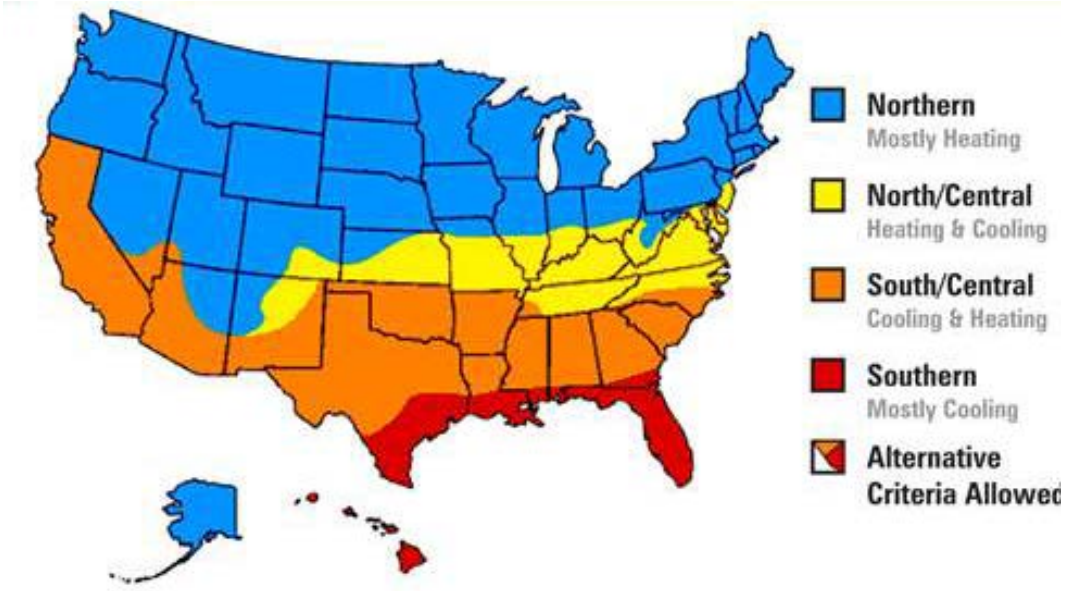
High Efficiency Cold Climate Heat Pump

2016 Building Technologies Office Peer Review



Copeland Scroll

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: **May-Sep-2017**

Key Milestones

1. Tandem fixed-speed system: Meet 76% capacity at-13°F vs. 47°F; COP=4.2 at 47°F - March/2014.
2. Tandem vapor injection system: Meet 88% capacity at-13°F vs. 47°F; COP=4.4 at 47°F - June/2015.
3. Field investigation of a prototype CCHP: eliminate auxiliary heat down to -13°F in an occupied home– April/2015.

Budget:

Total Project $ to Date:

- DOE: $2,839K
- Cost Share: partner in-kind cost share exceeds DOE cost

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Key Partner:

CRADA with Emerson/Copeland:

Copeland Scroll

EMERSON Climate Technologies

Solution: Single-stage compression system development and assessment.

Project Outcome:

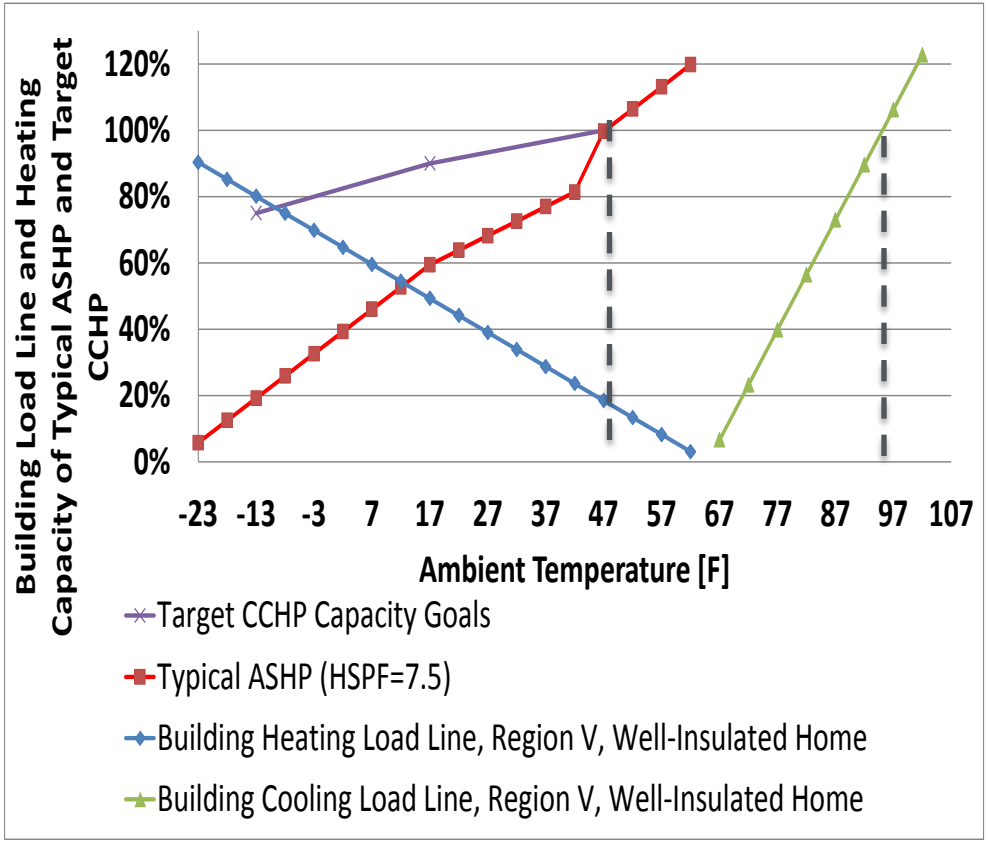
- Achieve COP@47°F > 4.0; achieve capacity@-13°F > 75%, vs. rated capacity@47°F.
- Maximize COP at 17°F and -13°F with acceptable payback period.

Two prototypes of 3-ton, split CCHPs achieved the project goals.

Purpose and Objectives

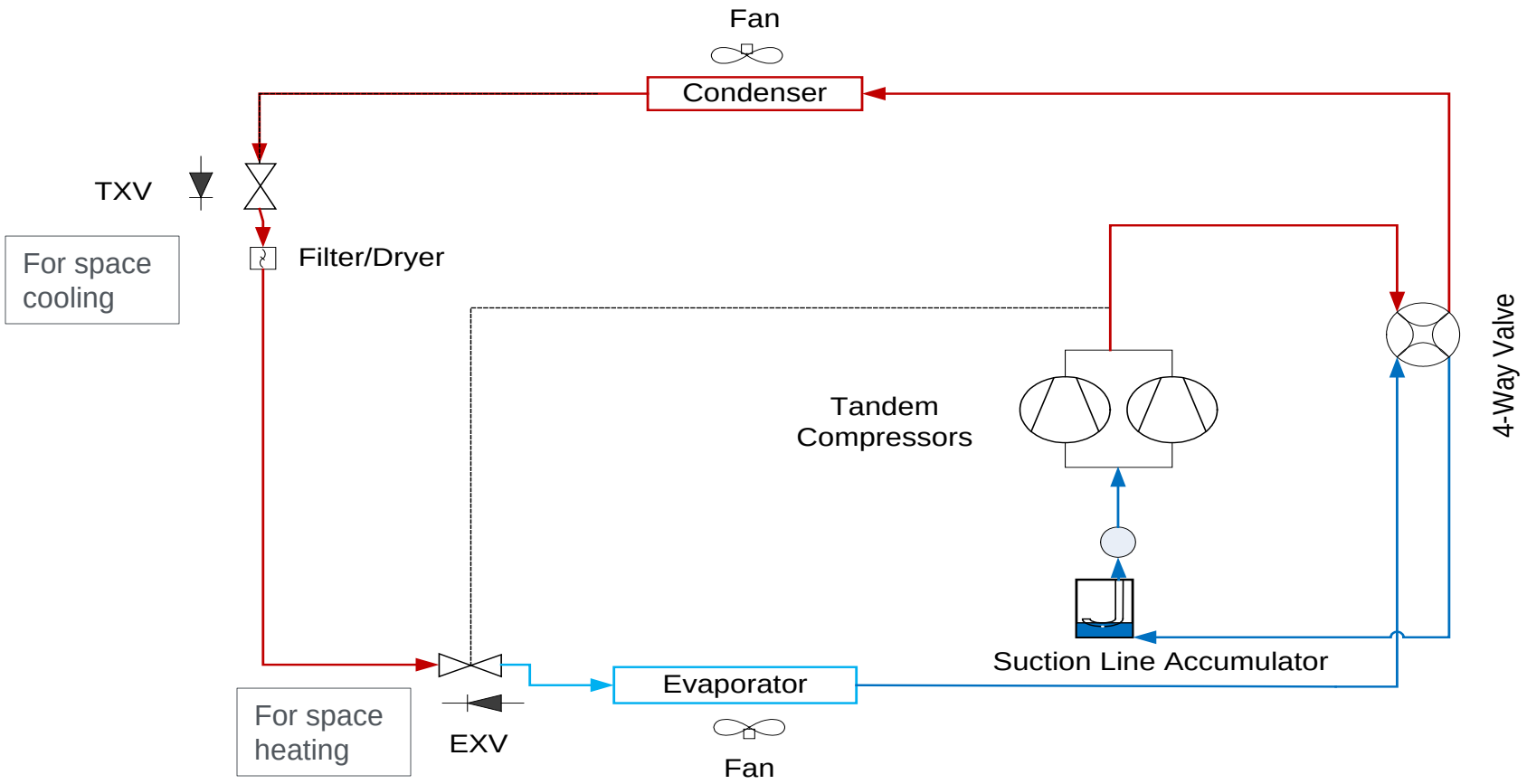
Problem Statement:

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



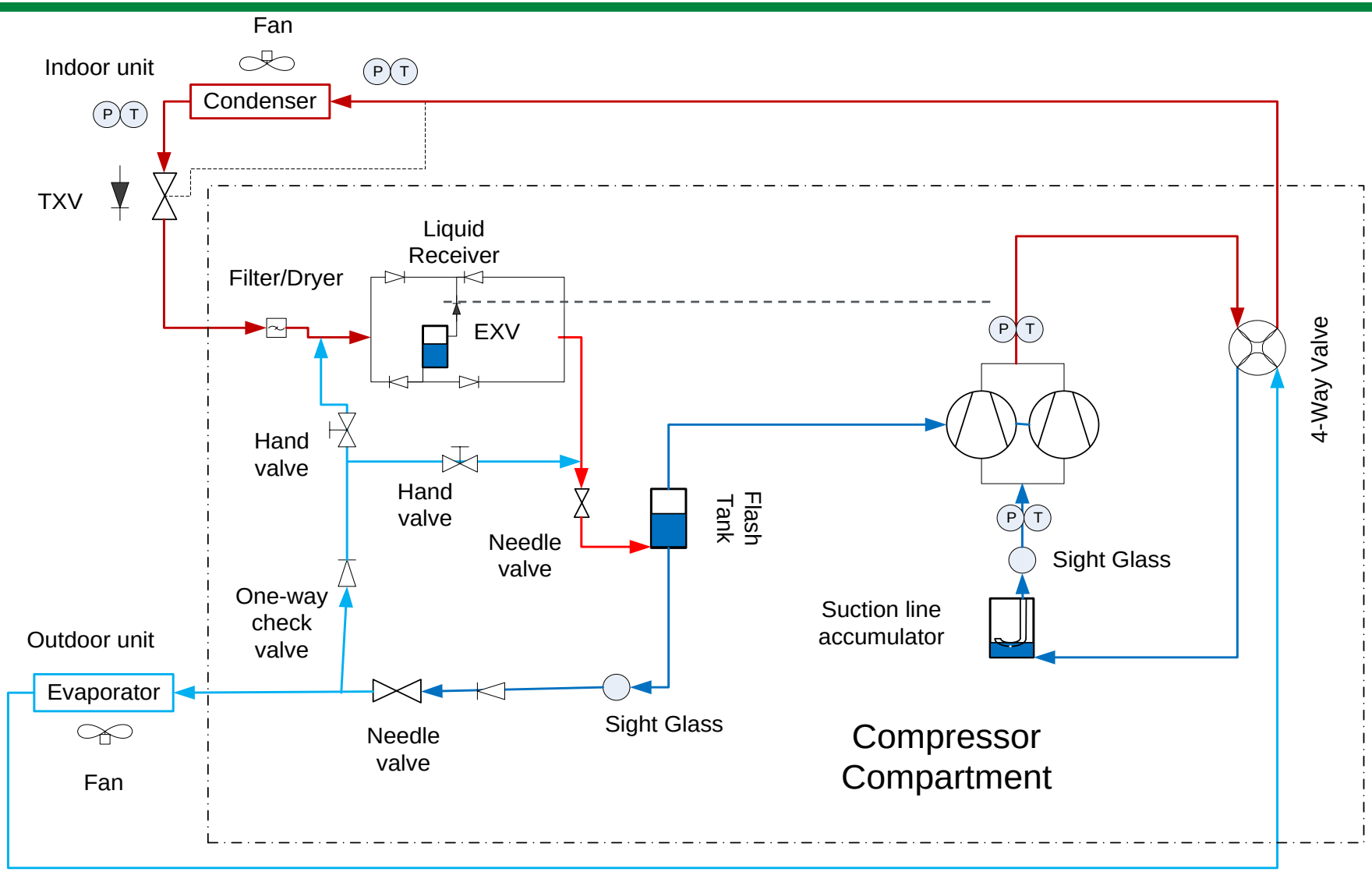
Target market/audience: The principal target market is 2.6M electric-heated dwellings in cold regions. It would contribute to annual site energy savings of 3,664,405 MMBTU and CO2 emissions reduction of 470,000 tons.

Approach: 'More Cost Effective' Configuration



1. *Two identical, fixed-speed compressors, specially optimized for heating mode , tolerate up to 280°F discharge temperature.*
2. *A single compressor to match cooling load, and heating load at moderately cold temperatures, turn on both compressors at low ambient temperatures when needed.*
3. *(Suction line accumulator+ EXV discharge temperature control) facilitates charge optimization in a wide ambient temperature range. →using TXV and optimizing charge for heating mode is an alternative.*

Approach - ‘Premium’ Configuration



- ***Equal Tandem, Vapor Injection Compressors + Inter-Stage Flash Tank + EXV Discharge Temperature Control .***

Progress and Accomplishments

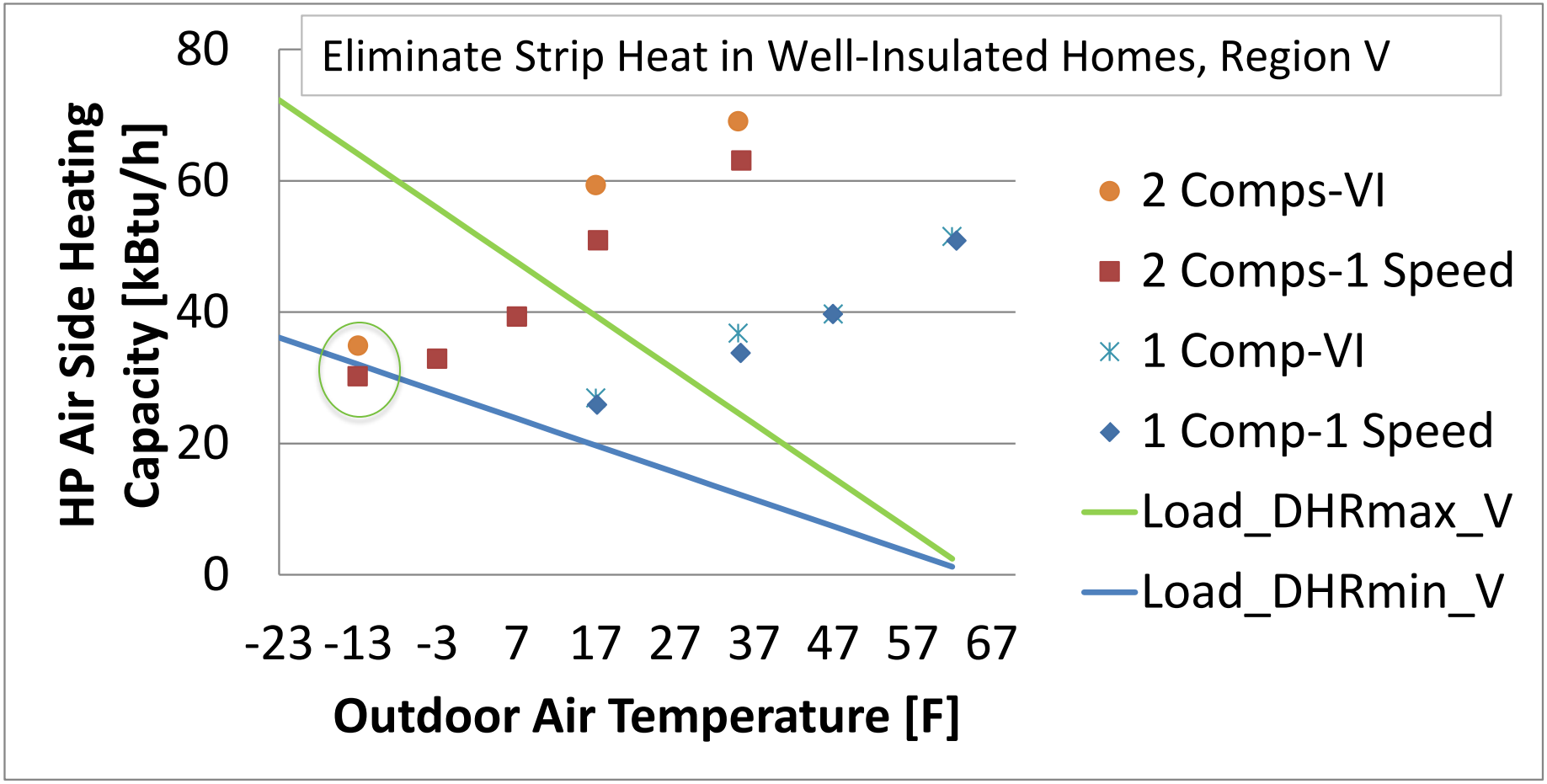
Market Assessment | Concept Design | Lab Prototyping | Optimization | Field Verification

Accomplishments:

Achieved the project goals, i.e. >75% capacity at -13°F, COP >4.0 at 47°F

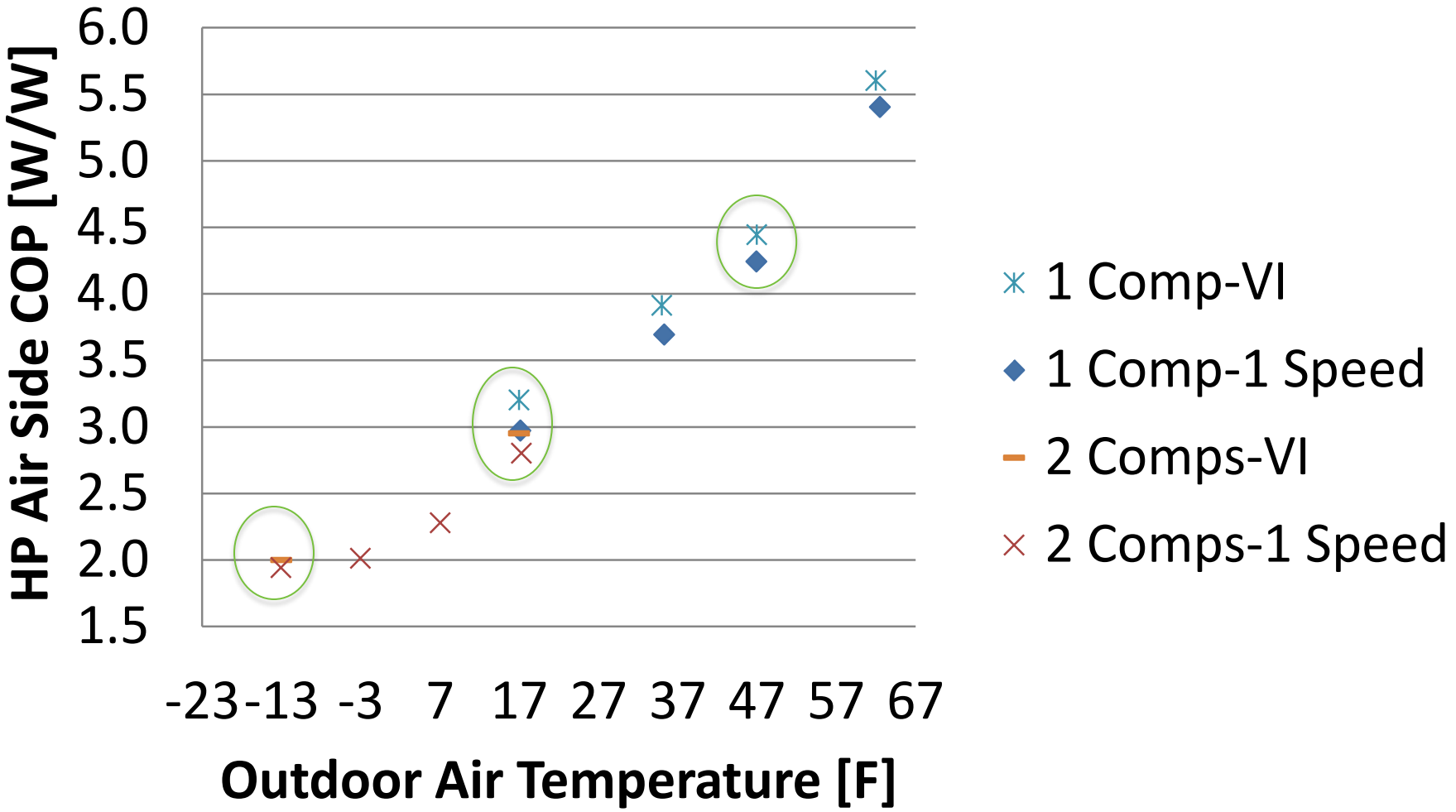
1. Lab prototype with tandem fixed-speed (76% capacity at -13°F vs. 47°F; COP=4.2 at 47°F)
2. Lab prototype with tandem vapor injection (88% capacity at -13°F vs. 47°F; COP=4.4 at 47°F)
3. Field prototype (tandem fixed-speed) operated down to -12°F without auxiliary heat, achieved >40% energy saving vs. a baseline fixed-speed HP.
4. Project final report complete (CRADA with Emerson)

Lab Measured Heating Capacities



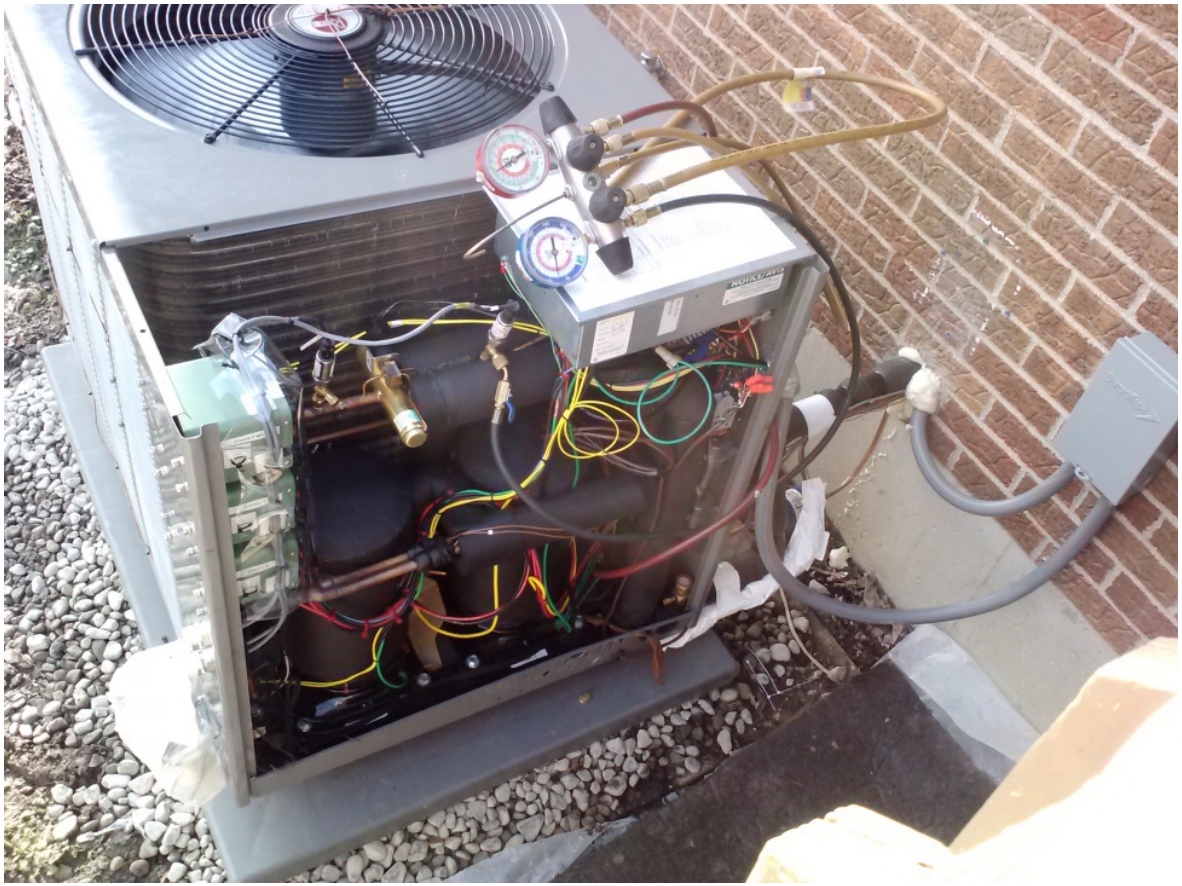
- *CCHPs eliminate auxiliary strip heating down to -13°F in US cold regions.*

Lab Measured Heating COPs



- *The 'premium' system with tandem VI compressors achieved 5% better COPs than the 'more cost-effective' fixed-speed compressor version at various ambients.*

Field Testing of a ‘More Cost-Effective’ System, from Feb 2015 to April 2016

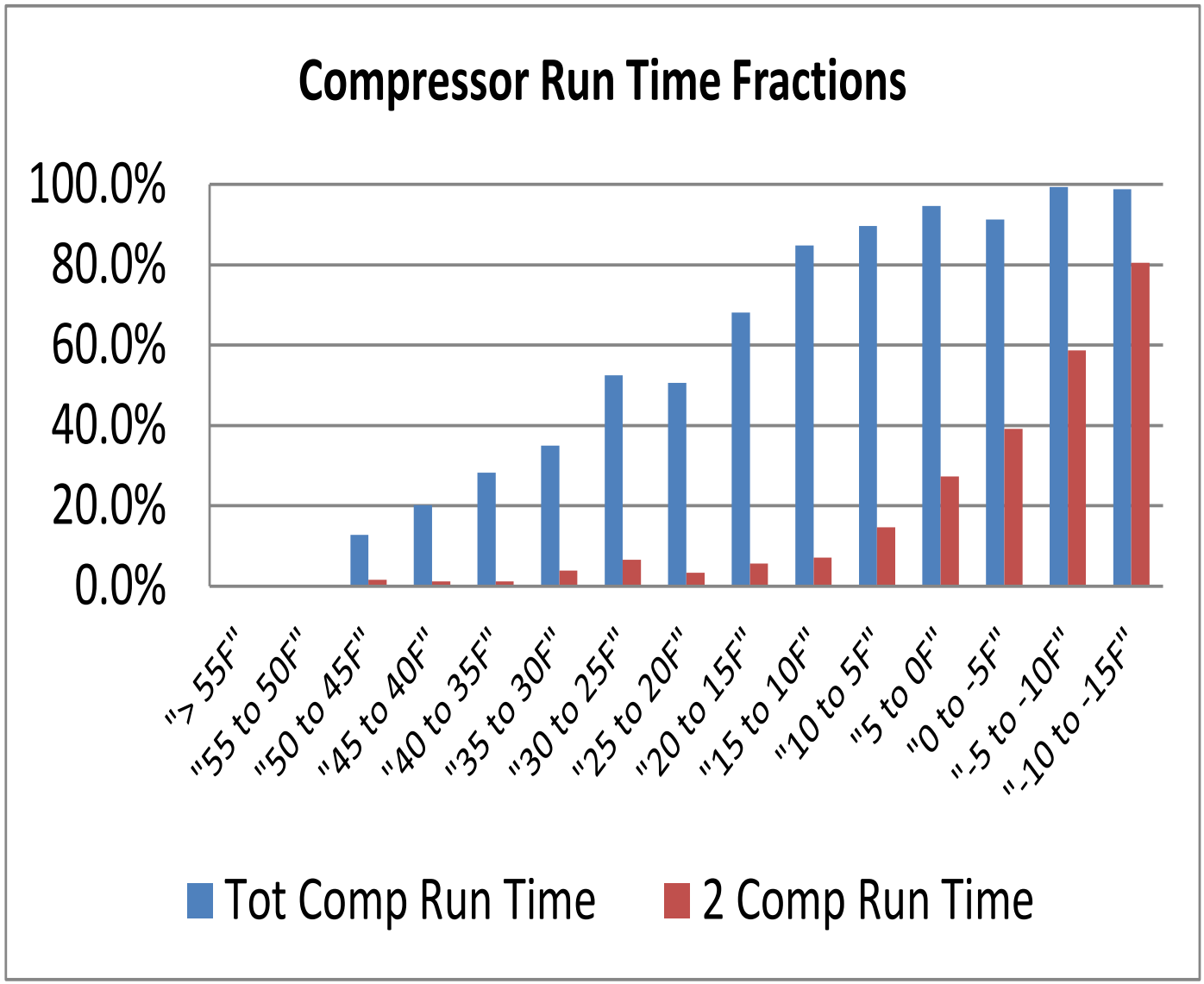


Field testing in Ohio outdoor unit, at a residential home having a design cooling load of 3-ton

Field testing in an occupied home in Ohio

Indoor unit and DAQ

Compressor Running Time Fractions

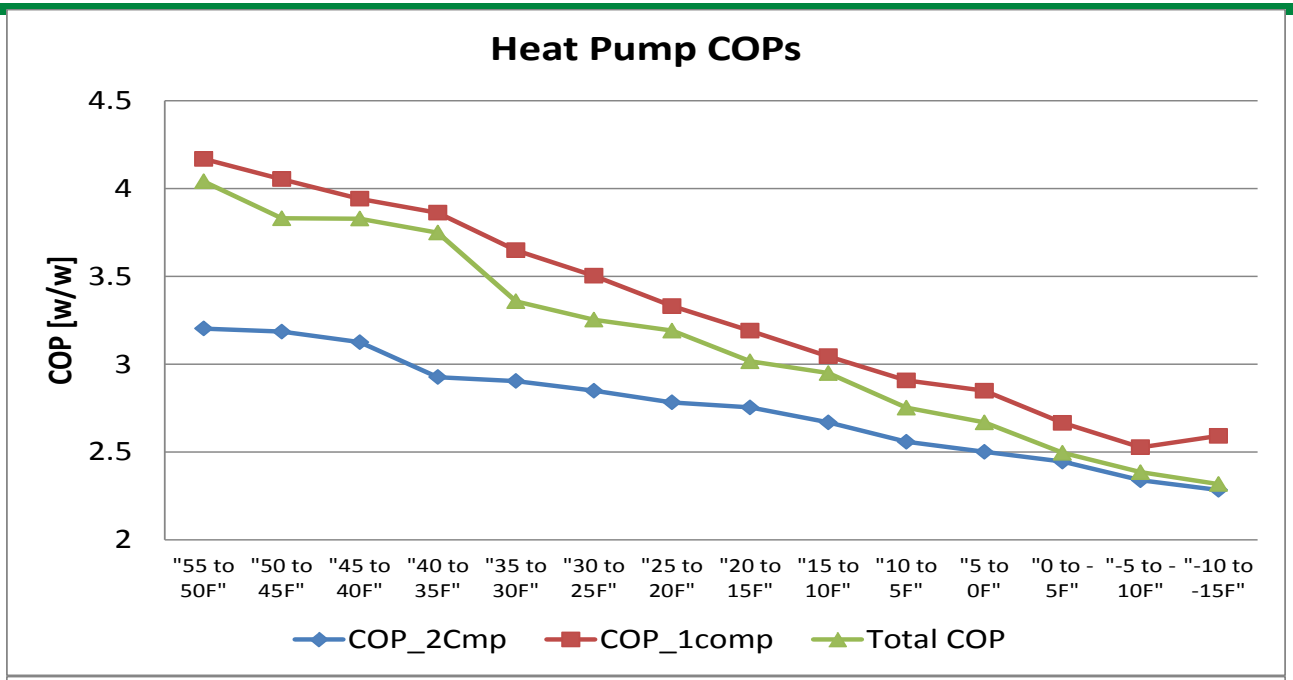


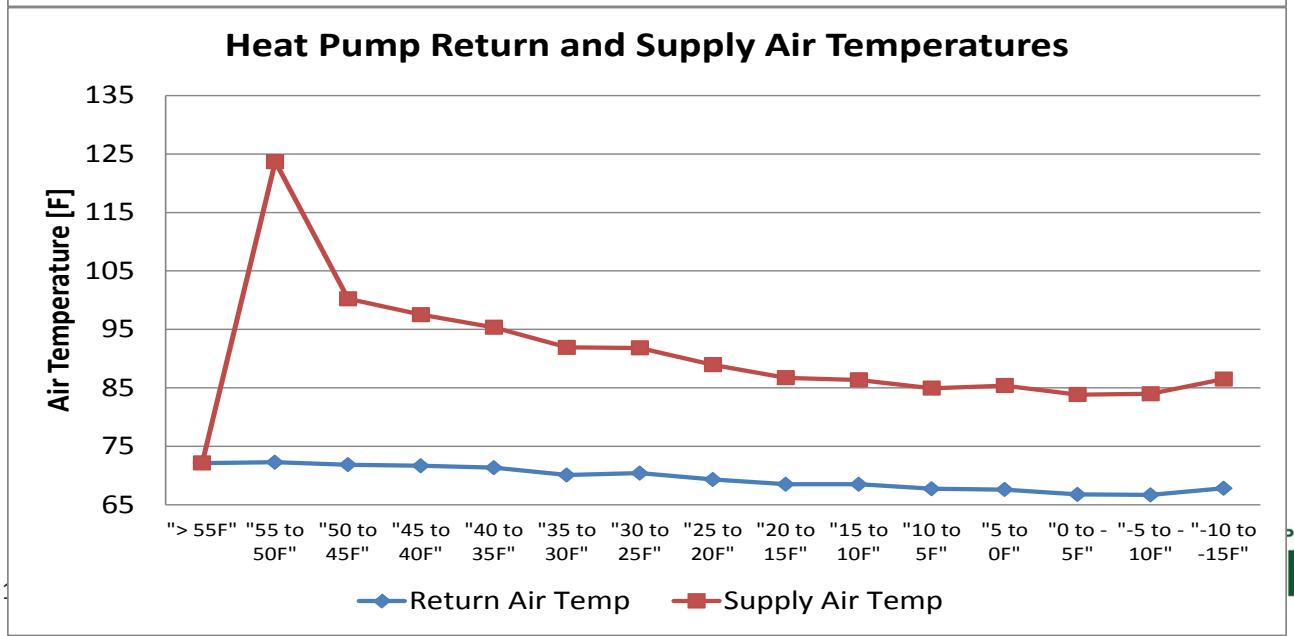
1. Field ambient temperature went down to -12°F.

2. The second compressor cycled with 80% running time, even at -12°F (having room for more capacity).

No auxiliary heat needed down to -13°F.

Field Heating COPs and Comfort Level





1. Heat pump COP at -13°F > 2.0.

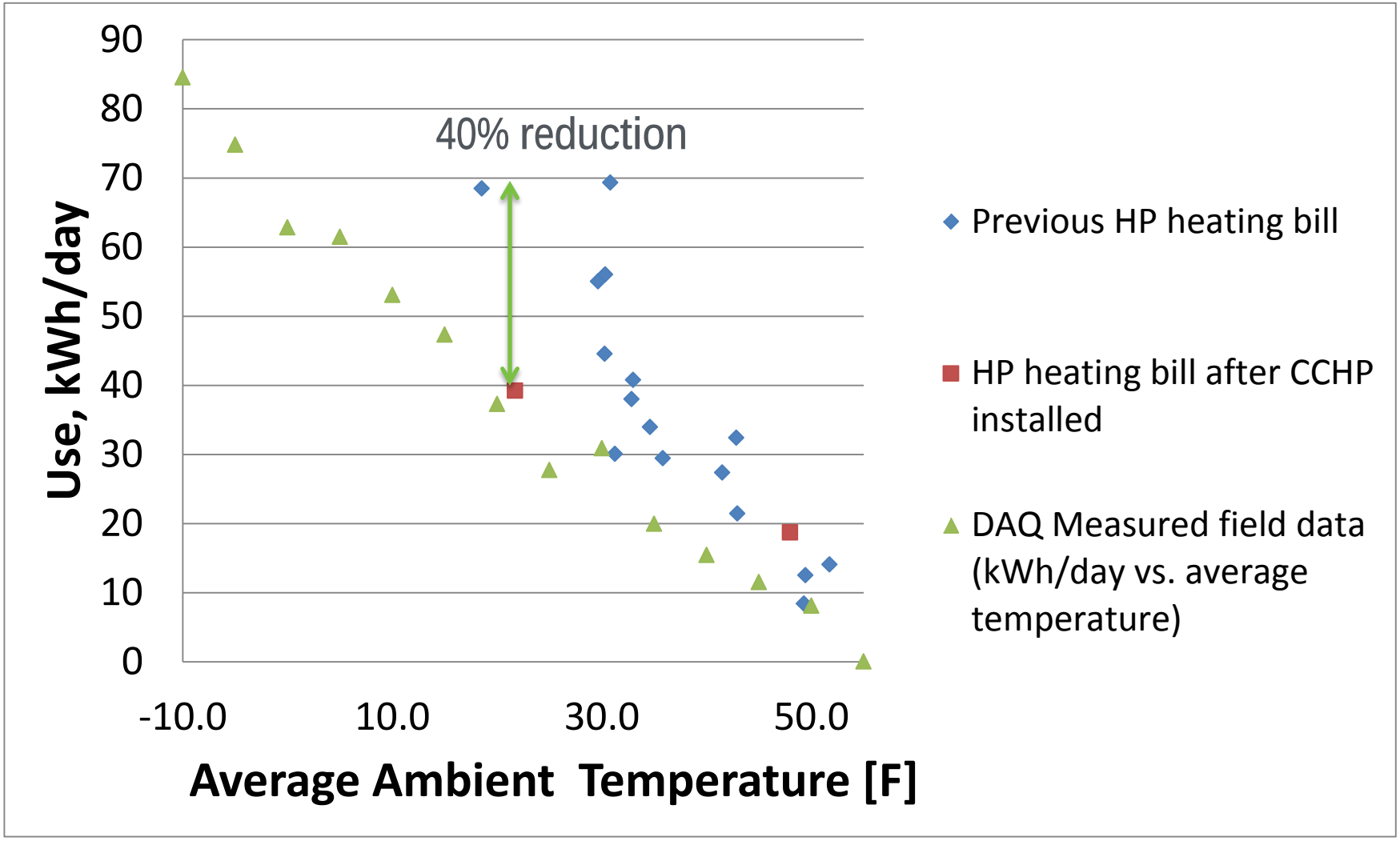
2. Seasonal, average, heating COP was 3.16, i.e. 10.8 HSPF.

Note: Total COP includes cyclic and frost/defrost losses, etc.

– Maintain 20°F air temperature increase at low ambient temperatures.

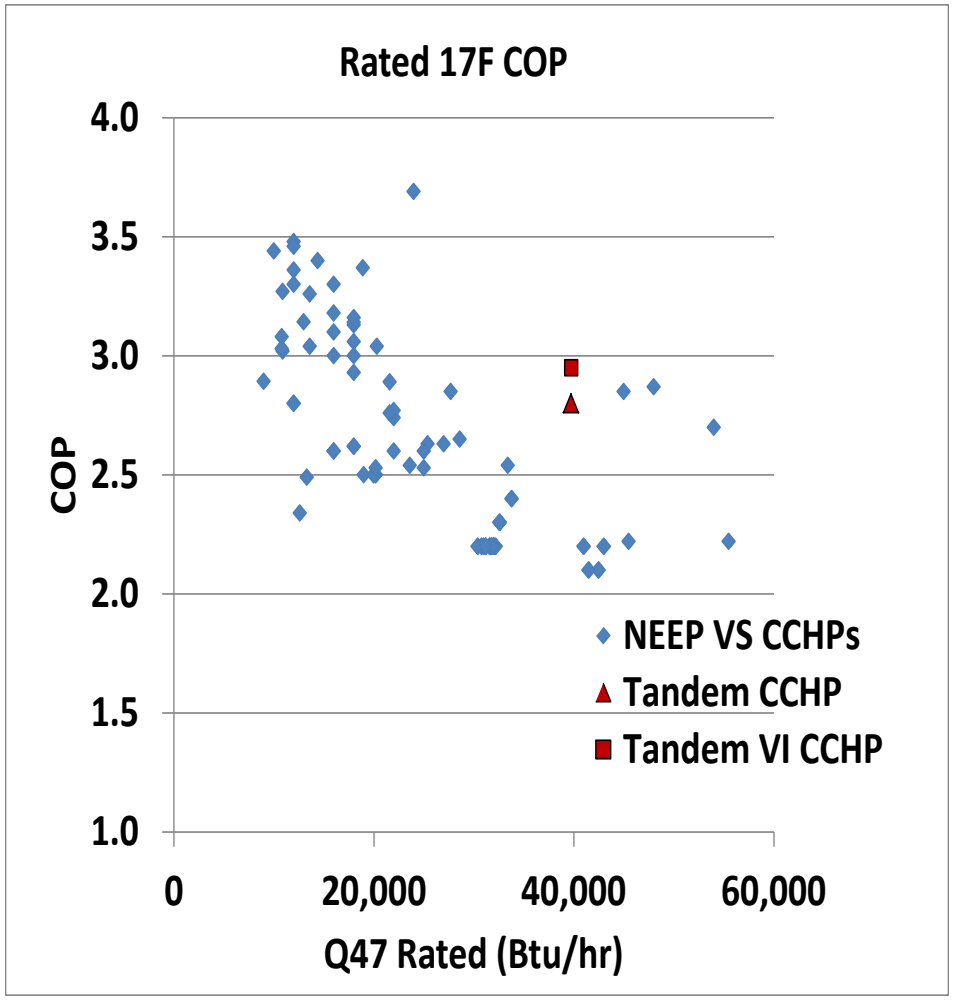
* Temperature setting at 68°F with 2R dead band.

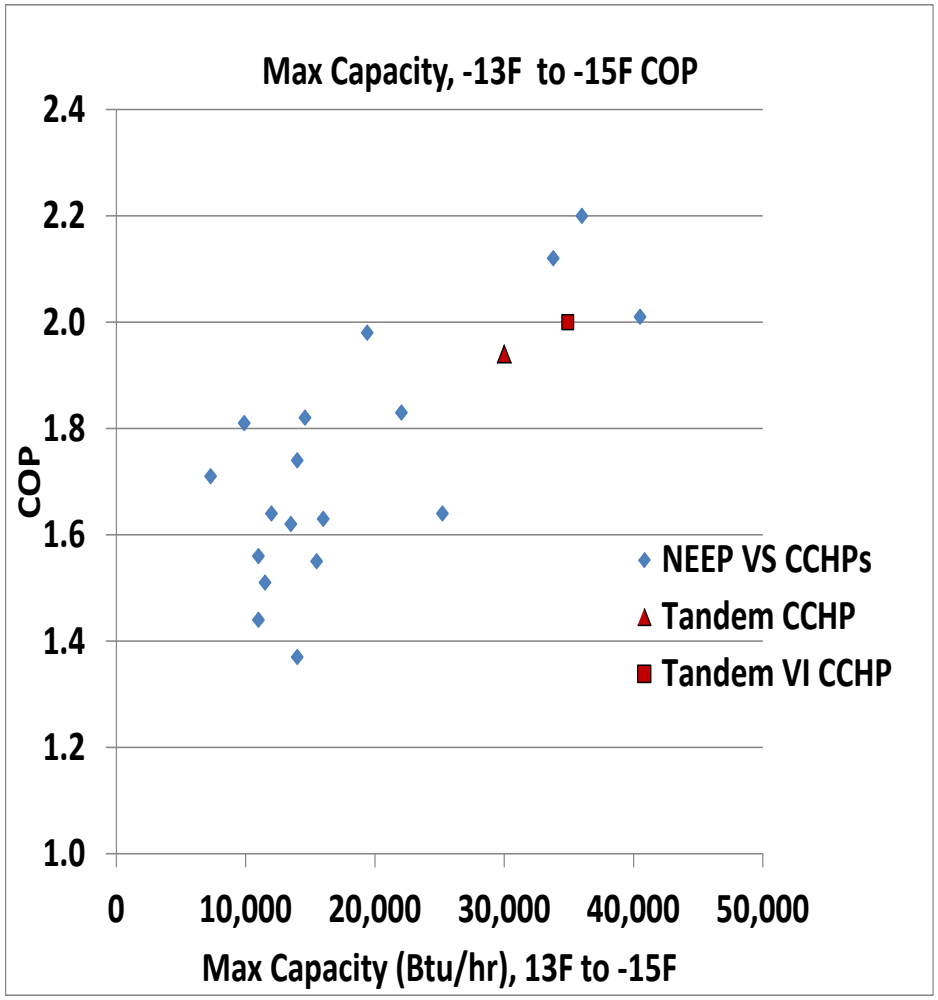
Huge energy reduction in coldest months compared to previous conventional HP (13.0 SEER/8.0 HSPF)



- >40% energy reduction vs. previous HP with similar average temperatures of 20°F

Compared to other CCHPs on the market (Northeast Energy Efficiency Partnerships, CCHP Listing)





1. *ORNL prototypes reached top efficiency level in the target capacity range, as compared to Japanese VRF mini-split and multi-split units.*
2. *ORNL prototypes are much less expensive (estimated cost: $4K for a 3-ton split CCHP).*

Project Integration and Collaboration

Project Integration:

Compressor 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.

Heat pump development: 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)
- Four presentations for Annex 41, International Energy Agency.
- Five conference papers and ORNL reports, one journal paper.
- One project final report.

Next Steps and Future Plans

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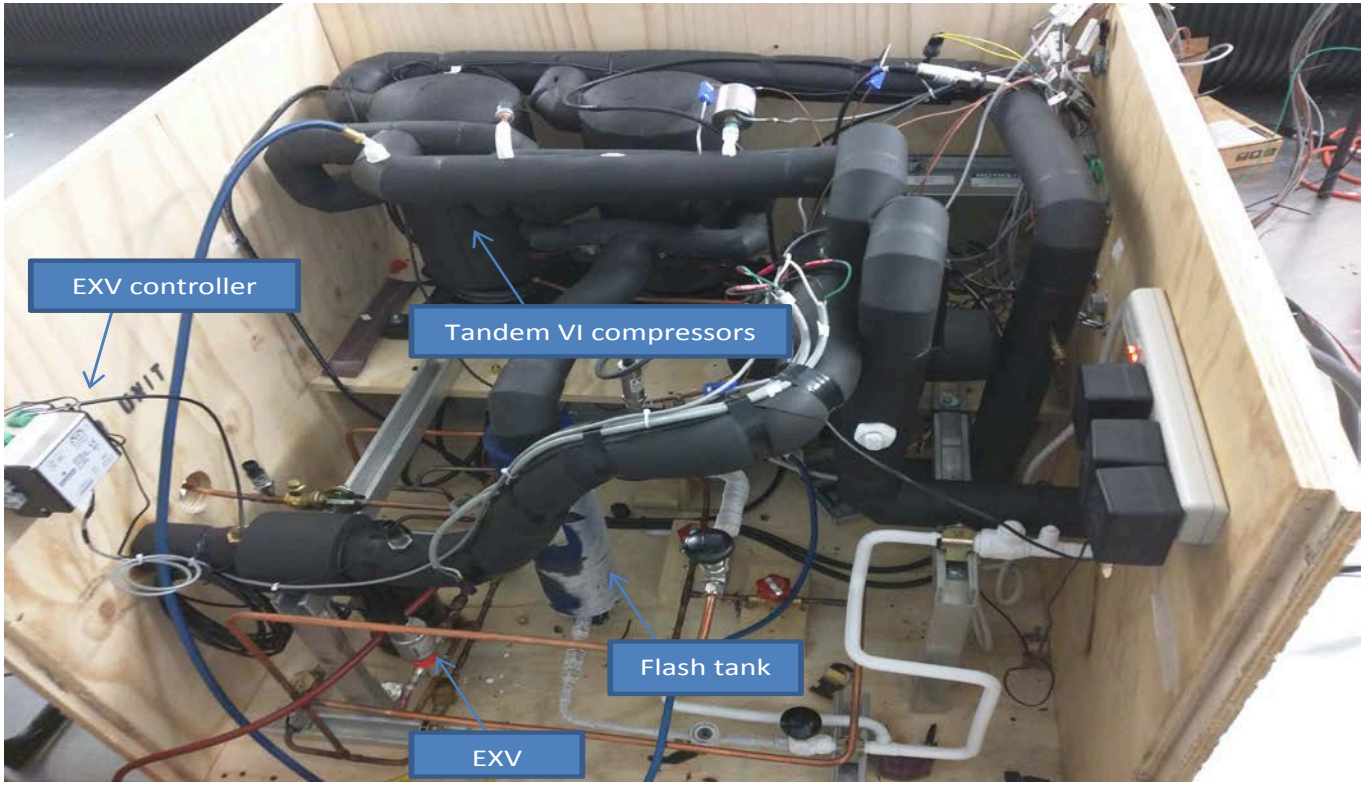
- Field testing a CCHP with tandem VI compressors in Alaska - 2016 to 2017



Market Impact:

- Emerson Climate Technologies to provide compressor solutions to US OEMs interested in developing CCHPs.
- Unico to put equipment on the market.

REFERENCE SLIDES

Project Budget

Project Budget: DOE total $2,839K- FY11-16
Cost to Date: ~$2,439k through March 2016
Additional Funding: None expected

Budget History					
FY 2011 to FY 2015 (past)		FY 2016 (current)		FY 2017 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$2,439K	*	$400k	*	NA	NA

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

Project Plan and Schedule

Original initiation date: 01-Oct-2010 -- Planned completion date: 30-May-2017
(minor delays in lab prototype fabrication and testing schedules)
Go/no-go decision points
* March 2014 Tandem fixed-speed lab prototype met project goals– ***Passed***
* September 2015 Field testing of HP using tandem fixed-speed compressors– ***Passed***
* June 2015 Tandem vapor-injection lab prototype met project goals– ***Passed***