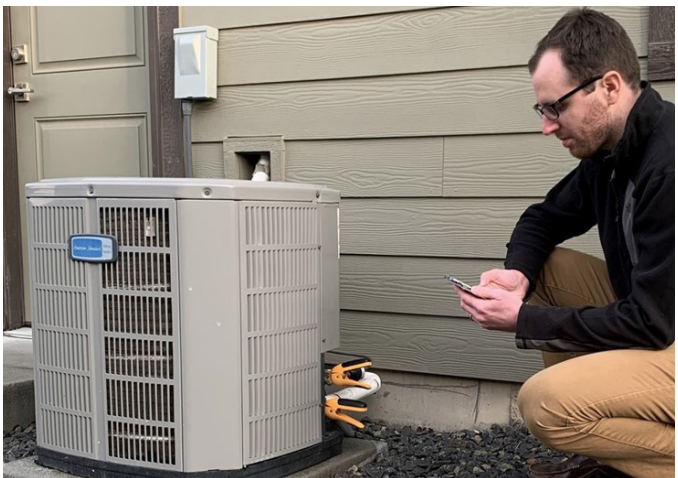
Transforming the Market for Residential Electric Heat Pump Technologies

Heating, ventilation, and air conditioning (HVAC) systems account for 51% of residential energy use nationwide. The systems used for heating household water account for another 7%. Around 50% of this energy is considered wasted due to inefficiency and costs ratepayers an extra $140 billion annually.

Moving homes to more efficient HVAC and water heating technologies is pivotal to decarbonizing the building sector by 2050, an ambitious target set and shared by the White House and the international community. Heat pump technologies offer a solution to this challenge because they can ultimately be powered by renewable energy like solar and wind power. However, meeting this ambitious decarbonization milestone will require significant consumer education and subsequent action to replace their existing gas systems with heat pumps—at an accelerated pace and on a massive scale.

Increasing the technical and market readiness of the heat pump and heat pump water heater (HPWH) technologies across climates and communities is critical to achieving accelerated, widespread adoption. Building science teams at Pacific Northwest National Laboratory (PNNL) are leveraging deep expertise in energy-efficient technologies, data analysis, and workforce development to help tackle this challenge in multiple ways.



An example of HVAC Smart Diagnostic Tools.
(Photo courtesy of Pacific Northwest National Laboratory)

LAB TESTING

PNNL has completed multiple laboratory tests to analyze various aspects of heat pump technologies and assess broad deployment and successful decarbonization potential. Recent examples include:

- Installing and performing third-party testing on a commercially available combined heat pump and HPWH (combi) system in the Lab Homes located on the PNNL campus in Richland, Washington.
- Assessing heat pump and HPWH system performance under various operating conditions and providing independently verified data and analysis to manufacturers that help increase product usability and market penetration. This includes several experiments analyzing fault detection and controls related to heat pumps to explore potential energy savings and other benefits.
- Collaborating with the Florida Solar Energy Center (FSEC), a research institute of the University of Central Florida. With funding from the Department of Energy (DOE), researchers from FSEC and PNNL tested load shifting with HPWHs for demand flexibility at the FSEC laboratory in Orlando.

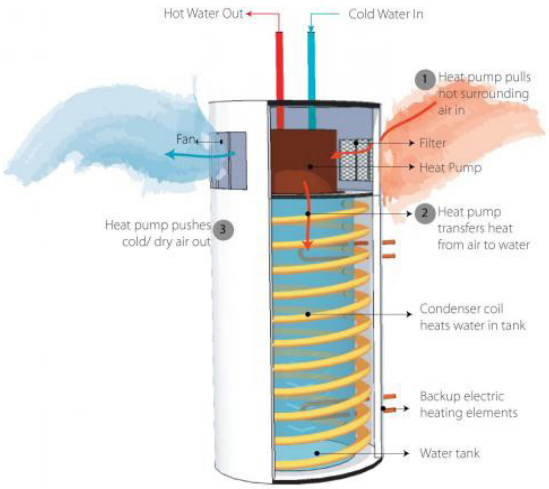
FIELD VALIDATION

PNNL's field validation work moves the testing of technologies and approaches beyond the laboratory scale into a real-world environment. Researchers are currently working in the field to validate:

- The impact of adding controllers to heat pumps and HPWHs that can be adjusted to use off-peak electricity supply while maintaining acceptable energy performance during periods of peak demand (peak events). Data from tests of this load-shifting

approach shows that HPWHs adapt quite easily to load-shifting because they efficiently maintain a reservoir of heated water that occupants could use during peak events. For space conditioning, the length of time a heat pump system can maintain interior comfort during a peak event is tied closely to how efficient the home's envelope is—the walls, windows, and ceiling that separate its interior from exterior elements. Field validation studies yield and confirm key data that can guide implementation decisions. One study team in rural Alaska is exploring how much the technology paired with a load-shifting approach could reduce the load on the power plant that a small city relies on for all its electricity.

- New HPWH technology in New Orleans, Louisiana, that can plug into standard 120-volt (v) outlets rather than requiring the 240 v wiring common to conventional electric and heat pump water heaters. The ability to heat water at lower voltage lightens the load for home electrical circuits which can greatly help reduce the cost of transitioning to an all-electric home that can be powered by renewables. This technology looks especially promising for homes with smaller water heating loads, like smaller homes and warmer climates.
- The performance of advanced cold climate heat pumps (CCHPs) developed by manufacturers to meet the DOE Residential Cold Climate Heat Pump Challenge. The challenge is intended to advance the development and commercialization of next-generation high-performance CCHPs that can offer higher efficiency and heating capacity at very cold temperatures (5° F and below) compared to commercially available units today. PNNL and its partners are conducting real-world performance validation of these prototype units in homes across North America.



Components of a heat pump water heater.
(Image courtesy of CARB, Steven Winter Associates, SWA)

- A mechanism in Houston, Texas, to train and connect people from disadvantaged communities whose homes would be good candidates for heat pump technology retrofits with weatherization programs and resources that can assist with funding and installation.

MARKET TRANSFORMATION

For residential buildings to successfully contribute to meeting decarbonization goals, energy-saving technologies including heat pumps and HPWHs must quickly achieve the highest level of market readiness possible. This includes becoming broadly cost-effective, supported by utilities and energy-related programs, adopted into building codes, and deployed by a workforce of sufficient size and training. PNNL is actively working toward these outcomes, including but not limited to efforts in:

- **Promoting quality installation.** Currently, HVAC system installation faults use about 9% more energy and cost consumers an extra $2.5 billion annually in utility bills. DOE is investing in transforming the market for electric heat pumps by speeding adoption of new tools that significantly improve the quality of HVAC installation, commissioning, and maintenance. The Smart Tools for Efficient HVAC Performance (STEP) Campaign, which PNNL manages for DOE, aims to support decarbonization efforts by minimizing energy waste in residential HVAC systems.
- **Workforce development.** Successful market transformation for heat pump technologies requires an adequately trained workforce to support it—at a time when workforce shortages persist. To enhance the skills of the existing workforce, building science teams at PNNL are working with HVAC contractor credentialing organizations nationwide to include heat pump and smart diagnostic tool content in training curricula. The teams are also beginning to develop recruitment strategies to address industry labor shortages that could directly affect the adoption rate for heat pump technologies.

For more information about PNNL's work to support residential building decarbonization through heat pump technologies—or to explore collaboration—contact:

Cheryn Metzger, Program Manager
cheryn.metzger@pnnl.gov | 503.227.3099

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