Commercial Absorption Heat Pump Water Heater

2017 Building Technologies Office Peer Review

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

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Project Summary

Timeline:
Start date: 10/1/13
Planned end date: 6/30/18

Key Milestones

1. Field site selection: 3/31/17
2. Report evaluation of field study to date: 9/30/17

Key Partners:

A.O. Smith

Stone Mountain Technologies, Inc.

Budget:

Total Project $ to Date:

- DOE: $1792.9K
- Cost Share: *

Total Project $:

- DOE: $1,920K
- Cost Share: *

Project Outcome:

An 140,000 BTU/hr GAHP achieving a cycle COP of 1.63 at the rated condition of 47°F ambient.

The target market is the hospital, hotel and full service restaurant gas hot water heating market.

Field test unit in FY17.

* In-kind contribution from CRADA partner – exceeds DOE funding level; exact total is confidential information

Purpose and Objectives

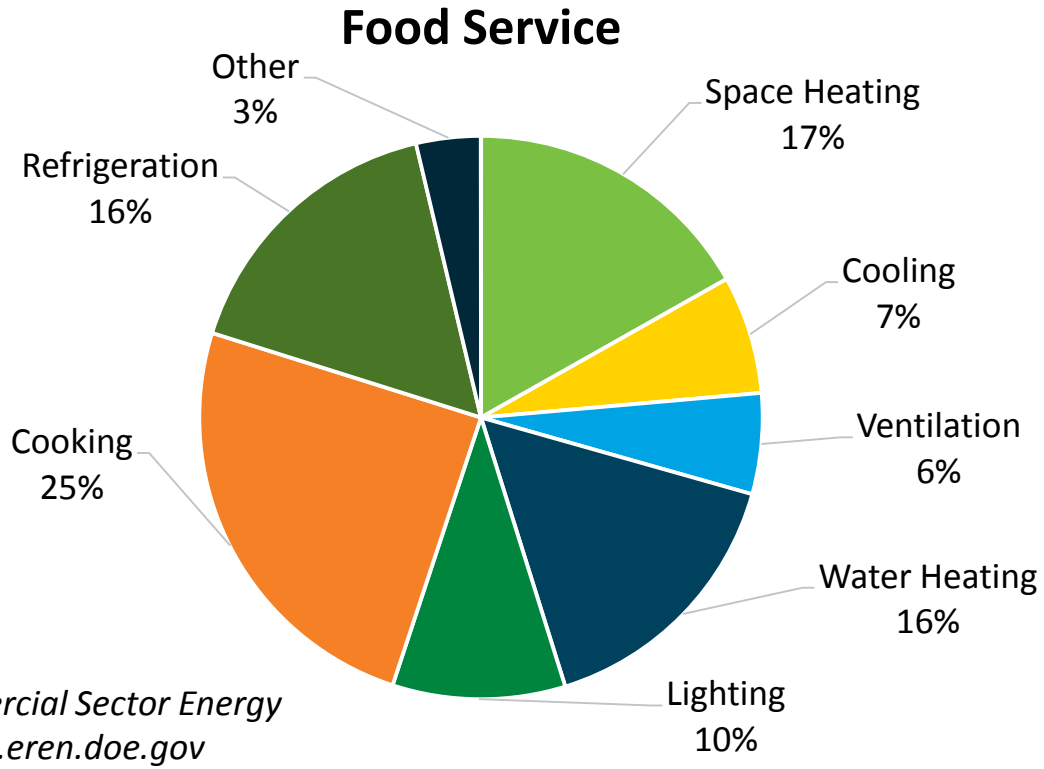
Problem Statement:

As stated in the BTO's MYPP

- **2020** Energy use intensity for WH **25%** lower than **2010** energy-efficient baseline – part of 1.8 quads energy savings
- In **2014**, natural gas provided **3** quads of the estimated **18** quads of commercial buildings energy use
- AHPWH achieving **45%** energy savings compared to ENERGY STAR-certified gas storage water heater

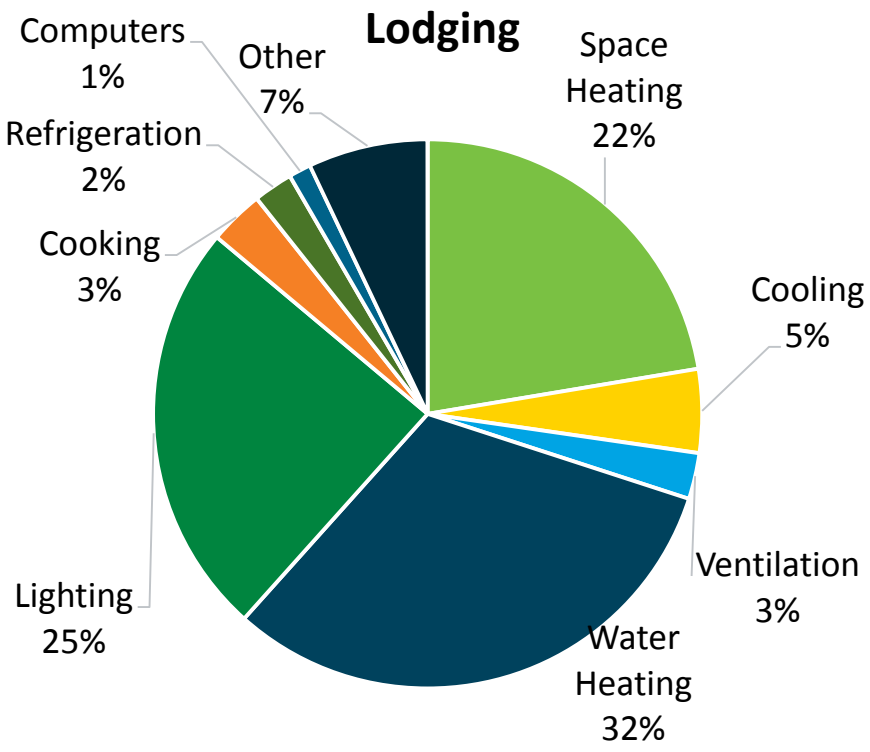
Purpose and Objectives

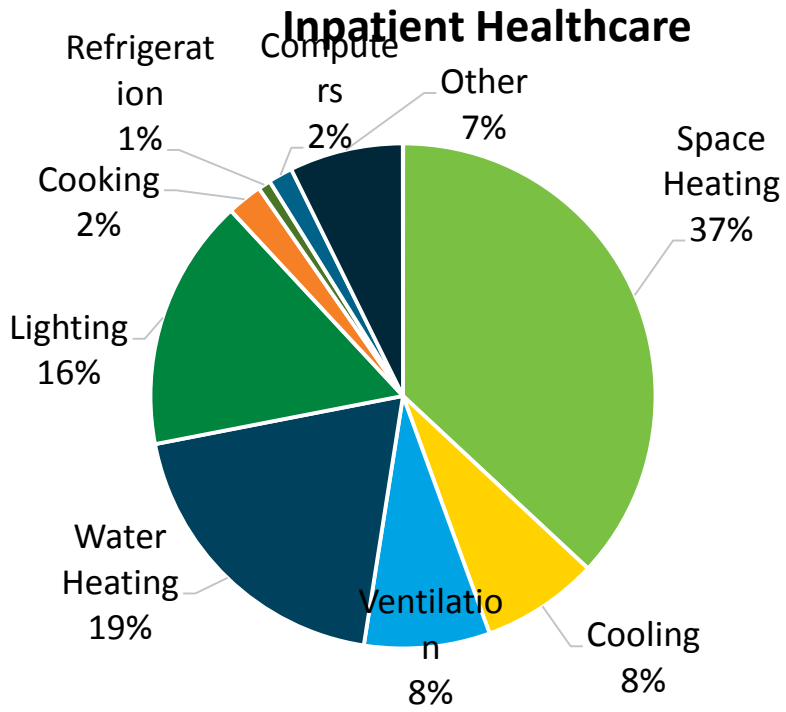
Target Market and Audience:
The natural gas commercial water heating market with a special emphasis on retrofits with minimal total installed cost.



Buildings Energy Data Book: 3.1 Commercial Sector Energy Consumption, http://buildingsdatabook.eren.doe.gov

Purpose and Objectives

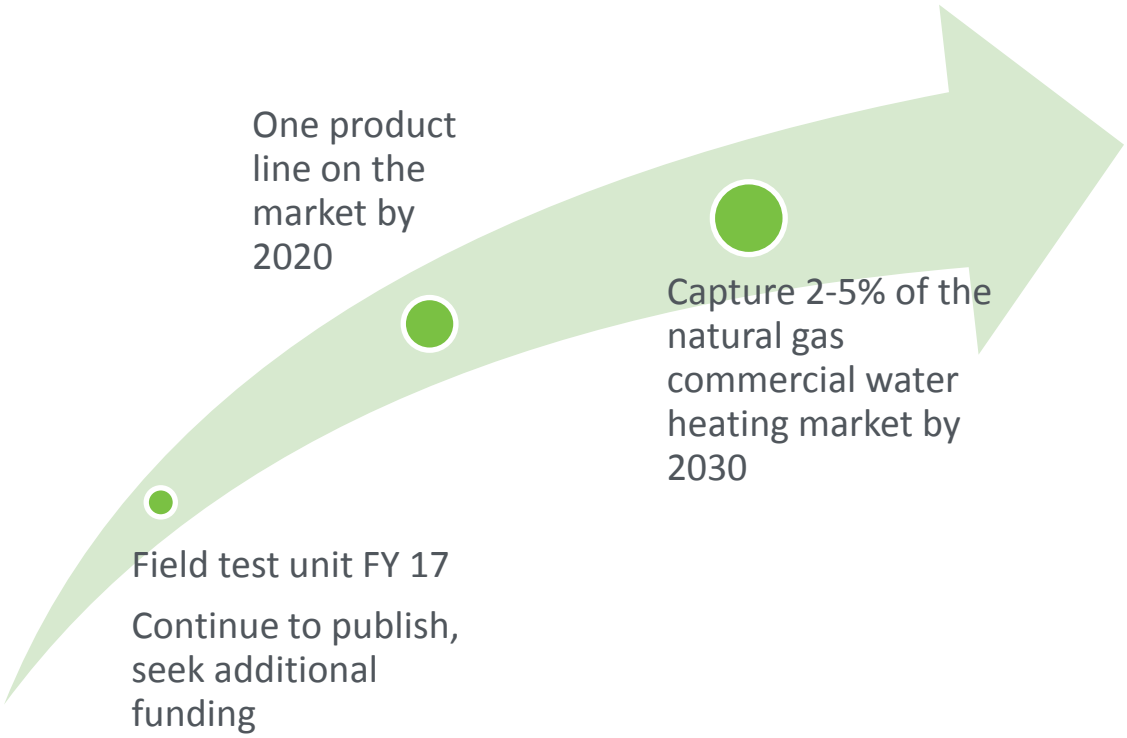




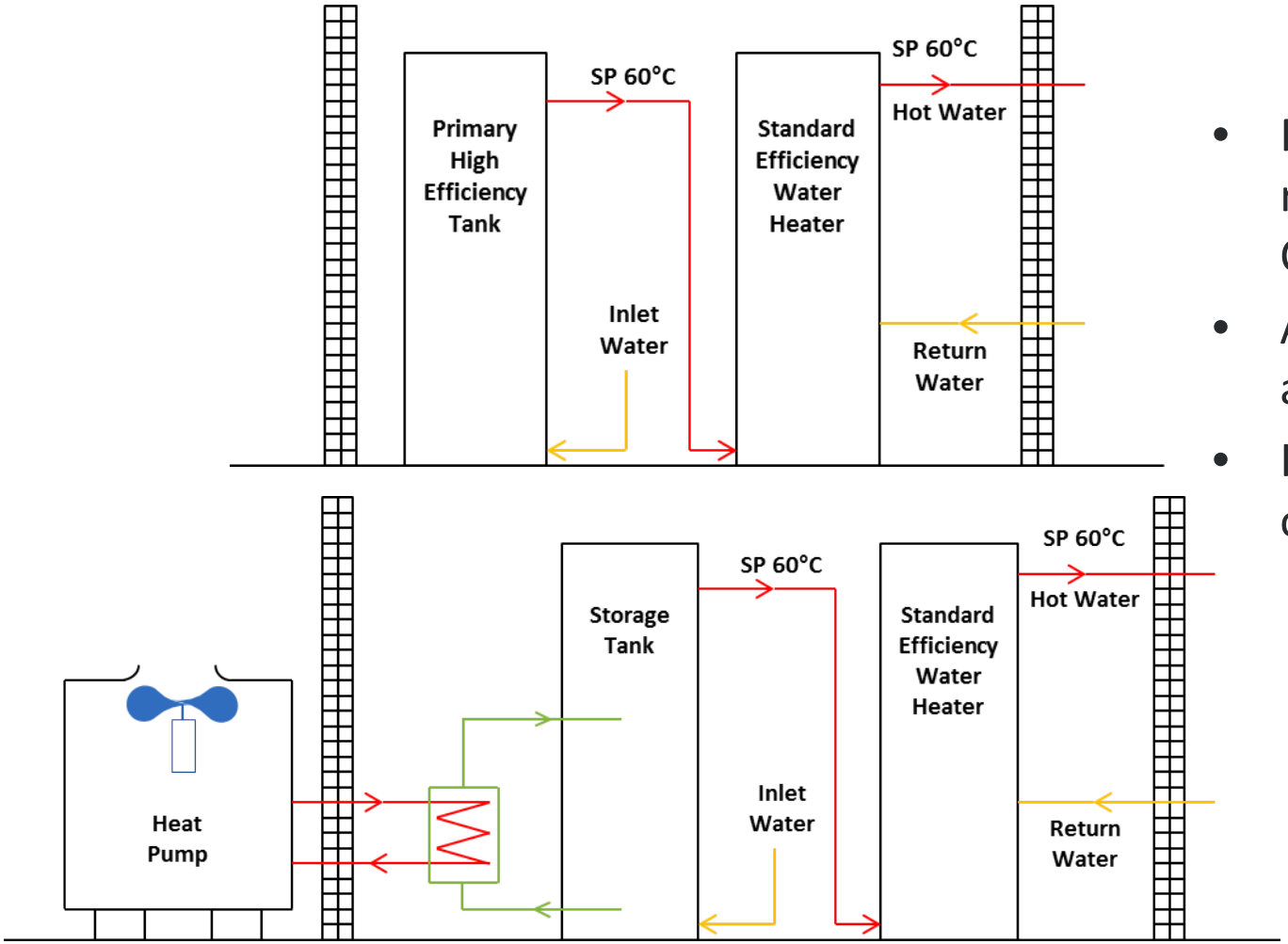
Buildings Energy Data Book: 3.1 Commercial Sector Energy Consumption, http://buildingsdatabook.eren.doe.gov

Purpose and Objectives

Impact of Project:
An 140,000 BTU/h HPWH unit achieving a cycle COP of 1.63 at 47°F rated ambient conditions



Introduction - Layout



- Mechanical compressor replaced by Thermal Compressor
- Ammonia-water absorption system
- Heat Pump Unit sits outside building

Approach

- Thorough single-effect cycle modeling to predict target performance
- System and Component analysis of the prototypes to identify areas of improvement
- Dedicated fabrication team at SMTI

Key Issues: Field site location

Distinctive Characteristics: Harnessing energy from the outside ambient to push well beyond COP values of 1

Progress and Accomplishments

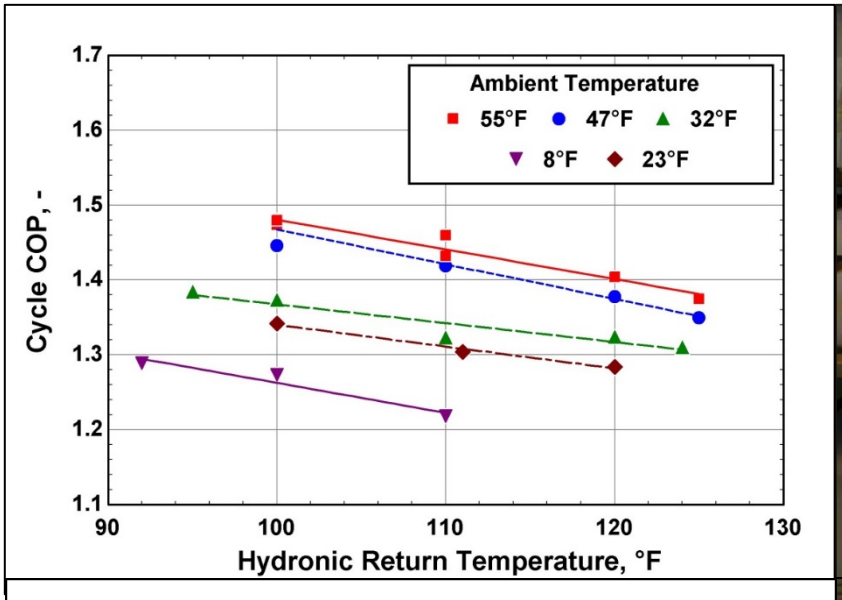
- Optimized single-effect cycle model to predict target performance

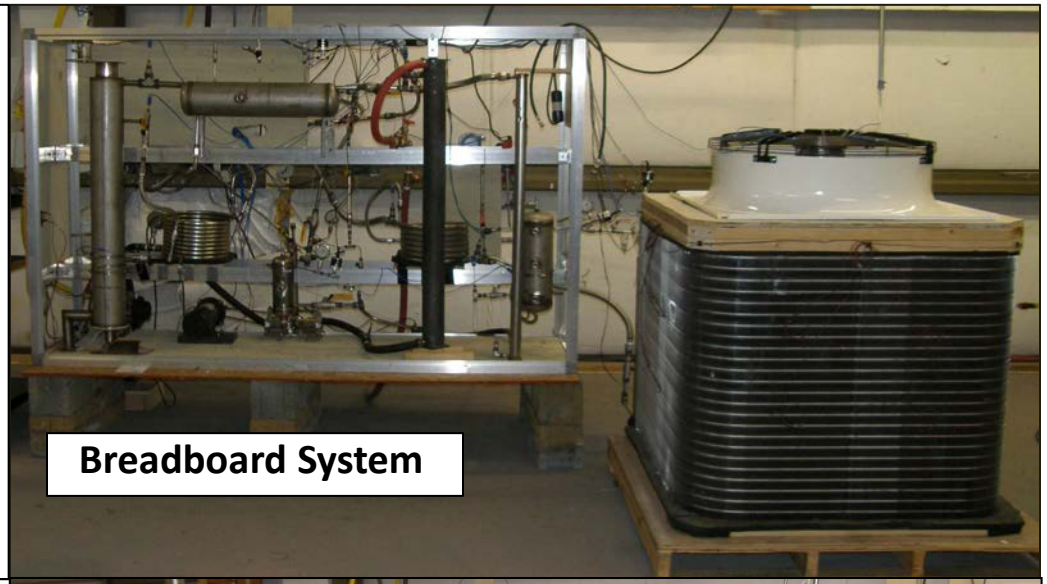
- Breadboard testing complete
  - 87% of performance target at design condition
  - 3:1 modulation achieved

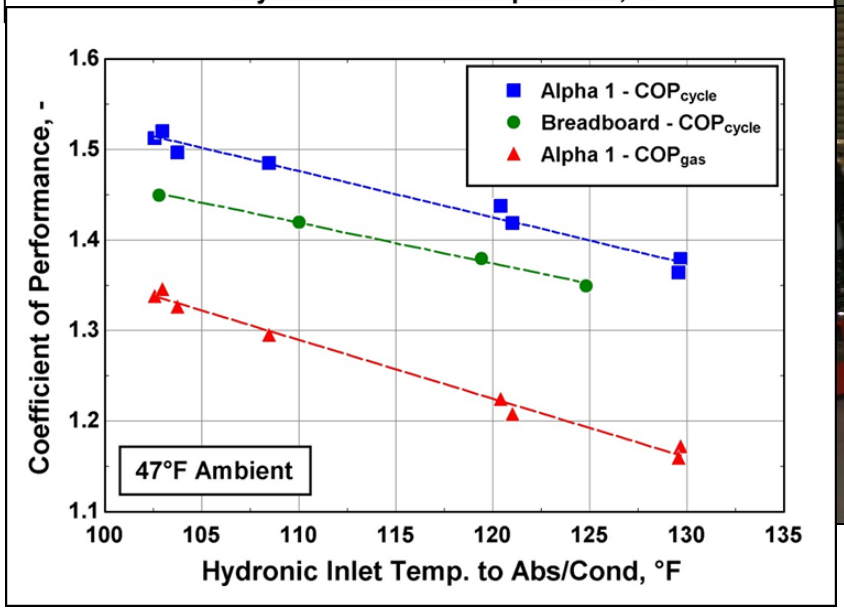
- Alpha packaged prototype fabricated and tested
  - 92% of performance target at design condition
  - 3:1 modulation achieved

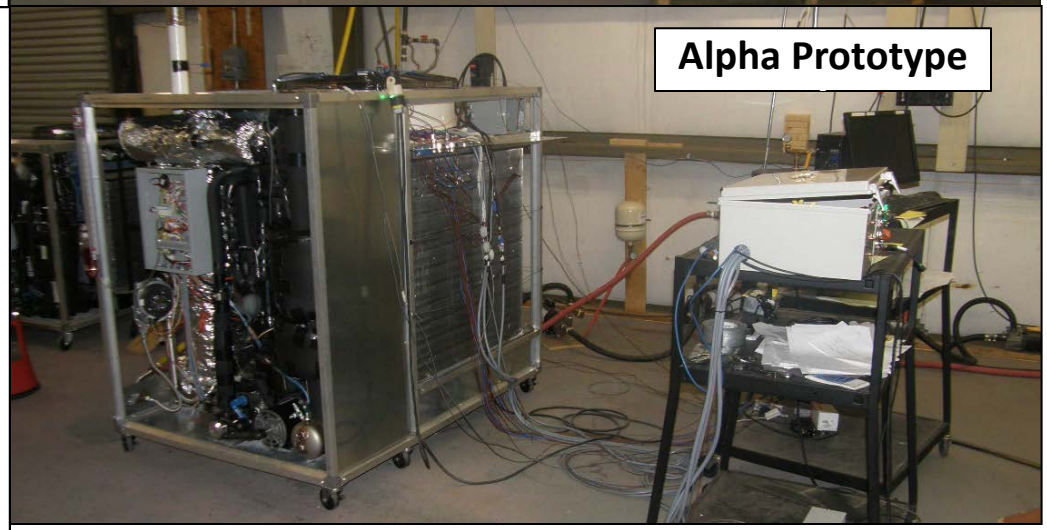
- Beta packaged prototype fabricated and tested
  - 97% of performance target at design condition
  - 3:1 modulation achieved

Progress and Accomplishments









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Progress and Accomplishments

30% reduction in size from Alpha to Beta Prototype

Beta Prototype

Nominal Output :
140,000 btu/hr (41.0 kW)

Gas Input:
97,000 btu/hr (28.4 kW)

Max Supply:
160°F (71°C)

Size:
56.25” × 40.75” × 61.25” (1.43 m × 1.04 m × 1.56 m)

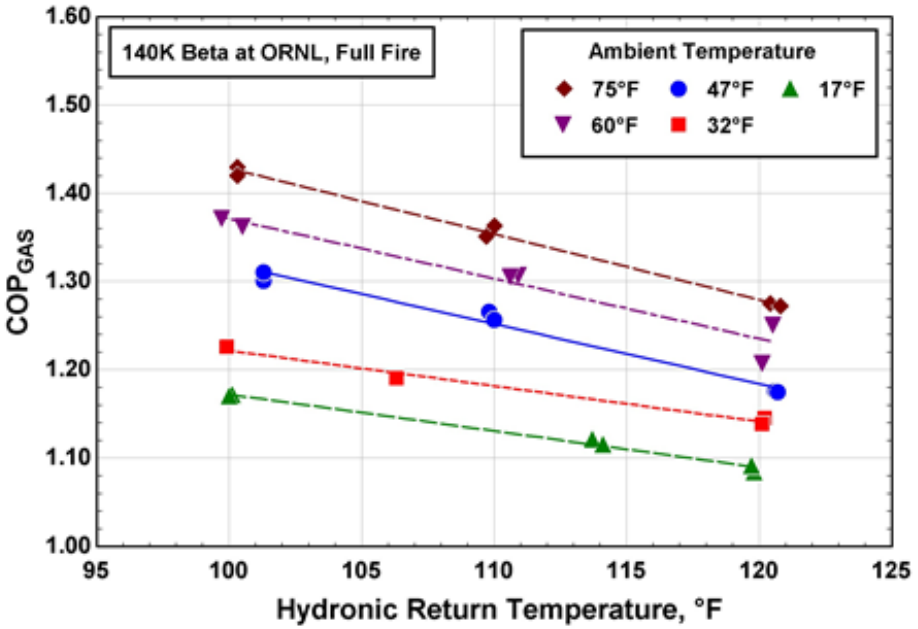
Weight:
~850 pounds

Modulation:
3:1

Progress and Accomplishments

Beta unit testing at ORNL:

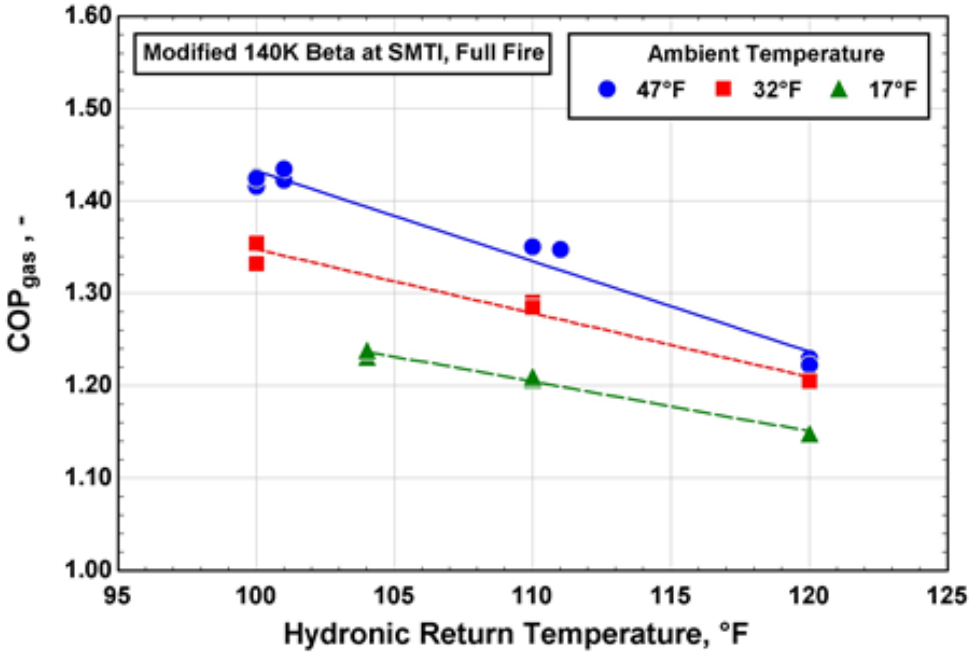
- Testing performed at full and reduced firing rates
- COP of 1.31 at 47/100°F design ambient/return (90% of 1.45 target)
- Performance limited by underperforming Rectifier



Progress and Accomplishments

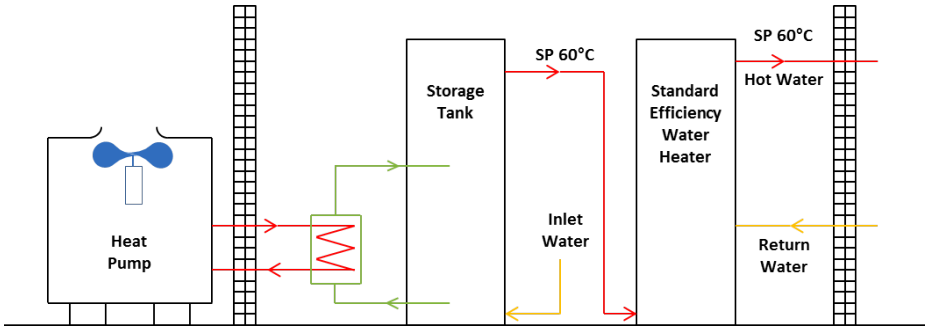
Beta unit testing at SMTI:

- Alternative Rectifier design investigated and installed in unit
- Performance improved to highest level to date
- COP of 1.41 at 47/100°F design ambient/return (97% of 1.45 target)

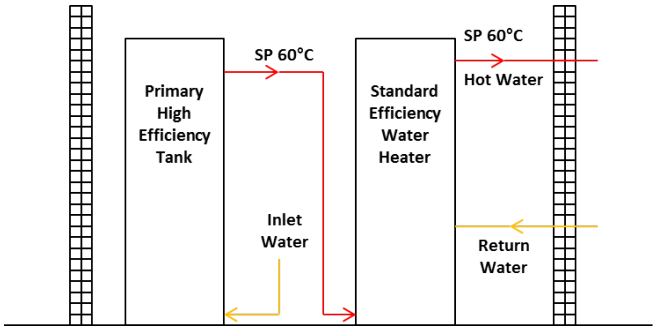


Progress and Accomplishments

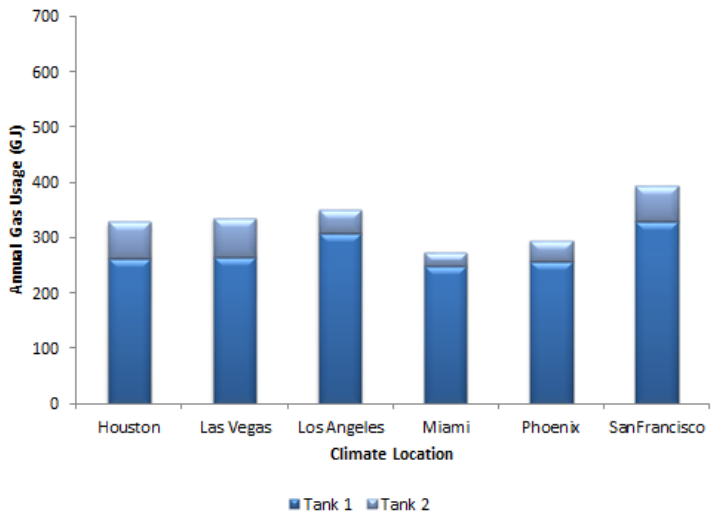
GAHP Configuration

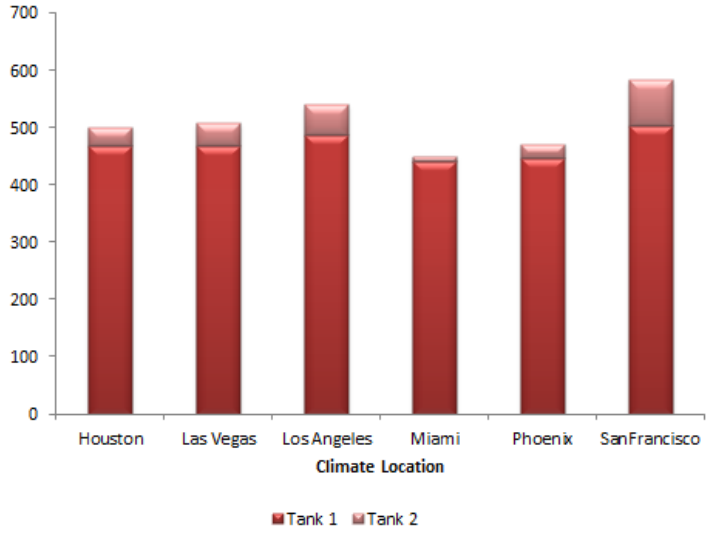


Conventional High Efficiency Configuration



On average, the GAHP configuration offered an annual gas savings of 35%

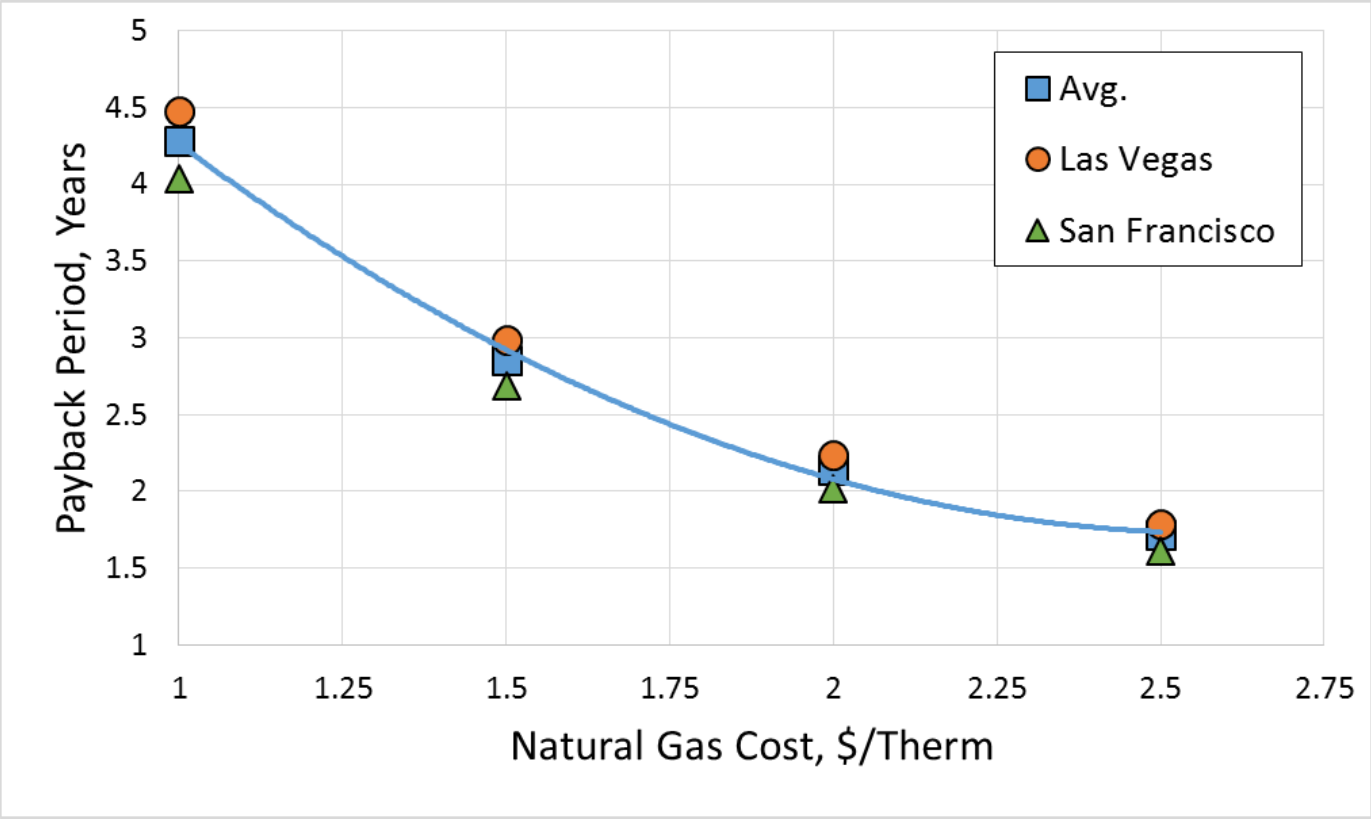




*Geoghegan, P., Shen, B., Keinath, C., Garrabrant, M., "Regional Climate Zone Modeling of a Commercial Absorption Heat Pump Water Heater – Part 1: Southern and South Central Climate Zones," *16th International Refrigeration and Air Conditioning Conference at Purdue,* July 11-14, 2016

Progress and Accomplishments

- Payback analysis for 7 cities studied by Geoghegan *et al.* (2016)
- Capital cost of conventional high efficiency system assumed to be $11,500
- Capital cost of GAHP system assumed to be $18,800
- At national average of $1.20/therm, payback is 3.7 years



Next Steps and Future Plans

- Ongoing reliability testing with Beta 1 at SMTI
- Flyer distributed to identify potential field sites
- Fabrication & Testing of Beta 2 prototype at SMTI (June 2017)
  - Target incremental performance improvements
  - Controls optimization
  - Test under commercial water heating conditions
- Beta 2 Field Test (July 2017)
  - Installed in commercial application in Northeast Tennessee
- Pursue Commercial Buildings Integration funding

Johnson City, TN

Project Integration and Collaboration

Partners, Subcontractors, and Collaborators:

- **ORNL:** Expertise in building equipment performance evaluation and modeling
- **AO Smith (OEM):** Provides component design, fabrication, testing support, market research, and cost share to the project
- **SMTI:** Provides component and system design, fabrication, testing, testing support, and market research

Project Integration:

- In constant communication with ORNL via conference calls, emails, and task reports

Communications:

ACEEE Hot Water Forum, Portland OR, 2016 and 2017
ASHRAE, St. Louis, 2016
Purdue Conference, 2016
IEA Heat Pump Conference, 2017

REFERENCE SLIDES

Project Budget

Project Budget: DOE Total $1920k
Cost to Date: $1792.9k
Additional Funding: None expected

Budget History					
10/1/13 – FY 2017 (past)		FY 2017 (current)		FY 2017 – 9/30/17 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$1760k	*	$160k	*	$0k	*

* In-kind contribution from CRADA partner – exceeds DOE funding level; exact total is confidential information

Project Plan and Schedule

	◆	Milestone/Deliverable (Originally Planned) use for missed										
	◆	Milestone/Deliverable (Actual) use when met on time										
		FY2016				FY2017				FY2018		
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													
Q4 Milestone: submit beta performance report					◆								
Current/Future Work													
Q1 Go/No Go: Field Site selection						◆							
Q4 Milestone: Report Field Study evaluation to date													