High-Efficiency Commercial Cold Climate Heat Pump

2014 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. 6/ 2014 Experimental testing of 1st prototype CCCHP system meets (within 10% relative) targeted COP=2.5 at -13F design point.
3. 5/ 2014 TRL5 demonstration of 2nd prototype CCCHP system and TRL6 plan

Budget:

Total DOE $ to date (2/ 2014): $718k

Total CS $ to date (2/2014): $179k

Total future DOE $: $775k

Total future CS $: $194k

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.

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

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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.

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Progress and Accomplishments

Lessons Learned:

- UTRC accelerated the project schedule by >4 months and added to the scope of work fabrication of a proof-of-concept (POC) CCCHP system

- POC system testing pointed to challenges associated with wide-speed range compression and design optimization for cold climates that are being addressed during prototype testing stages

Accomplishments:

Down-selection , design and fabrication of key enabling technologies

- Wide speed range high-efficiency compressor
- High-efficiency fans and heat exchanger design
- Optimization and integration of system for cold climate operation

High-fidelity test data from POC system (<4% energy balance at design point) to confirm modeling projections as to the contribution of key enabling technologies in pursuit of DOE goals

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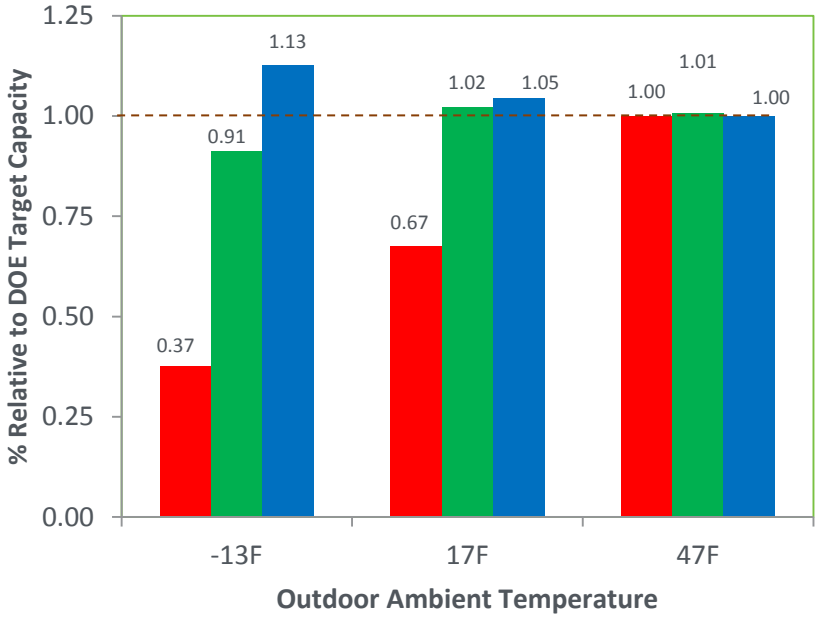
Progress and Accomplishments

Preliminary POC system tracks target heating capacity; Opportunities identified to close COP gap



DOE Targets **<25%** **<10%** **0%**

Baseline HP : premium tier high-efficiency 10TR HP

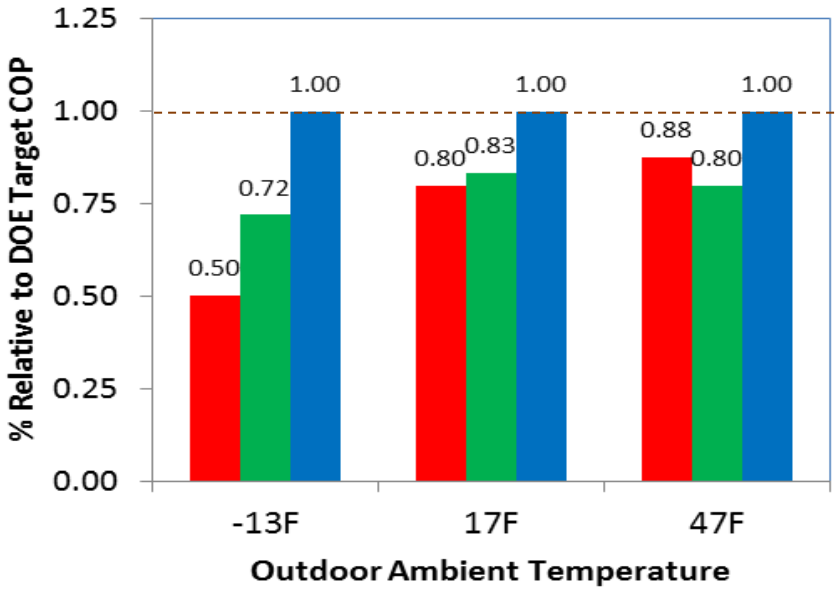
POC System* : baseline compressor, improved fans & heat exchanger, system optimization for -13F

Target CCCHP : POC System w/ modifcations to meet DOE targets

*lowest temperature tested at UTRC facility is -11F; modifications have been made to achieve -13F

UTRC CCCHP Proof-of-Concept (POC) System

Baseline HP
POC System Test
UTRC Target CCHP



DOE Targets **>2.5** **>3.0** **>4.0**

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Progress and Accomplishments

Market Impact: The UTRC team is heavily 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.

Awards/Recognition: Project is in early stages of development

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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

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Next Steps and Future Plans

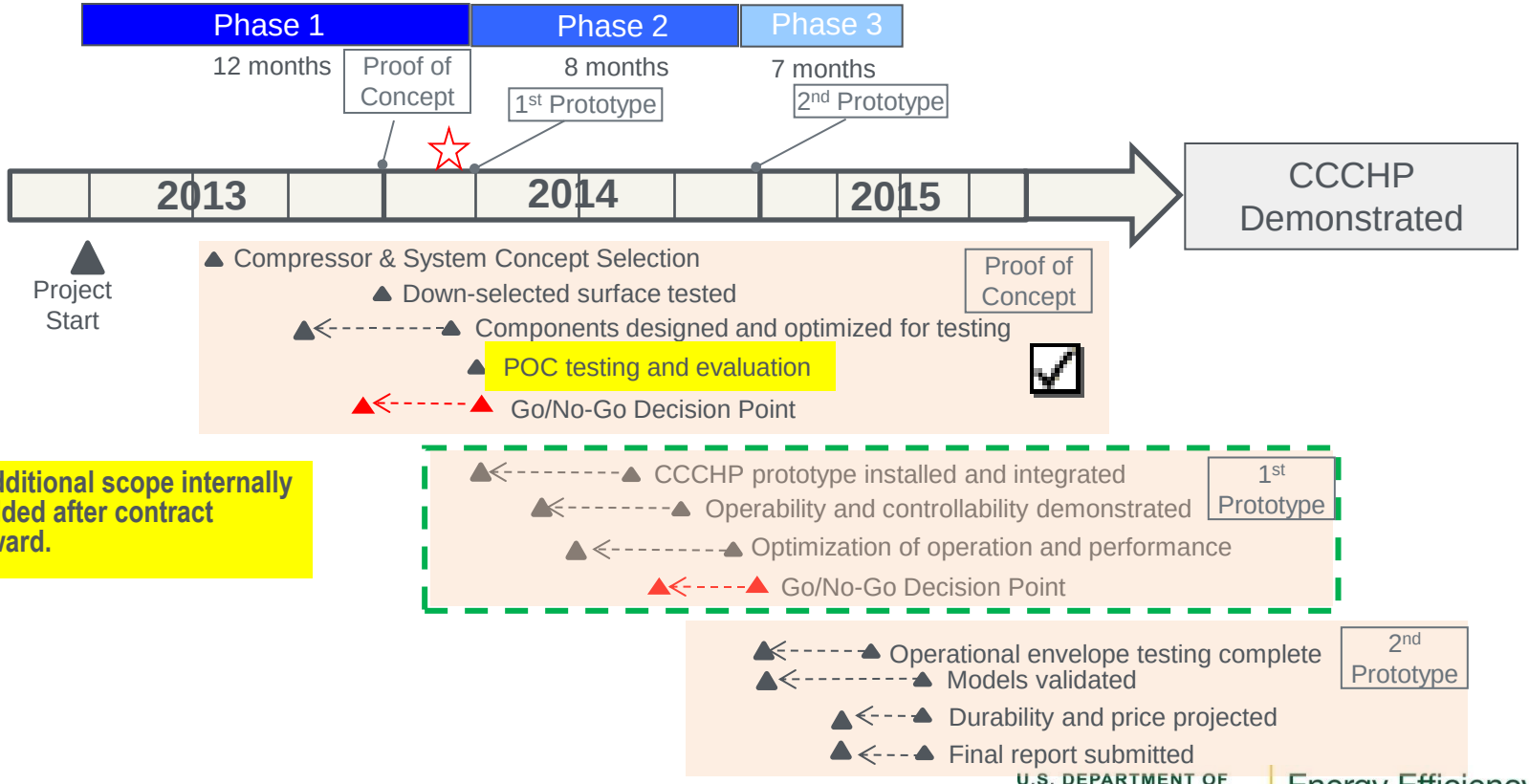
Proof-of-concept system tests positions UTRC for Phase 2 success

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



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Project Budget

Project Budget: See below Table
Variances: None. All UTRC acceleration is within original schedule and budget constraints
Cost to Date (2/2014): 48%
Additional Funding: None.

Budget History					
3/1/2013 – FY2013 (past)		FY2014 (current)		FY2015 – 5/28/2015 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$544,987	$136,246	$172,939	$43,235	$774,946	$200,297

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