# BPA Emerging Technologies for Energy Efficiency Technology Focus Area: Heat Pump Water Heaters

## Technology Background

According to a recent assessment of the residential building stock in the Pacific Northwest, 55 percent of the region's residences have electric water heaters, of which only 0.02 percent are heat pumps. The region's 6th Power Plan calls for a 50 percent penetration of heat pump water heaters (HPWH) in the Pacific Northwest by 2030. Also, beginning in 2015, federal standards for electric water heaters will require any heater sold that is 55 gallons or above to meet an energy factor only attainable by a heat pump.

Commercially-available HPWHs use a vapor compression cycle to move heat from ambient air to water in a storage tank. In the US market today, HPWHs are integrated split systems and typically use R-410a. In the near future, at least one manufacturer intends to introduce a split system unit using carbon dioxide (CO2) as the refrigerant. In addition to being more environmentally friendly, CO2 HPWHs produce high water temperatures more efficiently.

Some concerns expressed about this technology include the effect on comfort and overall energy use when installed in conditioned space, the sufficiency of hot water supply, the demand response potential, and performance of the technology in colder climates. BPA has collaborated with several outstanding researchers, utilities, and institutions to fund research projects to address these concerns and promote the adoption of the technology in the Pacific Northwest.

## Current Research Projects

**Advanced Heat Pump Water Heater Research**
Timeline: Oct 2013 – Sep 2015
Collaborators: Washington State University (WSU) Energy Program

Split system, CO2HPWHs with dedicated, variable-speed outdoor compressors are subjected to the same lab and field tests as the integrated HPWHs that are currently marketed in the Pacific Northwest. In the first year, the equipment was imported and lab tested. Field testing is proceeding in four single-family homes representing all three of the region's heating zones. A final laboratory test report and interim field test reports are available.

**Demand Response Potential of Heat Pump Water Heaters**
Timeline: Oct 2013 – Sep 2015
Collaborators: WSU Energy Program

The demand response potential of CO2 refrigerant HPWHs will be explored for both a unitary configuration with a small storage tank and a split system design with a large tank. The overall research goals are to develop detailed protocols for demand response testing of water heaters including HPWHs in lab and controlled field situations, and to fully characterize the potential of these HPWHs for all classes of demand response capabilities. Field tests are being conducted in the Pacific Northwest National Laboratory (PNNL) Lab Homes.

**Combined Space and Water CO2 Heat Pump System Performance Research**
Timeline: Oct 2014 – Sep 2016
Collaborators: WSU Energy Program

This project will conduct lab and field tests on a prototype combined space and water heat pump system using CO2 refrigerant in highly energy efficient new homes. The research will take place over 24 months. The main goal is to determine the performance of the prototype for both space and water heating through a wide range of temperatures and use patterns. Secondary goals include exploring the interaction between space and water loads and the impact on system performance, and logistical findings such as HVAC installer, builder and home occupant response to the systems. The field study will begin in the fall of 2014 with the installation of the prototypes and continue to collect a full year of data for all sites.

## Completed Research Projects

**Impact of Heat Pump Water Heaters on Space Conditioning Energy Use and Comfort**
Timeline: Oct 2012 – Sep 2014
Collaborators: Pacific Northwest National Laboratory (PNNL)

This recently completed field evaluation of two HPWHs in PNNL Lab Homes was designed to measure the performance and impact of exhaust air on the heating, ventilating and air conditioning system during heating and cooling seasons. We conducted testing with two pairs of configurations: (1) a HPWH configured with exhaust ducting vs. an unducted HPWH and (2) a HPWH with both supply and exhaust air ducting vs. an unducted HPWH.

In general, installing exhaust-only ducting on a HPWH in conditioned space increased whole-house energy use, while full ducting decreased whole-house energy use. Full ducting was observed to substantially mitigate the impact of the HPWH on the HVAC system. The fully ducted HPWH decreased HVAC energy use 8 percent as compared to the Lab Home with an un-ducted HPWH. Although relatively small in comparison to HVAC savings, full ducting increased water heater energy use 4 percent for the HPWH operating in “Heat Pump” mode. In addition, the experimental data indicate that the penalty of installing a HPWH in conditioned space may not be as large as modeling studies suggest, due to the buffering of interior walls resulting in localized cooling in the water heater closet, with very little impact on surrounding interior temperatures.

**Northwest Heat Pump Water Heater Demonstration Project**
Timeline: 2009 – 2012
Collaborators: Electric Power Research Institute (EPRI)

This project installed HPWHs and metering equipment in 40 treatment sites and metering equipment in an additional 13 control sites throughout the Pacific Northwest. The purpose of this work was to monitor the homes for efficiency, performance, reliability, electric demand, application issues and customer behavior. BPA and 14 Northwest utilities partnered with EPRI as part of a national demonstration project that field tested 160 units around the country.

**Laboratory Test of Integrated Heat Pump Water Heaters**
Timeline: 2009 – 2011
Collaborators: Ecotope, National Renewable Energy Laboratory

Three models were thoroughly investigated through laboratory testing and modeling. The reports summarize research findings, identify factors of energy consumption, and estimate operating efficiency and typical annual electricity use in unheated buffer spaces and interior conditioned spaces throughout the Pacific Northwest.
The combined lab and modeling results suggest the determinants of efficient HPWH operation:

- Resistance element runtime and operational strategies
- Compressor characteristics including efficiency, operating range, and capacity
- Tank storage volume relative to hot water load
- Ambient air temperature surrounding the HPWH

**For more information on this technology, reports, and collaboration opportunities, please visit our website.**
**www.bpa.gov/goto/E3T**