

The Decarbonization Melting Pot: Household Energy Adoption & Preferences

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Current PNNL Project Team



Energy Efficiency & Renewable Energy

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



Original research article

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

Decisions and decision malvarse Manning

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In Progress: Technology Deep Dives, Publish Dataset, Equity/Vulnerability Analysis Energy Policy 185 (2024) 113940
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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



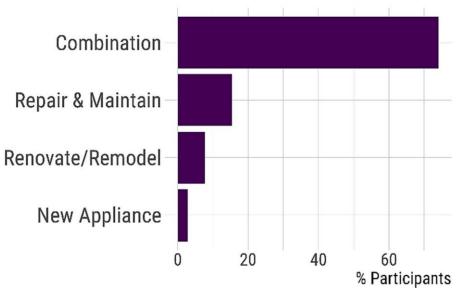


Source: https://www.energystar.gov/



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.



a) Project Type (n = 104 participants)

Each Retrofit Unique Challenge

- Old construction, little to no insulation and air sealing, thus increasing infiltration
- Dated systems, inefficient appliances

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- 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

Source: RMLS



- 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





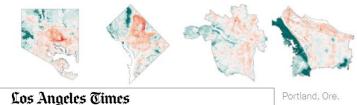
The New York Times

Pacific Northwest

Equity & Vulnerability To Climate Extremes



By Nadja Popovich and Christopher Flavelle Aug. 9, 2019



Portland, Ore. Albuquerque



Building **Energy Equity** barriers (e.g., increased energy burden) Built Vulnerability Environment barriers barriers (e.g., increased (e.g., less efficient presence of chronic Low-Income homes) health issues) and Vulnerable **Households** Urban Technology Landscape Access barriers barriers (e.g., (e.g., cooling/air increased ambient cleaning) heat & UHI)

f The luxury air business is booming — as many Californians s on a scorching struggle to breathe



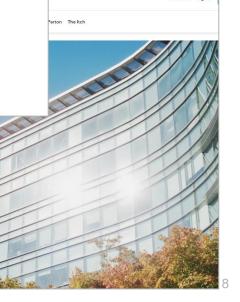
A firefighting jumbo jet is dwarfed by the smoke from the Apple fire in the hills above Beaumont on Aug. 1. (Luis Sinco / Los Anzeles Times)

ANNALS OF A WARMING PLANET OCTOBER 18. 2021 ISSUE

SEVENTY-TWO HOURS **UNDER THE HEAT** DOME

A chronicle of a slow-motion climate disaster that became one of Oregon's deadliest calamities.

> By James Ross Gardner October 11 2021



Newsletter Sign



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).

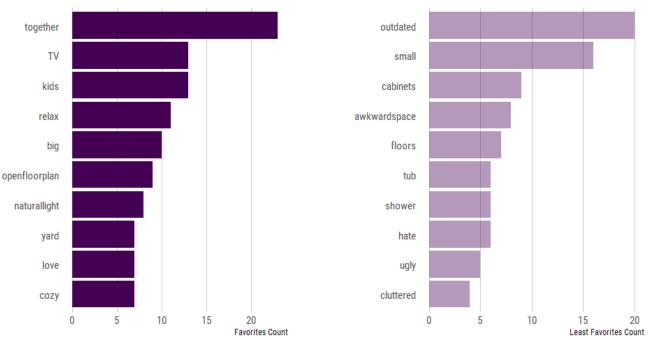
Frequency of Home Modifications by Homeowners (n = 7019) and Renters (n = 2900) 🔴 owner 🔵 renter frequency (%) 20 Yard Interactive Effect. Kitchen Visible Tech & Spaces Lighting Heating and Cooling Interactive Effect. Hot Water Appliances Behind-the-scenes Tech. **Building Materials** Electrical Effects realized Smart Technology over time. Behind-the scenes Tech. Renewable Energy or EVs No Changes

Skipped

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."

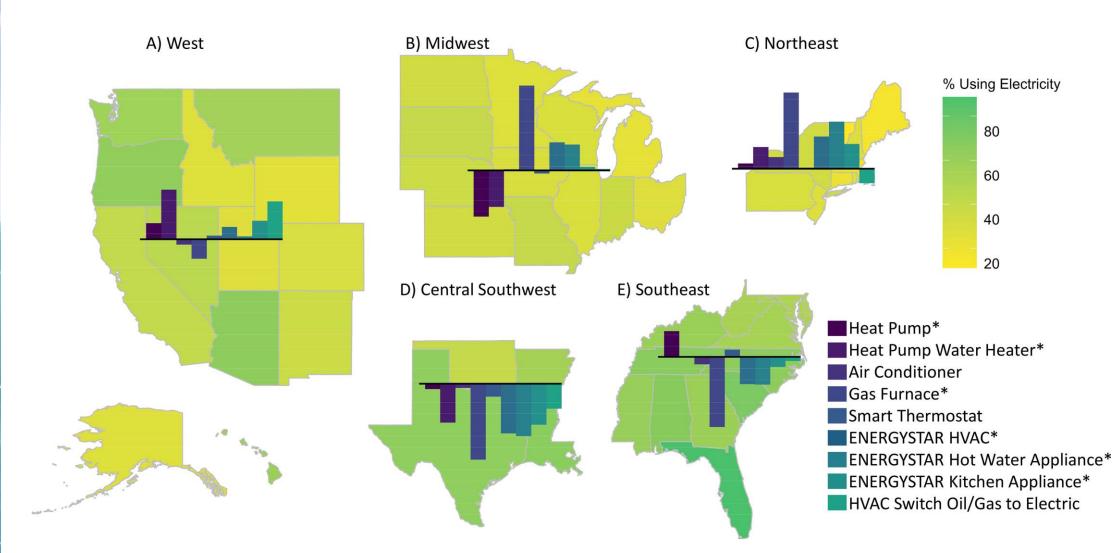
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Most Common Descriptors Associated with Favorites/Least Favorites

- Respondent 237 (GA)

What does decarb technology adoption look like throughout the US? Northwest



Pacific

Big Gap Between Willingness and Actual Adoption

Technology adoption by region Smart Home Tech West actual Electric/Induction Stove West willing Midwest actual Heat Pump Midwest willing Northeast actual Solar Panels Northeast willing **Electric Vehicle** Central Southwest actual <Central Southwest willing Heat Pump Water Heater Southeast actual Southeast willing Solar Thermal 60 20 % residents who made modification (actual) or willing to adopt technology (willing)

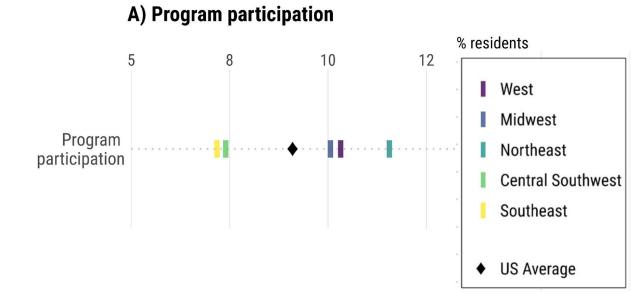
How do we close this gap?

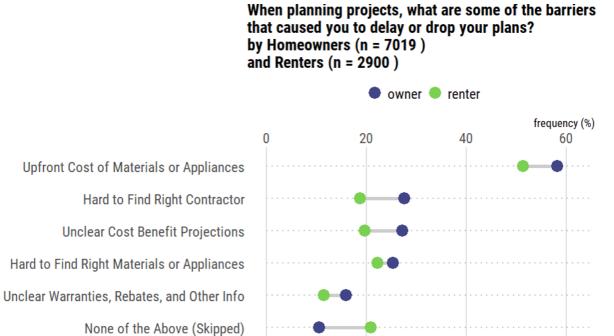
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- Most residents not participating in home energy upgrade programs (~9% nationwide).
- Renter participation is lower (~6%)
- Of the residents that have participated in programs, 71% indicate that the program helped them make the planned upgrade.
-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







Part 2: Influencing Factors for Upgrades

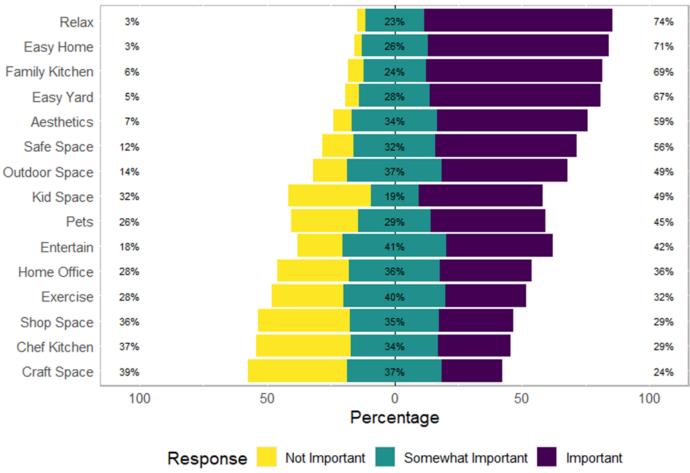


Ideal Household Environment

We asked what <u>general</u> <u>preferences</u> 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)





Not All Decisions are Based on Cost

Homeowners care about more about the top benefits associated with decarbonization and nonenergy benefits more than cost!

But for renters – cost was highest rated factor!

Durable and Can Repair 3% 74% Safety Certified 3% 72% Low Maintenance 68% 4% Fewer Health Risks 67% 5% Low Install and/or Maintain Cost 66% 4% Superior Performance 4% 66% Low Cost 6% 63% ENERGYSTAR 6% 63% Easy To Find Retail 6% 58% Easy To Find Contractor 56% 8% Safe Around Children and Pets 13% 56% 31% Trusted Brand 7% 54% Low Cost to Replace 54% 8% **Operates During Power Failure** 53% 8% Accessible for Seniors/Disabled People 14% 52% 34% Less Enviro Impact 49% 12% Aesthetics/Match Other Appliances 10% 41% 49% Familiar 9% 44% 48% 42% Can DIY 16% 41% Latest Features 19% 38% Nostalgia 23% 40% 50 100 100 50 % of 7,019 homeowners Not Important Somewhat Important

Response

How important are the following factors

when buying appliances or home technology?

Important



Households Prioritize Many Non-Energy Factors

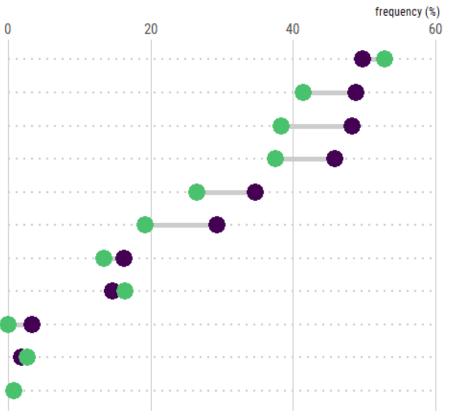
We asked what influences modifications:

- 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.

Comfort and Safety of Household Needed Fix/Repair Improve Appearance Reduce Energy Bills Change Space to be More Useful Reduce Maintenance Reduce Environmental Impacts Reduce Harmful Health Impacts Required by HOA/Landlord Other Skipped

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

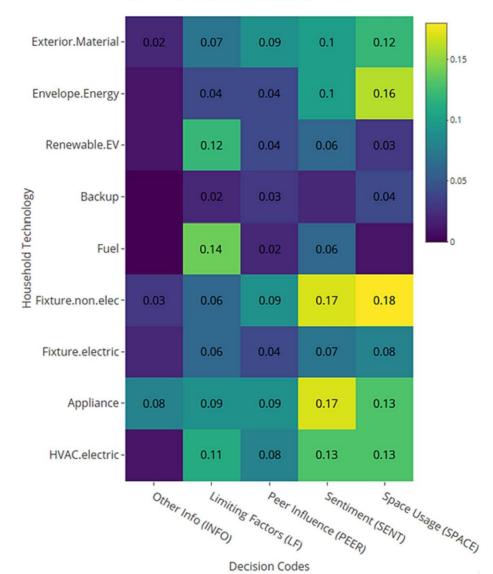
🕨 owner 🌒 renter





Decision factors and household technology

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



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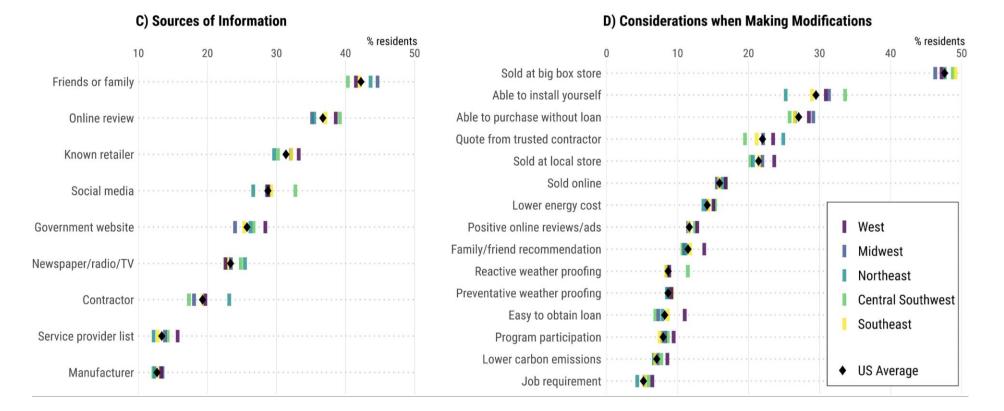
Influential factors when choosing <u>specific technologies</u>:

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



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Information Sources and Considerations



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

Regionally Targeted Recommendations

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Region	Primary Policy Recommendations	
West	 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	 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	 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		
Southeast	 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	 Enhance efforts to reach renter households. Promote decarbonization through big box stores. Develop programs to reduce upfront costs. 	



Pacific Northwest

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!

Correlations Between Envelope Upgrades/Heat Pump Installations and Other Factors barrier_find_material 0.05 0.08 0.09 0.08 0.11 0.11 0.05 0.08 0.08 consider_could_div consider easy financing 0.08 0.12 0.07 0.08 0.1 0.08 0.12 consider_program_eligible 0.07 0.07 0.12 0.09 0.08 demog_education 0.11 demog_fuel_electric demog_own0_rent1 0.15 0.07 0.05 demog_vearsinhome econ_afford_20k 0.13 0.1 0.11 0.08 0.17 0.17 0.1 econ afford 9k 0.1 0.1 0.08 0.08 0.12 0.08 0.15 0.08 0.07 0.07 0.08 0.11 0.08 0.14 econ_income -0.06 0.14 0.18 0.08 0.07 0.11 0.15 econ_mortgagerent 0.1 -0.06 0.05 0.1 (labeled if aeoa zillowcountyval p < 0.001) misc_willinghphvac 0.05 0.05 0.09 0.07 0.12 0.2 nodification_electrical 0.21 0.12 0.21 0.23 0.2 0.16 0.13 0.17 0.19 0.1 0.18 0.14 0.05 0.18 0.0 0.14 0.13 0.11 nodification_heatpumpwh 0.09 -0.1 modification_Kitchen 0.13 0.13 0.16 0.09 0.07 0.12 0.1 0.16 0.08 0.16 0.16 0.13 0.12 0.08 0.13 0.14 modification Lighting nodification_Renewable 0.06 0.13 0.12 0.09 0.1 0.13 0.14 0.15 0.06 0.1 0.08 0.07 0.12 0.12 0.17 modification_Smart 0.1 0.16 0.19 0.17 0.09 0.17 0.1 0.11 0.09 modification_Water 0.08 modification var 0.13 0.09 0.12 0.1 0.11 0.09 0.06 motiv_appearance 0.09 0.08 0.1 0.12 motiv_comfort 0.09 0.11 0.12 0.1 0.1 0.12 0.1 0.09 0.07 0.07 motiv_easy_maintain 0.08 0.07 0.09 0.06 0.07 0.13 0.06 motiv environment 0.06 0.14 0.12 0.08 0.07 motiv_fix_broken 0.06 0.06 0.12 0.08 0.14 0.1 motiv health motiv reduce hill elope: Sidina Envelope: Roof invelope: 22



Thank You!

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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