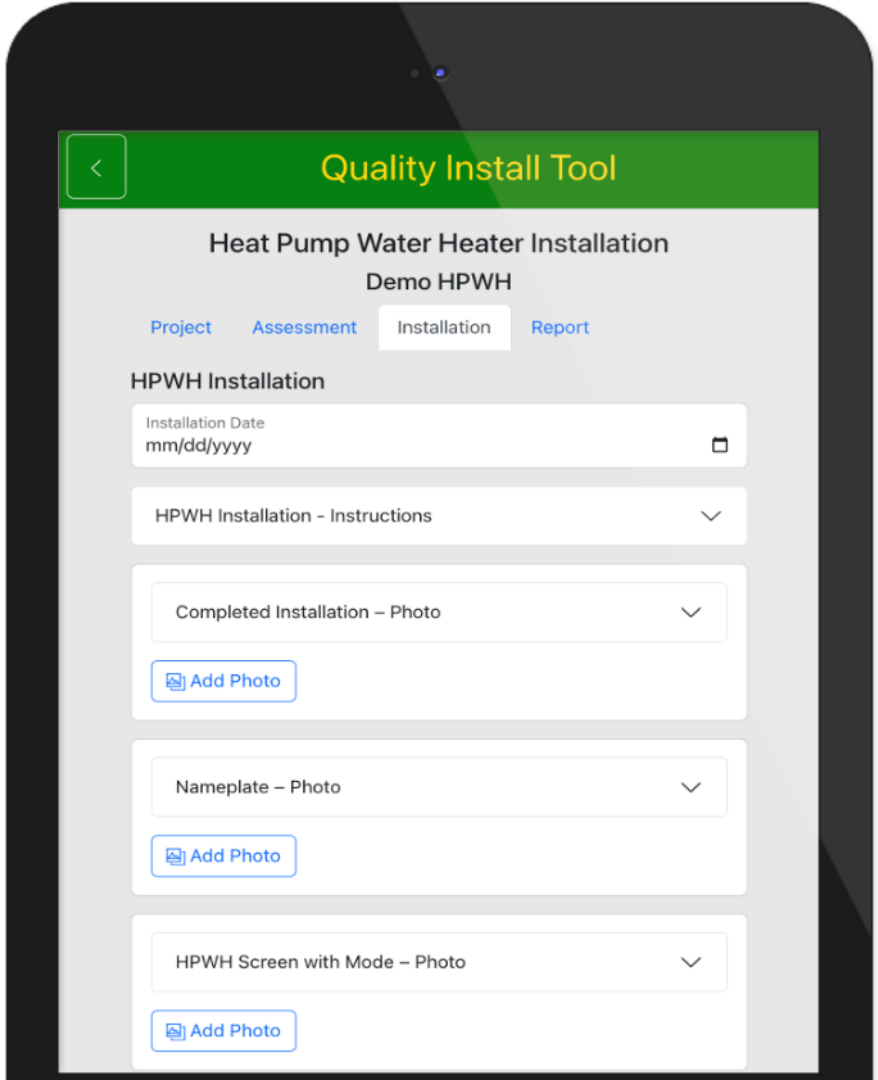
2024 PROJECT PEER REVIEW

U.S. DEPARTMENT OF ENERGY
BUILDING TECHNOLOGIES OFFICE

# BTO Peer Review: Quality Install Tool (QIT)

Pacific Northwest National Laboratory
Edward Louie
Building Energy Efficiency Research Engineer
(509) 375-6797, Edward.Louie@pnnl.gov
WBS # 1.4.1.19

PNNL

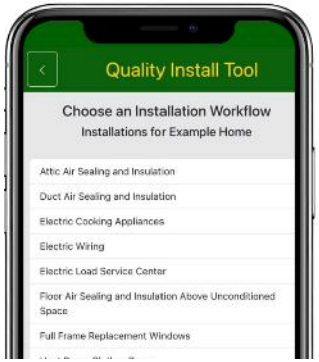


# Project Summary

## OBJECTIVE, OUTCOME, & IMPACT

Refrigerant-based systems alone waste 20.7 terawatt hours (TWh) of energy per year due to equipment faults. That's 9% of national central air conditioner and air source heat pump energy consumption, costing equipment owners $2.5 billion annually[1]. Air sealing and insulating the envelope can be dangerous to the occupants if done improperly to cause mold and mildew issues. PNNL's **Quality Install Tool (QIT)** provides a free, open source, and easy-to-use solution that helps installers do the job right the first time and enables utilities and program implementers to check work remotely, savings time and money on site QA visits.

**Free, easy-to-use QIT is available for use at Quality-Install-Tool.pnnl.gov**




## TEAM & PARTNERS

PNNL
WISE Home Energy
fyxify
CLEARLYENERGY
BCD HVAC & ELECTRICAL
ecolong
Learning Edge, LLC

## STATS

Performance Period: FY21–FY25

DOE Budget: $660k, Cost Share: $0k

Milestones:

FY21 Q3: QA protocol for 3 residential measures

FY22 Q3: QA guidance for high priority measures (HP & HPWH)

FY23 Q3: Remote QA tool update & report

FY24 Q3: Updated remote QIT tool interface

FY25 Q3: Outreach plan & execution for state & utility programs



[1]Winkler et al. 2020. Impact of installation faults in air conditioners and heat pumps in single-family homes on U.S. energy usage. Applied Energy, Volume 278

# Problem

**Residential energy efficiency measures are frequently installed incorrectly, leaving energy and money savings that are not realized**

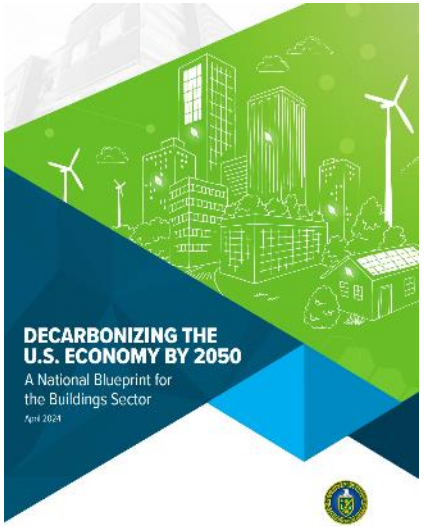
- In a random sample of 100 new construction homes, only 1 had an ACH50 of under 5.[1]
- A typical installation process rarely includes performance-related verifications or optimization of airflow, refrigerant charge, and control settings.[2]
- In walls, insulating panels lose more than 36% of their performance if gaps represent only 0.5% of the insulation volume.[3]
- The two most common faults in heat pumps are low indoor airflow rate and incorrect refrigerant charge level, a 9% increase over baseline (no-fault) usage, costing homeowners ~$2.5 billion annually on utility.[4]

These problems have the greatest impact on low-income households, who are counting most on the anticipated savings

# Alignment and Impact

This project squarely addresses the following Blueprint objectives:

- By 2035, 3% annual efficient envelope retrofit rate for existing residential is achieved and maintained or exceeded thereafter. Reduce the market barriers of envelope retrofits
- Heat pumps for residential and small-to-medium commercial applications reach 75% of space heating sales by 2035 and >90% sales by 2050.
- By 2050, All primary electric resistance space and water heating is replaced by heat pumps.

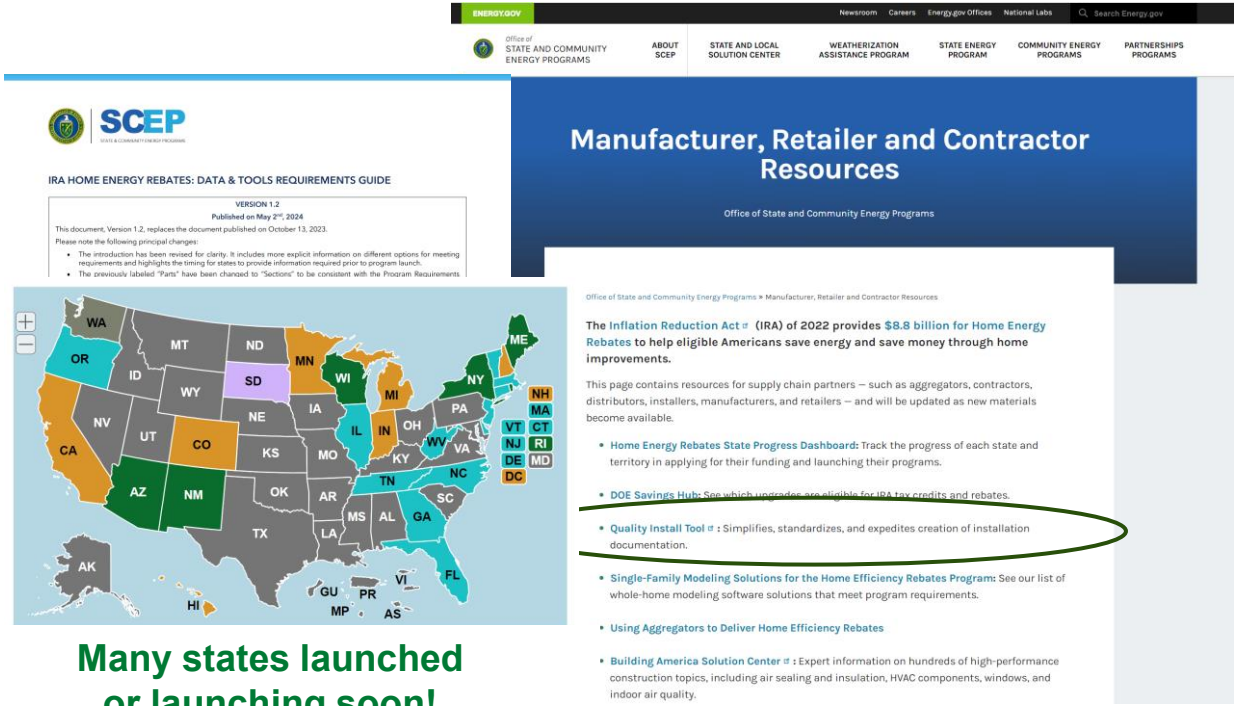



Quality installation is assumed and required to reach these goals.

# Alignment and Impact

## The PNNL Quality Install Tool (QIT) is the easiest way for states to meet Home Energy Rebates Quality Assurance requirements in the Inflation Reduction Act (IRA)

**The QIT is recommended frequently in the Data and Tools Guide published by the State and Community Energy Programs (SCEP) Office for the IRA rebates.**

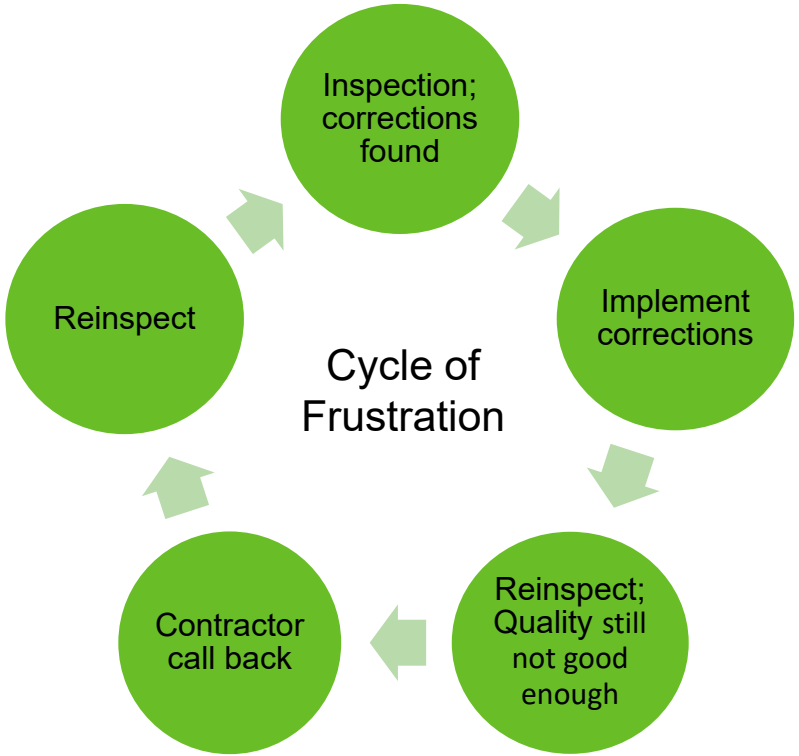



**Many states launched or launching soon!**

# Prevailing Approach

**Most quality inspections are currently done in person just to verify correct product install and non-comprehensive after-the-fact quality checks**

- Typically, only completed for 5% of projects
- On-site inspection results in tons of wasted emissions from travel
- 3rd party onsite validation is expensive—as such, all projects cannot be validated
- Some programs opt for installing contractor checklists in-lieu of on-site inspections
  - This provides no proof of proper installation
- Many elements are impossible or difficult to inspect/check afterwards



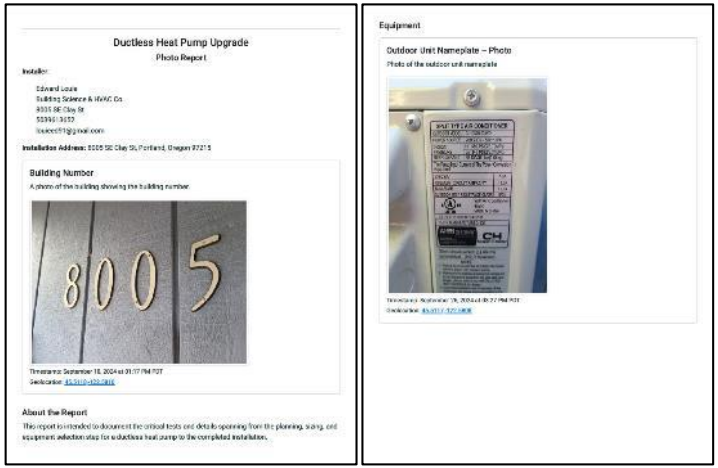
# Modern Approach

**The Quality Install Tool (QIT) works seamlessly to provide best-practice guidance to installers while documenting the quality installation for a wide range of stakeholders**

## Typical Process Flow Using the QIT:

**1)** Contractor takes prompted pictures throughout the installation process


**2)** Tool converts picture series into PDF for sharing purposes (similar to a home inspection process)




**3)** PDF can be shared with many stakeholders for documentation of quality installation

Designed by FreePik

# Modern Approach

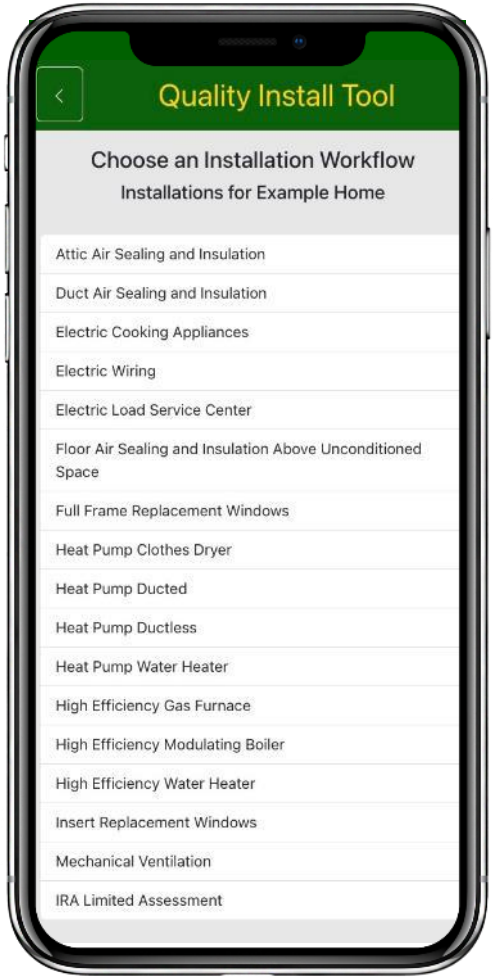
**Automated documentation available for consumers, contractors, third party verifiers, realtors and insurance companies**

| | |
|---|---|
| Customer | Documents quality of the retrofit they have invested in |
| Contractor | Documents work completed and its quality at the time of completion; also serves as installation guide for trainees |
| 3rd Party Verifiers | Supports review of work done without travel or logistical inconvenience |
| Utilities | Helps utilities have evidence that their program's incentives will realize full savings potential |
| Insurance | Photo documentation of assets for accurate risk assessment |

# Modern Approach

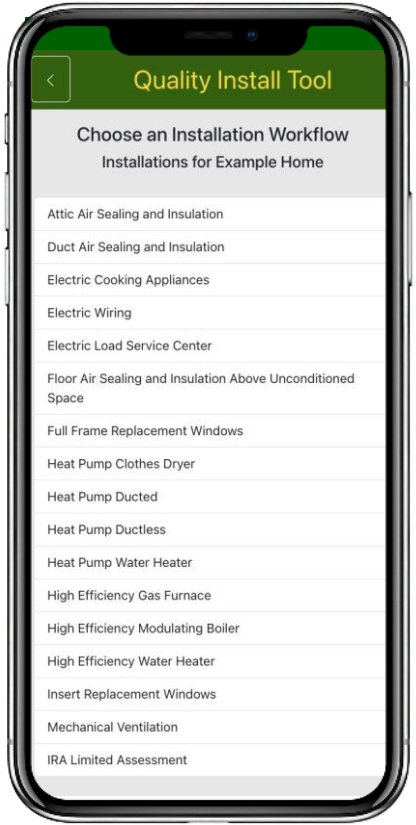
## Features to support wide-scale adoption and market transformation

- No other tool easily and systematically documents critical details and test results
  - Streamlines quality install workflow for contractors
  - Points to other standards and tools where possible
  - Built-in geotagged and timestamped photos for proof of install at particular location
  - Automated PDF report generation – easy to share via email
- Free to use
- No download needed, “Web-app” works offline, saves offline, sends PDF when back online
- Open-source code/adaptable – programs can use the code and change the requirements if desired (DOE version is best practice)



# Progress

## Most common and IRA-related energy efficiency upgrades are live




### HVAC Workflows

- Heat Pump Ducted
- Heat Pump Ductless
- High Efficiency Gas Furnace
- Duct Air Sealing and Insulation
- Mechanical Ventilation
- IRA Limited Assessment

### Plumbing Workflows

- Heat Pump Water Heater
- High Efficiency (Gas/Oil) Water Heater
- High Efficiency (Gas/Oil) Modulating Boiler

### Safety Workflows

- Combustion Safety Testing

### Envelope Workflows

- Attic Air Sealing and Insulation
- Wall Air Sealing and Insulation
- Floor Air Sealing and Insulation Above Unconditioned Space
- Foundation Wall Air Sealing and Insulation
- Slab Foundation Air Sealing and Insulation
- Full Frame Replacement Windows
- Insert Replacement Windows

### Electrical & Appliance Workflows

- Electric Wiring
- Electric Load Service Center
- Heat Pump Clothes Dryer
- Electric Cooking Appliances

Workflows reviewed by industry experts before and after going live!

# Progress

**Working through solutions to industry challenges**

## Challenges Encountered

- Unmotivated workforce – poor installs take less time than quality installs, why change?
- Data privacy, collection of personally identifiable information
- Industry experts requested the following features:
  - Allow more ways to assess duct leakage
  - Ability to enter contractor and customer info once to do multiple retrofits
  - Line set length and additional refrigerant added documentation

## Solution Strategies

- Workforce training to alleviate testing concerns and emphasize on their importance
- Localized data on the technician's tool (phone or tablet) without any large-scale centralized storage
- The following features were added based on industry feedback
  - Expanded options to duct leakage fan, pressure pan, and airflow capture hood
  - Reworked the workflow so that project info is entered once then many retrofits can be done inside that project
  - Added a section for documenting and calculating refrigerant additions for line set length

# Progress

## Mostly positive feedback from ~60 contractors to date

"The Quality Install Tool you developed seems to meet many of our program needs." - Municipal Utility

"I have recently come across the Quality Install Tool and found it really helpful in many respects." - Electrification Non-Profit

"I've checked out the Quality Install Tool and I'm impressed with its format and simplicity to use and generate reports." - Energy Program Manager

"Thank you so much. We are genuinely excited to implement the testing measures your providing. We're developing procedures to implement with the app you have made." - Owner of an HVAC company

"We'll need sometime to thoroughly digest but this is exactly what we are looking for." - Owner of a renewable energy trading platform company

"This is a really nice tool to offer to the market as it directly targets our industry. I like how it generates the report pdf and there are a lot of good install details in this tool." - Senior Consultant at a sustainable housing non-profit

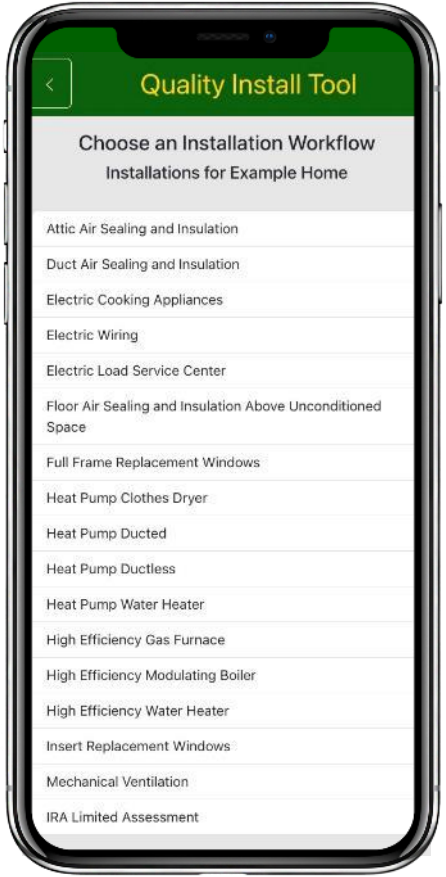
"Homeowners will like the reports and will encourage future improvements." - Owner of a Home Performance Contracting Business

"If you ain't testing you're guessing"- President of a major HVAC and Plumbing Company

"I would say a lot of the core HVAC tests you have listed are commonly run by our technicians in the field and they provide all this data pretty seamlessly." - Housing & Weatherization Director for a municipality

# Progress Summary

- Created workflows for common residential retrofits covering HVAC, domestic hot water, envelope, and electrical upgrades
- Created state-of-the-art tool and received substantial positive feedback
- All deliverables completed on-time and in-budget
- 3 state offices have adopted the Quality Install Tool (QIT) to document installation quality for IRA rebates and 4 are in the process of requiring QIT documentation.
- Presentations delivered at:
  - National Home Performance Conference 2023, and 2024
  - ACEEE Hot Air Forum and Hot Water Forum
  - ACEEE Summer Study
  - National HVACR Education Conference
  - Better Buildings Residential Network Webinar
  - GreenHome Institute Webinar
  - NORESCO Webinar



# Future Work

## Leveraging industry feedback to improve use case examples and training

- Continual engagement with:
  - Federal, state, utility, local EE programs
  - Contractors in the HVAC, insulation, plumbing, and electrical industry
  - Software developers to include the Quality Install Tool open-source code in their product's features
- Documenting contractors who use the QIT and their lower call-back rates
- More examples provided in Energy Skilled training materials

**Energy Skilled™ Recognition**

The Department of Energy built this program to distinguish credential programs as leaders in preparing workers for meaningful and in-demand job opportunities. Recognition as Energy Skilled™ signifies that training programs and certifications align with clean energy transition goals.

Specific job families for recognition currently include:

- Heat Pump Programs
- Heat Pump Water Heater Programs
- Energy Assessment Programs

# Thank you

Pacific Northwest National Laboratory
Edward Louie
Building Energy Efficiency Research Engineer
(509) 375-6797, Edward.Louie@pnnl.gov
WBS # 1.4.1.19

2024 PROJECT PEER REVIEW
U.S. DEPARTMENT OF ENERGY
BUILDING TECHNOLOGIES OFFICE

PNNL

# Reference Slides

# Project Execution

| | FY2021 | | | | FY2022 | | | | FY2023 | | | | FY2024 | | | | FY2025 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Planned budget | $160,000 | | | | $160,000 | | | | $133,500 | | | | $135,000 | | | | $71,000 | | | |
| Spent budget | $138,500 | | | | $114,000 | | | | $113,900 | | | | $114,000 | | | | - | | | |
| | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| **Past Work** | | | | | | | | | | | | | | | | | | | | |
| QA protocols for 3 residential retrofit measures | | | | | | | | | | | | | | | | | | | | |
| Analyze HPwES QA protocols | | | | | | | | | | | | | | | | | | | | |
| QA guidance for high priority measures (HP and HPWH) | | | | | | | | | | | | | | | | | | | | |
| Remote QA tool update & report | | | | | | | | | | | | | | | | | | | | |
| Updated tool interface based on stakeholder feedback for ccHP | | | | | | | | | | | | | | | | | | | | |
| **Current/Future Work** | | | | | | | | | | | | | | | | | | | | |
| Outreach plan & execution for state and utility EE programs | | | | | | | | | | | | | | | | | | | | |
| Implement workflow changes as needed based on state offices' feedback | | | | | | | | | | | | | | | | | | | | |

# Team

**Edward Louie**

Principal Investigator

PNNL

**Charlie Holly**

Development Team Lead

PNNL

**Sudha Eswaran**

Lead Programmer

PNNL

**Mark Borkum**

Supporting Programmer

PNNL

**Teressa Chizeck**

User Interface Design Consultant

PNNL

**Abinesh Selvacanabady**

Project Manager

PNNL

**Cheryn Metzger**

Program Manager

PNNL

**Alexander Rees**

Residential HVAC and Water Heating lead in the Building Technologies Office (BTO)

# References


1. Katz, A. 1997. What's Being Built Out There? Performance Tests on 100 New Homes. In Home Energy September/October 1997. https://www.aivc.org/sites/default/files/airbase_10851.pdf
2. Valoria, C., Esaki-Kua, L., Dymond, C., & Alliance, N. E. E. (2024). Increasing Uptake of Residential HVAC Commissioning with Advanced Technologies. 2024 ACEEE Summer Study.
3. Aïssani, A., Chateauneuf, A., Fontaine, J. P., & Audebert, P. (2016). Quantification of workmanship insulation defects and their impact on the thermal performance of building facades. Applied Energy, 165, 272-284.
4. Winkler, Jonathan, Das, Saptarshi, Earle, Lieko, Burkett, Lena, Robertson, Joe, Roberts, Dave, & Booten, Chuck. Impact of installation faults in air conditioners and heat pumps in single-family homes on U.S. energy usage. United States. https://doi.org/10.1016/j.apenergy.2020.115533