

Demonstration of 120-volt Heat Pump Water Heaters in a Warm/Hot Climate (New Project)



Pacific Northwest National Laboratory
Josh Butzbaugh
Joshua.Butzbaugh@pnnl.gov
WBS # 1.4.1.19

Project Summary

Objective and Outcome:

Evaluate the energy efficiency and hot water delivery performance of 120-volt heat pump water heaters (HPWHs) in a warm climate (climate zone 2A) and identify challenges for 120-volt HPWH installations.

Team and Partners:

PNNL

Josh Butzbaugh, Tabitha Artuso, Tyler Pilet, Travis Ashley, Abinesh Selvacanabady, Cheryn Metzger

Partners

Advanced Water Heating Initiative

Rheem

All Hours Plumbing



*Shaded region:
manufacturer
recommended
120-volt HPWH
applications*

Stats:

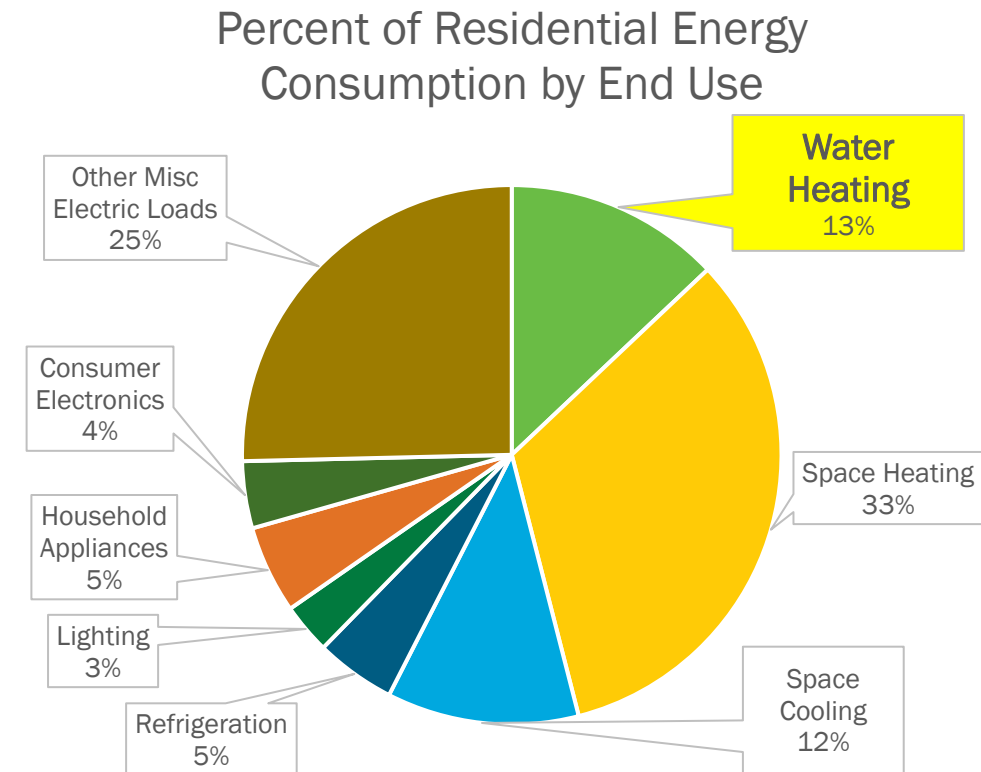
Performance Period: FY22–FY24

DOE FY23 Budget: \$300k, Official Cost Share: \$0k

Milestone 1: Preliminary results of 120v HPWH performance

Problem

- Water heating is the second largest energy end use in the U.S. residential sector
- As the U.S. seeks to decarbonize the buildings stock, **65 million homes** currently using fossil fuel water heating will need to convert to electric water heating systems
- Fuel switching from gas water heating to **240-volt HPWHs** has **many complications**, namely:
 - Limited panel capacity and/or limited electrical service
 - Wiring and receptacle requirements
- Installing a **240-volt HPWH** often requires **multiple contractors on site**, which results in **additional time and cost** compared to a like-for-like system swap out



Source: 2023 Annual Energy Outlook, Table 4.
Residential Sector Key Indicators and Consumption

Technology Alignment and Impact

- Conversion of fossil fuel and electric resistance water heaters to HPWHs has the potential to **avoid substantial CO₂ emissions** produced by residential water heating in the U.S.
- **Plug-in 120-volt HPWHs** are a recently-commercialized water heating technology intended to **facilitate cost effective electrification of the fossil fuel water heater stock**:
 - 120-volt HPWHs operate on a 120-volt, 15-amp circuit and can accommodate homes **without the electrical service or panel capacity** for 240-volt HPWHs
 - 120-volt HPWHs allow for **quicker and cheaper installation** because they do not require installation of new breakers, new wire runs, and specific receptacles.



Study Alignment and Impact

- Manufacturers recommend installing 120-volt HPWHs in **IECC climate zones 1–3** (shaded portion of map on the right)
- This field study was developed to demonstrate the performance of 120-volt HPWHs in their **manufacturer-recommended climate zone**, and seeks to:
 - Understand whether 120-volt HPWHs can efficiently meet loads in **climate zone 2 based on home size, water heater location, and temperature/humidity conditions**
 - Determine **lessons learned for siting, sizing, and installing** 120-volt HPWHs at demonstration sites.
- The anticipated impact of this study is to:
 - **Develop best practices** for 120-volt HPWH siting, sizing, and installation
 - **Help DOE develop electrification policies** for residential water heating,
 - **Provide feedback to manufacturers**, and **provide guidance** to the supply chain and homeowners/consumers

For optimal operation, installation in shaded map zone is recommended.
When installing outside of the shaded zone, consult your local plumbing contractor.



Average Ambient Air Temp in January

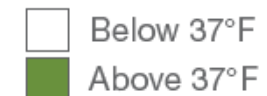


Image Source: Rheem Sales Company Inc.; Author

Approach

The selected location for this field study is the New Orleans, Louisiana metro area.

- New Orleans was selected due to:
 - Location in manufacturer-recommended climate zone
 - Significant percentage of fossil fuel water heating, both storage and tankless
 - Variety of water heater locations and installations, including space constrained and non-traditional locations (e.g., outdoor enclosures, sheds, attics)
- HPWH installations in New Orleans provide:
 - A diverse range of home sizes and water heater locations
 - Opportunities for unique ducting configurations
 - Interesting HPWH relocation scenarios (e.g., replacing tankless units)
 - Strategies for electrification in a gas-prevalent market

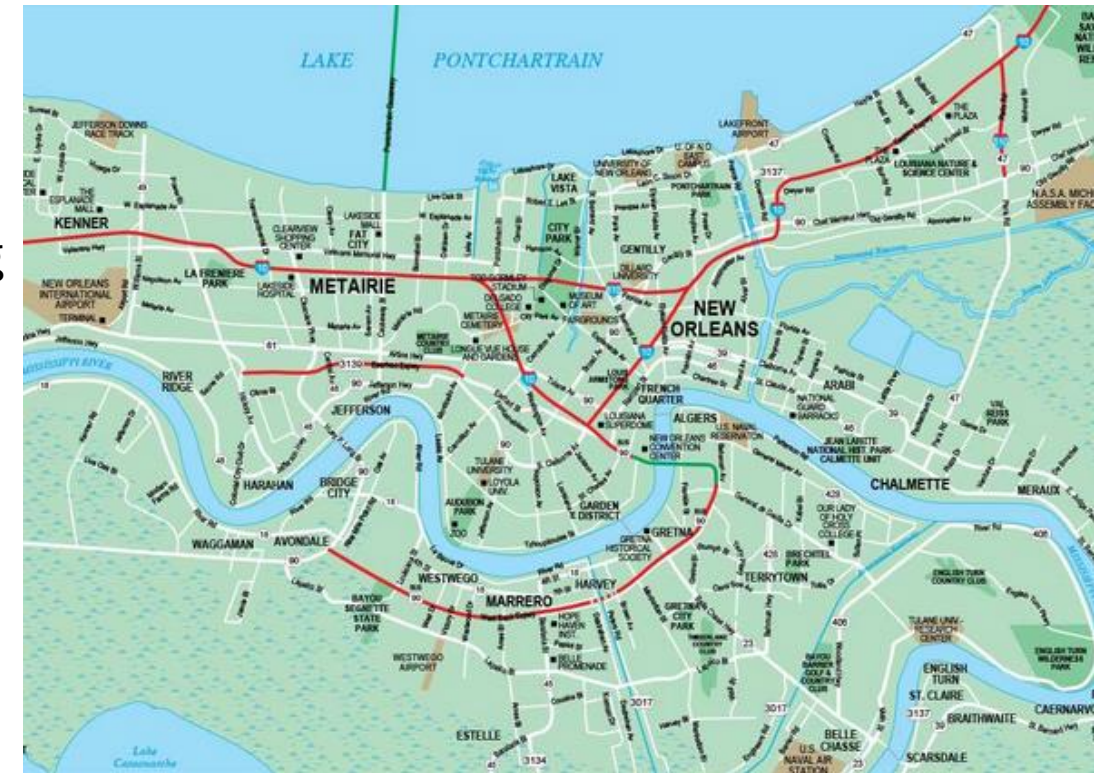


Image Source: Adobe Stock Images

Approach (continued)



- To perform the demonstration, PNNL recruited single-family homes in the New Orleans area with existing natural gas water heaters.
- For the first 10 installs, Rheem was selected as a manufacturer partner, the first manufacturer to bring a drop-in 120-volt HPWH product to market.
- A licensed plumber was selected, and a Rheem representative attended the first two installs to train the plumber on HPWH installation practices.
- Monitored data to assess energy efficiency and hot water delivery performance
 - Energy consumption
 - Surrounding air temperature
 - Inlet and outlet water temperatures
 - Hot water flow

Progress - Recruitment

Recruitment Approach:

1. Postcards

- Home criteria –
 - Single-Family Detached
 - Owner occupied
- 5 rounds of targeted mailers
- ~8,000 postcards sent

2. Local references



Recruitment Results:

- Response rate of ~1%
- 48% of respondents had no follow-up response
- 24% of respondents who followed up were eligible to participate
- 28% of respondents who followed up were ineligible
 - Inadequate space
 - Lack electrical outlet availability
 - Not owner occupied

Progress – Sensor Deployment

Water Flow – Inlet Install

- Piston Displacement Water Meter
- Measures every 5 seconds



Water Temperature – Inlet & Outlet Install

- Thermistor
- Measures every 5 seconds



HPWH Plug Load

- LoRaWAN Smart Plug Power Meter
- Measures every minute

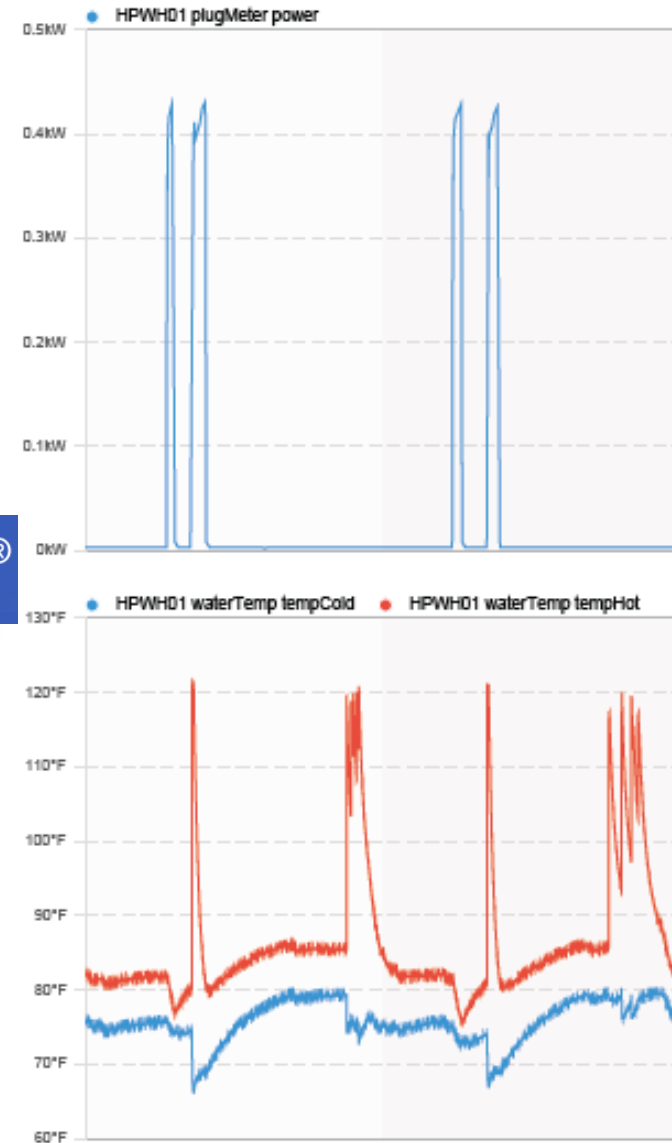
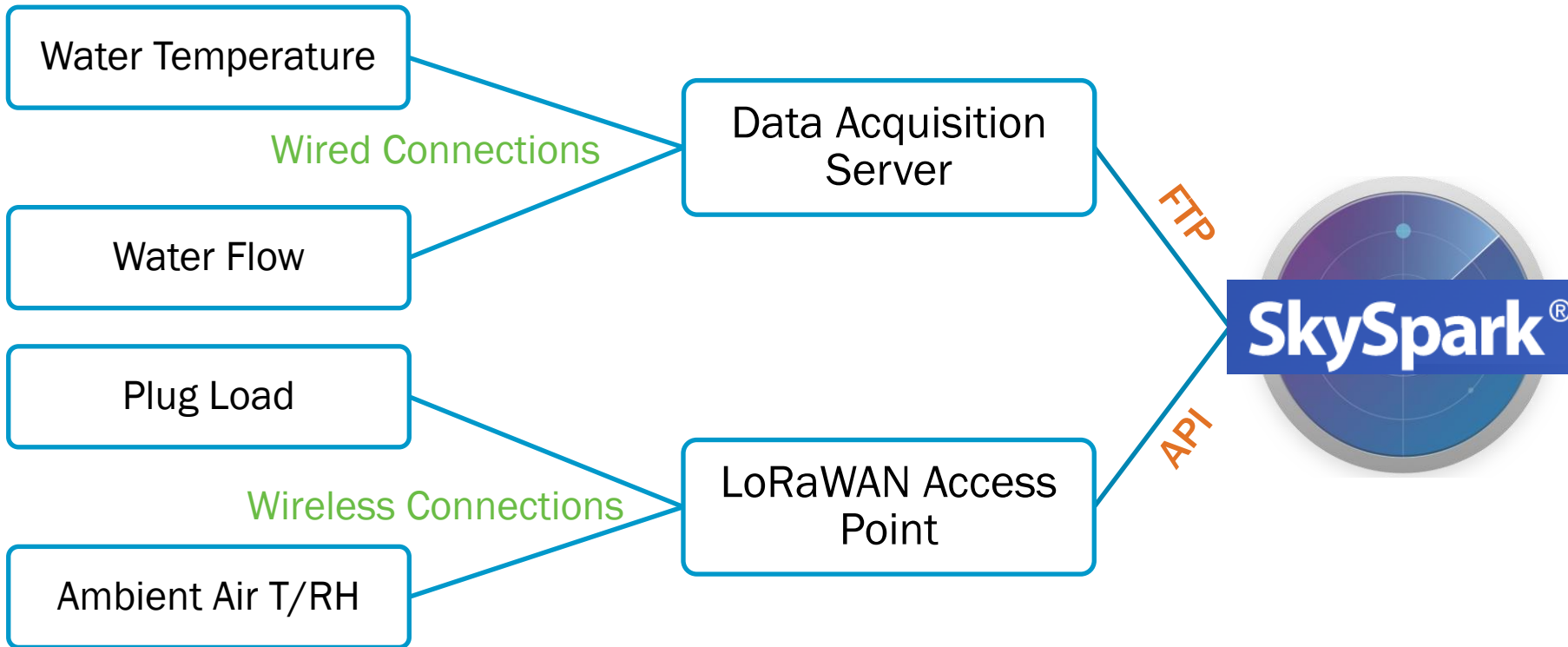


Ambient Air Temperature & Relative Humidity

- Built-in & External Temperature Sensors
- Built-in Humidity Sensor
- Measures every 20 minutes



Progress – Sensor Deployment (continued)



Progress – Accomplishments to Date

Summary of Accomplishments to Date:

- Received IRB approval for participant recruitment materials (e.g., Informed Consent)
- Carried out targeted **participant recruitment**
- Secured a manufacturer partner to **supply 120-volt HPWHs**
- Secured an installation partner
- **Recruited nine participants** (with manufacturer and installer approval of installation plans)
- **Developed a monitoring plan, assembled/configured equipment**
- **Installed nine 120-volt HPWHs** in participant homes, along with monitoring equipment
- Conducting preliminary analysis of 120-volt HPWH energy efficiency and hot water delivery performance

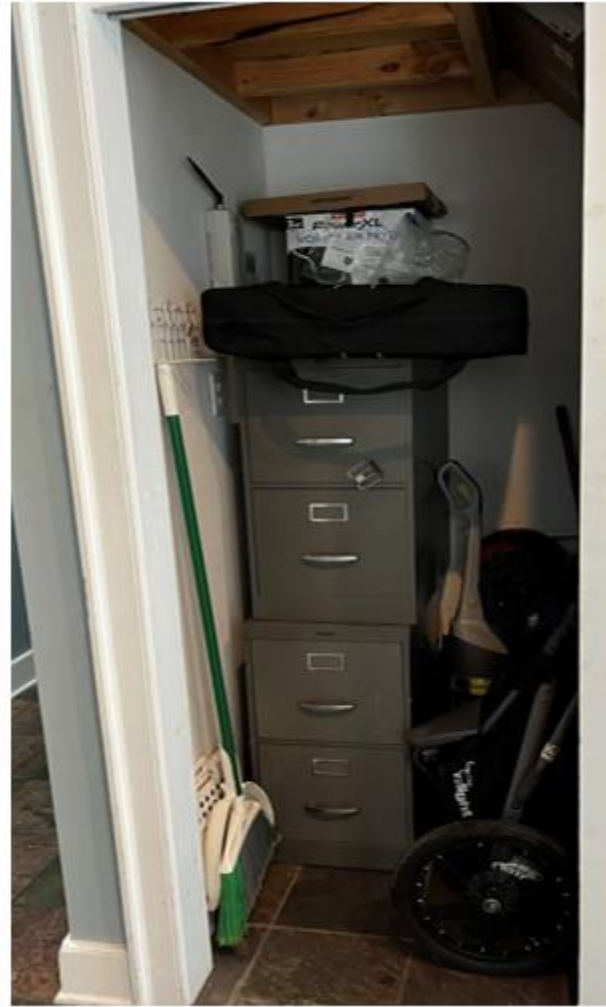
Progress – Challenges to Date

Challenges	Mitigation Strategies
Procuring 120-volt HPWHs	<ul style="list-style-type: none">• Stay in contact with manufacturer, coordinate on their timeline• Confirm the installation plan meets the manufacturer’s requirements
Securing / maintaining installation partner	<ul style="list-style-type: none">• Communicating an installation plan and timeline• Collaborating with manufacturer to provide on-site guidance• Provide timely payment
Siting, sizing, and installing HPWHs <ul style="list-style-type: none">• Size / clearance• Air volume / flow• Condensate drainage• Access to 120V receptacle• Sound / vibration	<ul style="list-style-type: none">• Require potential participants to fill out survey and provide pictures of current water heater location• Review every participant’s installation scenario with manufacturer and installer. Provide relevant survey responses and pictures.• Identify solutions to space constraints, air volume/flow, condensate drainage, and electrical ahead of time• Request that participants contact research team in the event of hot water run out, unusual noise, unusual vibration, or other issues
Assembling, configuring, installing, and maintaining monitoring equipment	<ul style="list-style-type: none">• Prepare monitoring equipment so it’s plug-and-play prior to installation• When needed, return to participant’s HPWH for a tune-up of monitoring equipment or installation

Progress - Sample Install #1 Photos



Progress - Sample Install #2 Photos



Progress – Considerations and Lessons Learned (continued)

Initial lessons learned:

- While 120V HPWHs often don't require multiple contractors on-site for a gas replacement, **expect plumbers to be onsite longer than a conventional install. Every installation thus far has taken 6+ hours.**
- HPWHs require planning for air volume, ducting, clearance, condensate drainage, and possible installation contingencies.
- The **lack of electric resistance backup in 120V HPWHs can limit their possible install locations**, even in warm-hot climates (e.g., detached garages, sheds)
- Direct swap-out of gas storage to 120V HPWH may not always be possible, depending on the circumstances (e.g., access to 120V receptacle). **Water heater relocation may be necessary.**

Future Work

Next steps

- Recruitment of next round of 10+ installations is underway
- Communicating with two other 120-volt HPWH manufacturers regarding product availability and specifications
- Continue data collection, validation, and analysis for installed sites

Thank You

Pacific Northwest National Laboratory

Josh Butzbaugh

joshua.butzbaugh@pnnl.gov

WBS # 1.4.1.19

REFERENCE SLIDES

Project Execution

	FY2022				FY2023				FY2024			
Planned budget	\$252,585				\$416,537							
Spent budget	\$207,254				\$302,440							
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Past Work												
Receive IRB approval of study design, informed consent, and materials to begin the recruitment process. - Email update with attachments.		◆										
Installation updates and lessons learned				◆								
Current/Future Work												
Preliminary results of 120V HPWH performance - PPT								◆				

Team



Josh Butzbaugh



Tabitha Artuso



Tyler Pilet



Travis Ashley



Abinesh Selvacanabady



Cheryn Metzger

