

# 2024 PROJECT PEER REVIEW

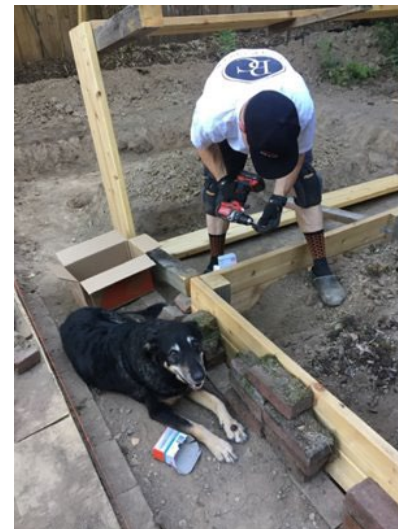
U.S. DEPARTMENT OF ENERGY  
BUILDING TECHNOLOGIES OFFICE

## Advancing Residential Building Decarbonization

Homeowner/Renter Upgrade  
Survey



# Advancing Residential Building Decarbonization: Homeowner/Renter Survey

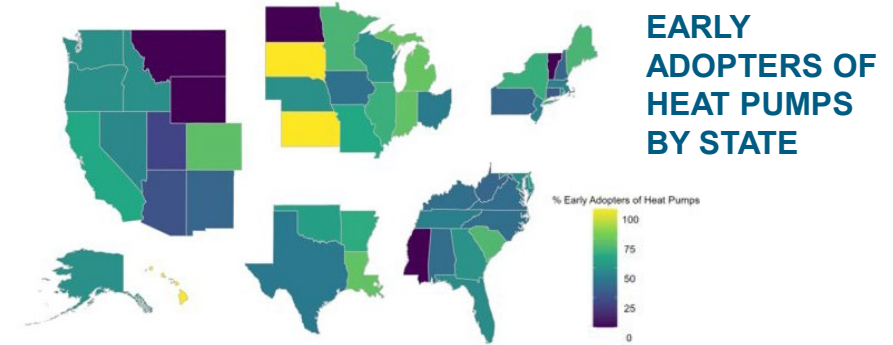


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WBS # 3.4.6.73

# Project Summary

## OBJECTIVE, OUTCOME, & IMPACT

Using mixed-methods, investigate household energy-efficiency behavior and how residents make decisions about energy-related purchases and home improvements. Identify barriers and opportunities in support of residential decarbonization. Use a data-driven approach to expand energy efficiency messaging to scale decarbonization.



## TEAM & PARTNERS

### PNNL Team (lead):

Chrissi Antonopoulos, PhD (PI), Building Scientist  
Tracy Fuentes, PhD, Terrestrial Ecologist  
Kieren McCord, PhD, Building Scientist  
Charlotte Roiger, Data Scientist

### University of Arizona:

Jonathan Bean, PhD, Social Scientist

Additional Collaborators: LBNL, NREL, Illume Advising.

## STATS

Performance Period: 2022-Present

DOE Budget: FY22: \$750k, FY23: \$400k, FY24: \$600k

Milestone 1: Lit review & IRB approval

Milestone 2: Residential data collection complete

Milestone 3: Draft initial findings

Milestone 4: Equity and Technology Deep Dive outlines

Milestone 5: Draft and final Deep Dive and Equity reports



# Problem

- **Nearly 2/3 of U.S. homes constructed before DOE energy conservation measures** (later formalized in building codes). These homes:
  - **Consume 15%+ primary energy**
  - **Responsible for 20% of total U.S. GHGs.**
- Tech advancement alone won't ensure sufficient uptake to meet climate goals.
- Understanding household energy-related behaviors across socio-demographic groups is important, but **we know far too little about how households make energy-related decisions.**
- Programs and policies require this difficult-to-obtain information to effectively meet goals.
- This national-scale social-science study (focused on program enhancement through messaging) addresses this gap.

Typical U.S. Housing is Inefficient



Source: RMLS



How Do We Convert to High Performance Housing?



Source: DOE ZERH



# Alignment and Impact



DECARB BLUEPRINT THEME  
Increase building energy efficiency



DECARB BLUEPRINT THEME  
Accelerate onsite emissions reductions

The DOE Decarbonization Blueprint calls for a **65% reduction in GHG Emissions by 2035 and 90% by 2050**: Retrofits need to increase 10-fold to meet this goal, and understanding decision-making is key to developing messaging and programs



Reduce **90% of total GHG emissions\*** from the buildings sector



Avoid **7 quads of annual energy use\*\*** while converting many building loads to clean electricity



Save consumers more than **\$100 billion in annual energy costs\*\*** through efficiency improvements



Avoid **\$17 billion in annual health costs†** and add **\$1 trillion of investment in high-quality jobs\*\***

Figure 10. The impact of achieving the 2050 vision is far-reaching and includes significant greenhouse gas, energy use, cost savings, health, and high-quality jobs impacts.

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

## Impact of Homeowner/Renter Survey:

- Largest-scale study conducted at the household-level in the U.S., reaching 10,000+ households
- Quantify impacts of increased technology adoption and identify largest opportunities
- Quantify decision-making considerations made by households, including low income, or under-represented groups
- Better understand renter dynamics, barriers and opportunities
- Replicate study in manufactured housing sector
- Publish a publicly-available dataset for future research, with 300+ variables related to home energy decision-making



# Alignment and Impact

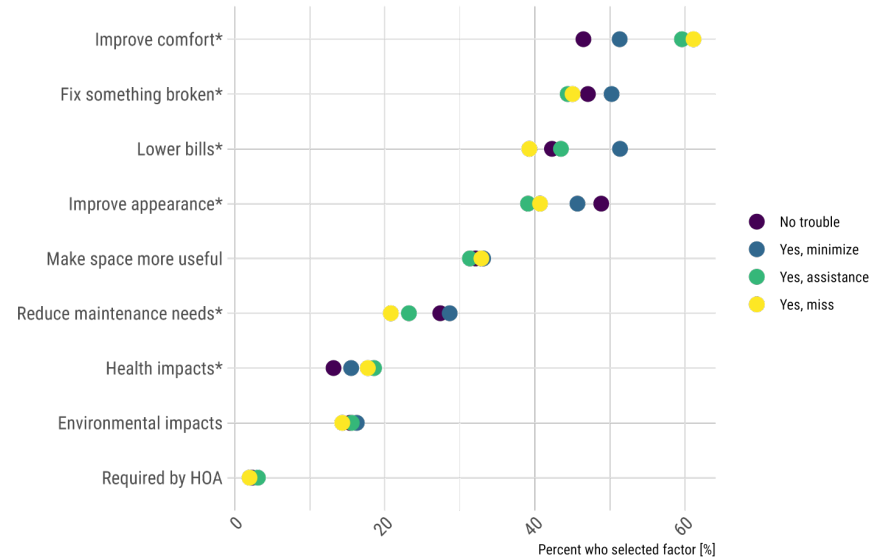
## Equity & Resilience



FY24 activities focus on important equity and resiliency actions in the Buildings Blueprint to determine:

- Energy burdens and household income by demographic groupings
- Drivers for home energy upgrades and technology adoption
- Energy upgrades by energy burdened versus non-energy burdened households, including which technologies are most adopted by both groups
- Program participation and financing dynamics for energy burdened households vs. non-energy burdened households
- Retrofit barriers for energy burdened vs. non-energy burdened households
- Climate-related risk assessment related to health and safety

### Energy Decisions & Equity: Households with higher energy burdens prioritize different factors





# Approach

## Project Scope

Department of Energy's Building Technologies Office is funding research to investigate how diverse residents make home energy decisions and to explore how those decisions help meet decarbonization goals.

### Research Questions:

1. What are the motivations and key decision points for energy-related home retrofits and upgrades?
2. How do different residential stakeholders decide to buy and use key technologies relevant for residential electrification?
3. How can these patterns be leveraged to increase technology uptake and meet decarbonization goals?



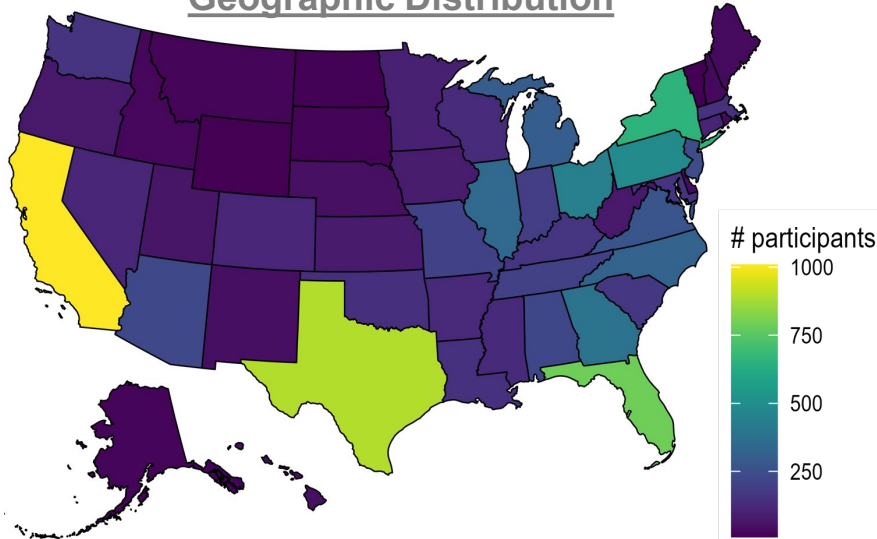
# Approach

## Strategically Distributed 10,000- Person Consumer Survey

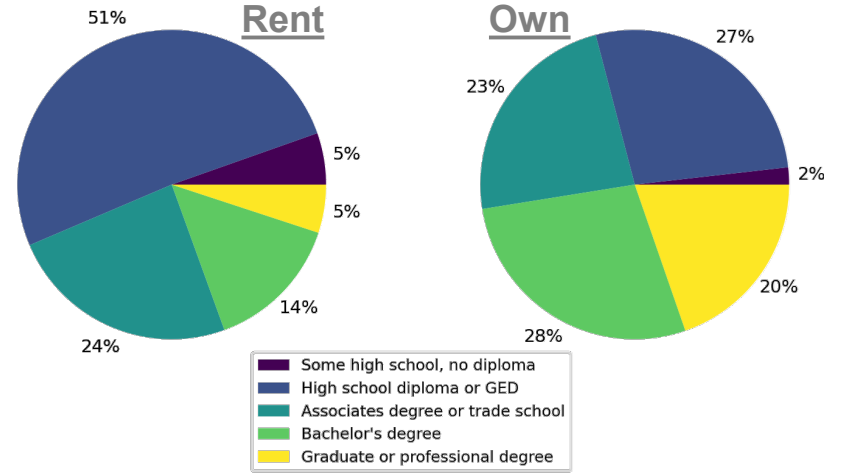
Emphasis on matching census distributions, with intentional oversampling of marginalized populations



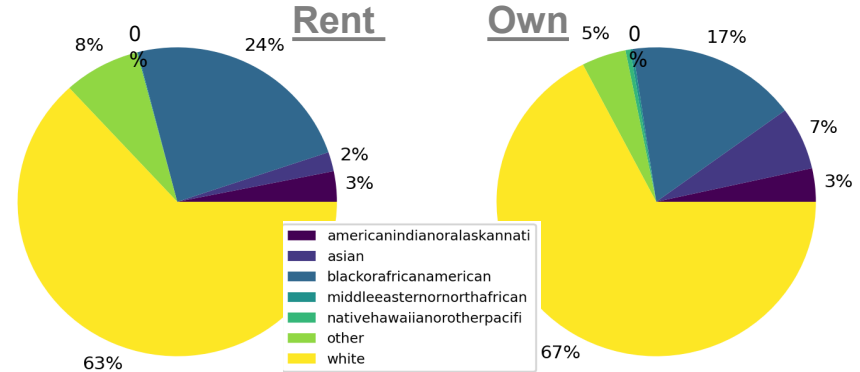
### Geographic Distribution



### Education Distribution



### Race/Ethnicity Distribution



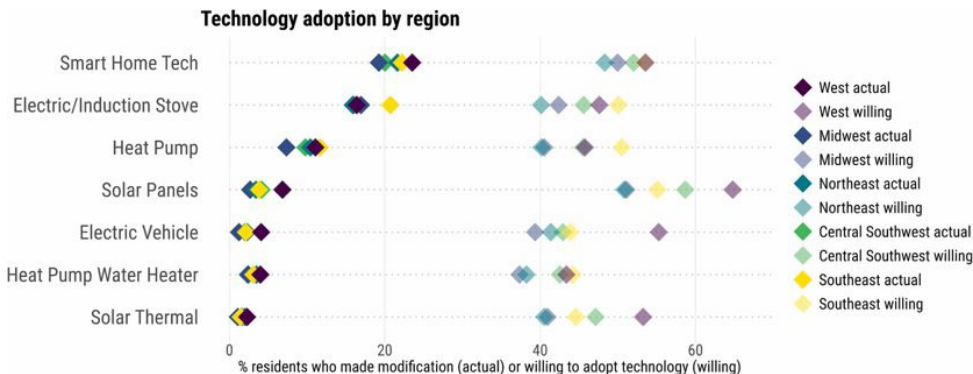




# Approach

## Research Activities Advancing Equity, Affordability, and Resilience

- Work with an international external **advisory board**, composed of experts in the field, to inform research protocol.
- **HVAC manufacturer outreach** to learn about customer discovery and marketing
- **Review literature** to identify previous study findings
- Develop research protocols, sampling strategy, participant criteria, analytical methods and gain **Institutional Review Board (IRB)** approval
- Conduct in-depth, semi-structured **interviews** with 150 households to better understand purchasing decisions, use patterns, and energy efficiency perceptions and behavior
- Execute national-scale **survey** to 10,000 homeowners and renters, using questions developed from interview outcomes
- **Synthesize results** from interviews and survey to inform decarbonization strategies
- **Collaborate** with relevant stakeholders to enhance findings and expand decarbonization efforts

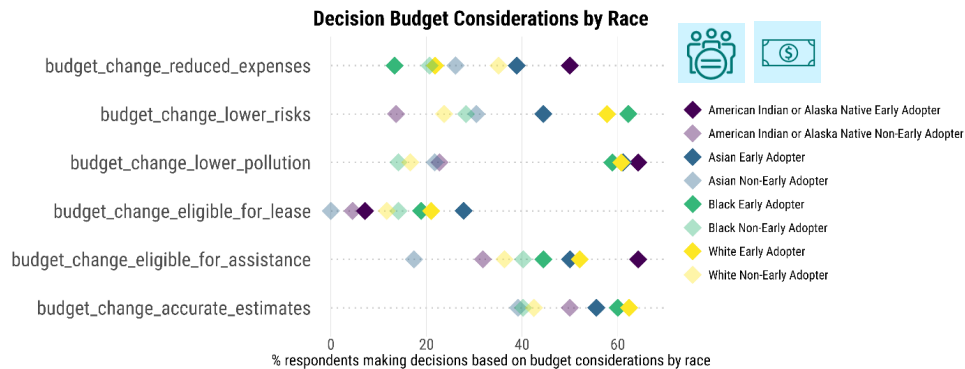
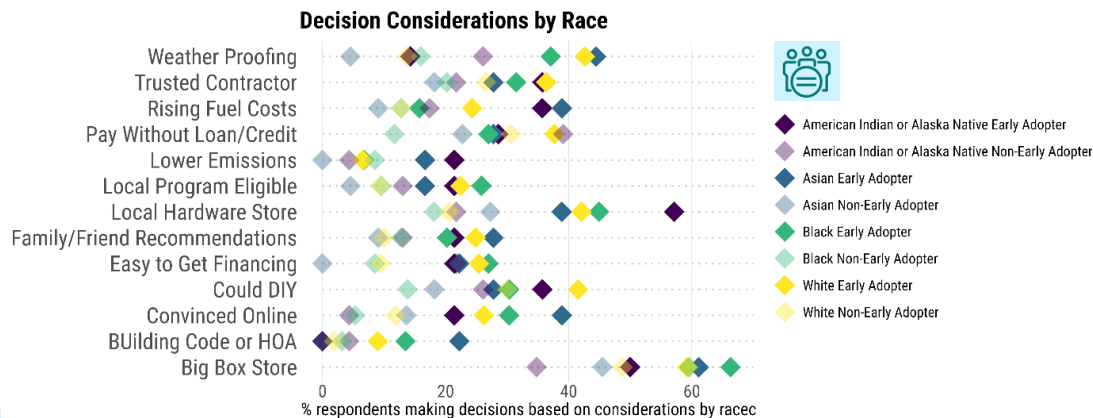




# Approach

Leveraging interview + survey mechanism to increase efficiency and accelerate EE tech adoption for the first time

- Conduct semi-structured interviews with residents in warm weather states (30 AZ, 31 GA) and cold weather states (30 IL, 30 MA)
- National-scale survey to 10,000 households with even regional distribution
- 70% homeowner, 30% renter
- Focus on higher response rates from low-income, non-white populations





# Approach

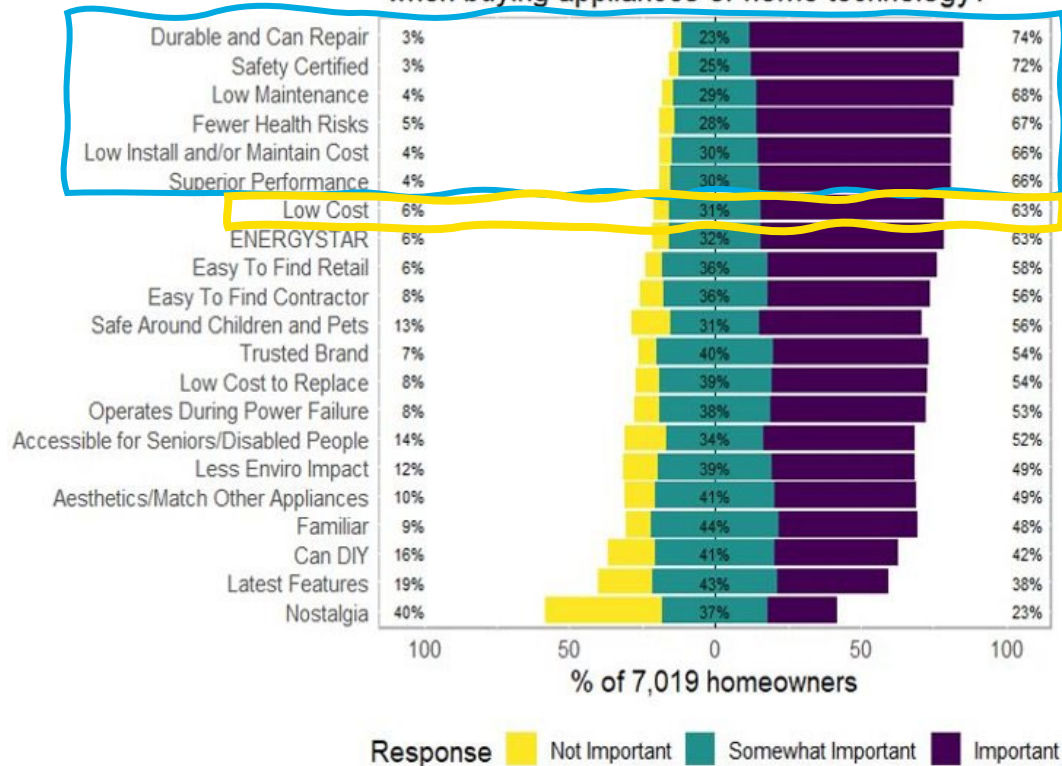
**Energy efficient buildings are critical for ensuring affordable, healthy, comfortable, and resilient indoor environments for occupants while reducing emissions, energy use, and electricity demand.**

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

Social-science studies support better understanding of upgrade drivers:

- Six decision-making factors are more important than low first-cost
- All are non-energy benefits

How important are the following factors when buying appliances or home technology?



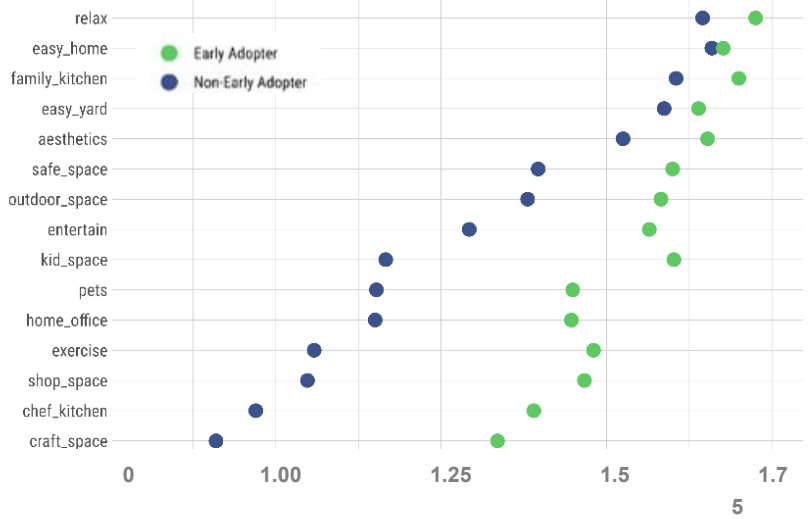
# Approach

## Occupant-Centric Investigations to Accelerate Heat Pump Adoption (Heat Pump Deep Dive)



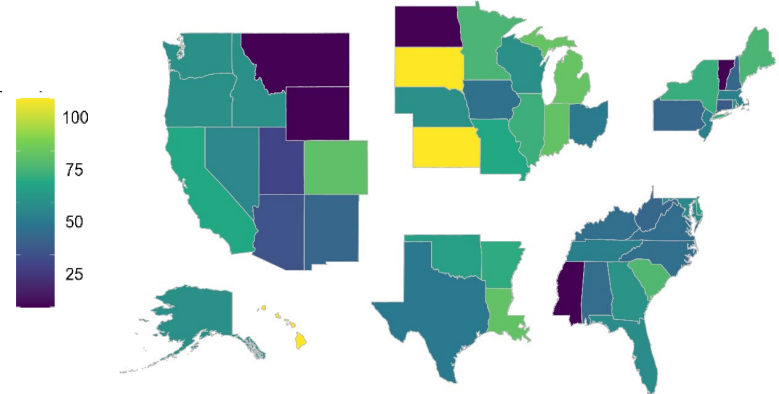
- Hypothesis: Heat pump adoption is currently driven by “early adopters”—advancing to “late majority” will require better understanding of occupant decision-making
- Research team built an analysis framework isolating early adopters of heat pumps, finding that early adopters:
  - Have different household preferences
  - Are motivated by different factors
  - Find information in different ways
  - Interact with contractors and programs more
- Outcomes inform touch points to dramatically increase adoption rates of residential heat pumps.

**Rated Importance of Household goals by Early Adopters vs Non-Early Adopters of Heat Pumps**



Avg value: 0 Not Important 1 = Somewhat important 2 = Important

**Percentage of Residents in each State who are Early Adopters of Heat Pumps**

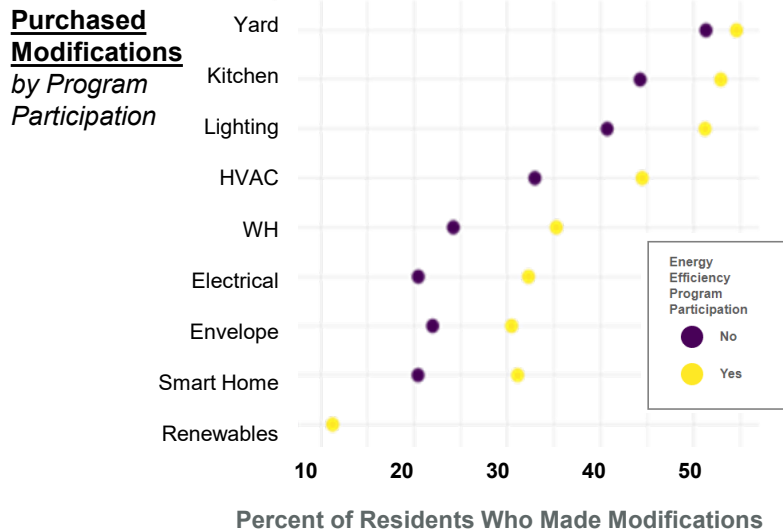
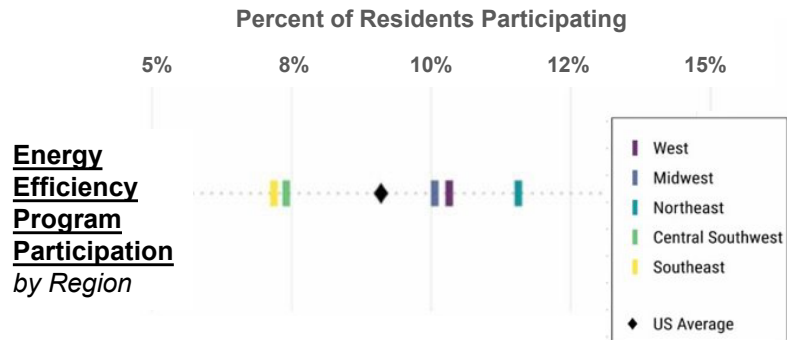




# Progress and Future Work

## Key Findings To-Date

- Homeowners and renters are willing to adopt decarbonization technology, but very few have done so to-date.
- Decision-making varies significantly based on demographics:
  - Race
  - Income
  - Early vs late adopters
- Focusing on specific goals of diverse populations can increase residential decarbonization.
- Improving comfort and safety for children/pets >> environmental benefits.
- Renters and homeowners value their kitchens highly and are likely to make different decisions specific to how they value a particular room/space.
- Program participation is LOW, but the outcomes show that THEY WORK!
- Cost is *not* the #1 driver for most decisions, but it's more of a consideration for renters than homeowners.



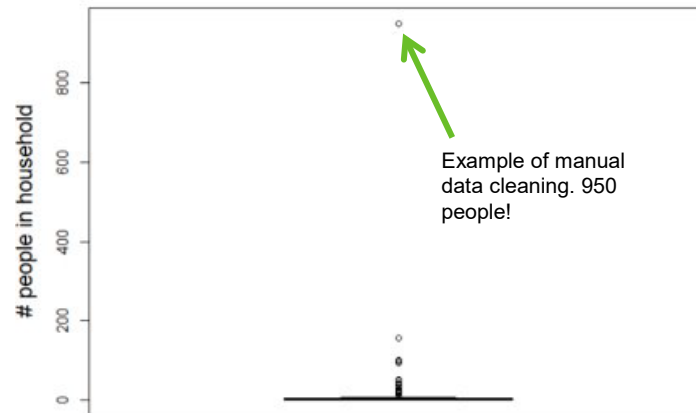


# Progress and Future Work

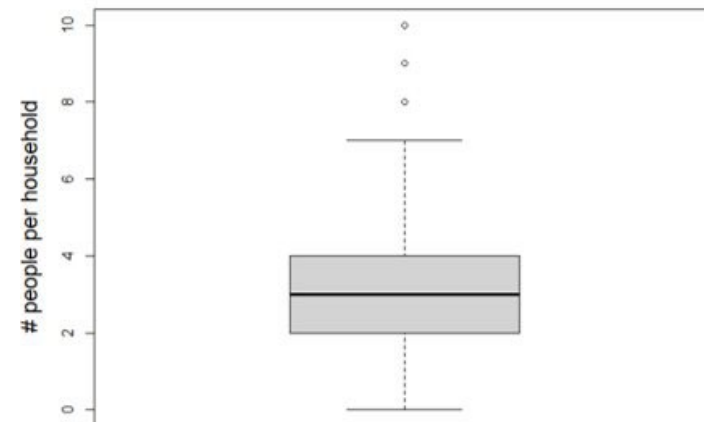
## Obstacles and Lessons Learned

- Large-scale data cleaning:
  - Requires both qualitative and quantitative approaches.
  - Cleaning data with hundreds of variables is onerous.
    - Multiple methods are necessary
    - Human QA is necessary
- Geo-location methods to remove PII while keeping a locator variable present both opportunities and drawbacks
- Intentional survey question design highly impacts the ability to successfully analyze and synthesize data

Need to get from this...



...to this:





# Progress and Future Work

## Disseminated Findings Through Various Engagement Activities

- BTO Peer Exchange Call
- Utility & Local government webinars
- 3 invited lectures/talks
- 10+ conference presentations

GETTING TO  
**zero**



**BUILDING  
PERFORMANCE**  
ASSOCIATION



Consortium for Energy Efficiency



behavior, energy & climate change



**Energy and Climate Transformations**  
3rd International Conference on  
Energy Research & Social Science



The Latest in Educating Homeowners on  
the Benefits of Energy Efficiency

Better Buildings Residential Network • The Latest in Educating Homeowners on the Benefits of Energy Efficiency

September 26, 2024 01:00PM to 03:30PM EDT



# Progress and Future Work

## Published Work:

- 2 journal publications
- 2 conference papers
- 1 public dataset

## In Preparation/Review:

- 2 journal publications
- 1 conference paper
- 2 technical reports

**States of mind: How decision-making patterns can influence uptake of residential heat pumps and enclosure upgrades**  
*Kieren H. McCord, Tracy L. Fuentes, Chrissi Antonopoulos, Pacific Northwest National Laboratory*  
*Núria Casquero-Modrego, Lawrence Berkeley National Laboratory*  
*Holly Carr, U.S. Department of Energy*



Energy Research & Social Science  
Volume 109, March 2024, 103411




Original research article  
**Decisions and decision-makers: Mapping the sociotechnical cognition behind home energy upgrades in the United States**  
Saurabh Biswas <sup>a, b</sup>, , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , ,   
Chrissi A. Antonopoulos <sup>a</sup>, , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , ,   
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Energy Policy  
Volume 185, February 2024, 113940




Regional assessment of household energy decision-making and technology adoption in the United States  
Chrissi A. Antonopoulos <sup>a</sup>, , , , , , , , , , , , , , , , , , ,   
Saurabh Biswas <sup>a</sup>   
Show more 

UPGRADE-E  
<https://doi.org/10.25584/2371918> 

RESIDENTIAL BUILDINGS

BUILDING, SYSTEM, HEATING, COOLING, POWER, LIGHTING, OCCUPANCY, ENERGY USE  
BEHAVIORS AND DECISIONS

UPGRADE-E: Understanding Patterns Guiding Residential Adoption and Decisions about Energy Efficiency  
*Recommended citation:* Fuentes, Tracy L., Kieren H. McCord, Adrienne L. S. Rackley, Saurabh Biswas, Wilfried Kabre, and Chrissi A. Antonopoulos. UPGRADE-E: Understanding Patterns Guiding Residential Adoption and Decisions about Energy Efficiency". Pacific Northwest National Laboratory. DNNI-SA-109875. <https://doi.org/10.25584/2371918>







# Progress and Future Work

## Collaborators

- Ongoing work with LBNL supporting decarbonization research
- Ongoing work with NREL to investigate alignment with ResStock
- Special issue of Transportation Letters in collaboration with UC Santa Barbara and NREL



**Special Issue Editor(s)**

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# Progress and Future Work

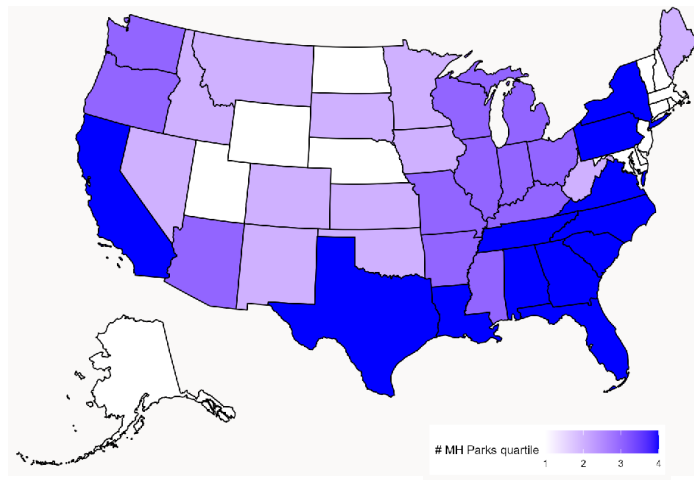
## Replication Study in Manufactured Housing (MH) Sector:

- Use lessons-learned from single-family survey
- Data collection underway (survey live); target 5,000 MH households
- Advisory board established and engaged

## Primary Goals:

- Identify motivations for technology uptake in MH sector
- Understand reasons for successful/unsuccessful upgrades in MH
- Identify opportunities/barriers for upgrades in MH
- Define attitudes towards energy efficiency upgrades

MH Park Location Density



# Thank you

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**WBS # 3.4.6.73**

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PEER REVIEW**



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BUILDING TECHNOLOGIES OFFICE



# Reference Slides



# Project Execution

	FY2022				FY2023				FY2024			
Planned budget	\$750k				\$450k				\$500k			
Spent budget	\$750k				\$450k				\$450k			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
<b>Past Work</b>	Past Work											
Q1 Milestone: Data Collection Plan	◆											
Q2 Milestone: Data Driven Summary/Lit Review		◆										
Q3 Milestone: Go/No-Go: IRB Approval/Subcontracts Placed			◆									
Q4 Milestone: Initial Data Complete				◆								
Q1 Milestone: High-Level Initial Findings					◆							
Q2 Milestone: Assessment & analysis: Journal Manuscript						◆						
Q2 Milestone: Collaboration Framework							◆					
Q3 Milestone: Communication Plan								◆				
Q4 Milestone: Draft Technical Report									◆			
Q1 Milestone: Deep Dive Outline										◆		
Q2 Milestone: Final Framework Equity Analysis											◆	
Q3 Milestone: Draft Analysis Supporting Deep Dives												◆
<b>Current/Future Work</b>	Current/Future Work											
Q4 Milestone: Draft Analysis Supporting Equity												



Milestone/Deliverable (Originally Planned) use for missed  
Milestone/Deliverable (Actual) use when met on time



# Team



**Chrissi Antonopoulos**  
PI/PM



**Tracy Fuentes**  
Methods, Analysis



**Kieren McCord**  
Methods, Analysis



**Ebony Mayhorn**  
Equity Analyst



**Charlotte Roiger**  
Data Scientist



Developed, conducted household interviews in 4 states



Analysis of heat pump adoption



Combined household and contractor surveys to look at synergies



Combined data with ResStock to investigate user-centric trends