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# Late-Stage Research Development and Demonstration Sub-activities Updates – FY24 Q3


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OAK RIDGE National Laboratory

ORNL IS MANAGED BY UT-BATTELLE LLC FOR THE US DEPARTMENT OF ENERGY

**ORNL/TM-2024/3447**

Buildings and Transportation Science Division

# LATE-STAGE RESEARCH DEVELOPMENT AND DEMONSTRATION SUB-ACTIVITIES UPDATES

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## ABSTRACT

Oak Ridge National Laboratory (ORNL), in collaboration with the Pacific Northwest National Laboratory (PNNL), the National Renewable Energy Laboratory (NREL), the Lawrence Berkeley National Laboratory (LBNL), and the Hummingbird Firm (a specialized consulting firm focused on promoting diversity, equity, and inclusion considerations), has initiated a national initiative known as the Heat Pump (HP) and Heat Pump Water Heater (HPWH) Field Validation Partnership. This effort involves active participation from numerous critical entities involved in research and market transformation within the field.

The ORNL team is responsible for leading Late-Stage Research Development and Demonstration (LSRDD) among the four different topics.

The overall outcomes of this project will be:

- A structured Field Validation Partnership between DOE, the national labs, research, implementation, and market transformation organizations. This will result in unique way to coordinate field validation plans and collect relevant data from around the country into the HP and HPWH Field Validation Database.

- The Field Validation Partnership will result in a continuous stream of information between DOE and the major industry players in the space of HPs and HPWHs. If desired, DOE could use this information to inform roadmaps related to HP and HPWH market adoption and research going forward.

- The structure of this Partnership provides a mechanism for sharing lessons learned directly between Late-Stage RD&D, Building Integration Barriers, Regional Market and Policy and Workforce Development efforts. The result will be training content that is well-reviewed by the Partnership which will lead to a workforce that meets the industry's quality and workforce supply demands.

- The structure of this Partnership also provides an opportunity for regions to share lessons learned on policy and market transformation with each other through the Market and Policy core Committee.

This report includes an update in Late-Stage Research Development and Demonstration.

# 1. INTRODUCTION

Oak Ridge National Laboratory (ORNL), in collaboration with the Pacific Northwest National Laboratory (PNNL), the National Renewable Energy Laboratory (NREL), the Lawrence Berkeley National Laboratory (LBNL), and the Hummingbird Firm (a specialized consulting firm focused on promoting diversity, equity, and inclusion considerations), has initiated a nationwide partnership for field validation of heat pumps (HP) and heat pump water heaters (HPWH). This initiative involves the active participation of numerous pivotal research and market transformation entities. Figure 1 shows the structure of this partnership. In this project, the ORNL team lead Late-Stage Research Development and Demonstration (LSRDD).

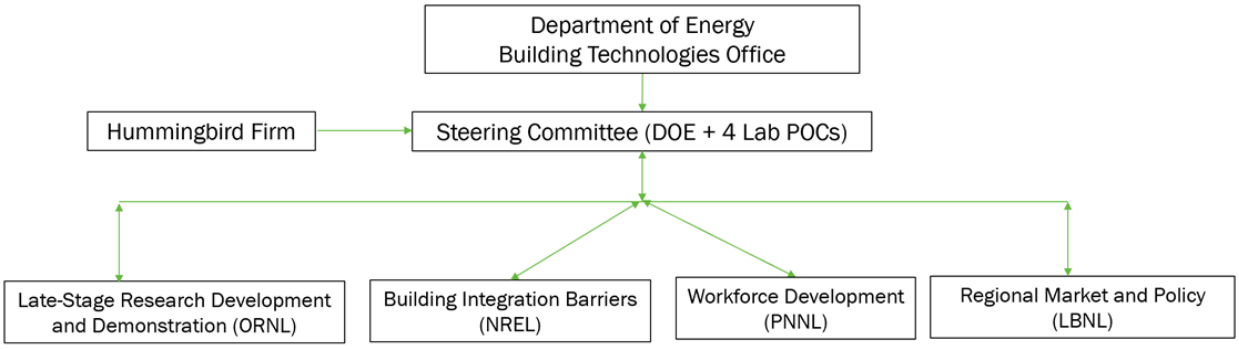


**Figure 1. Structure of the partnership**

The goal of this project is to establish a Partnership that helps drive adoption of HPs and HPWHs for both residential and commercial buildings. The objectives of this three-year project are to:

- Serve as a national clearinghouse for field test information from all relevant stakeholders
- Identify and inform DOE of remaining gaps and research questions associated with field validation
- Develop and coordinate collaborative efforts among relevant stakeholders throughout the nation
- Work with manufacturers and trade organizations to collect or develop training materials required for quality heat pump installation and maintenance
- Expand and clarify best practices to achieve market transformation in all regions of the U.S.

The Q3 milestone in FY 24 is as seen in table 1. This report will present the details of the Q3 progress of sub-activities under LSRDD, which is led by the ORNL team.

**Table 1. Q3 Milestone**

| Milestone Name/Description | Criteria | End Date |
|---|---|---|
| Update on progress towards activity gaps that ORNL is leading | Provide an update memo to DOE regarding the progress made in addressing the gaps identified in FY23, which ORNL is leading. | 6/28/2024 |

## 2. FORMING LSRDD SUB-ACTIVITY GROUPS

In FY 23, the ORNL team reviewed the existing gaps related to the HP and HPWH. Out of 290 gaps, 55 gaps are under the LSRDD. More than 50% of gaps under the LSRDD are related to the new product considerations as shown in Figure 2.

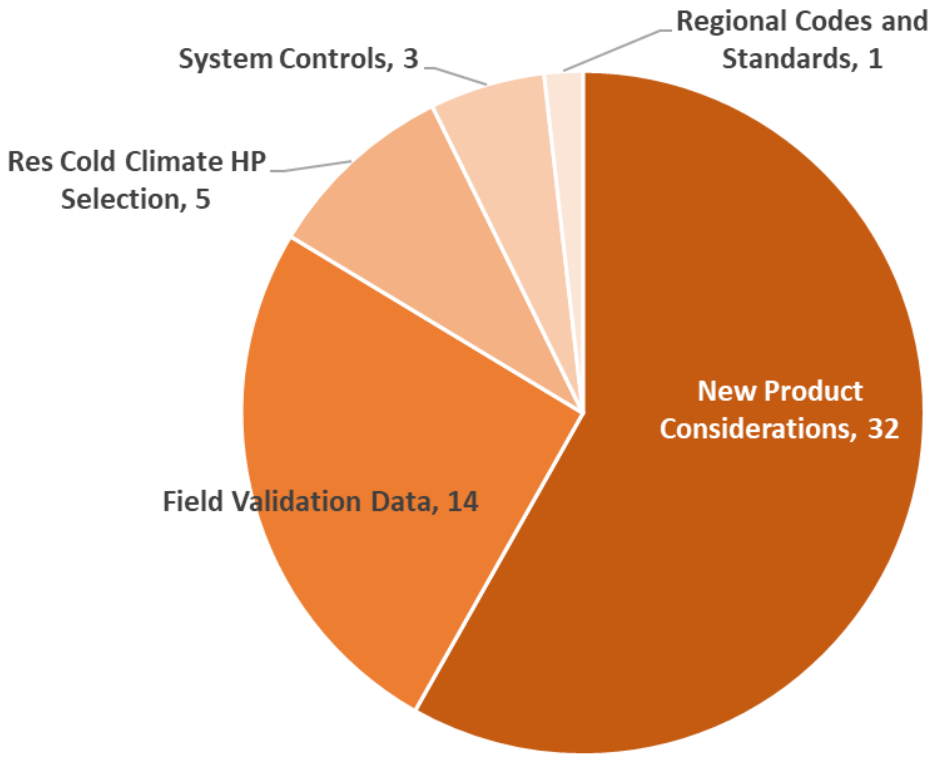


**Figure 2. Number of gaps in each subtopic under the LSRDD**

To identify the top 5 challenges, the ORNL team and other laboratories initially formed a core committee. In terms of the LSRDD, 54 members are currently working based on their expertise and interests. After forming the core committee, a survey was conducted in May 2023 to identify the top 5 challenges in LSRDD, and 14 members responded. Based on the survey results and internal discussions, the ORNL team identified and consolidated gaps, ultimately selecting the top 5 challenges. The challenges are outlined below.

- HP system price reduction
- HPWH system price reduction
- Lack of field test data/field performance
- HPWH technology development (e.g., CCHP-WH, Improve compressor performance, HPWH space constraints)
- Limited information about the performance characteristics about HPWHs

The ORNL team initiated five sub-activity groups based on these top five challenges. The ORNL team has assigned a maximum of three lead persons for future work on each sub-activity. The information about the lead person for each sub-activity is shown in Table 2.

**Table 2. Lead persons of each LSRDD sub-activity**

| Sub-activity | Lead Person 1 | Lead Person 2 | Lead Person 3 |
|---|---|---|---|
| **HP system price reduction** | Bo Shen (ORNL) | Christopher Dymond (NEEA) | |
| **HPWH system price reduction** | Noah Gabriel (NBI) | Vidhisha Moopnar (NBI) | Yeobeom Yoon (ORNL) |
| **Lack of field test data/field performance** | Piljae Im (ORNL) | Abinesh Selvacanabady (PNNL) | Jon Winkler (NREL) |
| **HPWH technology development** | Jon Heller (Ecotope) | Joe Wachunas (NBI) | Bethany Sparn (NREL) |
| **Limited information about the performance characteristics about HPWHs** | Tom Butcher (BNL) | Joe Rendall (ORNL) | Easwaran Krishnan (ORNL) |

The ORNL team reached out to all LSRDD core committee members to establish the sub-activity groups. The sub-activity group members include LSRDD core committee members who expressed interest in participating. Additionally, the lead person of each LSRDD sub-activity reached out to their communities for future work.

## 3. OBJECTVIES AND OUTCOMES OF LSRDD SUB-ACTIVITY GROUPS

The lead persons of each LSRDD sub-activity groups developed objectives, outcomes/outputs, and schedules for each LSRDD sub-activity. The schedule includes both FY24 and FY25. These objectives, outcomes/outputs, and schedules may be revised based on internal discussions within each sub-activity group. Table 3 displays the current objectives, outcomes/outputs, and schedules for each LSRDD sub-activity group. The lead persons of each LSRDD sub-activity group will provide updates every quarter until FY25 Q4. The ORNL team regularly reach out to the lead persons of each LSRDD sub-activity group, and the team attend the sub-activity group meetings to understand the status of work.

**Table 3. Objectives, outcomes/outputs, and schedules for each LSRDD sub-activity group**

| Sub-activity | | Description |
|---|---|---|
| **HP system price reduction** | **Key Objective(s)** | 1. Understand the cost allocation in the value propagation chain, including manufacturing, distribution, installation, and service.<br>2. Understand the cost distribution in heat pump unit, i.e., compressor, heat exchangers, fan and blower, expansion devices, electric accessories, control etc.<br>3. Survey candidate technologies to replace most premium components without degrading the unit performance significantly.<br>4. Conduct market survey, for various customer bases including low income families, in multiple climate regions. Identify regional solutions with good cost-effectiveness. |
| | **Key Outcome(s)/Output(s)** | 1. Solutions to remove the deployment barriers, i.e., smooth supply and distribution chains, hold training programs to develop more technical force and support the installation.<br>2. Identify lower-cost component technologies, and work with component manufacturers to develop system solution and prototype to demonstrate the feasibility.<br>3. Conduct online seminar to present conclusions of cost distribution and promote low cost solutions. |
| | **Timeline/Schedule** | FY24<br>- Market survey report to summarize cost distribution in heat pump manufacturing, distribution and supply chains<br>FY25<br>- Technical survey report to identify lower cost component technologies, predict performance results and cost reduction potential. |
| **HPWH system price reduction** | **Key Objective(s)** | 1. Review the Upfront Costs for Heat Pump Water Heaters (HPWH) Based on Fuel Conversion Type and Climate<br>2. Analyze the Component Costs Involved in HPWH Installation |

| | | |
|---|---|---|
| | | 3. Identify and Evaluate Cost Reduction Strategies for HPWH Systems<br>4. Assess the Expected Electrical Infrastructure Savings Resulting from 120-Volt HPWH Installations in Gas Fuel Conversions |
| | **Key Outcome(s)/Output(s)** | 1. Create memo on current upfront costs for HPWH installations nationally along with identified cost reduction strategies. |
| | **Timeline/Schedule** | FY24<br>- Literature review and stakeholder interviews for identified upfront costs and strategies to reduce them.<br>FY25<br>- Memo on research findings and recommendations |
| **Lack of field test data/field performance** | **Key Objective(s)** | 1. Review existing field data related to the HP and HPWH in commercial and residential buildings<br>- Search and collect data from public or private databases (from project partners).<br>- Categorize and analyze data (e.g., Location, Building type, Data resolution, Data interval, Level of detail (energy use, COP), Test type)<br>- Identify data gaps in each category.<br>2. Define use cases for existing and new data:<br>- Determine the specific purposes for which the data is needed to justify its importance.<br>3. Develop a roadmap to address data gaps:<br>- Utilize potential data sources, including existing data.<br>- Plan to generate new data for high-priority gaps identified in objective #1. |
| | **Key Outcome(s)/Output(s)** | 1. Create a memo or presentation: Review and analysis of existing dataset and new data needs<br>- Conduct a comprehensive review and analysis of the current dataset.<br>- Identify new data needs.<br>2. Create a memo or presentation: List of use cases for existing and new data<br>- Document use cases for existing and new data to justify the data needs.<br>3. Develop a roadmap for a nationwide HP/HPWH database<br>- Create a plan for establishing and/or maintaining a nationwide database.<br>- Prioritize gathering one or two high-priority datasets from the roadmap.<br>: Refine existing dataset - Enhance the existing dataset with detailed metadata and post-processed data.<br>: Use case demonstration |
| | **Timeline/Schedule** | FY24<br>- Review existing field data |

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|---|---|---|
| | | - Define use cases<br>FY25<br>- Develop a roadmap for nationwide database<br>- Potentially gather one dataset for high priority. |
| **HPWH technology development** | **Key Objective(s)** | 1. Expand heat pump product availability.<br>2. Optimize system design approaches.<br>3. Reduce cost and form factor.<br>4. Demonstrate and validate system performance. |
| | **Key Outcome(s)/Output(s)** | 1. Demonstration projects with detailed EM&V in multiple regions and climate zones.<br>2. Advanced Water Heater Specification with Qualified Product List.<br>3. Independent lab testing of range of products and design configurations.<br>4. Active research into simplified designs using unpressurized storage, PCMs, return-to-primary configurations. |
| | **Timeline/Schedule** | FY24<br>- Provide learnings from lab tests for return-to-primary, multipass, and swing tank configurations.<br>FY24-25<br>- Research and develop prototypes for unpressurized storage and return-to-primary configurations<br>FY24-26<br>- Bring 3-4 new lowGWP CHPWH products to US market. Demonstrate 8-10 different CHPWH manufactured systems in 3 different climate zones under BENEFIT projects. |
| **Limited information about the performance characteristics about HPWHs** | **Key Objective(s)** | 1. Review field data to assess the performance of installed HPWHs and identify the necessary data for characterizing HPWHs in both unitary and centralized configurations.<br>2. Deliver a concise informational resource to the residential buildings community, offering insights into the seasonal efficiency and characteristics of HPWHs. |
| | **Key Outcome(s)/Output(s)** | 1. A short report reviewing available, published information on basic performance characteristics and a summary of measured in-field performance and building energy use impacts with an emphasis on providing links to key studies and sources.<br>2. Identify what additional data is needed and recommendations.<br>3. If data is available: determine the HP and water heating performance. |
| | **Timeline/Schedule** | FY24<br>- Draft a report on the data required to determine performance characteristics and review existing resources.<br>FY25<br>- Publish/release the final report overviewing the results. |

## 4. Q3 PROGRESS OF EACH SUB-ACTIVITY GROUP

In FY 24 Q1, the sub-activity leaders focused on forming groups within their sub-activities through discussions with the ORNL team and their internal communities. Additionally, they exchanged ideas and thoughts related to objectives, outcomes, and future tasks in the leadership meeting. Since the sub-activity groups were formed in FY 24 Q1, they plan to have a meeting with all sub-activity members in January.

In FY 24 Q2, the sub-activity leaders continued to lead and work on their respective sub-activities to achieve their goals. During FY 24 Q2, sub-activity leaders created the Statement of Work (SoW) for each sub-activity. The SoW outlines the goals, deliverables, tasks, and timeline associated with each sub-activity.

In FY 24 Q3 the ORNL team participated in core-lead meetings organized by PNNL to prepare the update memo on April 22, 2024, and also participated in core-lead and sub-activity leaders meetings organized by PNNL to provide updates on the current status of the LSRDD sub-activity groups on April 30, 2024.

The sub-activity leaders continued to work on their sub-activities, aiming to achieve the ultimate goals and tasks specified in the SoW. The ORNL team is organizing bi-monthly recurring meetings with LSRDD sub-activity leaders. This quarter, we had a meeting with LSRDD sub-activity leaders to discuss FY 24 Q3 progress update on June 20, 2024. Additionally, the ORNL team presented LSRDD updates at the DOE Brown Bag meeting on May 23, 2024.

Table 4 illustrates the Q3 progress of each sub-activity group.

**Table 4. Q3 progress of each sub-activity group**

| Sub-activity | Q3 progress |
|---|---|
| **HP system price reduction** | - Questionnaire was completed.<br>- NEEA is subcontracting work out to Cadeo Group which is expected to commence in August.<br>  o We plan to allocate resources to subcontract the Cadeo Group for market interviews and data collection from all OEMs.<br>  o This initiative aims to gather detailed insights on the breakdown of hard costs for various heat pump components, including compressors, electronics, equipment, manufacturing, and other specific designations.<br>  o By obtaining this data, we aim to gain a perspective on potential opportunities for reducing hardware costs. |
| **HPWH system price reduction** | - Contacted and received installation price data from researchers at PNNL, Slipstream, and NB Power.<br>- Created a spreadsheet to understand existing price data.<br>  o This spreadsheet includes HPWH voltage, total cost, installation costs, plumber rate, plumber |

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|---|---|
| | hours, HPWH costs, and pipe miscellaneous costs.<br>- Read through DOE Technical Support Document to dig out installation cost breakdowns and data. |
| **Lack of field test data/field performance** | - Our team has internally reviewed a data gathering template.<br>- Currently, the sub-activity leaders are reviewing the existing HP and HPWH databases to understand the current status of field data and identify any needs for additional datasets.<br>o We are collecting HP/HPWH data regarding test building/chamber information, building location, system specifications, data period and resolution, and installed sensors.<br>- We will distribute the data gathering template to the sub-activity team to collect their inputs. |
| **HPWH technology development** | - Commercial:<br>o Presentations at Getting-to-Zero.<br>o Meeting with DOE leadership re barriers to natural refrigerants for HPWH equipment and need for unified national standards.<br>o Input collected from stakeholders for revisions to AWHSv8.1 draft.<br>o AWHI bi-weekly commercial core meetings and bi-monthly working group meetings.<br>o Presentation at AWHI all-stakeholders meeting.<br>o Input and alignment with AHRI1330 committee developing test standards for CHPWHs. Testing proposal is aligned around a performance map approach similar to AWHS and CA Energy Code<br>- Residential:<br>o The subgroup has conducted research into technologies identified as potential solutions for in-unit multi-family water heater replacements.<br>o The group focused its research on combi systems and split HPWHs and has created content that will eventually be folded into the end of year memo on all technologies. |
| **Limited information about the performance characteristics about HPWHs** | - The subcommittee continues to review characteristics on the performance of heat pump water heaters (HPWHs) under field conditions.<br>o In reviewing the scope for the work under this task, the group members have concluded that no significant effort should go into standard performance metrics such as UEF and 1st hour rating, which are widely available.<br>- Therefore, the work for this task will focus on performance characteristics in different climate zones.<br>o These characteristics will include: ambient temperature, incoming water temperature, storage |

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|---|---|
| | temperature, water usage, and installation space/ducting arrangements.<br>- The first task deliverable for this subcommittee: Review existing performance characteristics for HPWHs and report their capabilities to represent field performance. This deliverable is due on July 31, 2024 and we are currently working on completing this. |

## 5. CONCLUSIONS

During FY24 Q3, all lead persons of each sub-activity group remained committed to leading and actively working on their respective sub-activities to attain their goals. Vidhisha Moopnar from NBI has joined as the lead person for the "HPWH System Price Reduction". The lead persons scheduled meetings with both internal leaders and external experts to gather valuable insights and input.

In FY24 Q4, the ORNL team will provide updates on each sub-activity group.