline:

Start date: January 1, 2018

Planned end date: December 31, 2019

Key Milestones

1. Milestone 3.1; 4 GAHPs tested at SMTI with COP at design of at least 1.40
2. Milestone 8.1.1; Benchtop demonstration of automated assembly of Absorber and Condenser
3. Milestone 9.2; ANSI Z21.40.1 Testing Complete, pass 90% of requirements
4. Milestone 9.4; ALT of prototype for at least 4000 hours
5. Milestone 9.6; Pre-commercial prototype testing completed with COP at design of at least 1.40

Budget:

Total Project \$ through 28 Feb 2019

- DOE: \$1,214,026
- Cost Share: \$7705,937

Total Project \$:

- DOE: \$1,881,537
- Cost Share: \$822,523

Key Partners:

Ingersoll Rand-Trane
Gas Technology Institute

Project Outcome:

Advance the maturity of SMTI's 80 kBTU/hr residential space/water heating GAHP from the current engineering prototype stage to pre-production readiness by addressing remaining manufacturing, balance of system design, installation, cost reliability and field application questions.

Team



Stone Mountain Technologies, Inc

- Michael Garrabrant, PI
 - Absorption Heat Pump Innovation and R&D
 - Gas Appliance Design & Volume Manufacturing Expertise
- Dr. Christopher Keinath, Dir. Engineering
 - 10 years experience investigating absorption heat pumps
 - Fundamentals, Modeling, Experimental Expertise
- Scott Reed, VP Marketing and Strategy
 - Advanced technology marketing and commercialization
 - Business development and strategy expertise



Ingersoll Rand-Trane

- Leading Global HVAC Manufacturer, Product Engineering, Volume Manufacturing, Marketing and Sales Distribution
- Jason LeRoy, Dir. Advanced Solutions



Gas Technology Institute

- Paul Glanville, R&D Manager
 - Gas Appliance R&D, Innovation, Natural Gas Industry Representation
 - HVAC-Water Heating Field Test Expertise

Challenge – Improve Efficiency of Heating



What We Use For Gas Heating Has Not Changed Much in 50+ years

Furnaces | Boilers | Water Heaters

Non-Condensing Models Are 75 – 83% Efficient

Condensing Models Are 90 – 98% Efficient

BUT

We are getting close to changing that with

Gas Absorption Heat Pumps

Condensing, 4:1 Modulation, 140% AFUE

Outdoor Installation, SCAQMD NOx Compliant, GWP = 0

- ✓ Reduce Operating Cost by 30-50%
- ✓ Maintain a High Level of Comfort
- ✓ Reduce Carbon Footprint by 30-50%
- ✓ Target Total Installed Cost <\$7,500
 - ✓ Simple Payback 3-5 Years

Background: SMTI Business Model

Thermal Compressor

SMTI



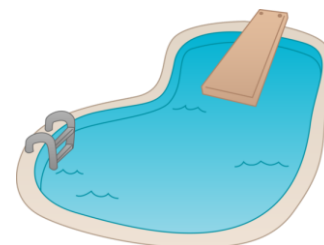
Sell To

HVAC & WH
OEMS

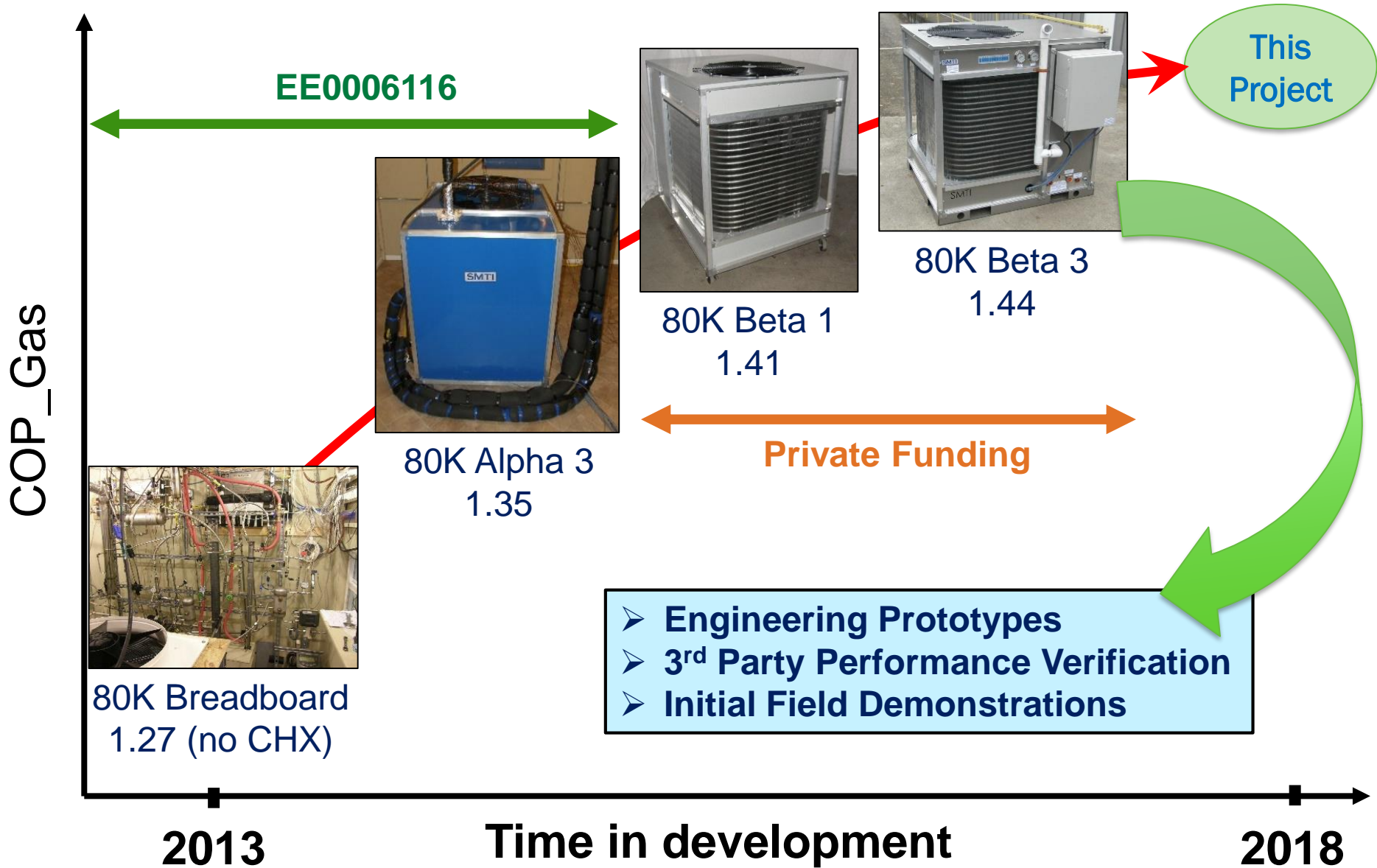


End Use Products

- ✓ Partners, not competitors
- ✓ Maximize existing brand & marketing power
- ✓ Least-cost, Fastest-to-market, Lowest-risk pathway to Product Differentiation



80 kBtu/h GAHP Development Timeline



Approach of This Project

End Goal: Advance Development to Commercial Readiness

- **Design for Manufacturing and Cost**
 - Sealed System
 - Balance of System
 - Integrated Control Board
- **Fabricate & Test Four Prototypes of DFM Design**
 - Cold-Climate Field Demonstration
- **ANSI Certification Tests**
- **Direct Manufacturing Cost and Capital Equipment Required**
 - Benchtop Automated Assy Demonstration
- **Techno-Economic Analysis**
- **Reliability Test Plan**
- **Market Research**
 - Quantitative and Qualitative
 - Consumers & Contractors
 - Five Year Sales Estimate
- **Codes & Standards Review & Analysis**
- **Fabricate & Test Two Commercial-Ready Prototypes**

Green = Complete or Nearly Complete; Blue = In Process or Pending

Impact

GAHP:	140% AFUE
Gas Furnace Min:	80% AFUE
Gas Furnace Max:	97% AFUE
Energy Savings:	30 – 50%

For 80 kBth GAHP

Total Installed Cost:	< \$7,500
Typical Payback:	3–5 yrs (for <i>HDD</i> >4000)

Residential Space Heating Market

3.4 million gas furnaces sold annually
~2.2 million in HDD > 4000 climate zones
20% Market Share = 440,000 units annually

Therms Saved per home per year: 400 - 800

For Charts on Next X Pages 

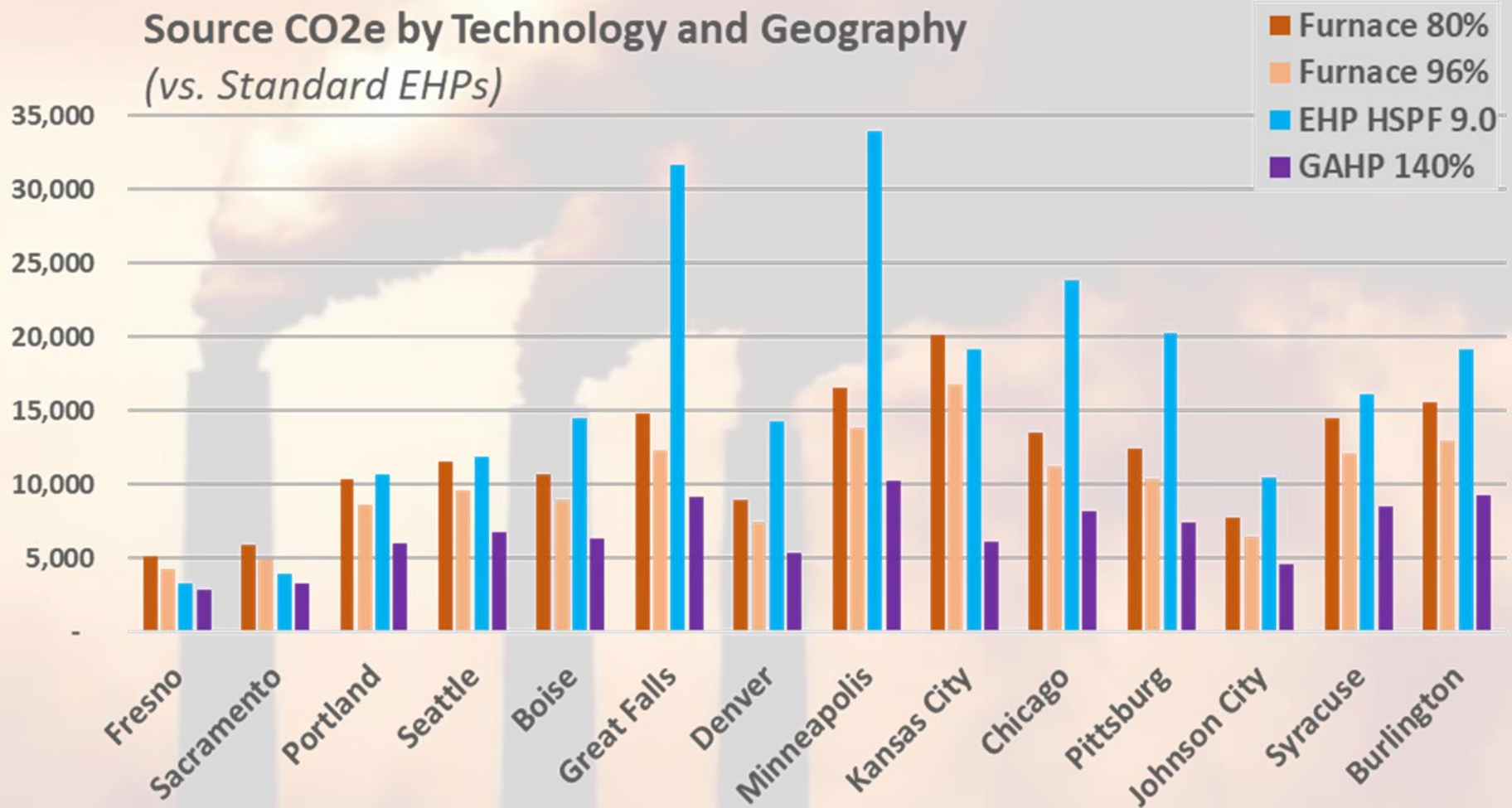
Method and Assumptions

- 2,700 sqft home
- 4 occupants
- Space-heating load only
- eGrid 2016
- Energy Planning Analysis Tool (GTI – based on EnergyPlus)
- Performance: mfr data except GAHP (prototype test data)

<http://epat.gastechnology.org/>

Impact

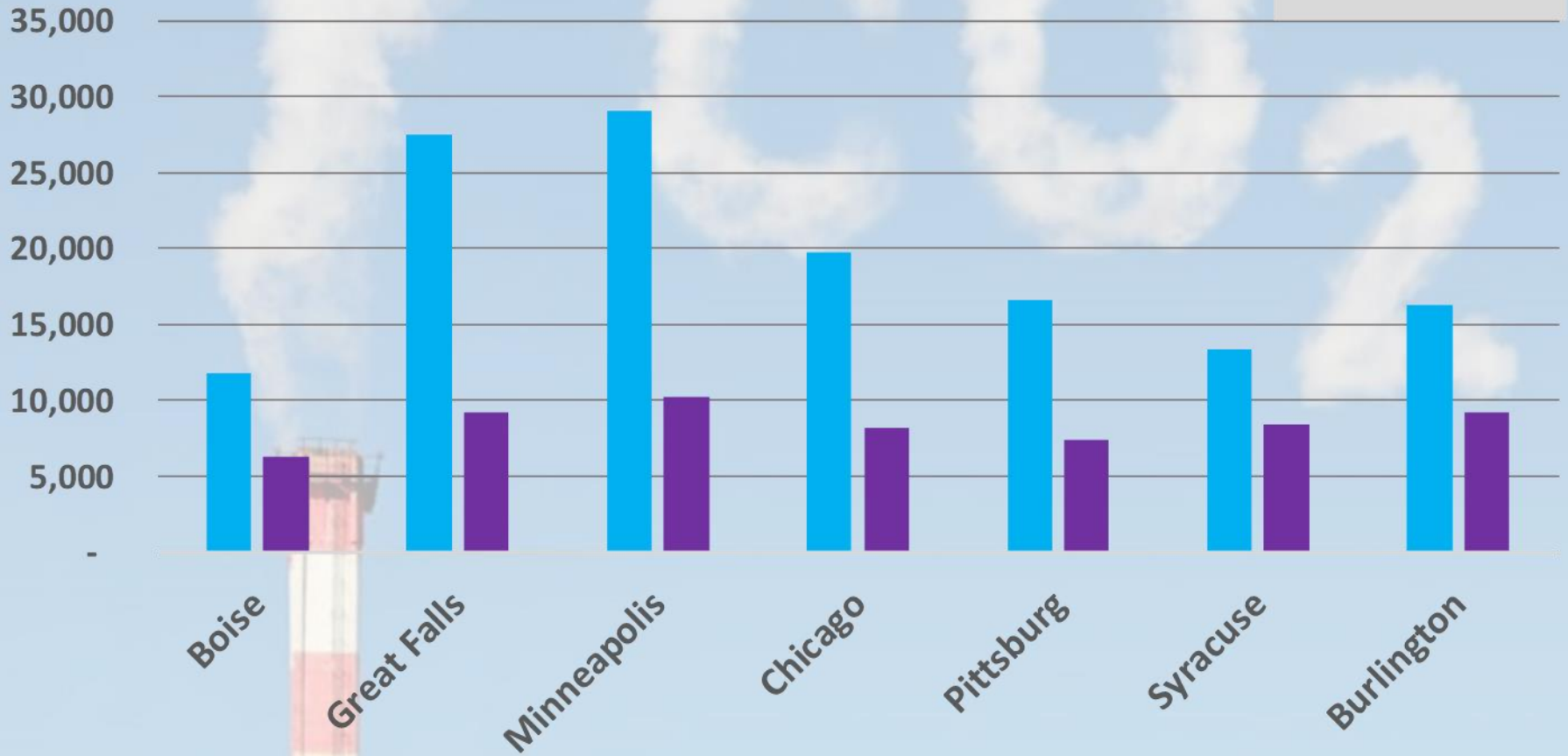
Source CO2e by Technology and Geography (vs. Standard EHPs)



Impact

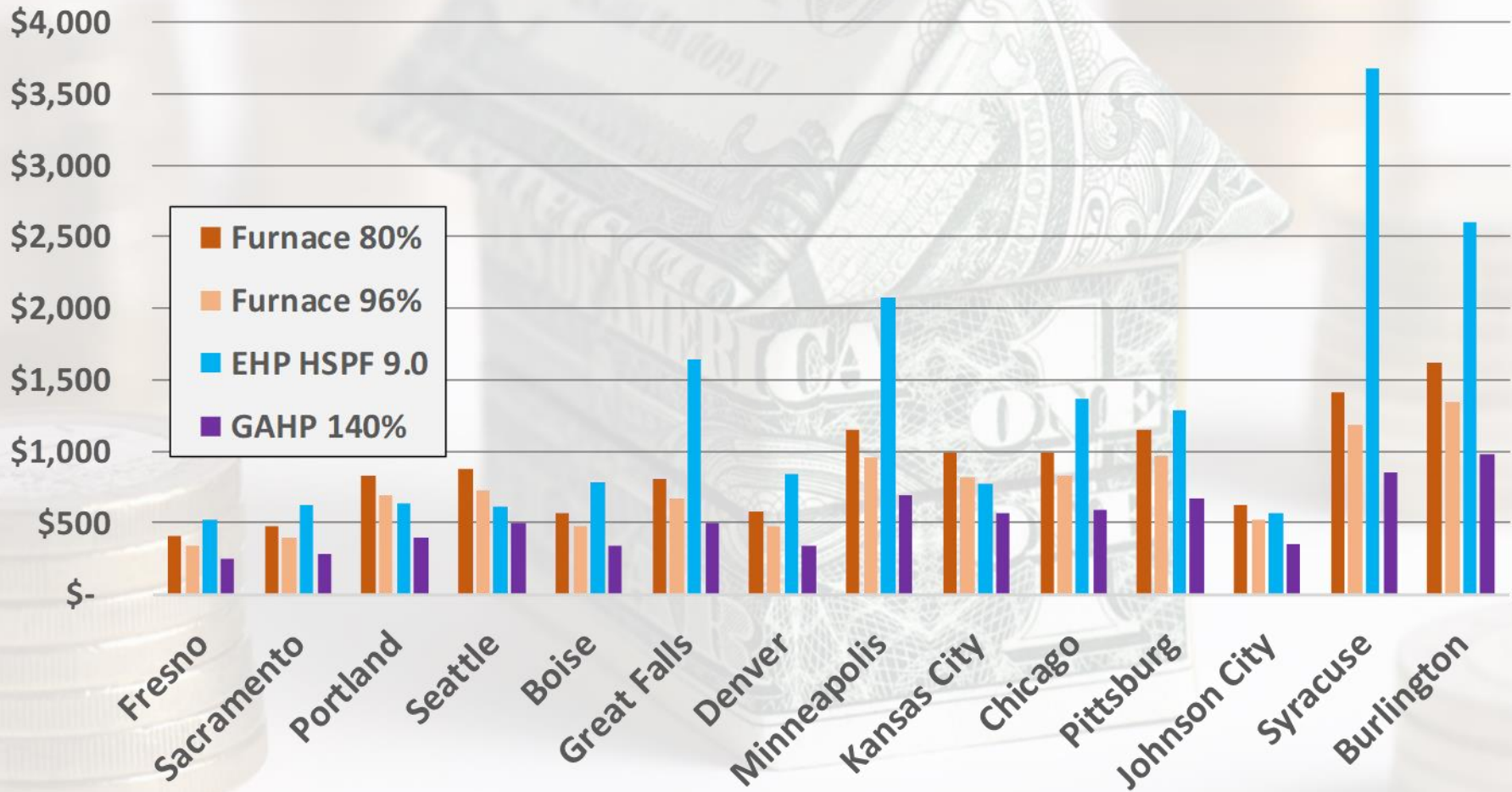
Source CO₂e by Technology and Geography
(vs. Cold-Climate EHPs)

■ CCEHP HSPF 13
■ GAHP 140%

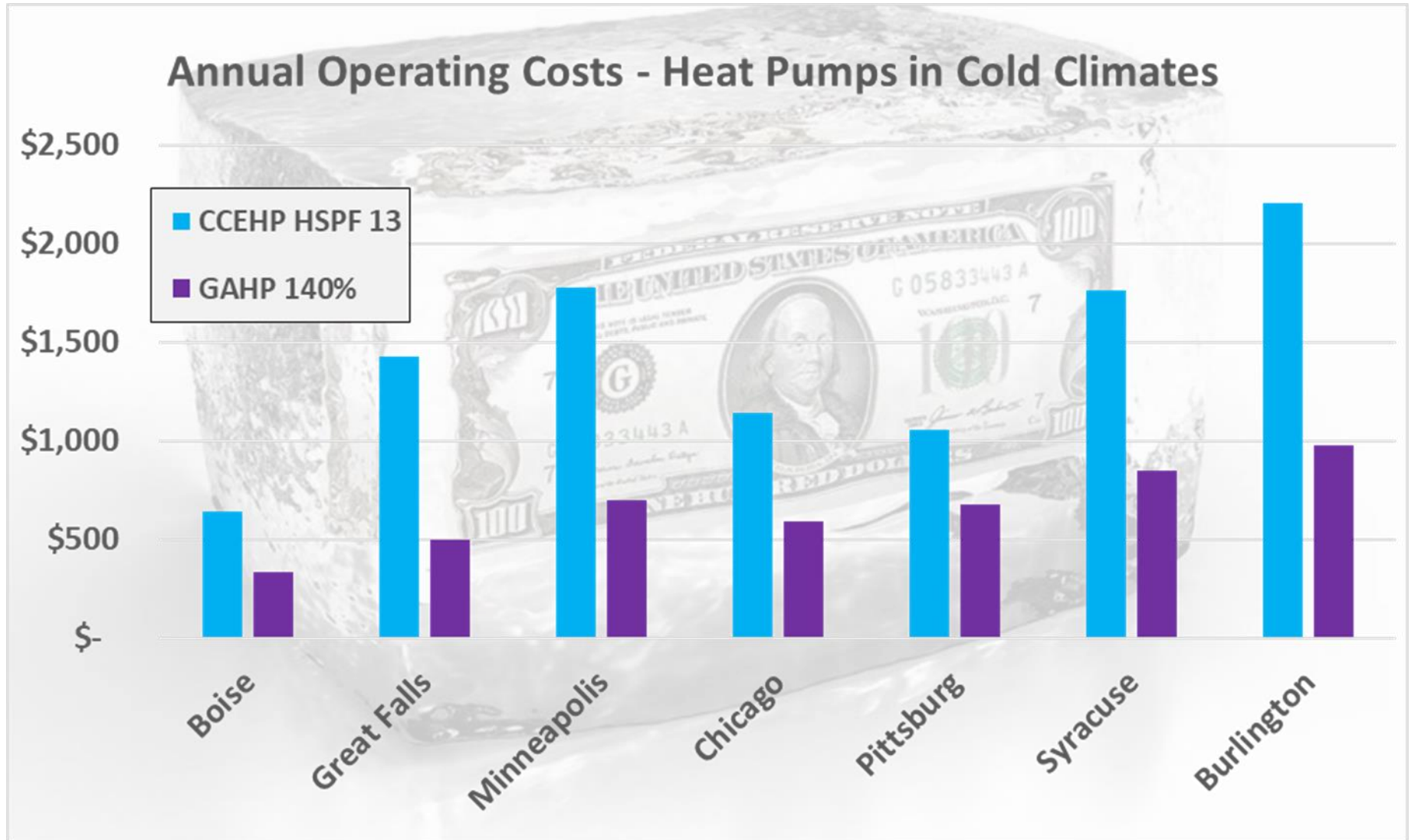


Impact

Annual Operating Costs - Space Heating Technologies

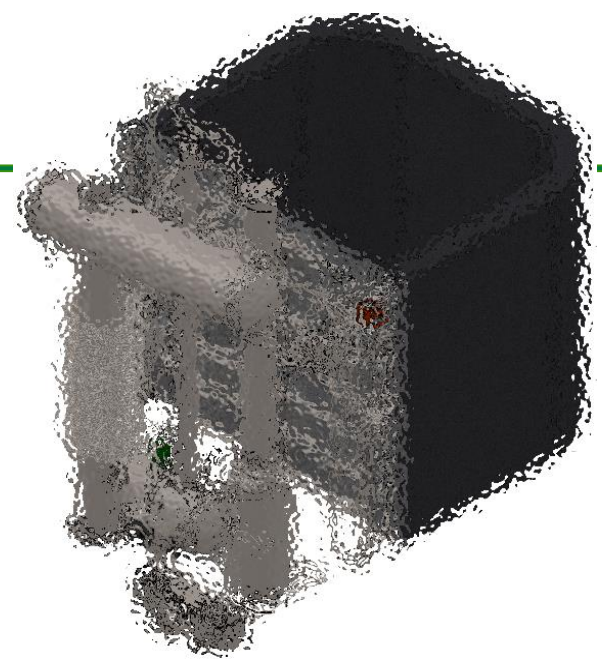


Impact



Progress – DFM

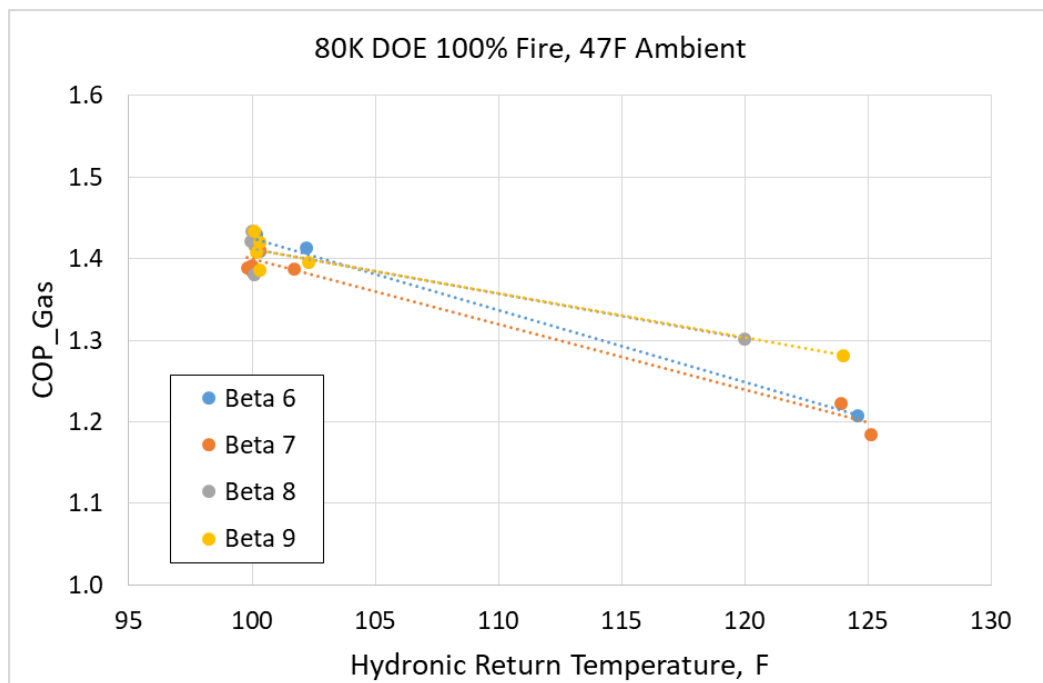
- **Sealed system**
 - Integration of several components
 - Elimination of ~6 tube runs
 - Elimination of ~20 weld joints
 - Reduction in part count
 - Simplification of design
 - Reduced width by 2.5 inches
- **Balance of system**
 - Tech Transfer to Commercialization Partner
 - Commercialization Partner controls development and integrated circuit board design
 - Combustion system supplier controls and component design & development
 - Cabinetry based off commercialized products



Apologies for blurred pictures due to confidentiality

Progress – Prototype Testing

- Four (4) prototype fabricated and tested at SMTI
 - Significant DFM design revisions
 - Commercialization partner GAHP controls
 - Combustion supplier controls and combustion assembly
 - Initial ANSI Certification Testing Completed (combustion)
- ✓ Q4 Milestone - COP of at least 1.4 at design confirmed
- Two (2) units sent to field test in WI
- One (1) unit sent to CP facility in TX



Progress – Field Demonstration

Site	Home Details	Occupants	Existing HVAC	Existing DHW Equipment
Site 1	Two-story, 1973 build, 2,451 sf	2 – 2 Adults	Gas Furnace, Dual stage, 100 kBtu/h input, 96.7% AFUE	Standard Gas Storage, 40 kBtu/h, 40 gal.
Site 2	Two-story, 1978 build, 1700 sf, full basement	2 – 2 Adults	Gas Furnace, Single stage, 80 kBtu/h input, 78% AFUE	Standard Electric Resistance, 80 gal

Site 1



Site 2



Some Images courtesy of GTI

Progress – Codes and Standards Reviewed

GAHP Performance and Test Standards

- ANSIZ21.40.4/CGA 2.94
- ASHRAE 40
- EN 12309
- CAN CSA P.9-11
- ANSI/AHRAE 124-2007 (R2016)

Product Safety

- ANSI Z21.40.1/CGA 2.91
- ASHRAE 15
- IIAR-2

Installation and Maintenance

- NFPA 54,
- IMC
- Condensate (outdoor) handling
- NH3 disposal
- Double-wall heat exchangers (hot water heating)

Shipping

- 49 CFR 173.306
- 49 CFR 173.307
- 49 CFR 173.154

Emissions

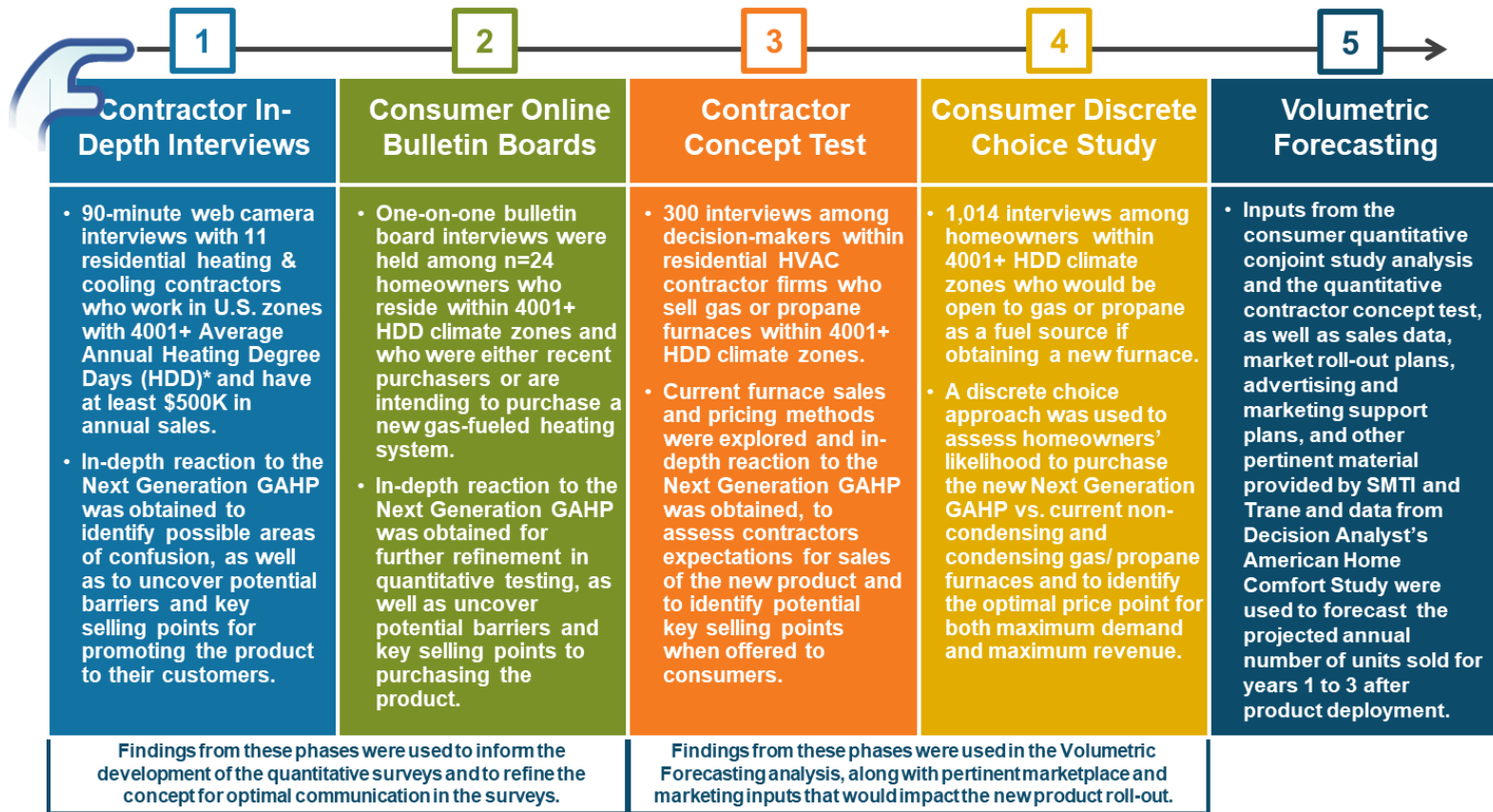
- EPA
- SNAP
- CARB
- SCAQMD
- California AB 32
- Canadian Carbon Levy

No major roadblocks with codes and standards are expected in the commercialization and roll out of a GAHP product

Progress – Market Research

Research Design

- The following five research phases were conducted:



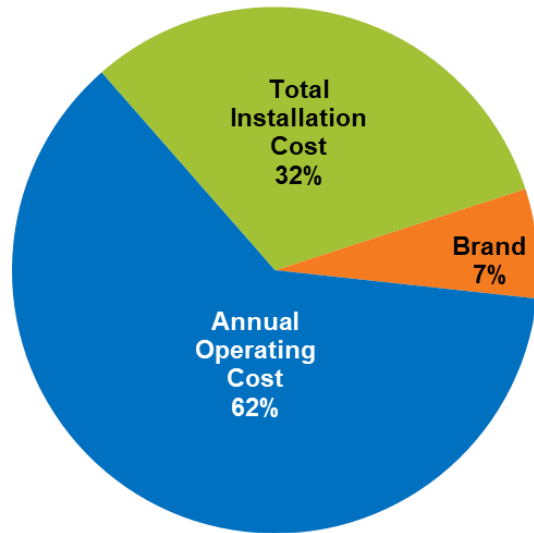
*A heating degree day (HDD) is a measurement designed to quantify the demand for energy needed to heat a building. It is derived by multiplying the number of days that the average temperature falls below 65° by the number of degrees to which it falls below 65°.

Progress – Market Research

Total Respondents

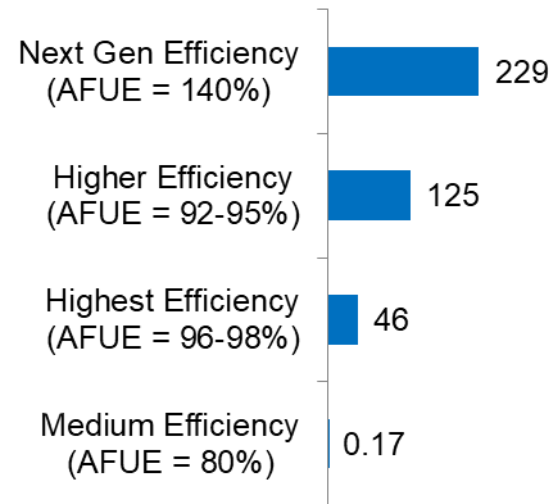
- Overall, *Annual Operating Cost* constitutes 62% of the decision to purchase a heating system. *Total Installation Cost* is second most important, accounting for 32% of the decision.
- Homeowners prefer the *Next Gen (GAHP)* furnace followed by the *Higher Efficiency* furnace.

Attribute Importance



Base: Total Respondents (n=1014)
Source: Advanced Analytics

Furnace Preference

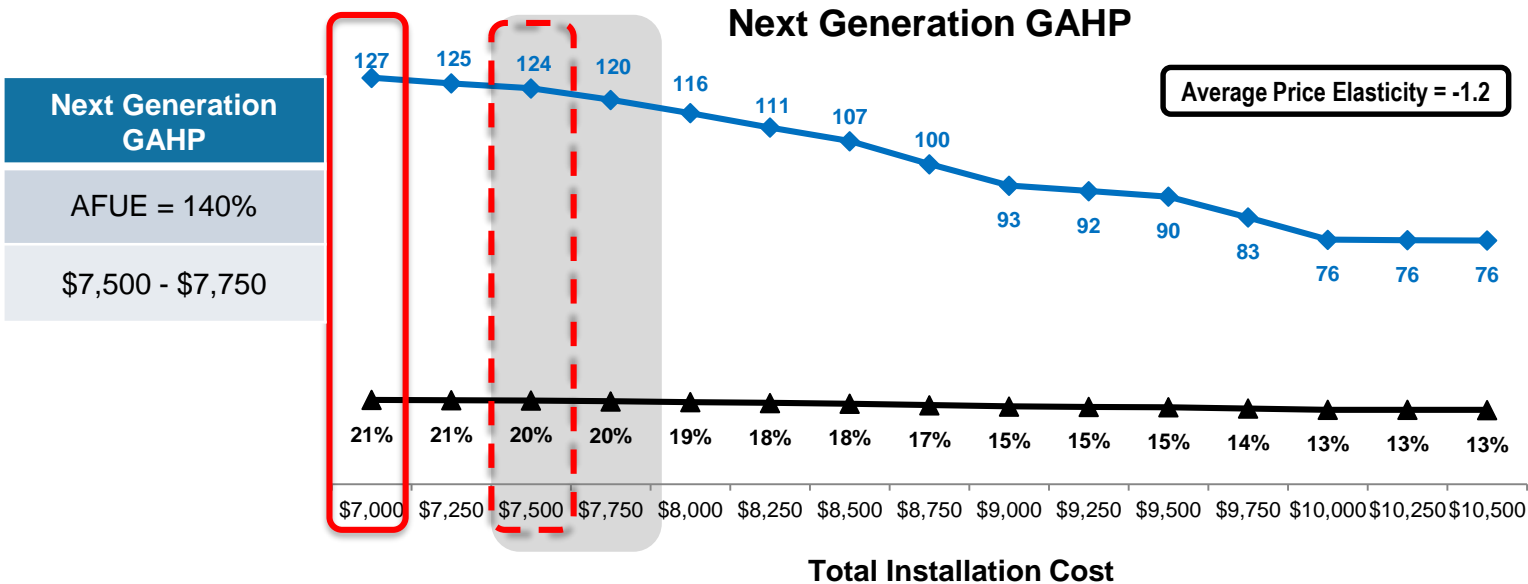


Notes: Values in the bar chart illustrate the relative preference for each product type. The raw level utilities are rescaled to the average preference (index = 100) across all product types. The higher the index, the more preferred the product type.

Progress – Market Research

Total Respondents

- Overall, demand is maximized at \$7,000 for the Next Generation GAHP total installed cost. Demand decreases by about 40% as *Total Installation Cost* increases from the lowest cost of \$7,000 to the highest cost of \$10,500.



The black line reports the Preference Share, which is the percentage of consumers who would purchase the product. The Demand Index (solid blue line) is the indexed Preference Share of the Next Gen (GAHP) furnace across the price points tested. A Demand Index of 100 represents the Preference Share at the middle price point, \$8,750.

Note: Results shown assume 100% awareness and 100% distribution.
 Base: Total Respondents (n=1,014)
 Source: Advanced Analytics

Stakeholder Engagement

- **Top 3 HVAC Market Share OEM Commercialization Partner**
- **Natural Gas Utilities**
 - **NW Natural, CenterPoint Energy, ConEd, National Fuel (all providing cost share)**
 - **Confidential Major Gas Utility - Seed Investor in SMTI**
 - **Gas Technology Institute (Major Sub-Contractor)**
 - **Constant communication path to gas utilities**
 - **Gas Utility Working Group for Gas Heat Pumps**
 - **14 major gas utilities (U.S. and Canada)**
 - **Goal of helping accelerate market adoption of gas heat pumps**
- **Other Industry Stakeholders**
 - **Northwest Energy Efficiency Association (NEEA) – providing cost share**
 - **Propane Education and Research Assoc (PERC) – providing cost share**
 - **Energy Solutions Center (ESC) – presenting at TMAF in June**
 - **Center for Energy Efficiency (CEE) – helping us work with EnergyStar**
 - **ACEEE – multiple presentations at Hot Water Forum (2018 and 2019)**
- **International**
 - **GRDF/Engie (France) - sponsored R&D, helping enter EU market**
 - **NRCAN – testing SMTI prototype, evaluation for Canadian climate**
- **ASHRAE**
 - **Presentations (with GTI) at conferences**
- **NREL**
 - **Selected to “pitch” at Industry Growth Forum (May, 2019)**

Remaining Project Work

Demonstration (Task 7)

- Continuation of the field test through the end of the project

Manufacturing Process and Demonstration (Task 8)

- Assembly Demonstration (Absorber, Condenser, Desorber & Solution Pump)
- Process, Tooling, Equipment definition for production GAHP
- ***Final direct manufacturing cost for Sealed System and Final Heat Pump Assembly***

Reliability Assessment (Task 9)

- Final ANSI Z21.40.1 Testing and Evaluation
- ALT of prototype GAHP, 4000 hours of operation
- Development of a long term reliability test plan
- Fabrication and testing of two (2) pre-commercial GAHPs

Techno-Economic Analysis (Task 10)

- Modeling of different Homes, Regions and Equipment
- Energy, cost, emissions, payback and other analyses

Thank You

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REFERENCE SLIDES

Project Budget

Project Budget: \$1,881,537(Fed) + \$822,523 (CS) = \$2,704,060














Variances: Currently Under Budget

Cost to Date: **Federal:** **\$1,214,026 of \$1,881,537 (64.5%)**
 Cost Share: **\$705,937 of \$822,523 (85.8%)**

Budget History

01/01/18 – FY 2018 (past)		FY 2019 (current)		FY 2020 – 12/31/19 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
\$666,484	\$344,237	\$1,075,053	\$438,286	\$140,000	\$40,000

Project Plan and Schedule

Project Schedule												
Project Start: January 1, 2018	Completed Work											
Projected End: December 31, 2019	Active Task (in progress work)											
	 Milestone/Deliverable (Originally Planned) use for missed											
	 Milestone/Deliverable (Actual) use when met on time											
	FY2018				FY2019				FY2020			
Task	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)
Past Work												
M1.0: IPMP Signed and Submitted												
M3.3: Field Test Baseline M&V Report												
M2.4: Cold Climate Gas Valve Demonstration												
M3.1: Prototype COP _{gas} of 1.4 at design conditions												
Current/Future Work												
M7.1: Prototype testing at CP, COP _{gas} of 1.4												
M8.1.1: Benchtop Assembly Demonstration of Absorber/Condenser												
M8.1.2: Benchtop Assembly Demonstration of Desorber												
9.2: ANSI Z21.40.1 Testing, 90% pass												
M8.1.3: Bench Assembly Demonstration of Solution Pump												
M9.4: ALT of prototype for at least 4000 hours												
M9.6: Pre-commercial prototype testing with COP of at least 1.40									