



The Decarbonization Melting Pot: Household Energy Adoption & Preferences

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Current PNNL Project Team



U.S. Department of Energy (DOE) Building Technology Office (BTO) funded research to investigate how residents make home energy decisions and to explore whether those decisions help meet decarbonization goals.

- Interdisciplinary Project Team, advised by international advisory board of 25 experts
- ILLUME Advising conducted interviews in AZ, GA, IL, MA (**n = 121 residents**)
- National scale survey (**n = 9,919 residents**)



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Understanding Household Decision-Making



Energy Research & Social Science








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Original research article

Decisions and decision-makers: Mapping the sociotechnical cognition behind home energy upgrades in the United States

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In Progress: Technology Deep Dives,
Publish Dataset, Equity/Vulnerability
Analysis

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Regional assessment of household energy decision-making and technology adoption in the United States

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Mixed Methods Approach

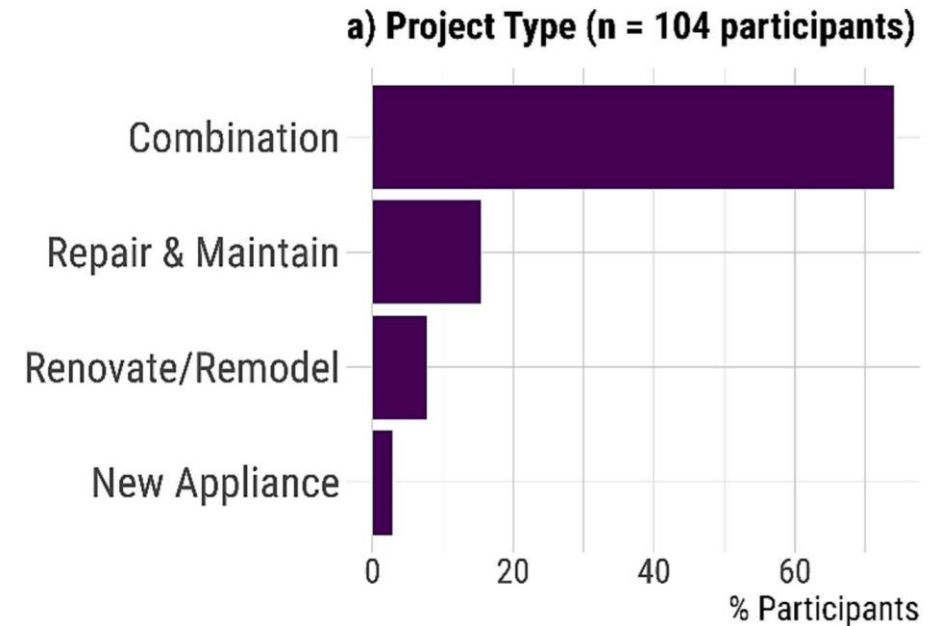
- Explore lived experiences in homes and with home energy technologies
- Identify human dimensions to home energy technology decisions: attitudes, habits, experiences
- Allow for more nuanced understanding about the influence of culture and lifestyle
- Provide frameworks for problem-solving at the household level



Source: <https://www.energystar.gov/>

Households make changes in combination

- Nearly 70% of interview participants undertaking a house project were making multiple changes.
- Shows there is an opportunity for contractors to integrate decarbonization tech/measures during *other* types of projects.



Each Retrofit Unique Challenge

- Old construction, little to no insulation and air sealing, thus increasing infiltration
- Dated systems, inefficient appliances
- Increased likelihood of hazardous materials (lead, asbestos, mold)
- Likely no air conditioning installed
- No whole-house mechanical ventilation or active filtration
- Energy intense, increased CO₂ emissions



Median Year Built

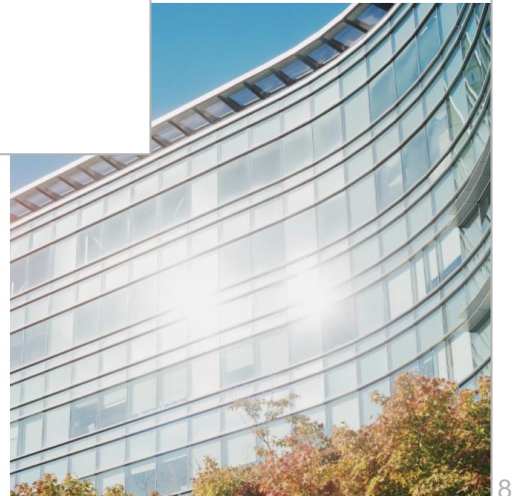
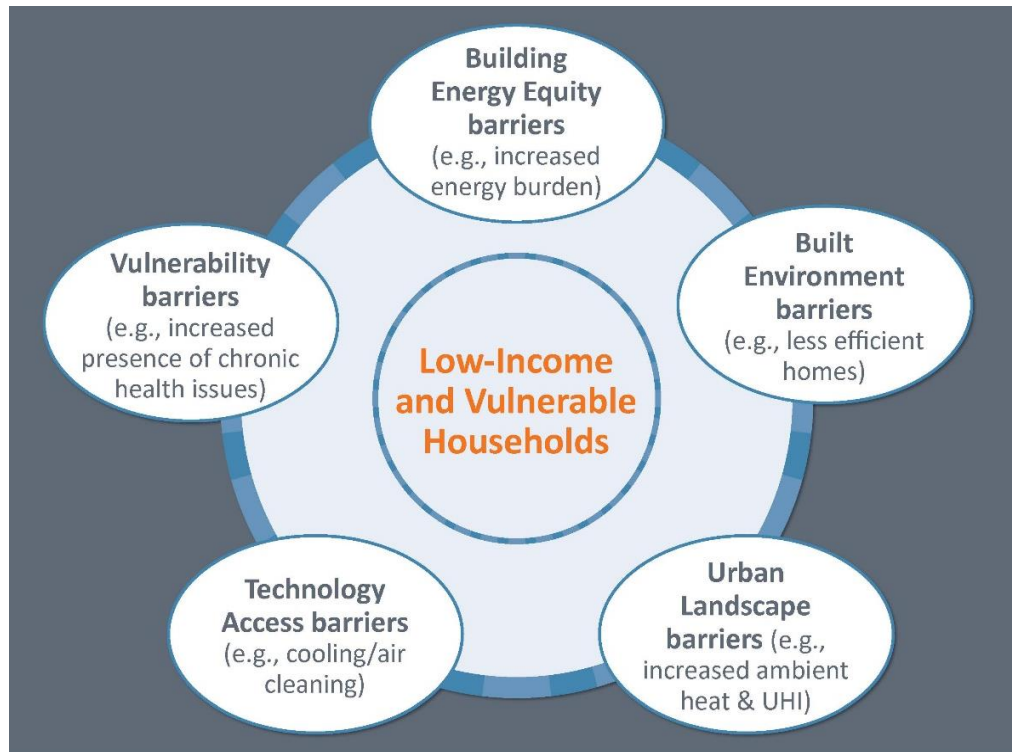
Interviews: 1977
Survey: 1980-1990

There's No Place Like Home

- Human behavior is at the center of interactions between people, and the homes they live in.... and the technology they interact with.
- Utilities, contractors, and residential building researchers grapple with complex sociotechnical dynamics when promoting/diffusing/researching technology in residential buildings.
- Many factors make this dynamic more complex:
 - Building stock characteristics
 - Region and community density
 - Income
 - Race, cultural background, ethnicity
 - Education, including technology background
 - Age, life-stage
 - Preference



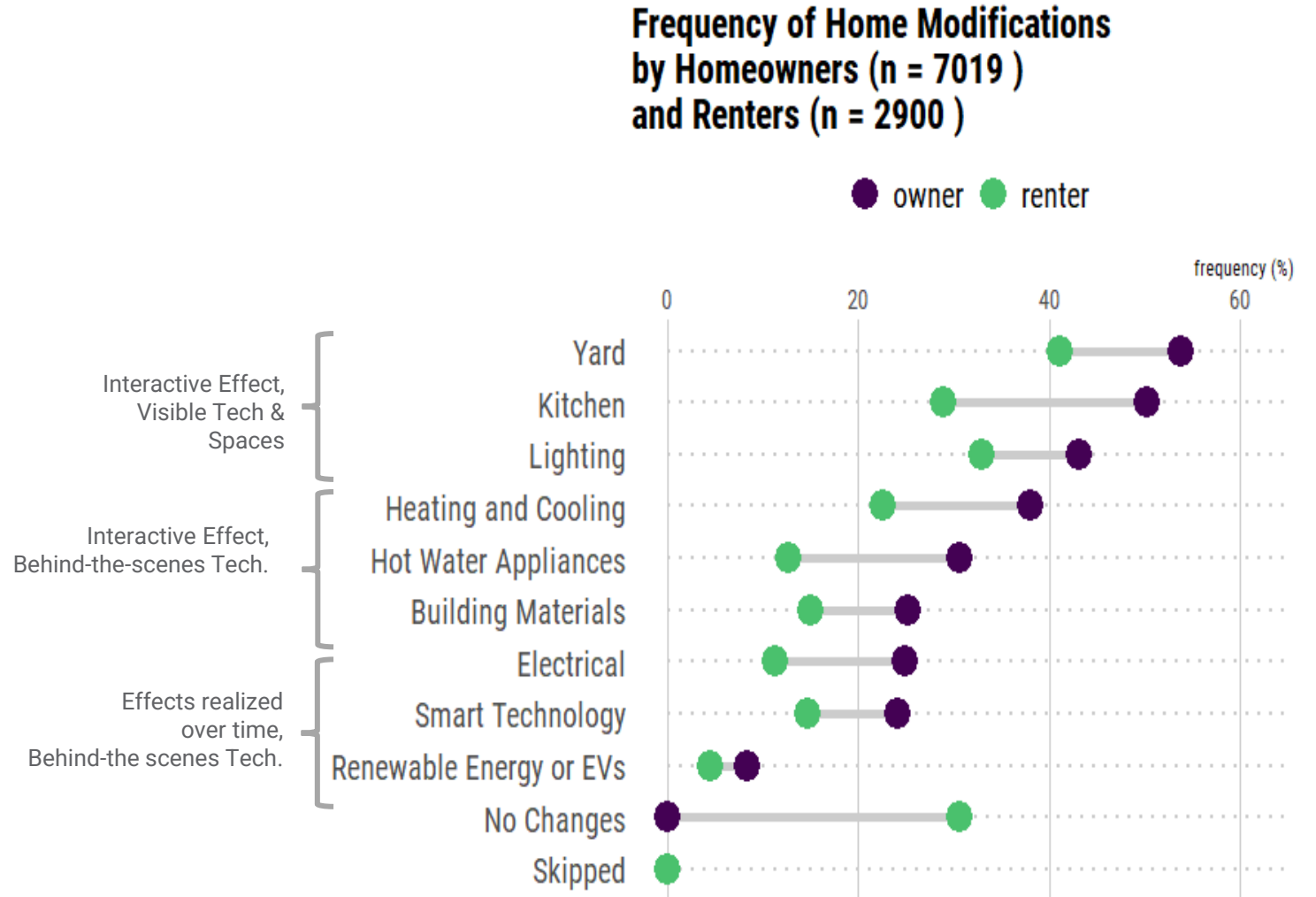
Equity & Vulnerability To Climate Extremes



Part 1: Household Upgrades

Common Changes to Homes

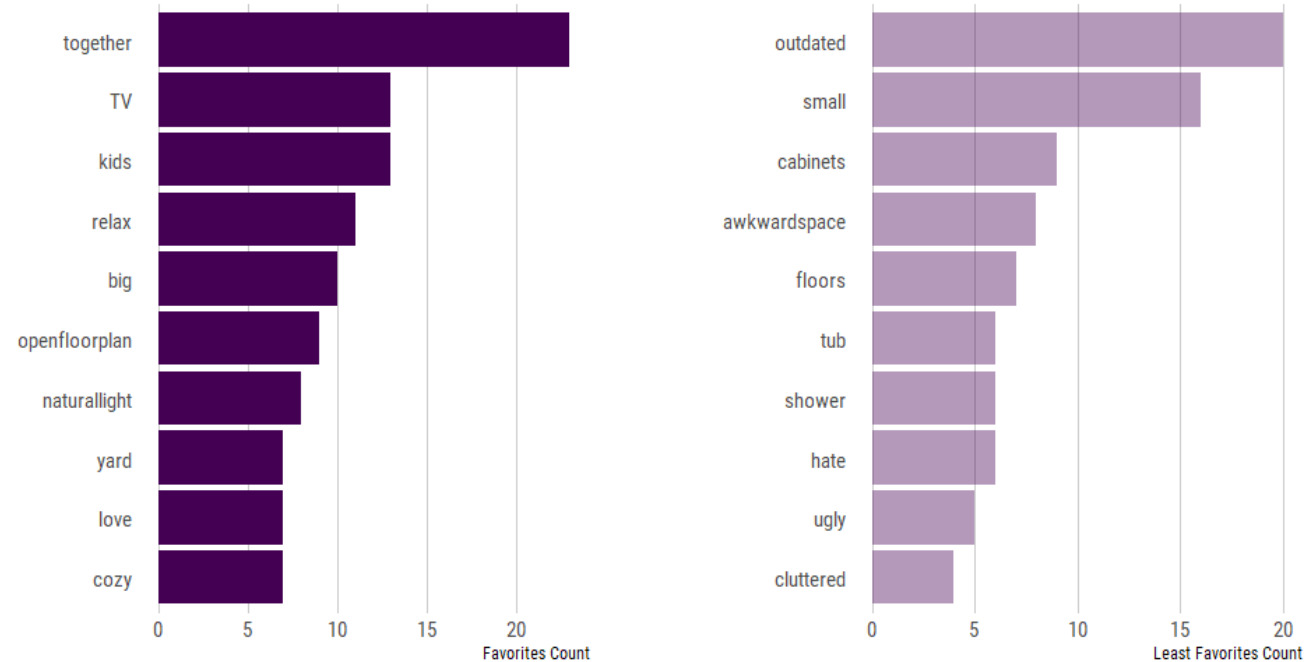
- Overall, homeowners more likely to make changes than renters.
- More homeowners and renters changed **visible, interactive technologies and spaces** compared to "behind-the-scenes" technologies.
- 50% of homeowners and 29% of renters have made changes in the **yard** and **kitchen**.
- Fewer changes to **HVAC** for both groups (38% owners, 23% renters).



Agency, Visibility, and Daily Interaction

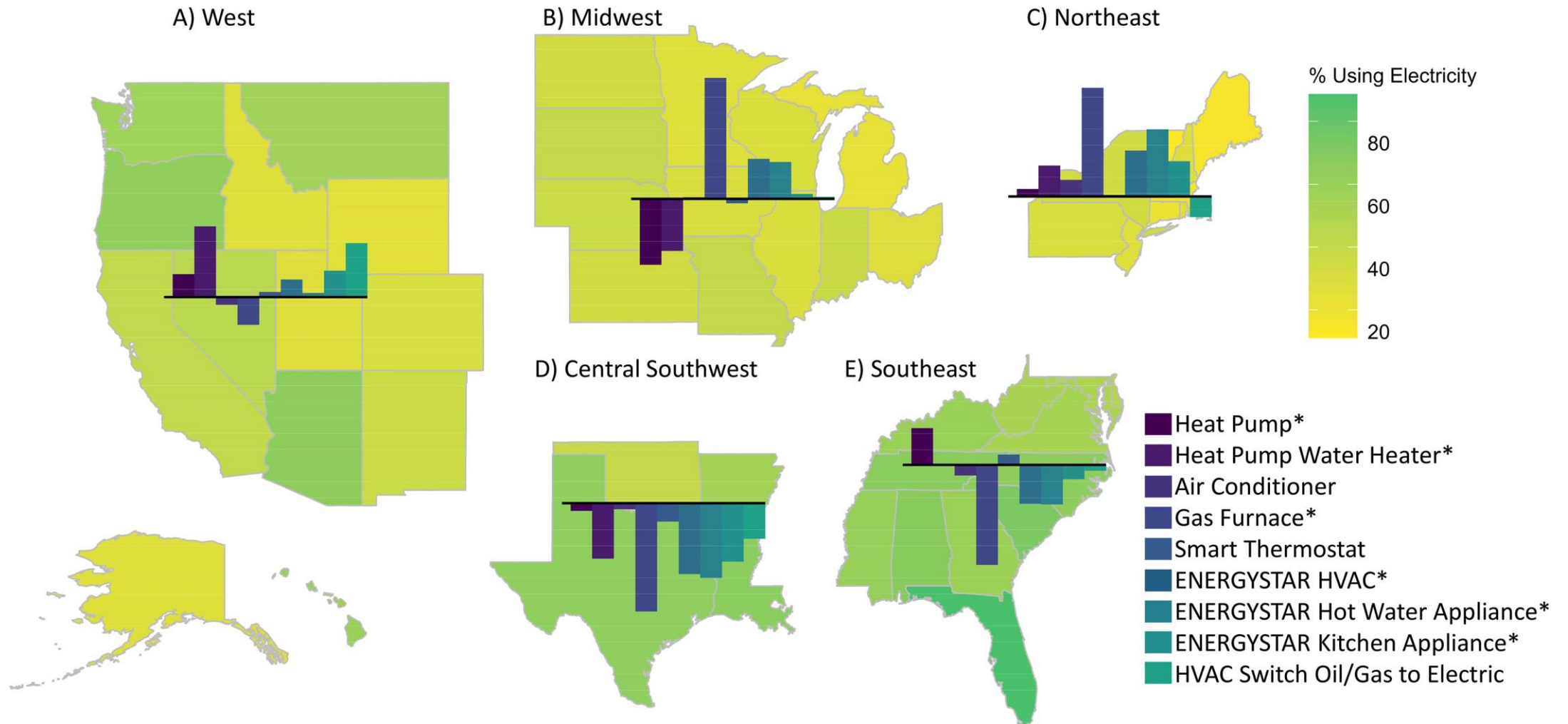
“Well, for myself, it's kind of a split, honestly, between the two, because for me, the **outside of your home is a representation of you for the outside world, for your neighbors, for your neighbors' guests, for anybody who's just driving through your neighborhood.** So, we both, my husband and I, take a very big interest in the presence and the appearance and the presentation of the outside of our home. But, of course you live on the inside of your home **and that's really what you're utilizing more or less on a daily basis.** So, a lot of the times, if we've got a decision to make on whether or not we're going to do an outdoor project or an indoor project, and they kind of have the same weight as far as importance or anything like that, we'll probably tend to do the inside one first, **have things set up the way that we want them to be.**”

Most Common Descriptors Associated with Favorites/Least Favorites



- Respondent 237 (GA)

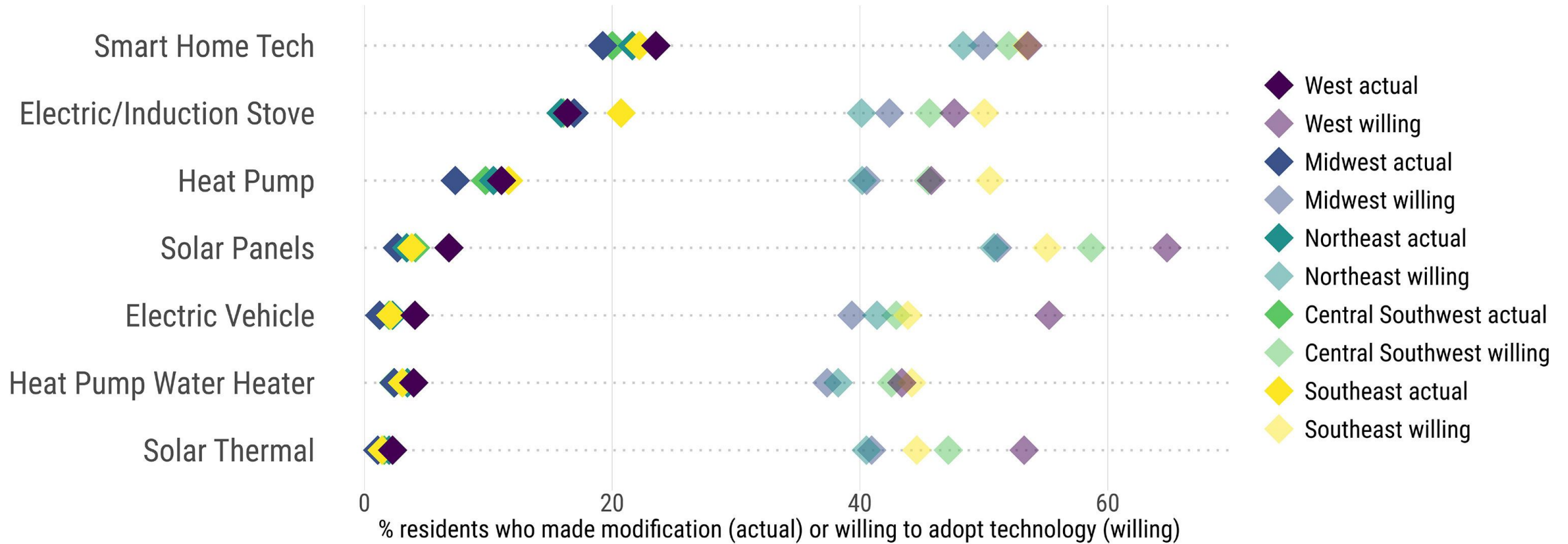
What does decarb technology adoption look like throughout the US?



Bars represent tech adoption relative to the national mean. They are unitless. * indicates significant difference between regions.

Big Gap Between Willingness and Actual Adoption

Technology adoption by region

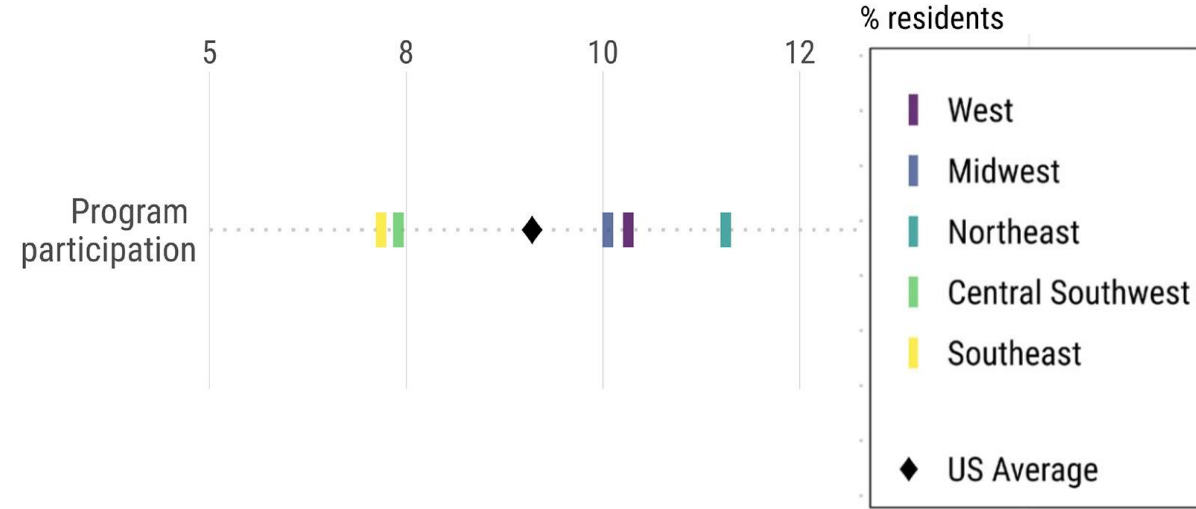


How do we close this gap?

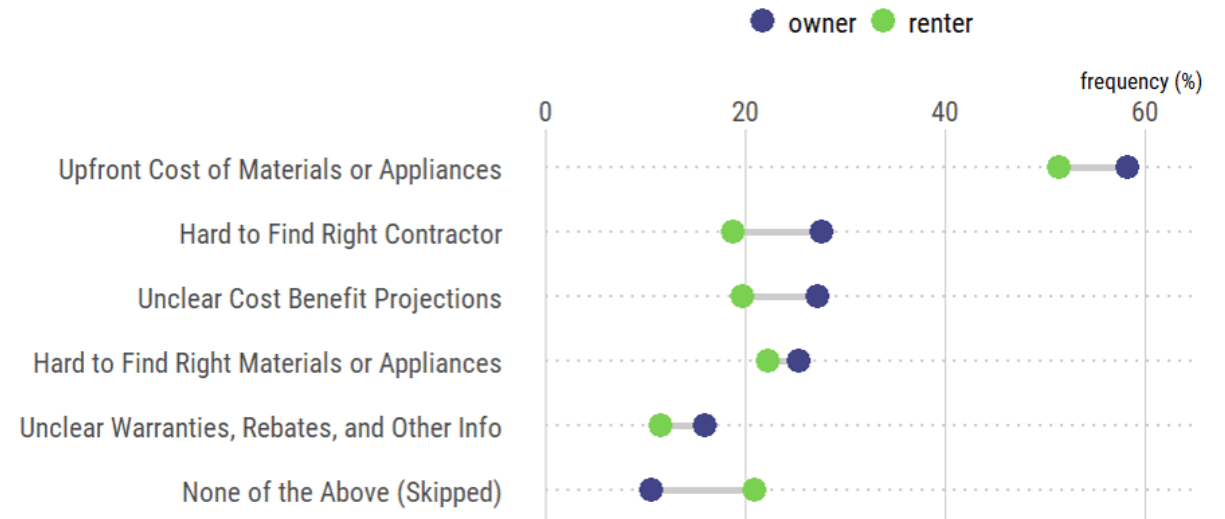
Addressing the Willingness Gap

- Most residents not participating in home energy upgrade programs (~9% nationwide).
- Renter participation is lower (~6%)
- Of the residents that have participated in programs, 71% indicate that the program helped them make the planned upgrade.
- Opportunity for IRA or other well-executed programs to enhance decarbonization technology in residences.
- Opportunity for contractors

A) Program participation



When planning projects, what are some of the barriers that caused you to delay or drop your plans?
by Homeowners (n = 7019)
and Renters (n = 2900)



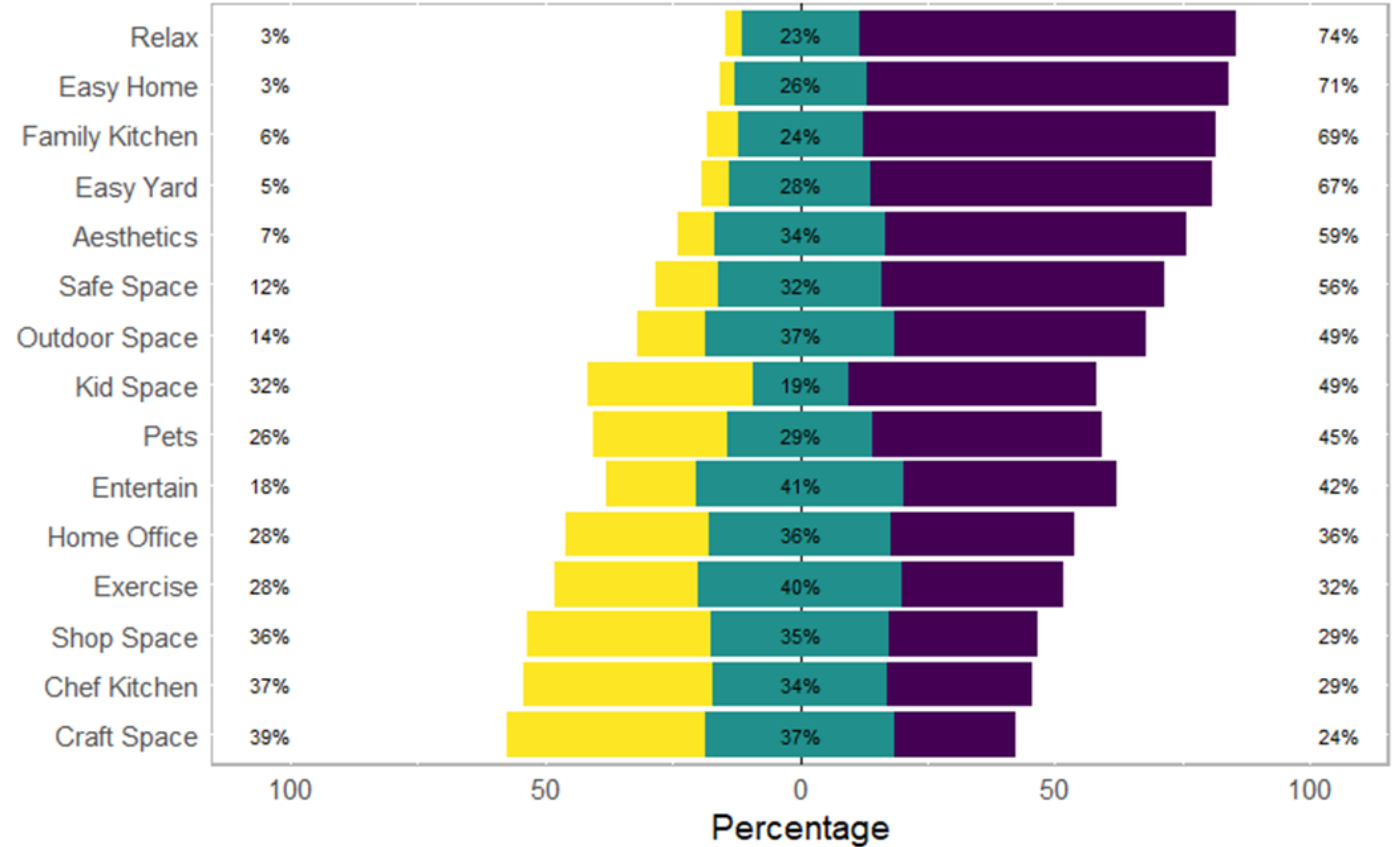
Part 2: Influencing Factors for Upgrades

Ideal Household Environment

We asked what general preferences residents have for their home:

- **Most important:** A place to relax and a home/yard that is easy to care for (74%, 71%).
- **Important:** A family kitchen (69%).
- **Important:** Residents highly value the look of their home (60%).
- **Noted:** Safety and access to outdoor space were noted by about 50% of respondents.

Resident Space Preferences (n=9,919 residents)



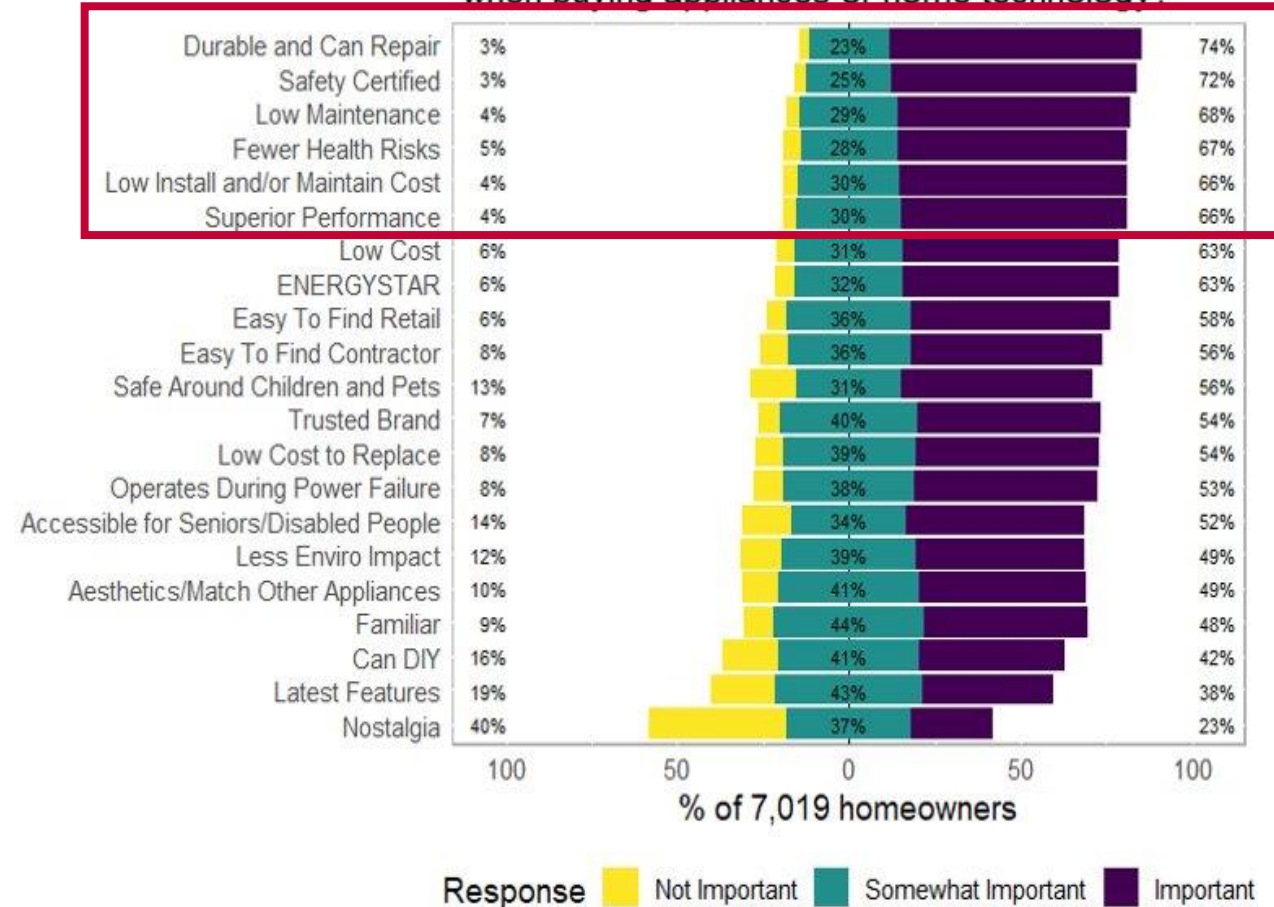
Response ■ Not Important ■ Somewhat Important ■ Important

Not All Decisions are Based on Cost

Homeowners care about more about the top benefits associated with decarbonization and non-energy benefits more than cost!

But for renters – cost was highest rated factor!

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

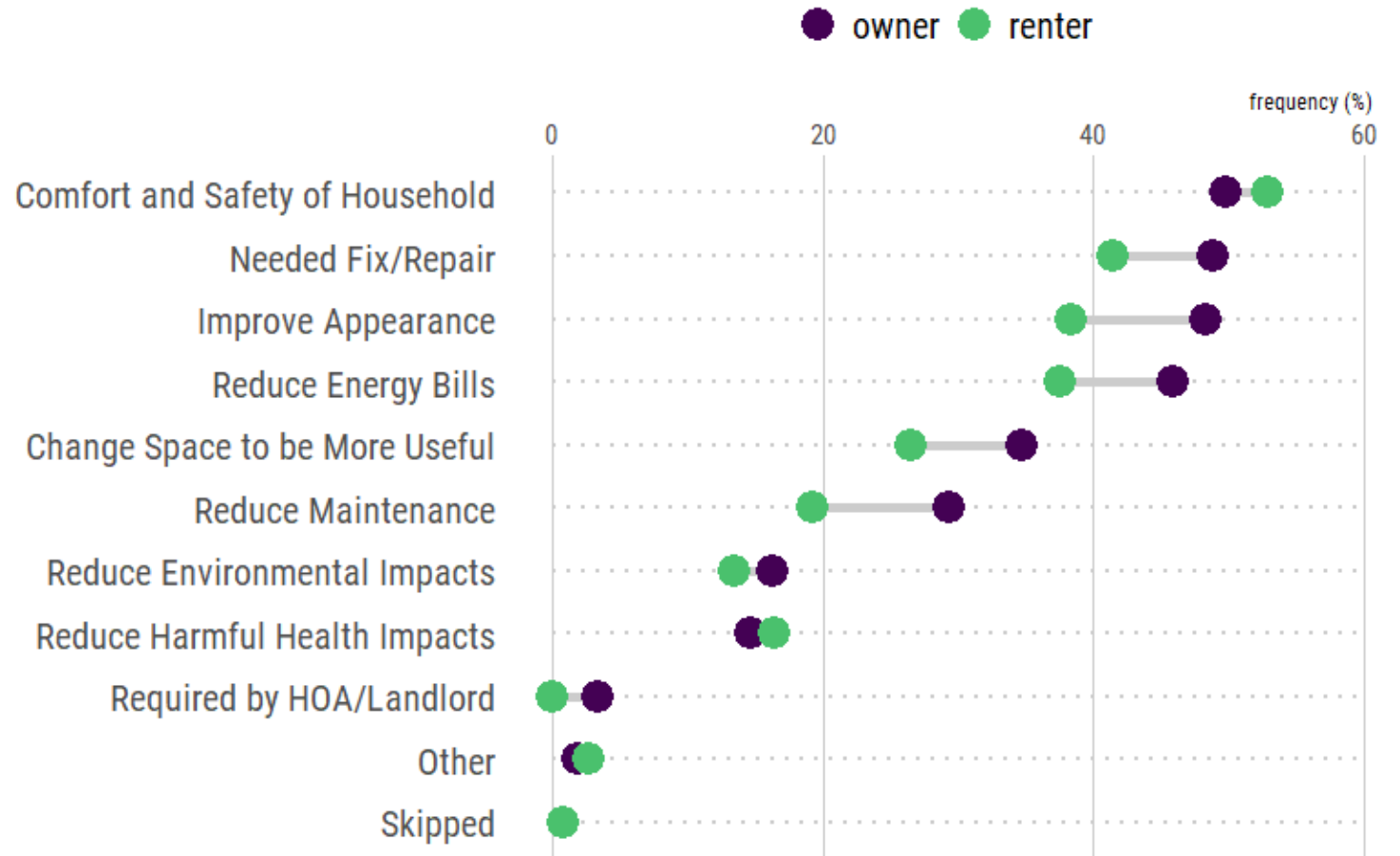


Households Prioritize Many Non-Energy Factors

We asked what influences modifications:

- **Comfort/safety for pets/children** is the most important decision-making factor for home modifications.
- **Repairing/replacing something broken** is second for both homeowners and renters.
- **Improving appearance** and **reducing energy bills** are also important.

Factors Influencing Home Modifications by Homeowners (n = 7019) and Renters (n = 2900)

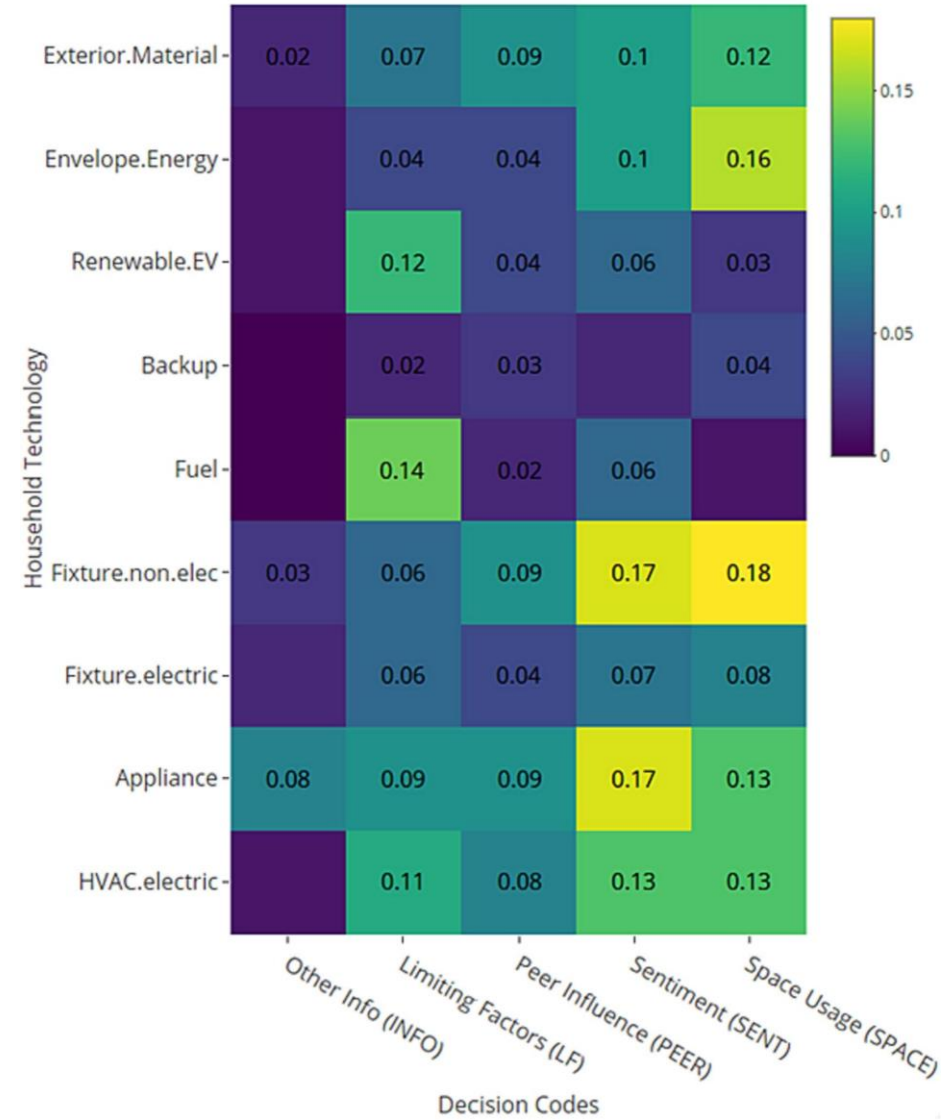


Decision factors and household technology

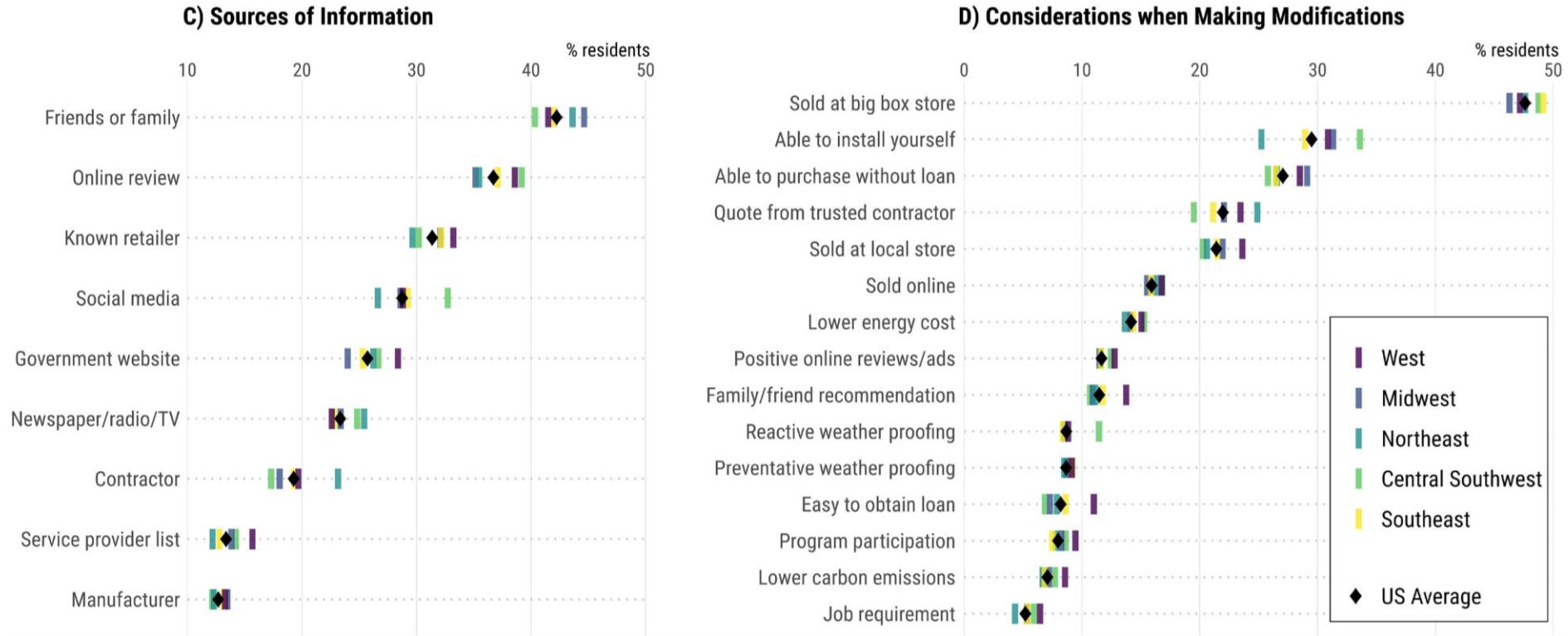
Influential factors when choosing specific technologies:

- How space is used
- Personal sentiment
- Limiting factors/barriers (often economic and contractor related)
- Peer influence

Technology Correlation with Decision Codes by Paragraph
(n = 104 participants, n.paragraphs=13951)



Information Sources and Considerations



- Households rely on friends/family, online/social media, and big box stores for information

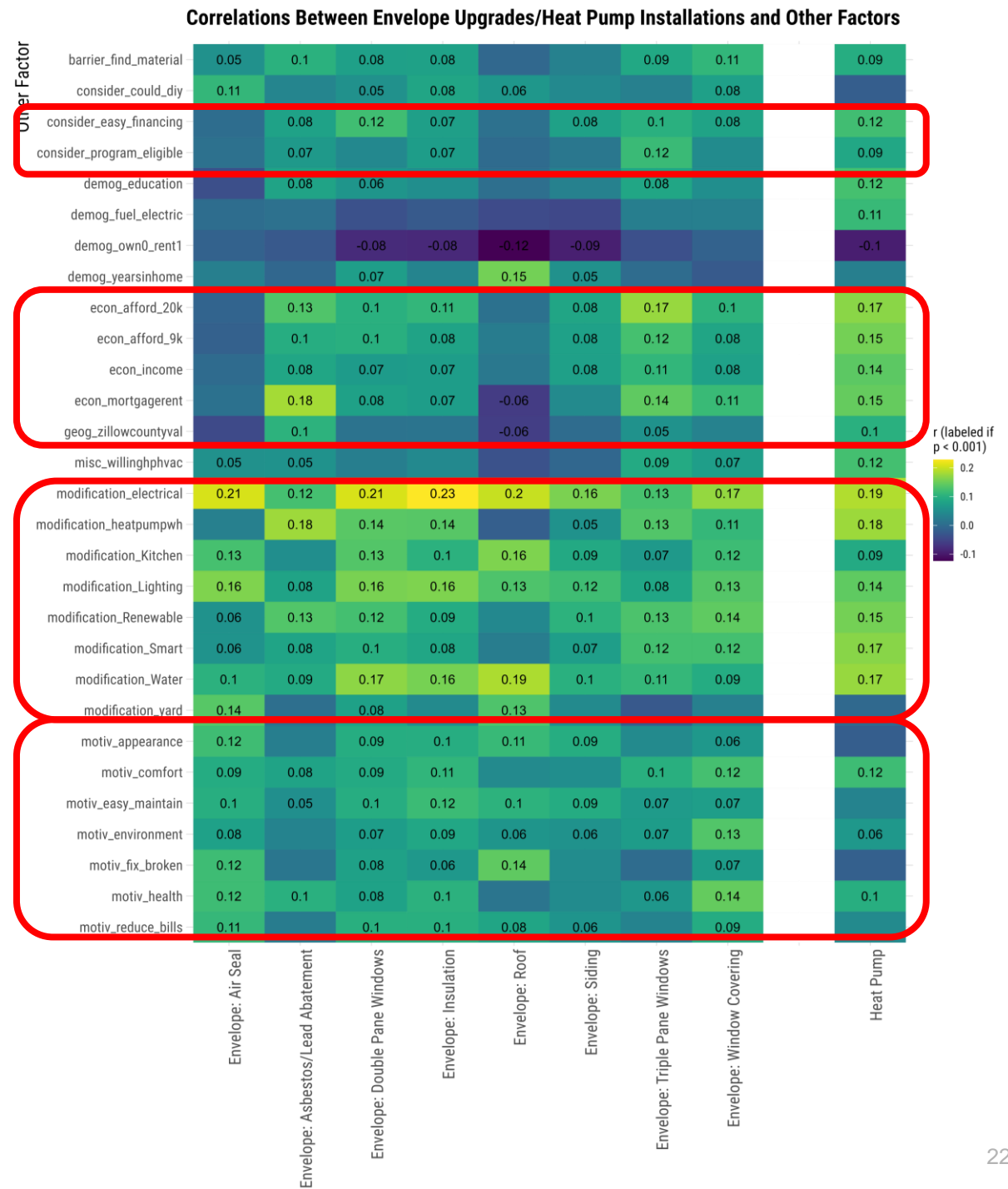
Regionally Targeted Recommendations

| Region | Primary Policy Recommendations |
|-----------------------|--|
| West | <ul style="list-style-type: none"> •Focus program messaging on reducing health and environmental impacts as it relates to technology choice. •Promote induction stove installation, highlighting occupant health. •Promote heat pump technologies to households without cooling. |
| Midwest | <ul style="list-style-type: none"> •Increase heat pump technology uptake. •Focus program messaging on increasing comfort and reducing energy bills. •Promote decarbonization technologies through friends and family programs. •Emphasize safety in messaging around electrification. |
| Northeast | <ul style="list-style-type: none"> •Develop robust heat pump initiatives, pair with efforts to minimize the need for increasing electric panel capacities in homes. •Utilize contractor pipeline for sharing information on decarbonization options. •Emphasize cooling capacity of heat pumps as alternative to portable AC. |
| Central Southw est | <ul style="list-style-type: none"> •Promote heat pump technologies as alternatives to electric furnaces and electric resistance water heating. •Focus program messaging on reducing energy bills. •Use social networks as a source of information for decarbonization efforts. |
| Southeast | <ul style="list-style-type: none"> •Increase program focus on heat pump water heaters and continue momentum in heat pump efforts •Pilot more demand response through promotion of smart thermostats/energy management systems. •Tie program incentives to others focused on home aesthetics. |
| All Regions | <ul style="list-style-type: none"> •Enhance efforts to reach renter households. •Promote decarbonization through big box stores. •Develop programs to reduce upfront costs. |

Preliminary Results: Envelopes & Heat Pumps

We looked at what factors motivate households to upgrade envelopes and adopt heat pumps:

- Most correlations occur between tech and combo projects, especially electrical upgrades.
- Household economics, programs and ability to finance plays a role.
- Many non-energy factors also are important!





**Pacific
Northwest**
NATIONAL LABORATORY

Thank You!

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Approaches to Behavior Change in Residences

The Challenge:

- Household behavior and technology adoption patterns are difficult to predict.
- Even with incentives, many energy-efficient technologies and home upgrades have had slow uptake.

| Typology | Intervention | Examples |
|----------|---|---|
| Stick | Regulation Prohibiting Behavior | Ban on natural gas installations in new home construction |
| | Regulation Requiring Behavior | Building codes requiring high levels of energy efficiency |
| Carrot | Reward for Discouraging Behavior | Utility rate system tiered to actual energy use |
| | Reward for Engaging in Behavior | Subsidy for installing energy efficient appliances |
| Sermon | Provide Information About Energy Conservation | Utility information campaigns |
| | Provide Feedback About Household Energy Use | Utility inserts, smart meters |

Typology from Vedung et al. (1998); Harrison (1998) and Pacheco-Vega (2020) are examples of how typology applies to environmental regulation and governance