2024 PROJECT PEER REVIEW

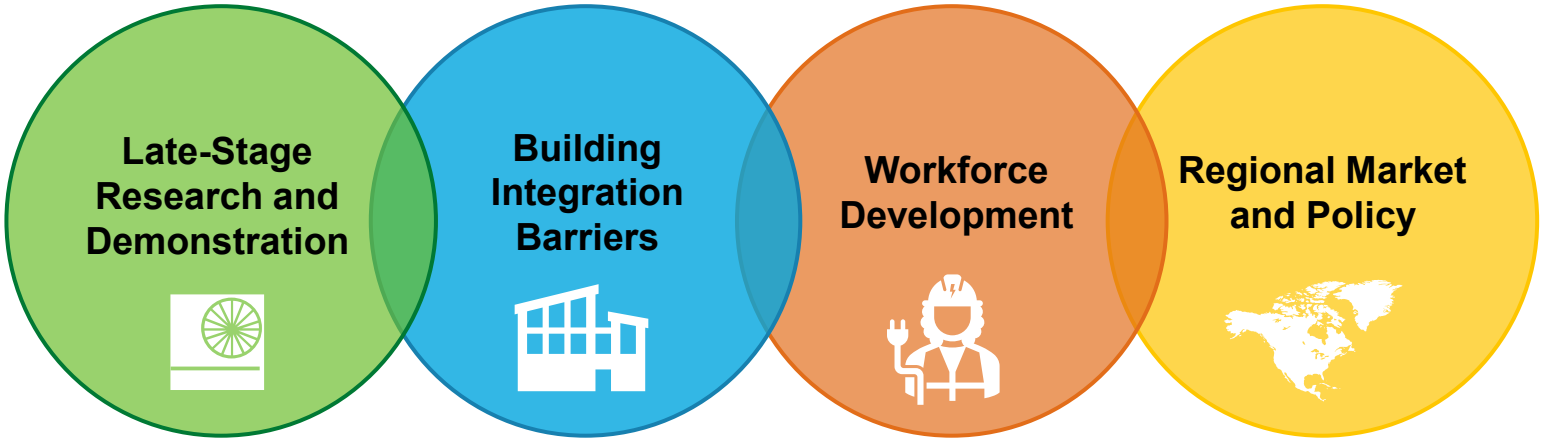
U.S. DEPARTMENT OF ENERGY
BUILDING TECHNOLOGIES OFFICE

Heat Pump and Heat Pump Water Heater National Partnership

Catalyzing heat pump and heat pump water heater technology adoption across the U.S.

PNNL

Heat Pump and Heat Pump Water Heater National Partnership



Performing Organizations: PNNL, ORNL, NREL and LBNL
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PNNL

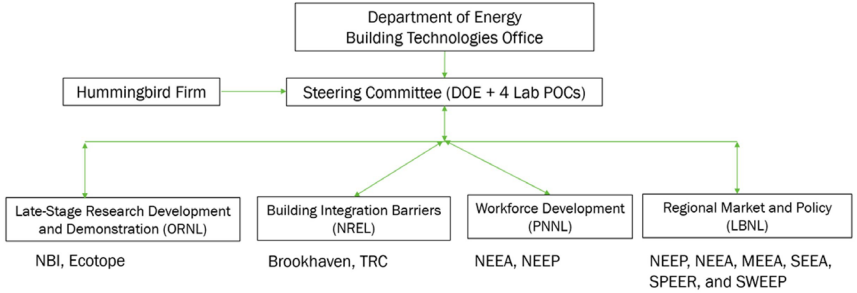
Project Summary

OBJECTIVE, OUTCOME, & IMPACT

This work establishes a **national partnership** to address issues that hinder higher heat pump technology adoption rates, such as cost, installation, performance in various climates, and consumer acceptance.

The partnership identifies, prioritizes, and fills top gaps that hinder widespread adoption of heat pumps and heat pump water heaters.

PROJECT STRUCTURE



TEAM & PARTNERS

Pacific Northwest National Laboratory
U.S. Department of Energy — Energy Efficiency & Renewable Energy
Oak Ridge National Laboratory
Berkeley Lab
NREL
Brookhaven National Laboratory
TRC
MEEA
neea
SEEA
AHRI Certified
SWEEP
Hummingbird
nbi
SPEER
nep
Ecotope
cee
slipstream
Tre'Laine Associates
NP

STATS

Performance Period: FY23-FY25 (FY22 Lab Call Award)

DOE Budget: $4.8M (including all labs and subcontractors)

FY23 Key Milestone 1: Prioritized list of issues/gaps

FY23 Key Milestone 2: Go/No-Go: Sub-activity structure including identification of the key objectives, outputs, outcomes, and schedules relevant to each of the priority issues/gaps prioritized.

FY24 Key Milestones: Quarterly updates on high priority activities

FY25 Key Milestone: Final upload of products that will help close the high priority gaps

Problem

- 100 million homes within the U.S. do not currently use a heat pump for heating[1], and less than 15% of commercial spaces are heated by heat pumps[2]
- **Heat pump (HP) adoption needs a 10-fold increase** in residential alone to meet climate goals; heat pump water heaters (HPWH) lag even further behind
- These challenges affects **all regions of the U.S.,** with adoption rates and specific challenges varying regionally
- To understand the scope of the problem, 50+ organizations contributed to a list of gaps (300+ gaps identified), and worked together to prioritize the top ~20
- This work reaches both the **residential and commercial** sectors and deals with a variety of heat pump and heat pump water heater system types in various stages of development and deployment
- A **unified, cross-sectoral, multi-regional** effort is needed to transform the HP and HPWH market space, which is the gap this work fills

[1] https://www.energy.gov/eere/decarbonizing-us-economy-2050-national-blueprint-buildings-sector

[2] https://www.nrel.gov/docs/fy23osti/85390.pdf

Alignment and Impact

DECARB BLUEPRINT THEME
Accelerate onsite emissions reductions

DECARB BLUEPRINT THEME
Increase building energy efficiency

The DOE Decarbonization Blueprint aims for a 65% reduction in GHG Emissions by 2035 and 90% by 2050 requires a decrease in energy use intensity in both residential and commercial buildings.

Heat pumps and heat pump water heaters are essential to these goals (see example below). The blueprint assumes "widespread…conversion from fossil-fired equipment to efficient heat pumps by 2050"

The Heat Pump Partnership seeks to fill 20 high-impact gaps that are preventing this widespread adoption of HP/HPWH through addressing:

- Technology cost
- Building integration barriers
- Workforce development
- Market and policy barriers

- Deliverables include quarterly updates on gap progress and a summative report of the products created and gaps filled

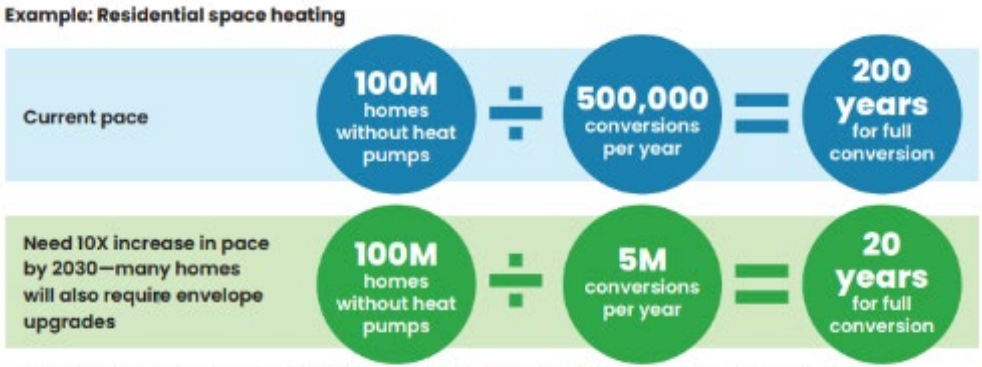


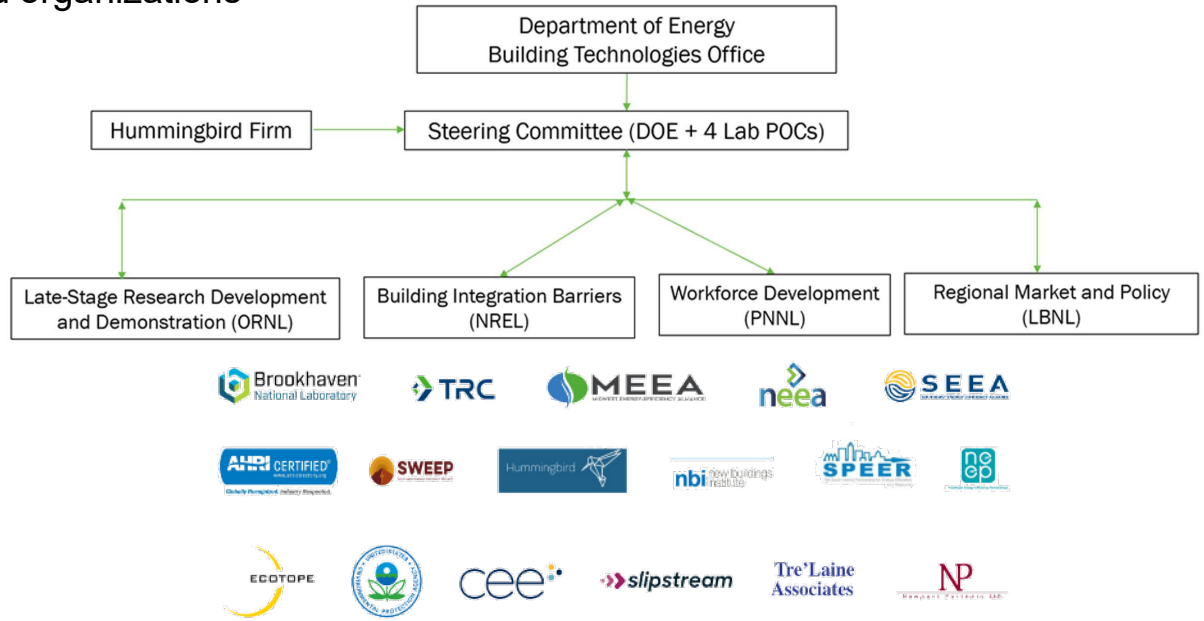
Figure 11. To convert 100 million existing homes to heat pumps by 2050, the current pace of conversion—including envelope upgrades where needed—needs to increase tenfold from 500,000 conversions per year to 5,000,000 conversions per year by 2030. Current conversion rate estimated based on U.S. Energy Information Administration Residential Energy Consumption Survey 2015 and 2020 data.

Source: Decarbonizing the U.S. Economy by 2050: A National Blueprint for the Buildings Sector

Approach

Organized Team Leads to Streamline National Coordination

- While many organizations recognize the need for change in this market, lack of unified efforts leads to duplication of work and unfilled gaps
- This project synthesizes technical leadership from DOE and its national laboratories, nationwide reach from regional energy efficiency organizations, and on-the-ground perspectives from energy-focused organizations

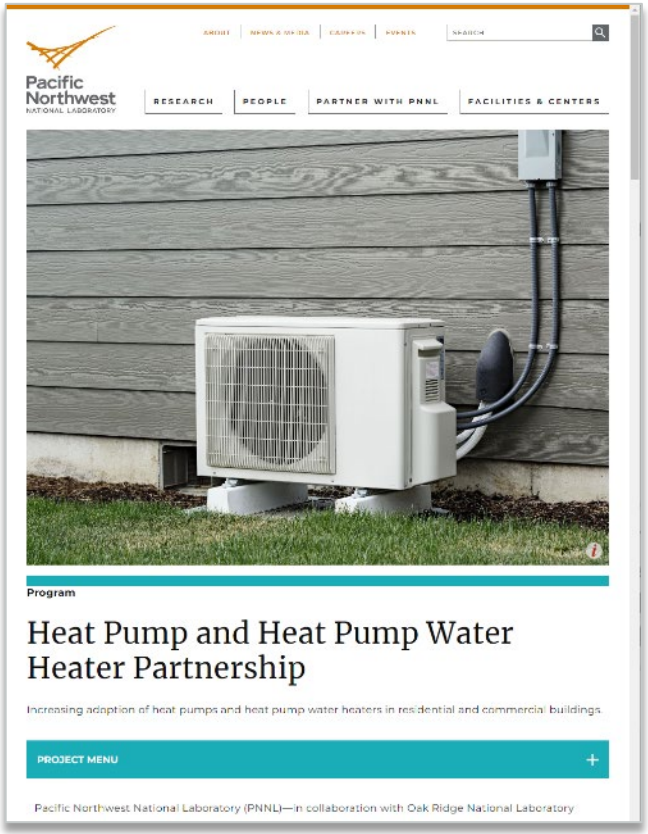


Approach

Targeting High Priorities to Overcome Key Barriers

The Partnership focuses on addressing the challenges that encumber higher heat pump and heat pump water heater adoption rates for both residential and commercial buildings. The project:

- Identifies and prioritizes gaps that hinder wide scale adoption of heat pumps and heat pump water heaters
- Serves as a national clearinghouse for field test information from all entities and identify means for more widespread dissemination of field test results (https://heatpumpdata.energy.gov/)
  - Develop and coordinate plans for collaborative field test efforts among stakeholders
  - Evaluate data and identify heat pump issues to inform research and development priorities
- Works with manufacturers, trade organizations and other key industry stakeholders to curate training and recruitment materials
- Expands the dissemination of relevant information regionally to achieve market transformation

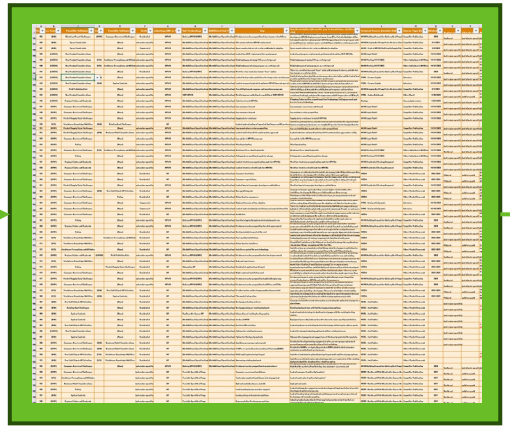


Approach

Industry Support to Complete Gap Identification and Prioritization

Stakeholder gap solicitation (50+ organizations)

300+ gaps collected



Top ~20 gaps selected

TABLE 1 Top gaps identified in each of the DOE Heat Pump Partnership Core Committees.

LATE-STAGE RESEARCH DEVELOPMENT AND DEMONSTRATION	BUILDING INTEGRATION BARRIERS	WORKFORCE DEVELOPMENT	REGIONAL MARKET AND POLICY
Need for HP system price reduction	Cold climate HP selection criteria, load calculations and system design	Address skilled labor shortage	Clarify consumer value proposition for HP/HPWH adoption
Need for HPWH system price reduction	Retrofit sequencing needs, determining when weatherization or duct improvements are necessary	Curate residential HP/HPWH pre-field training for installers and service techs	Misalignment in electrification policy in some regions hindering adoption
Lack of field test/ performance data	Cost to upgrade electrical panels and need for lower cost options	Curate residential HP/HPWH in-field, on-the-job training for installers and service techs	Utility retail electricity rates not favorable for electrification in many cases
Need for HPWH technology development (e.g., CCHP-WH, compressor performance)	Need for integrated/ dual fuel HP controls, better on-board controls and performance monitoring	Curate residential HP/HPWH training for distributors and sales technicians	Customers will benefit from knowing installed costs (and cost components) of HP/HPWH in their region.
Limited information about the performance characteristics of HPWHs	Integrated sensors and controls necessary to enable central HPWHs to shift their hours of operation	Provide resources for ensuring contractor comfort with HP technology (especially in cold climates)	Enhance consumer awareness of accredited local installers of HP/HPWHs

Table from our recent ASHRAE Journal publication (https://www.ashrae.org/technical-resources/ashrae-journal)

Approach

Tackling Challenges Under Four Major Umbrellas

DECARB BLUEPRINT THEME
Prioritize Affordability

Late-Stage Research and Demonstration

- HP system price reduction
- HPWH system price reduction
- Lack of field test data
- HPWH technology development

Building Integration Barriers

- CCHP selection and sizing
- Retrofit sequencing needs
- Electrical infrastructure solutions
- Integrated/dual fuel HP controls
- Controls for central HPWHs to shift hours of operation

Workforce Development

- Skilled labor shortage
- Pre-field training for installers
- On-the-job training for installers
- Distributor/sales rep training
- Contractor resistance resources

Regional Market and Policy

- Clarify customer value proposition for HP/HPWH
- Electrification policy alignment
- Address unfavorable utility retail electricity rates
- Provide customers with region-specific installed cost info

Approach

Prioritizing Equity Throughout Project Execution

DECARB BLUEPRINT THEME
Prioritize Equity

To encourage equitable considerations throughout project efforts, The Hummingbird Firm was contracted to guide efforts within each core committee.

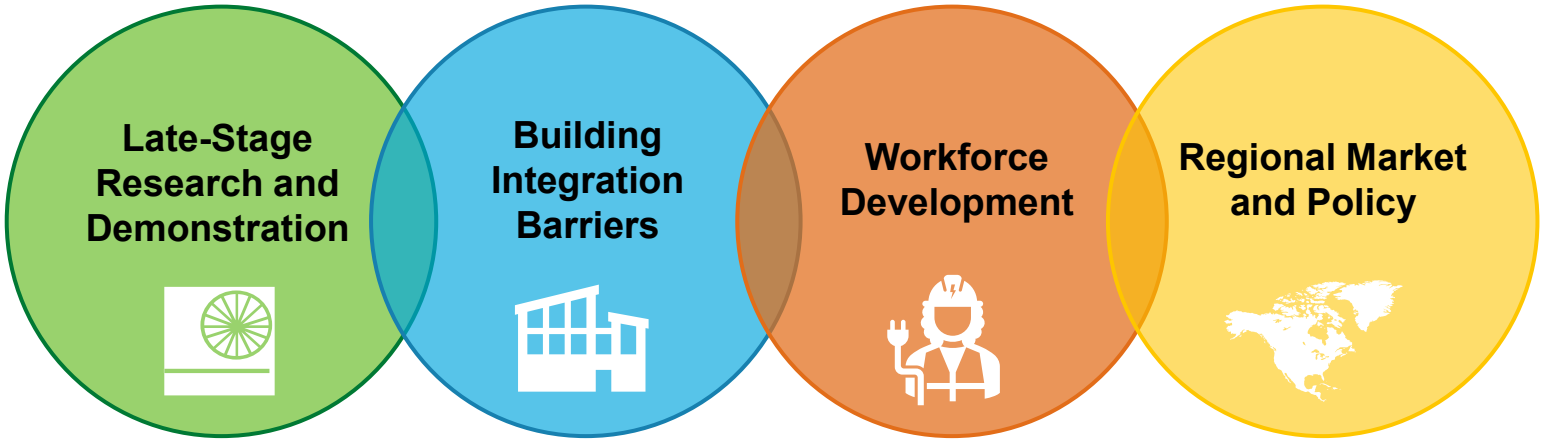
Additionally, they conducted HP/HPWH stakeholder listening sessions. Key themes include:

- Promoting equitable access to green jobs
- Community-centric pilot projects
- Address financial and distributional barriers
- Engage diverse stakeholders

Hummingbird

Progress and Future Work

Summarizing Progress and Future Work



Progress and Future Work

Major Accomplishments

Late-Stage Research and Demonstration

- **Completed questionnaire** on HP price reduction strategy.
- Collected **installation price data for HPWHs**.
- Analyzed **publicly accessible HP and HPWH datasets**.
- Organized working group, industry review and input for **DOE National Test Standard**.
- **Reviewed HPWH performance** in field conditions.

Building Integration Barriers

- Literature review completed on **heat pump sizing and selection methods** and recommended practices.
- **Survey of HVAC contractors** on sizing and selection methods, distribution system integration, and other retrofit questions is undergoing review.

Workforce Development

- **Dissemination of recruitment materials** aimed at resistant contractors
- **Focus on cost reduction of installation process**
  - Training resource **landscape analysis** for various stakeholders and stages
  - Analysis of crucial but overlooked **distributor role**

Regional Market and Policy

- Regional consumer-facing **fact sheet** showing potential energy cost saving and other **benefits** of HP home retrofits.
- Existing **policies** anti- or pro- electrification in the US.
- Regulator-facing information on **electricity vs gas rates** comparison.
- Real-world **installation costs**.

Progress and Future Work

Key Findings

Late-Stage Research and Demonstration

- Gain a perspective on potential opportunities for reducing hardware costs.
- **Lack of publicly accessible HP/HPWH field datasets**
- Identify needs for unified HPWH standards

Building Integration Barriers

- **Very little existing literature about retrofit sequencing**
- Waiting on other on-going synergistic projects to begin outreach efforts

Workforce Development

- Difficult to reach distributors
- **Sizing guidance can be different between different stakeholders**
- Wide variety in quality and availability of training materials
- Coordination with DOE programs (e.g. Energy Skilled) is essential

Regional Market and Policy

- Heat pump home retrofits has high costs; utility bill savings is essential for consumers
- Electricity price can be high compared to gas
- **Field measured HP energy & bill savings data is hard to find**

Progress and Future Work

Future Work

Late-Stage Research and Demonstration

- **Publish technology cost reduction report on Heat Pump Partnership webpage**
- Addition of multifamily HPWH datasets to database

Building Integration Barriers

- Work with REEOs and the Building Science Education Solution Center (BSESC) to **distribute training material for low-power electrification**
- Incorporate sizing lessons learned into https://basc.pnnl.gov/cchp_decision_tool
- Collect, process, and share results from HVAC contractor survey

Workforce Development

- Continue to expand outreach for recruitment materials (e.g. training organizations, high schools, etc.)
- Upload relevant new pre-field and on-the-job training that will help lower installation costs to BSESC
- **Develop outreach strategy to distributors based on distributor interviews**

Regional Market and Policy

- Disseminate regional value proposition fact sheets through REEOs
- **Compile regional knowledge and policies. Clarify regional research needs**
- Request regional feedback on draft communication materials

Progress

Partnership-Level Outputs Are On-Track

- Published a website for partnership overview, featured outputs and information to join: https://www.pnnl.gov/projects/hp-hpwh-partnership
- Published a partnership overview and invite to join in ASHRAE Journal
- Held annual all-hands meetings with entire collaborative
- Produced a quarterly newsletter for industry partners outlining recent progress and successes
- Presented partnership and gathered more feedback on efforts at ACEEE Summer Study 2024

Department of Energy's Heat Pump Partnership

Kieren H. McCord, Cheryn Metzger, Fredericka Brown, Jingjing Liu, Jon Winkler, Piljae Im

With heat pump (HP) and heat pump water heater (HPWH) technology playing a critical role in building decarbonization, there is a need for unified efforts in understanding and addressing gaps in technology uptake. Under the direction of U.S. Department of Energy's Building Technologies Office, four national laboratories are leading a national partnership with the goal of identifying and addressing challenges in the adoption of HP/HPWH technology. This column presents the culmination of the first-year efforts, including the establishment of the partnership, identification of an extensive list of gaps in the space, and prioritization of gaps in key subcategories.

With the building sector contributing substantially to global carbon emissions, electrification of the building stock is one essential piece of decarbonization efforts. Since a substantial portion of building energy use includes space and water heating and cooling, heat pump (HP) and heat pump water heater (HPWH) technology present an opportunity in many cases to increase building energy efficiency and to electrify building loads in cases of fuel switching. However, across the United States, HP/HPWH technology adoption is generally low, with significant regional variation, establishing a need for unified efforts in understanding and addressing key issues in technology adoption. To strategically address this need, the DOE Heat Pump Partnership, a multi-organization effort organized under the Department of Energy's Building Technologies Office, was formed. The goal of this project is to establish a Partnership that helps drive adoption of HPs and HPWHs for both residential and commercial buildings.

Objectives and Anticipated Outcomes

The objectives of this three-year project are to (1) Serve as a national clearinghouse for field test information[1] from all relevant stakeholders; (2) Identify and inform DOE of remaining gaps and research questions associated with field validation; (3) Develop and coordinate collaborative efforts among relevant stakeholders throughout the nation; (4) Work with manufacturers and trade organizations to collect or develop training materials required for quality heat pump installation and maintenance; and (5) Expand and clarify best practices to achieve market transformation in all regions of the U.S.

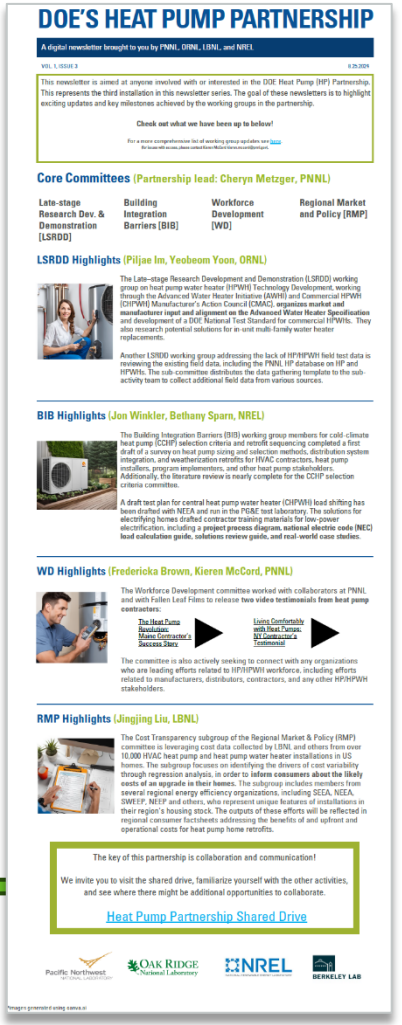
The primary outcome of this project is a structured Partnership between DOE, the national labs, and other research, implementation, and market transformation organizations. The Partnership results in a continuous stream of information between DOE and the major industry players related to HP and HPWH market transformation. Key stakeholders can use this information to inform HP and HPWH market adoption priorities and research going forward.

Partnership Structure

Four DOE-funded national laboratories lead core committees that each approaches the HP/HPWH space from a different angle. The four topics include *Late-Stage Research*

[1] https://heatpumpdata.energy.gov/

Published partnership overview and invite to join in ASHRAE



DOE'S HEAT PUMP PARTNERSHIP

A digital newsletter brought to you by PNNL, ORNL, LBNL, and NREL

VOL. 1, ISSUE 2 | 8.29.2024

This newsletter is aimed at anyone involved with or interested in the DOE Heat Pump (HP) Partnership. This represents the third installation in this newsletter series. The goal of these newsletters is to highlight exciting updates and key milestones achieved by the working groups in the partnership.

Check out what we have been up to below!

For a more comprehensive list of working group updates see here.
For issues with access, please contact Kieren.McCord@pnnl.gov or Jingjing.Liu@pnnl.gov

Core Committees (Partnership lead: Cheryn Metzger, PNNL)

Late-stage Research Dev. & Demonstration [LSRDD] | Building Integration Barriers [BIB] | Workforce Development [WD] | Regional Market and Policy [RMP]

LSRDD Highlights (Piljae Im, Yeobeom Yoon, ORNL)

The Late-stage Research Development and Demonstration (LSRDD) working group on heat pump water heater (HPWH) Technology Development, working through the Advanced Water Heater Initiative (AWHI) and Commercial HPWH (CHPWH) Manufacturer's Action Council (CMAC), organizes market and manufacturer input and alignment on the Advanced Water Heater Specification and development of a DOE National Test Standard for commercial HPWHs. They also research potential solutions for in-unit multi-family water heater replacements.

Another LSRDD working group addressing the lack of HP/HPWH field test data is reviewing the existing field data, including the PNNL HP database on HP and HPWHs. The sub-committee distributes the data gathering template to the sub-activity team to collect additional field data from various sources.

BIB Highlights (Jon Winkler, Bethany Sparn, NREL)

The Building Integration Barriers (BIB) working group members for cold-climate heat pump (CCHP) selection criteria and retrofit sequencing completed a first draft of a survey on heat pump sizing and selection methods, distribution system integration, and weatherization retrofits for HVAC contractors, heat pump installers, program implementers, and other heat pump stakeholders. Additionally, the literature review is nearly complete for the CCHP selection criteria committee.

A draft test plan for central heat pump water heater (CHPWH) load shifting has been drafted with NEEA and run in the PGAC test laboratory. The solutions for electrifying homes drafted contractor training materials for low-power electrification, including a project process diagram, national electric code (NEC) load calculation guide, solutions review guide, and real-world case studies.

WD Highlights (Fredericka Brown, Kieren McCord, PNNL)

The Workforce Development committee worked with collaborators at PNNL and with Fallen Leaf Films to release two video testimonials from heat pump contractors:

The Heat Pump Revolution: Maine Contractor's Success Story

Living Comfortably with Heat Pumps: NY Contractor's Testimonial

The committee is also actively seeking to connect with any organizations who are leading efforts related to HP/HPWH workforce, including efforts related to manufacturers, distributors, contractors, and any other HP/HPWH stakeholders.

RMP Highlights (Jingjing Liu, LBNL)

The Cost Transparency subgroup of the Regional Market & Policy (RMP) committee is leveraging cost data collected by LBNL and others from over 10,000 HVAC heat pump and heat pump water heater installations in US homes. The subgroup focuses on identifying the drivers of cost variability through regression analysis, in order to inform consumers about the likely costs of an upgrade in their homes. The subgroup includes members from several regional energy efficiency organizations, including SEEA, NEEA, SWEEP, NEEP and others, who represent unique features of installations in their region's housing stock. The outputs of these efforts will be reflected in regional consumer factsheets addressing the benefits of and upfront and operational costs for heat pump home retrofits.

The key of this partnership is collaboration and communication!

We invite you to visit the shared drive, familiarize yourself with the other activities, and see where there might be additional opportunities to collaborate.

Heat Pump Partnership Shared Drive

Pacific Northwest NATIONAL LABORATORY | OAK RIDGE National Laboratory | NREL | BERKELEY LAB

Launched a newsletter and website highlighting progress and successes

Future Work

FY25 and Beyond

In FY25:

- **PNNL will lead the team in a final report, summarizing the industry engagement to-date and proving more detail on the outputs developed through this project**
- The whole team will follow-through on the dissemination of the outputs developed
- **PNNL will lead a re-prioritization exercise for gaps that were not addressed and new gaps that have become higher priority**
- The team will suggest a restructuring of the committees and sub-activities based on the re-prioritization exercise for project continuation in FY26 and beyond

	Sub-activity	Output(s)	Dissemination Method
Late Stage RD&D	HP system price reduction	Market survey reports	DOE
	HPWH system price reduction	Spreadsheet Data visualization 1 – 2 page analysis	DOE, labs, implementers, REEOs, and utility programs
	Lack of field test data/field performance (HP)	Field data on HP/HPWH	HP database (PNNL website) and DOE newsletter
	HPWH technology development (e.g. CCHP-WH. Improve compressor performance)	Commercial HPWH: Input to DOE test standards Residential HPWH: Report on in-unit MF HPWH	DOE, labs, implementers, REEOs, and utility programs
Building Integration Barriers	CCHP selection criteria, load calculations and system design, and data needs and availability. Sizing heating pumps with existing ductwork.	Lit review, Interview report	REEOs Partnership Stakeholders
	Retrofit sequencing needs, determining when weatherization and/or duct improvements should be recommended, and whole-building integration issues	Recommendations for building upgrades Contractor practices	REEOs Partnership Stakeholders
	Solutions for electrifying homes, with insufficient electrical infrastructure and avoiding, unnecessary service upgrades.	Electrical panel upgrades data report, surveys summary report	BSESC, REEOs, other stakeholders
	Need for integrated and dual fuel heat pump controls, better on-board controls, and onboard AFDD & performance monitoring	Survey and interview report, Value Proposition factsheet	NEEA WGs Stakeholders, BSESC
	Integrated the sensors and controls necessary to enable central HPWHs to shift their hours of operation	Test plan for CHPWH Standarization plan for CTA-2045 commands real time pricing	ACEEE Hot Water Forum AWHI
Workforce	Address skilled labor shortage	Recruitment materials	IREC, EVIA, HVAC Excellence, AHWI, ASHRAE
	Curate residential HP/HPWH pre-field training for installers/service technicians	Training material	BSESC website Energy Skilled Network
	Curate residential HP/HPWH in field on-the-job training for installers/service technicians	Literature survey	BSESC, Energy Skilled Network, Manufacturer networks
	Curate residential HP/HPWH training for distributors/sales technician	Summary of interviews with distributors	Distributors, manufacturer networks
	Provide resources to ensure contractor comfort with HP technology in any climate (especially cold climates)	Videos	IHACI,PHCC, EGIA, ACCA, MCSA, REEOs
Market and Policy	Clarify the value proposition for HP/HPWH adoption for all consumers	Regional Fact Sheets	REEOs
	Misalignment in electrification policy in some regions is hindering adoption for all consumers	Policy Challenges	REEOs
	Utility retail electricity rates are not favorable for electrification in many cases	Barrier characterization/research	REEOs
	Customers will benefit from knowing installed costs (and what's included) of HP/HPWH in their region	Regional Fact Sheets	REEOs Partnership Stakeholders

Thank you

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BUILDING TECHNOLOGIES OFFICE

PNNL

Project Execution

	FY2023				FY2024				FY2025			
Planned budget	$ 1,200,000				$ 1,600,000				$ 1,600,000			
Spent budget	$ 1,000,000				$ 1,600,000				TBD			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Past Work												
Subcontract Update												
Establish core committee												
Top 5 challenges and existing activities for those challenges												
Solution Structure (Go/No-Go)												
Update on progress towards PNNL-led activity gaps												
Update on progress toward core committee gaps												
Current/Future Work												
Subcontract Update												
Update on current high priority activities												
Final report on current high-priority gaps												
Updated list of gaps that are yet-to-be addressed (industry input)												
Prioritized list of gaps that are yet-to-be-addressed (industry input)												
Future core committee and sub-activity structure												

Team

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Workforce Committee Co-Lead, PNNL

Kieren McCord

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Late-Stage RD&D Committee Lead, ORNL

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Building Integration Barriers HP Lead, NREL

Bethany Sparn

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