High-Efficiency Commercial Cold Climate Heat Pump

2015 Building Technologies Office Peer Review

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

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Project Summary

Timeline:

Start date: March 1, 2013

Planned end date: May 29, 2015

Key Milestones (SOPO)

1. 2/ 2013: Down-selection of key components that meet DOE capacity and COP targets (COP=2.5 at -13F ambient condition) through modeling.
2. 8/ 2014 Experimental testing of 1st prototype CCCHP system meets (within 10% relative) targeted COP=2.5 at -13F design point.
3. 5/ 2015 TRL5 demonstration of 2nd prototype CCCHP system and TRL6 plan

Budget:

Total DOE $ to date (12/ 2014): $1.3M

Total CS $ to date (12/2014): $326k

Total future DOE $: $192k

Total future CS $: $47k

Project Goal:

1) Design and develop a prototype 10 TR high performance cold climate commercial heat pump system

2) Execute a Technology Readiness Level (TRL) 5 prototype demonstration

3) Conduct psychrometric testing of prototype CCCHP system to demonstrate targeted COP=2.5 at -13F design point with <15% capacity degradation.

4) Meet COP and Capacity targets at 47F and 17F ambient conditions.

5) <3 year customer payback on price premium

Target Market/Audience:

Commercial building owners with a need for a superior heating and cooling solution air-source heat pump that operates over extreme heating and cooling seasons

Purpose and Objectives

Problem Statement:

- State-of-the-art industry standard heat pumps that can degrade by up to 60% in capacity and 50% in system Coefficient of Performance (COP) at the DOE-targeted -13F ambient condition
- Cold blow effect further cements that heat pumps are not a viable technology for space heating even in Climate Zone 3A (Memphis TN).
- Scalable and cost-effective compression technologies as well as system optimization/integration are necessary to deploy cold climate heat pumps

Target Market and Audience: Commercial building owners with a need for a superior heating and cooling solution air-source HP that operates over extreme heating and cooling seasons. Commercial buildings in cold climates represent 45% of the national building stock. 32% use electricity as the primary source of space heating representing 149 billion kWh and $9.2 billion.

Impact of Project:

End deliverable of project: TRL5 demonstration of CCCHP system that realizes >25% annual energy savings

Achievement towards your goal: Intermediate-term (2-3yr after project)

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Approach

Approach:

1) Evaluate and down-select a variable speed high-efficiency compressor concept that meets both performance and cost targets
2) Design, develop, and fabricate components that enable the proposed compressor performance
3) Design and integrate high efficiency evaporator and condenser fans and motors
4) Evaluate whether the specific characteristics of refrigerant fluids can be used to improve system efficiency
5) Demonstrate performance of an integrated 10TR CCCHP prototype over a wide range of ambient conditions
6) Document CCCHP performance, cost and short-term reliability characteristics.

Key Issues: Reduce component and system critical risks to sufficient level to ensure TRL5 demonstration is successful

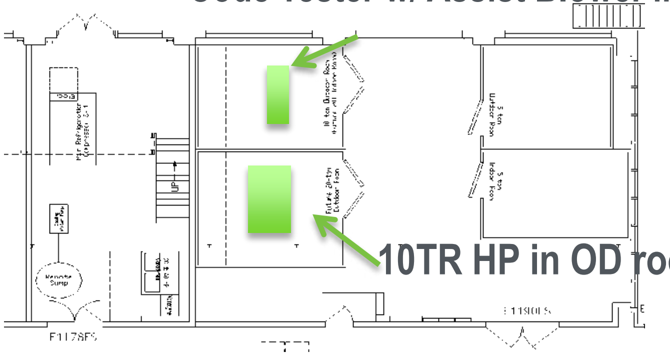
Distinctive Characteristics: Combination of compression with high efficiency over an unusually wide range of speed and pressure ratio, losses reduction and system-level design optimization for cold climates will enable this performance.

Lab Capabilities

This UTRC facility provides the ability to test air-to-refrigerant and hydronic systems under a wide range of operating conditions within world-class energy balances

- ***Capability***
  - Matching 5TR indoor and outdoor rooms
  - >10TR indoor and outdoor rooms
- ***Operating Ranges***
  - Air-side (indoor room): 45 to 145 ^{o}F, 30 to 95%RH, and 4,000 SCFM
  - Air-side (outdoor rooms): -15 to 145 ^{o}F, 20 to 95%RH, and 6,500 SCFM and 8,500 SCFM
  - Hydronic-side: 40 to 200 ^{o}F (5TR and 10TR)

Code Tester w/ Assist Blower in ID room



10TR HP in OD room

	Ambient	$1\text{-}Q_{air}/Q_{refrig}$	Typical
Test Energy Balance	47F	4%	~4%
	17F	8%	~11%
	-13F	<16%	unknown

Progress and Accomplishments

Lessons Learned:

- UTRC developed 3 prototype 10TR heat pump systems to optimize architecture necessary to test & demonstrate >25% annual energy savings

- Risk mitigation through sequential hardware demonstrations guided by modeling required to achieve success

Accomplishments:

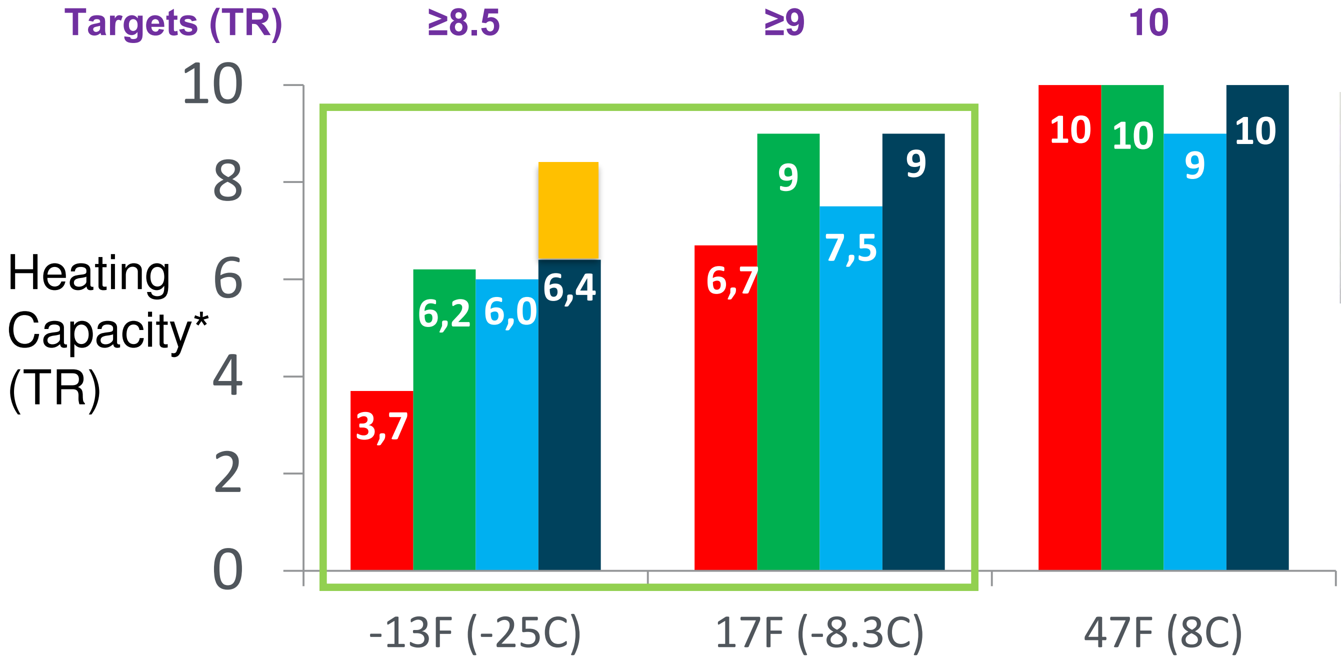
Demonstrated

- >65% capacity and >45% COP increase over baseline at -13F condition
- Demonstrated, within accuracy of measurements and conditions, DOE capacity goals at 17F/47F of 9TR/10TR while meeting 4.0 COP at 47F
- System and component-level model validation

In pursuit of DOE goals,
High-fidelity test data from POC system (<16% energy balance at -13F design point) to confirm modeling projections associated with the contribution of key enabling technologies

Progress and Accomplishments

Tested >65% capacity improvement at -13F ambient; Capacity at -13F and 17F critical for value proposition



UTRC CCCHP Prototype System

Gap to be closed through OD Coil Optimization Q2 '15

*Air-side capacity; energy balance quantified

Baseline HP : premium tier high-efficiency 10TR

POC System : wide speed range compressor +reduced losses and high-efficiency fans

1st Prototype : **POC System + charge management**

2nd Prototype : **1st Prototype + Optimized ID Coil + Optimized OD Coil**

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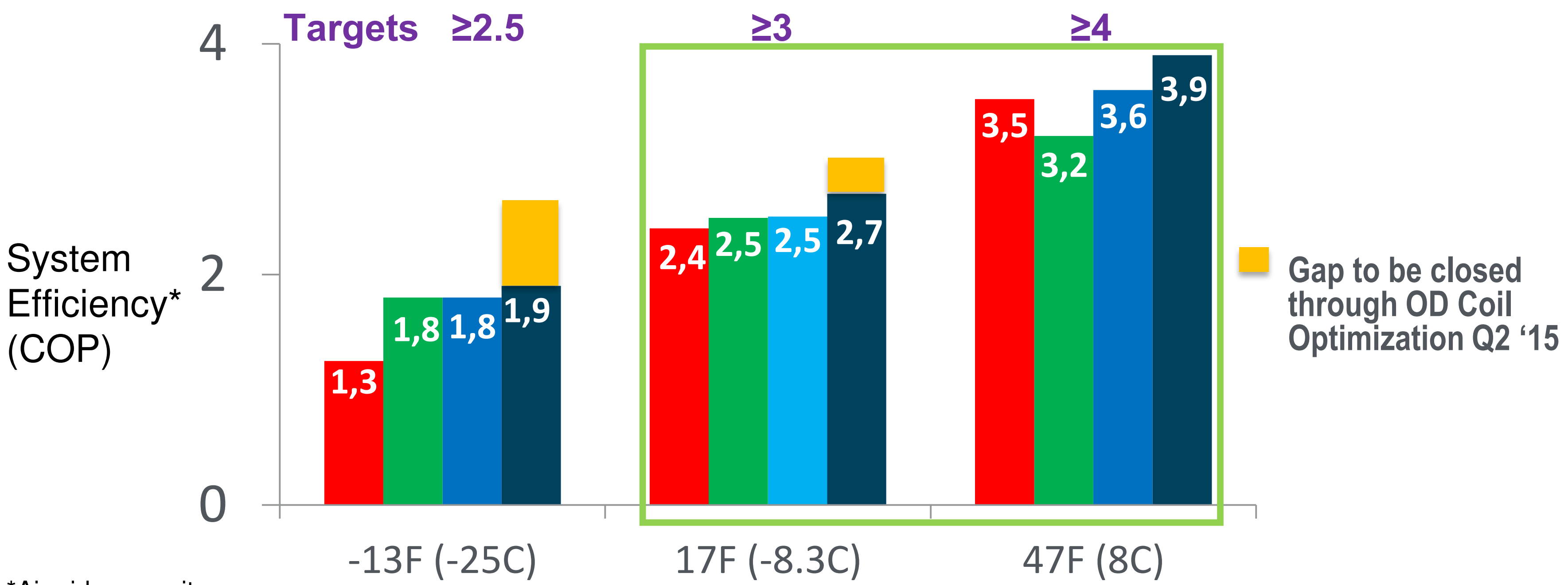
Progress and Accomplishments

Tested >45% COP improvement at -13F ambient; COP at 17F and 47F critical for value proposition



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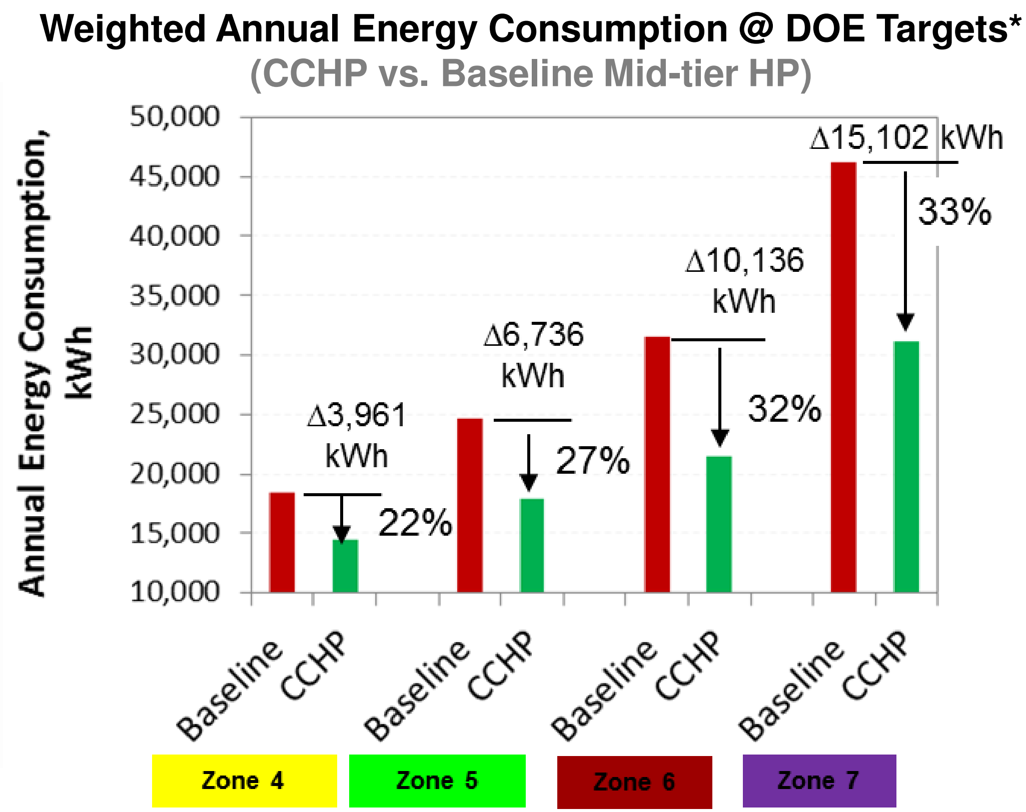
Progress and Accomplishments

>22% annual energy savings potential demonstrated through building hourly analysis



*Integrated capacity accounting for frost
Non-economized small office building

Market Impact: The UTRC team is engaged with the Commercial **North American** HVAC division of **Carrier Corporation**, an operating division of UTC Building and Industrial Systems. This engagement ensures that metrics are met during development to accelerate future transition. Carrier Corporation proprietary tools and other standard work are being used throughout the execution of the project which helps transition the developed system seamlessly.

Project Integration and Collaboration

Project Integration:

- Carrier Corporation is the commercialization path for HVAC technologies and concepts developed at UTRC.
- Carrier is the world's largest manufacturer and distributor of HVAC&R equipment and has a long history of developing successfully commercialized products.
- UTRC project team is closely engaged with product and engineering teams to ensure metrics are met during conceptualization and testing phases
- Carrier directly providing cost share for this project and significant in-kind contribution

Partners, Subcontractors, and Collaborators: UTRC is only performing organization under this contract

Communications: Project is in early stages of development

Next Steps and Future Plans

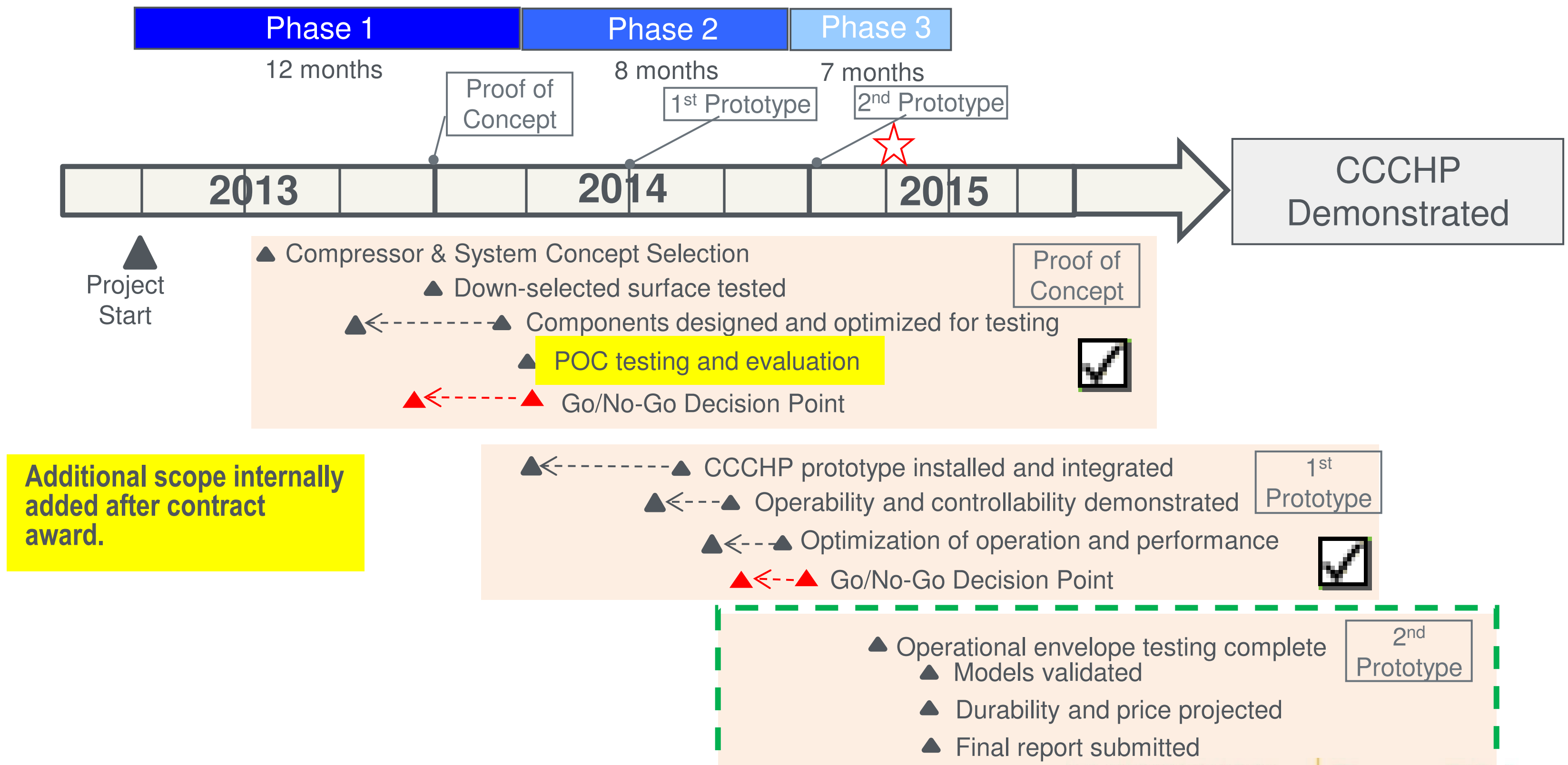
3 prototype system demonstrations positions project for success

Phase I GO/NO-GO DECISION:

- Down-selection of key components that meet (within <10% relative deviation of performance) DOE capacity and COP targets (COP=2.5 at -13F ambient condition) through modeling.

Phase II GO/NO-GO DECISION:

- Experimental testing of prototype CCCHP system meets targeted COP=2.5 at -13F design point
- Operability and controllability of compressor are demonstrated
- TRL5 test plan is developed



Project Budget

Project Budget: See below Table
Variances: None. All UTRC hardware modification and testing is within original schedule and budget constraints
Cost to Date (12/2014): 87%
Additional Funding: None.

Budget History					
FY2013 (past)		FY2014 (current)		FY2015 – 5/28/2015 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$535,322	$133,830	$765,752	$191,936	$191,873	$47,468

Acknowledgments

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CCCHP Photographs

Cut-away view of baseline heat pump system before retrofitting

CCCHP system as installed in Psychrometric chamber at UTRC

Integrated High-efficiency outdoor fans

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