Building America Case Study

Field Performance of Inverter-Driven Heat Pumps in Cold Climates

Connecticut, Massachusetts, and Vermont

PROJECT INFORMATION

Project Name: Field Performance of Inverter-Driven Heat Pumps in Cold Climates

Location: CT, MA, and VT

Partners:

Efficiency Vermont, *efficiencyvermont.com*

Consortium for Advanced Residential Buildings, *carb-swa.com*

Building Component: Heating, ventilating, and air conditioning

Application: New and retrofit; single-family and multifamily

Year Tested: 2013–2014

Climate Zone(s): Cold (5 and 6)

PERFORMANCE DATA

Cost of energy-efficiency measure (including labor): $2,500–$4,500/ton

Projected energy savings: electric resistance—45%; oil—19%; propane—42%

Projected energy cost savings: electric resistance—$2,374; oil—$681; propane—$2,101 (for a 100-MBtu load and New England utility rates)

Building America U.S. Department of Energy

Traditionally, air-source heat pumps (ASHPs) have been used in warm climates; however, heat pumps powered by new inverter-driven compressors are gaining ground in colder climates. The inverter technology adjusts the compressor speed, which allows the system to adapt more smoothly to shifts in demand with less temperature variation and expected lower energy use. These systems operate at subzero (Fahrenheit) temperatures without the use of electric resistance backup, but uncertainties remain about capacity and efficiency in cold weather. To better understand and characterize heating performance, the U.S. Department of Energy Building America team, Consortium for Advanced Residential Buildings (CARB), monitored seven inverter-driven ASHPs across the northeast United States during the winter of 2013–2014.

Researchers monitored heat output and electricity consumption. They then calculated coefficients of performance (COPs) over the course of the winter. The research included long- and short-term tests measuring power consumption; supply, return, and outdoor air temperatures; and airflow through the indoor fan coil. Airflow tests (Figure 1) proved challenging and surprising because measured flow rates were only 50%–80% of listed flow rates. Overall, measured monthly COPs were between 1.1 and 3.1 (see Table 1). Maximum heating capacities were also found to be generally in line with manufacturers' claims as outdoor temperatures fell to –10°F.

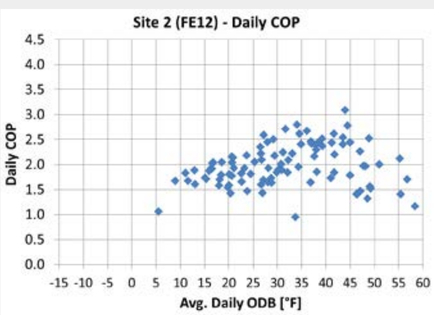
Figure 1. Flow testing configuration measured flow rates that were 50%–80% of manufacturer-listed rates.

CARB concluded that the wide range in heating performance was likely due to low indoor airflow rates, poor placement of outdoor units, relatively high return air temperatures, thermostat setback, integration with existing heating systems, and occupants limiting indoor fan speed. Even with lower

Monitoring Description

Power measurements were made using Powerhouse Dynamics' eMonitor system. The eMonitor was installed in the electrical panel. The eMonitor gateway was located near the panel and communicated through the home's network. Temperature sensors were installed at the supply and return air-streams of each heat pump. The photo shows sensor locations.

A current transducer was installed in each fan coil to measure electrical current; this current measurement was used to assess system flow rate. The flow-current relationship was calibrated at each site using a fan-assisted flow hood.



Daily COP versus outdoor air temperature was plotted for each test site. The graph shows an example plot from a Passive House monitored in the study.

For more information see the Building America report *Field Performance of Inverter-Driven Heat Pumps in Cold Climates* at *buildingamerica.gov*.

Image credit: All images were created by the CARB team.

efficiencies than published elsewhere, most of the heat pumps in this project still provided heat at a lower cost than oil, propane, or electric resistance.

Month	Site 1	Site 2	Site 4	Site 5	Site 8	Site 9	Site 10
Nov 2013	1.3	–	–	–	–	–	–
Dec 2013	1.6	–	2.3	–	–	–	–
Jan 2014	1.4	2.0	2.4	–	–	–	–
Feb 2014	1.6	1.9	2.2	1.8	–	–	–
Mar 2014	1.8	2.0	2.3	1.7	2.2	1.0	1.8
Apr 2014	2.2	1.9	3.1	–	2.5	1.3	2.4
Overall	1.6	2.0	2.3	1.7	2.3	1.1	2.1

Table 1. Seven of the original 10 sites studied provided usable data; this table shows a summary of monthly COPs observed at each site. CARB observed a wide range of operating efficiencies and outputs from site to site.

Lessons Learned

- Overall monthly COPs were in the range of 1.1 to 3.1.
- Systems seemed able to deliver rated capacities at low temperatures (when loads were present).
- All heat pumps provided useful heating at subzero (Fahrenheit) temperatures, but efficiency varied significantly from site to site (even between sites with the same model heat pump).
- Measured airflow rates were much lower than listed values.
- Manually setting the fan speed to "low" seemed to dramatically reduce capacity and efficiency.
- Higher return air temperatures near ceilings led to lower capacities and efficiencies.
- Setback strategies reduced electricity consumption, but frequent recovery did result in lower overall COPs.
- Most of the heat pumps in this project still provide heat at a lower cost than oil, propane, or electric resistance systems.

Looking Ahead

The results from this monitoring study are enlightening, but CARB's key conclusion is that more evaluations are needed. The results show a wide range of performance with many systems functioning below expectations. More work is needed to better assess energy use (and potential savings) and capacities of these systems in different climates and home configurations. CARB hopes to streamline this evaluation method and implement it across a wider range of systems and homes.

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

For more information visit
buildingamerica.gov

The U.S. Department of Energy's Building America program is engineering the American home for energy performance, durability, quality, affordability, and comfort.

DOE/GO-102015-4643 • September 2015