High Efficiency Cold Climate Heat Pump

2014 Building Technologies Office Peer Review

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EMERSON
Climate Technologies

The Unico System®
Small-Duct Central Heating & Air Conditioning

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

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Project Summary

High Efficiency Cold Climate Heat Pump -(CCHP) CRADA

Timeline:

Start date: **01-Oct-2010**

Planned end date: **30-Sep-2015**

Key Milestones (single-stage)

1. Equipment modeling and EnergyPlus simulation report - March/2013
2. Lab prototype fabricated and installed - Dec/2013
3. Meet 77% capacity at-13°F vs. 47°F; COP=4.1 at 47°F - March/2014

Budget:

Total DOE $ to date: **$2,299k**

Total future DOE $: **$300k**

Target Market/Audience:

The principal target market is 14.4 M electric-heated dwellings using 0.16 quad/year for heating in cold regions.

Key Partners:

CRADAs with both Emerson/Copeland and Unico:

The Unico System — Small-Duct Central Heating & Air Conditioning

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EMERSON Climate Technologies

Equipment: Two-stage compression system development

Solution: Single-stage compression system development and assessment

Project Goal:

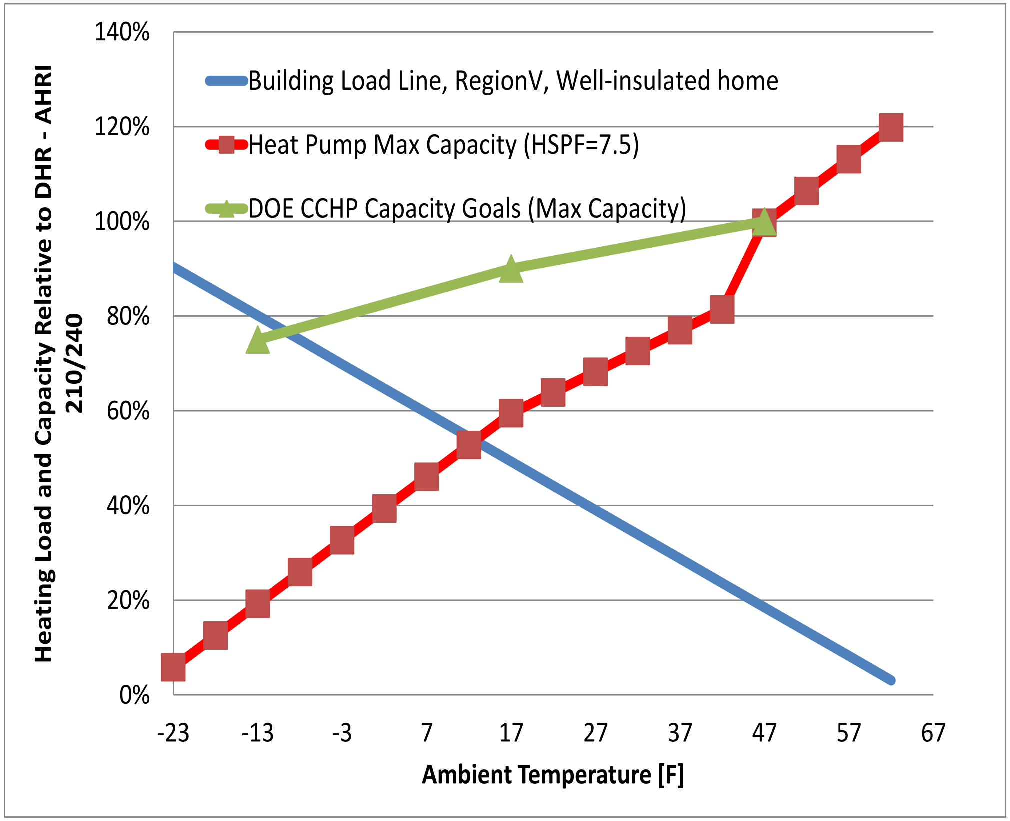
Develop a 3-ton, high efficiency CCHP to minimize resistance heating

- Achieve COP@47°F > 4.0; achieve capacity@-13°F > 75%, vs. rated capacity@47°F.
- Maximize COP at 17°F and -13°F with acceptable payback period.

Purpose & Objectives

Problem Statement:

- Typical HPs don’t work well at low ambient temps due to very high discharge temp and pressure ratio
- HP heating capacity not sufficient to match building load
- COP degrades significantly with ambient temperature



From March 2012 Buildings Energy Data Book

Target market/audience: The principal target market is 14.4 M electric-heated dwellings using 0.16 quad/year for heating in cold regions.

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Purpose & Objectives

Impact of Project:

1. High-performance CCHPs result in significant savings (> 60% compared to electric resistance heating); result in an annual primary energy savings of 0.1 quads when fully deployed, equivalent to 5.9 million tons of annual CO_2 emissions reduction – Long Term
2. Analytical tools development to facilitate best practice of CRADA partners – Near Term
3. Project outcomes (single-stage) transferred to US OEMs by Emerson Climate Technologies – Mid Term

Technical goals (project outputs):

Develop a 3-ton, CCHP to minimize resistance heating

- COP@47°F > 4.0; HP capacity@-13°F > 75%, vs. rated capacity@47°F.
- Maximize COPs at 17°F and -13°F with acceptable payback period.

Approach

Approach:

- Market assessment and extensive vapor compression system modeling
- EnergyPlus building energy simulation

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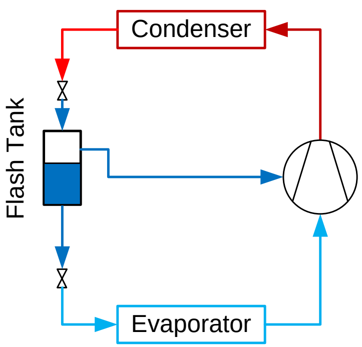
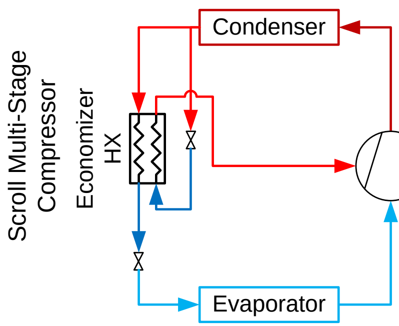
Single-stage compression concepts:

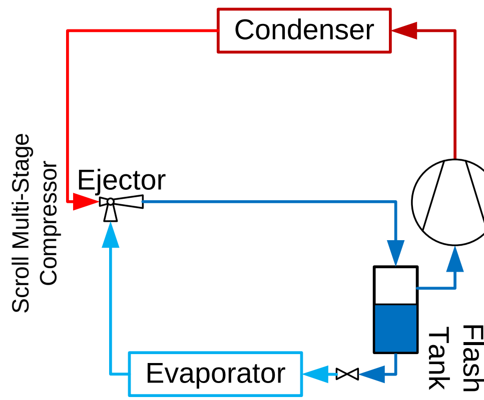
Vapor injection with flash tank



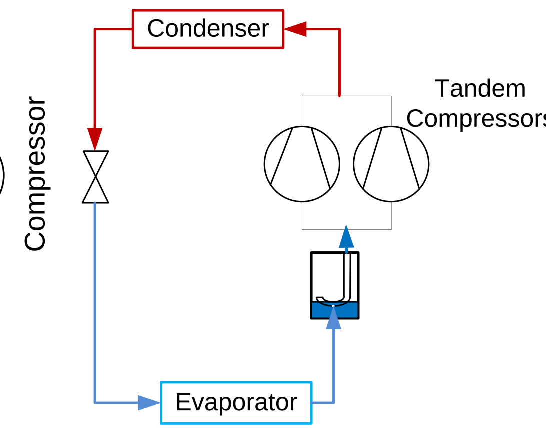
Vapor injection with economizer



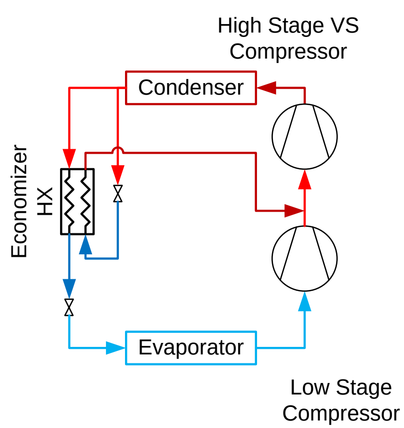
Ejector cycle



Tandem (parallel) and multi-capacity compressor(s)



Two-stage (series) compression w/ inter-stage economizing



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ORNL to assist in modeling, analysis, component sizing, and performance verification testing

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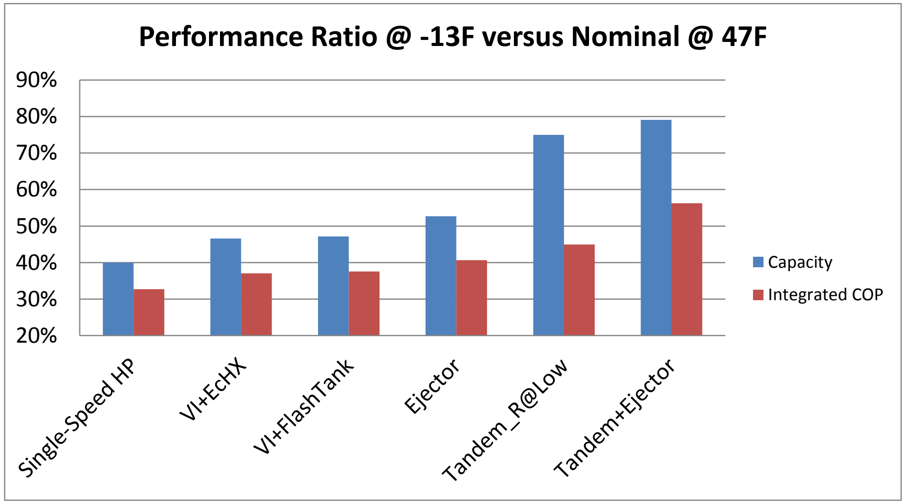
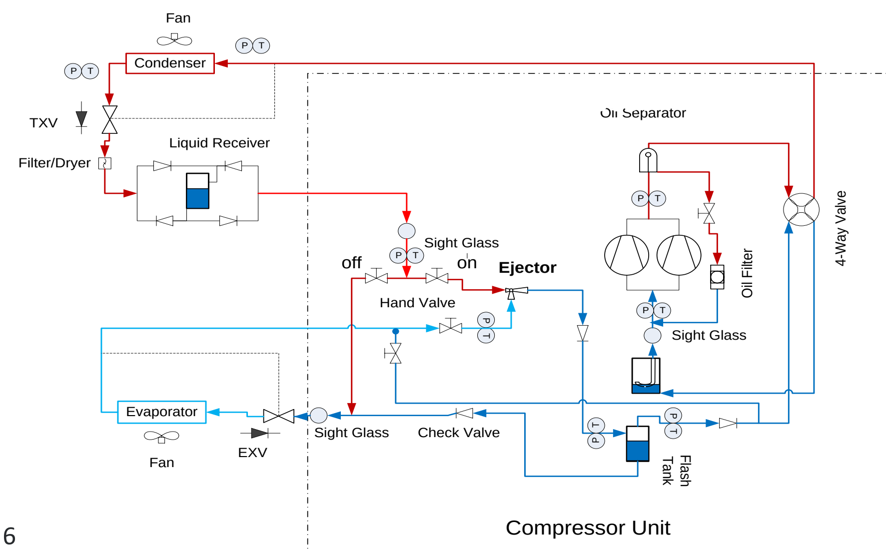
Approach

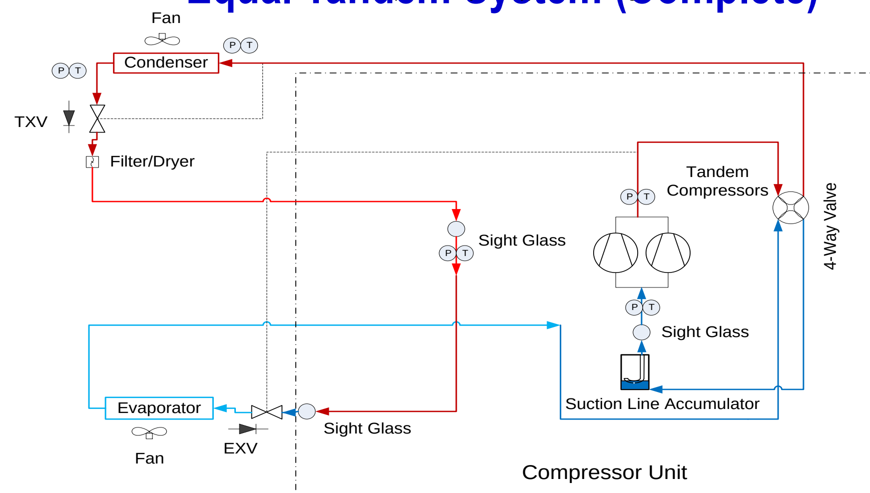
Approach: Single-stage lab prototype system development and testing

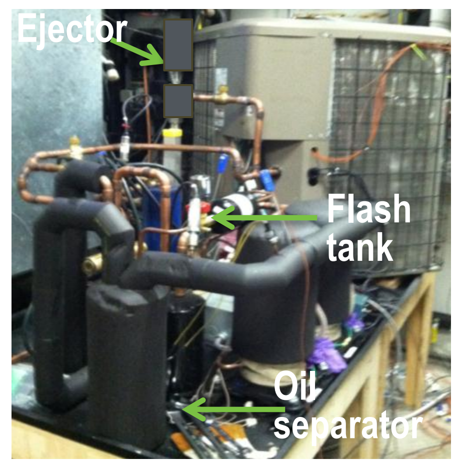


Established test rig to test multiple configurations (EXV vs. ejector, vapor injection system, etc.)



Equal Tandem System (Complete)

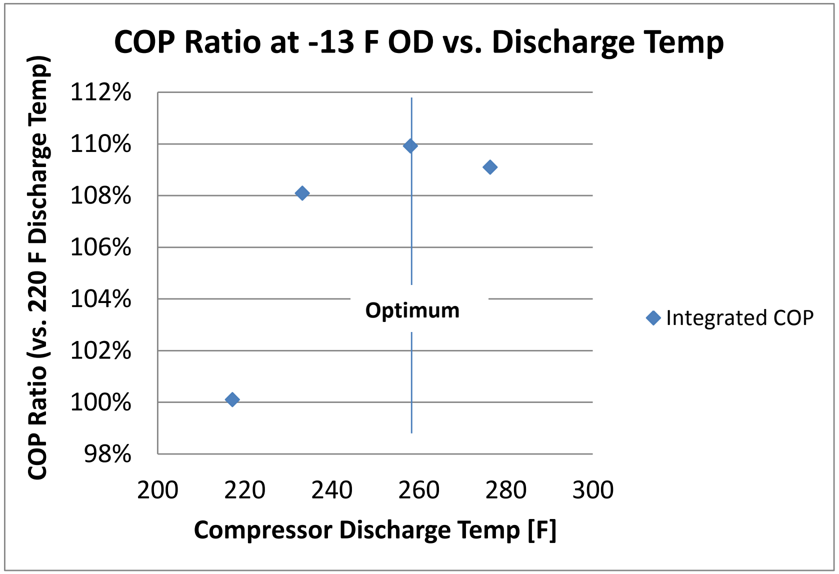




Approach

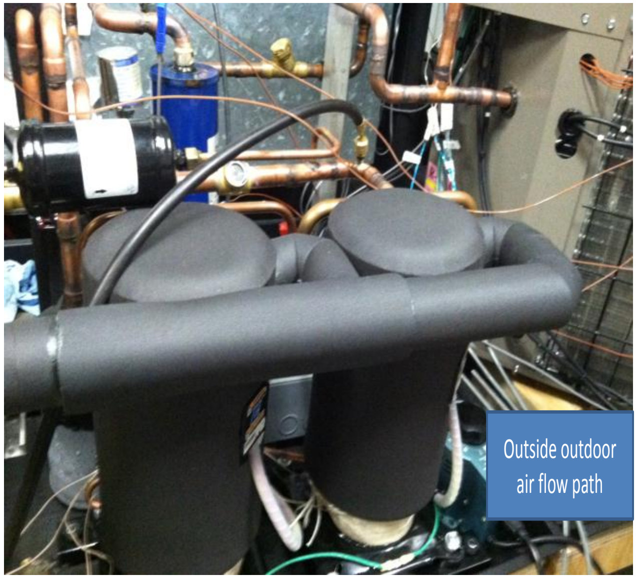
Key Issues – Equal Tandem System:

- Compressor(s) capable of high discharge temperature (up to 280°F)
- Tandem compressors provide overcapacity at low ambient temperatures, relative to 1 compressor running @47°F, rated point
- EXV controlling discharge temperature to optimize efficiency over a wide range
- Minimize heat losses from compressor shell and discharge line



Distinctive Characteristics:

- HP operates down to -20°F
- Significant reduction in supplemental resistance heat use, i.e. near zero in well-insulated homes
- Tandem+EXV is a simple option with good reliability



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Progress and Accomplishments

Market Assessment	Concept Design	Lab Prototyping	Optimization	Field Verification

Accomplishments:

- Lab prototype with tandem + EXV developed and verified
- Established test rig to test multiple configurations
- **Achieved capacity goals, i.e. >75% at -13°F (77%) → Go/No Go Milestone, 2014**
- **Achieved COP goal, >4.0 at 47°F (4.1)**

Progress on Goals:

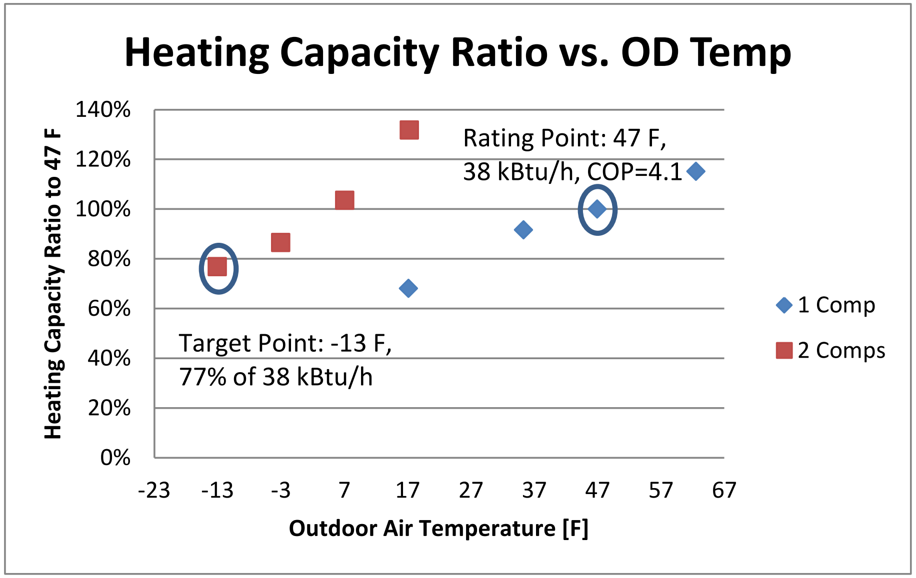
- Emerson Climate Technologies to optimize a compressor design for heating at low ambient temps (6% higher COP at low ambient temperatures)
- ORNL to test a tandem of vapor injection compressors
- Evaluate ejector cycle over an extensive operation range

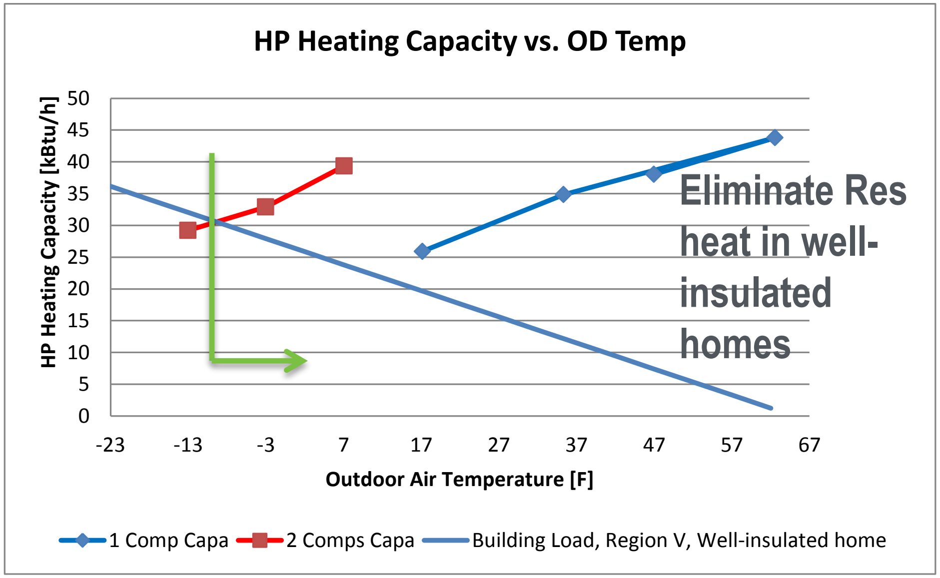
Market Impact:

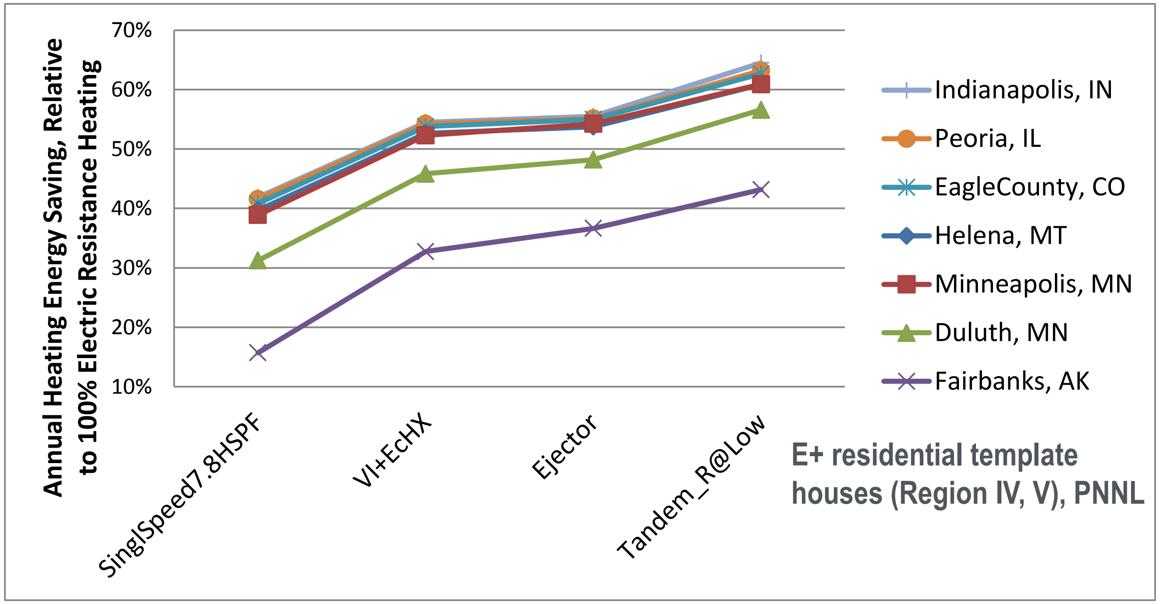
Emerson Climate Technologies to provide compressor and system solutions to US OEMs in the next three years

Progress and Accomplishments

Met Go/No Go Milestone (tandem + EXV):







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Project Integration and Collaboration

Project Integration:

Single-stage solutions: Collaborative R&D agreement (CRADA) with Emerson Climate Technologies (US component and control). World leader of compressor technologies. Outcomes of the project will be transferred to US OEMs.

Two-stage compression equipment: Provide design, analysis, laboratory and field testing support to Unico INC. (CRADA).

Partners, Subcontractors, and Collaborators: CRADA partners Emerson Climate Technologies and Unico Inc.

Communications:

- Market assessment report (ORNL research report, http://info.ornl.gov)
- 1 paper published in IEA Heat Pump Conference 2011
- 1 paper published in ASHRAE Winter Conference 2012
- 1 paper submitted to IEA Heat Pump Conference 2014
- International collaboration via IEA Heat Pump Program Annex 41 enables team to learn from recent developments in EU and Far East

Next Steps and Future Plans

Next Steps and Future Plans:

- Develop control strategy and design control board – June 2014
- Complete fabrication of field test units and initiate field installation- Sept 2014
- Complete field testing report for heating and cooling seasons – Sept 2015
- **Emerson Climate Technologies to provide compressors and system solutions to US OEMs - 2015**

REFERENCE SLIDES

Project Budget

Project Budget: DOE total $2,599k - FY11-15
Cost to Date: ~$1,680k through February 2014 (FY11-$206k; FY12-$304K; FY13-$678k; FY14-$492k)
Additional Funding: None expected

Budget History					
FY2011 – FY2013 (past)		FY2014 (current)		FY2015 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$1849k	*	$450k	*	$300k	*

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

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Project Plan and Schedule

Original initiation date: 01-Oct-2010 -- Planned completion date: 30-Sept-2015
(minor delays in lab prototype fabrication and testing schedules)
Go/no-go decision points
* March ’13 Equipment Modeling and Building Energy Simulation – ***Passed***
* March ’14 Achieve 75% capacity at -13°F – ***Passed***
* late CY14/early CY15 proceed to field testing (ORNL)