

Advanced variable speed air-source integrated heat pump (AS-IHP)

2014 Building Technologies Office Peer Review



Field test system

IHP concept – all HVAC/WH integrated into one highly efficient system



U.S. DEPARTMENT OF
ENERGY

Energy Efficiency &
Renewable Energy

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Project Summary

Advanced variable speed air-source
integrated heat pump (AS-IHP) - CRADA

Timeline:

Start date: 01-Oct-2011

Planned end date: 31-Dec-2015

Key Milestones

1. Complete system lab tests for model calibration; 31-July-2013

2. Complete annual performance simulations based on lab performance to verify $\geq 50\%$ HVAC/WH energy savings potential; 31-Mar-2014 (Go/No-go)

3. Complete system field test & draft final project report; 30-Apr-2015 & 30-Sept-2015

Budget:

Total DOE \$ to date: \$1620k

Total future DOE \$: \$500k

Target Market/Audience:

The principal target market is electric residential space heating & cooling and water heating – estimated at 3.1 Q in 2030. HVAC system OEMs and homeowners are the principal audiences.

Key Partner:



CRADA project with Nordyne US HVAC system OEM

Project Goal:

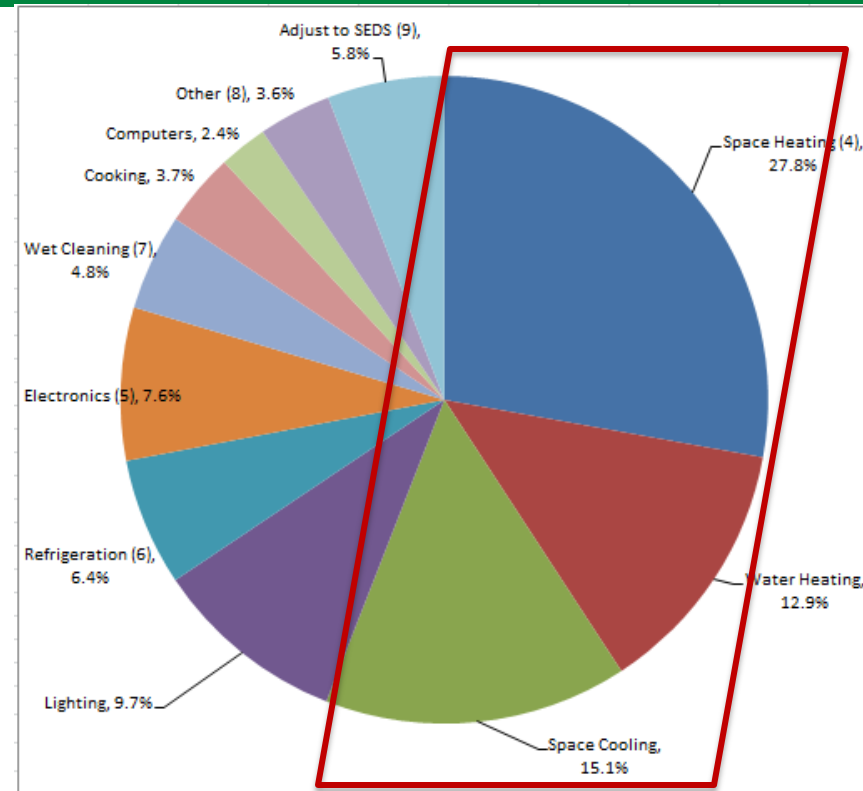
The goal is to develop an advanced HVAC/WH system based on IHP concept with $\geq 50\%$ energy savings vs. min. efficiency systems.

Purpose & Objectives

Problem Statement:

Space conditioning & water heating services are responsible for >55% of residential building energy use

Highly efficient HVAC & WH systems needed to enable achievement of DOE/BTO goal for 50% reduction in bldg. energy use by 2030



From March 2012 Buildings Energy Data Book

Target market/audience: Residential electric HVAC and water heating (WH); est. at ~3.1 quads with maximum adoption potential savings of ~1.3 quads/year in 2030. Principal audience is residential equipment OEMs and homeowners; secondary target/audience is small commercial buildings with significant hot water loads.

Purpose & Objectives

Impact of Project:

1. Goal - develop advanced HVAC/WH system with $\geq 50\%$ energy savings vs. minimum efficiency systems; initial product announcement by late CY2015 or early CY2016.
2. Measurable market uptake (sales/shipments) 3+ years after launch.

Collaboration with Nordyne (OEM) brings history of successful heat pump innovation (including the highest SEER variable-speed AC/HP units on the market), along with market savvy and distribution/service infrastructure. Past successes in similar CRADAs show that such close collaboration with manufacturers is best path to market success – e.g. GE HPWH, ClimateMaster Trilogy GS-IHP, NextAire GEHP, Trane CDQ hybrid desiccant AC system, etc.

Approach

Approach:

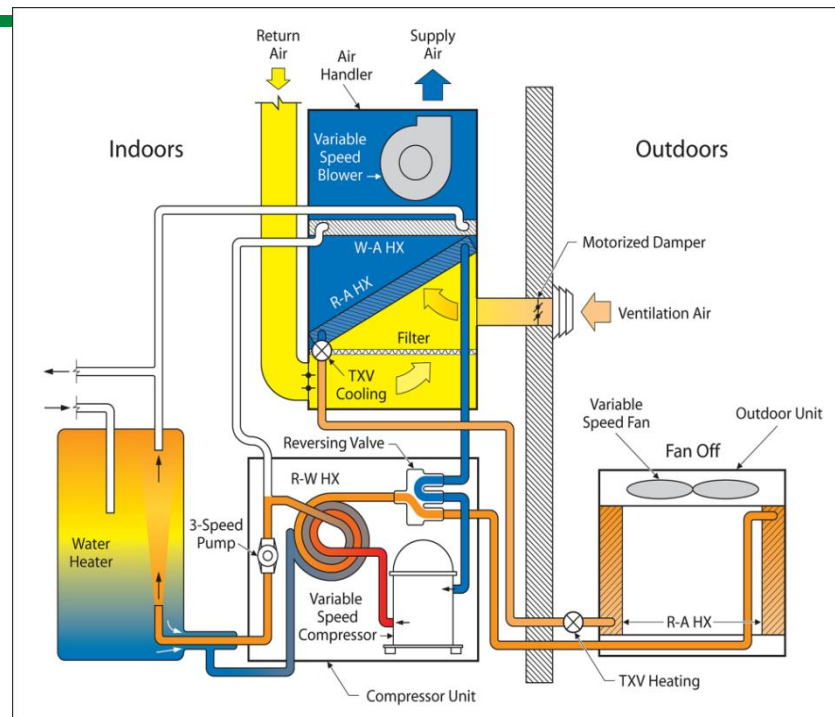
- Collaborative/iterative system development
- Experimental and modeling characterization of prototype systems and feedback to next generation prototype
- Through field test demonstration system

Key Issues:

- Balance charge and flow control among heating, cooling, water heating, and combined operational modes
- Determination of optimal component speed ranges for different modes

Distinctive Characteristics:

- Efficient high-capacity water heating
- Variable capacity control for maximum part load efficiency
- Multiple patents granted and applications pending on proprietary design aspects



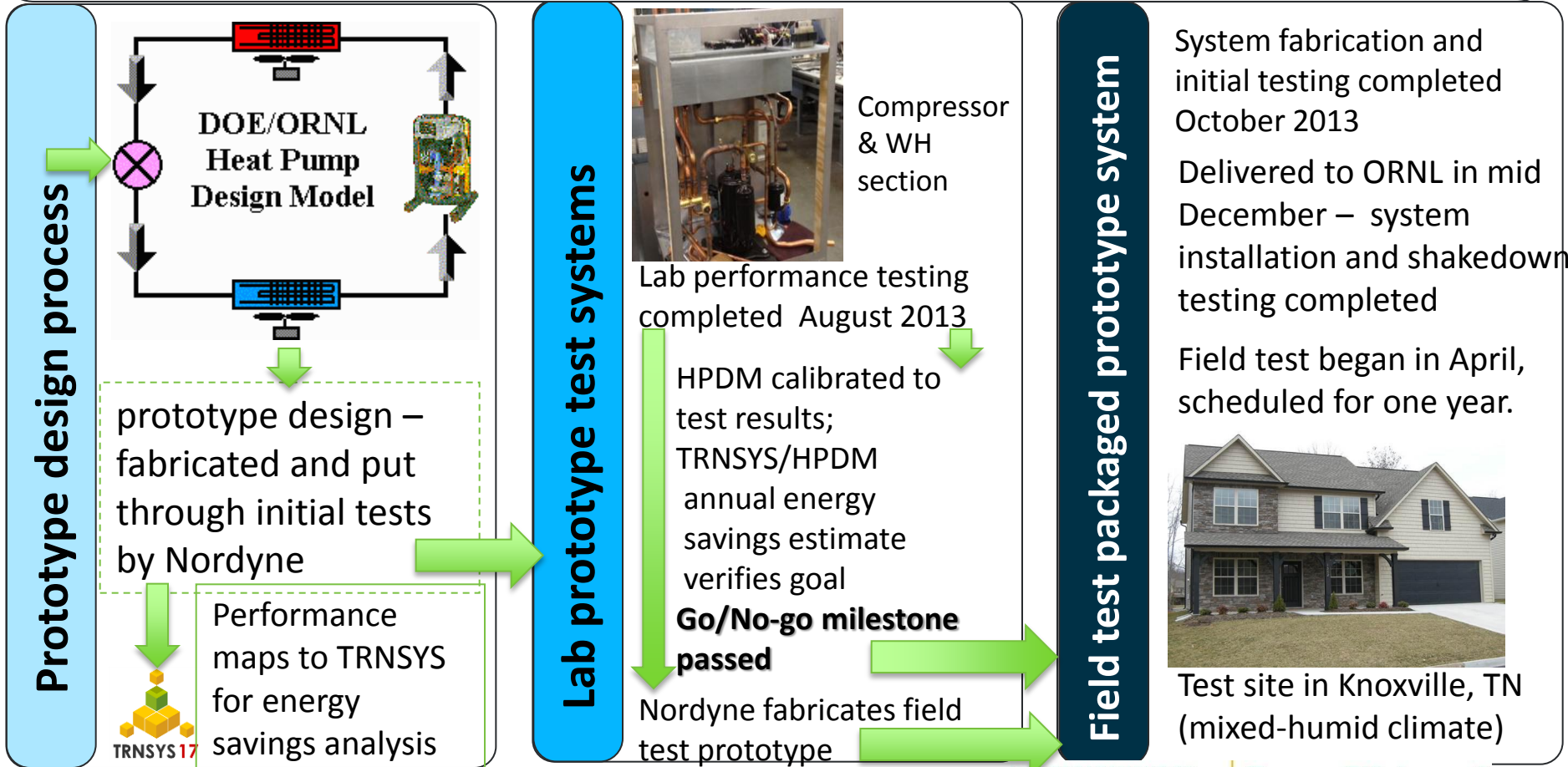
AS-IHP system concept



Possible AS-IHP packaging approach

Approach

From basic IHP concept – 2 iterations of lab prototype systems dev. by Nordyne and ORNL; tested at Nordyne and ORNL in FY12&13; estimated annual energy savings based on prototype design $\geq 50\%$ for range of US locations (**meets FY14 Go/No-go milestone target**).
Packaged prototype fabricated and installed at test site; field test started.



Progress and Accomplishments

Accomplishments:

- Initial lab prototype design completed and tested in FY12. Annual energy savings estimates based on initial design show 54% savings for Atlanta climate vs. $\geq 50\%$ target.
- **2nd prototype design completed and tested in FY13**
- **US average savings estimates based on 2nd prototype lab performance meet Go/No-go milestone target; $\geq 50\%$ vs. minimum efficiency baseline suite**

Milestone analysis results for AS-IHP prototype:

Energy Savings Predictions for 2600 ft² (242 m²) well-insulated house in 5 U.S Locations

Location	% Energy Savings Versus Baseline Heat Pump & Electric Water Heater Suite
Atlanta	53.3
Houston	54.7
Phoenix	46.7
San Francisco	60.9
Chicago	46.0
US average	52.3

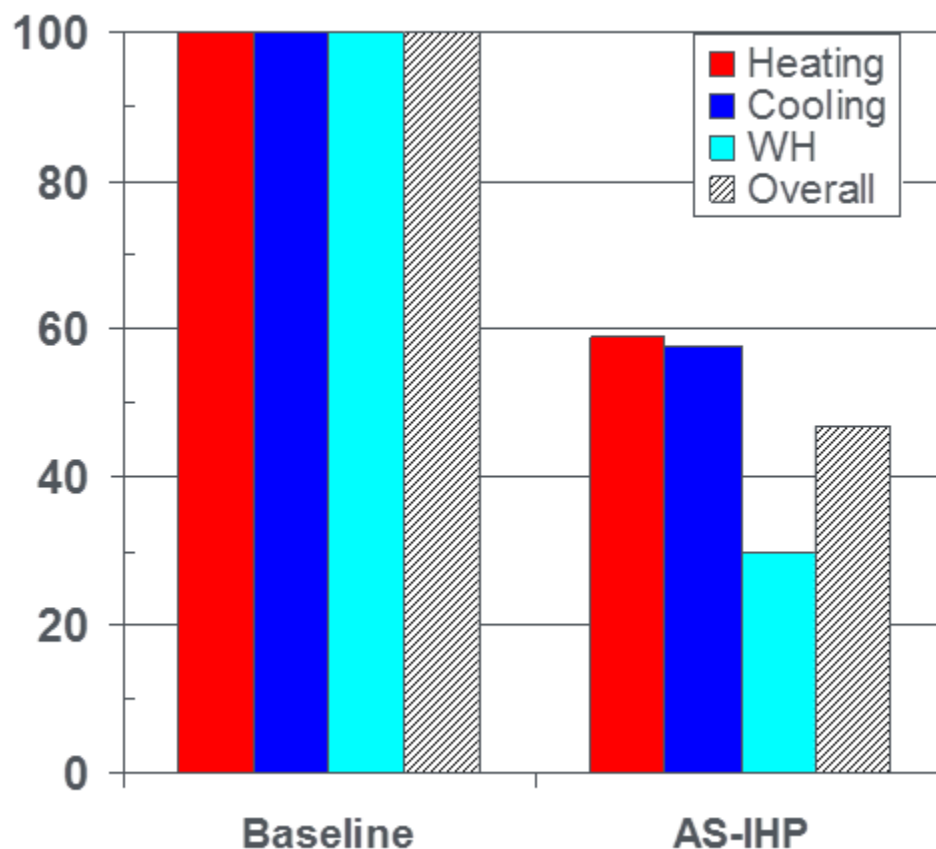
Atlanta analysis results

Efficiency Equivalent

	Baseline (air/air heat pump + electric resistance water heater)	AS-IHP
Seasonal heating COP	2.57	4.28
Seasonal cooling COP	3.62	6.38
WH Energy Factor	0.90	3.00

Base system – rated efficiencies - 13 SEER and 7.7 HSPF (per AHRI 210/240); 0.90 EF per DOE test procedure

% Energy Use



Progress and Accomplishments

Progress on Goals:

Field test prototype installed and field test just started

- ~six month delay vs. planned at FY14 beginning; planned test site became unavailable so we had to secure a new site and prepare and instrument it from scratch

Market Impact: Nordyne target for new product introduction based on field test prototype is late CY2015 or early CY2016

Lessons Learned:

- Involve committed manufacturer partner as early in project as possible
- Start field test planning ASAP – causes and fixes for potential delays are difficult to forecast

Project Integration and Collaboration

Project Integration: The project is based on a collaborative R&D agreement (CRADA) with Nordyne (US HVAC OEM).

Partners, Subcontractors, and Collaborators: CRADA partner Nordyne. Thermal Energy Systems Specialists (TESS) have a small subcontract for TRNSYS analyses. International collaboration via IEA Heat Pump Program Annex 40 enables project team to learn from latest RD&D efforts in Europe and Far East.

Communications: Summary paper is scheduled for presentation at the 11th International Energy Agency (IEA) Heat Pump Conference, May 12-16 in Montreal; regular progress reports, reviews, conference calls for DOE and Nordyne; Nordyne has several patents and patents pending on the system design.

Next Steps and Future Plans

- Complete field testing – April 2015
- Complete draft final CRADA report - early 4th Q FY 2015
- Proceed with system commercialization activities - Nordyne



Test house at Yarnell Station
Community in Knoxville

- System installation complete
- DAS/instrumentation installed
- Shakedown complete; test started

REFERENCE SLIDES

Project Budget

Project Budget: DOE total \$2120k FY12-16

Variances: Cost increase of ~\$250k in FY14; original test site became unavailable in October 2013; we had to select, procure and set up a new site from scratch causing 6-7 month delay in field test start.

Cost to Date: ~\$1320k through February 2014

Additional Funding: None expected.

Budget History

FY2012 – FY2013 (past)		FY2014 (current)		FY2015-FY2016 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
\$1120k	*	\$500k	*	\$500k	*

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

Project Plan and Schedule

Original initiation date: 01-Oct-2011 -- Planned completion date: 31-Dec-2015
 (minor delays in prototype fabrication and testing schedules; 6-7 month delay due to unexpected need to procure and prepare a new field test house from scratch)

Go/no-go decision points:

- Sept '12 proceed to packaged prototype – **Passed**
- March '14 verify >50% national average energy savings potential of prototype – **Passed**
- late CY '15/early CY '16 proceed to product introduction (Nordyne)

Project Start: 01-October-2011	Completed Work											
Projected End: 31-December-2015	Active Task (in progress work)											
	Milestone/Deliverable (Originally Planned) use for missed											
	Milestone/Deliverable (Actual) use when met on time											
	FY2013				FY2014				FY2015			
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												
G/ng decision to proceed to packaged prototype	◆											
Build 2nd prototype and begin lab tests	◆	◆										
Complete 2nd prototype lab tests			◆	◆								
G/ng milestone; verify ≥50% energy savings				◆	◆	◆						
Fab. FT prototype, install, begin tests					◆	◆	◆					
Current/Future Work												
Complete FT & data analysis; draft final project report											◆	◆
G/ng decision to proceed to market - CY15/CY16												◆