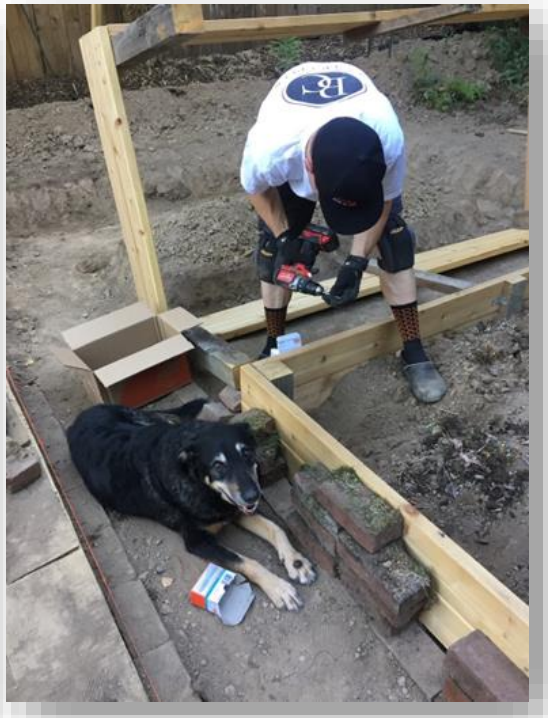
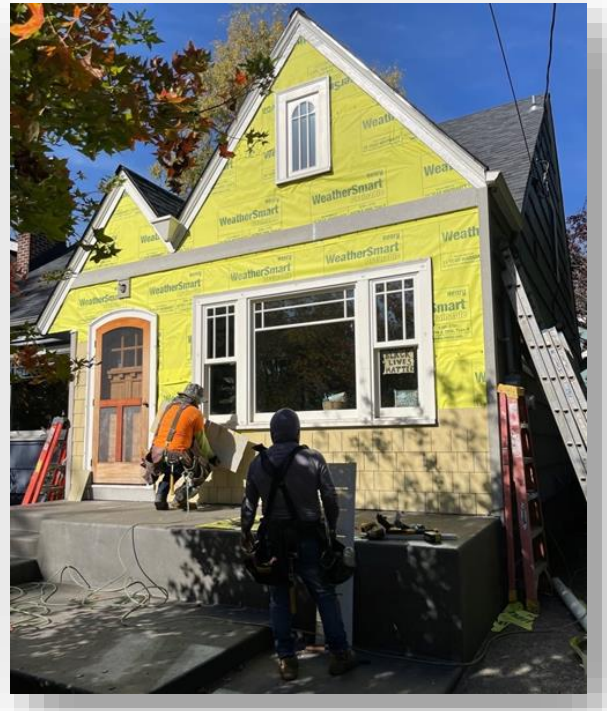
# Advancing Residential Building Decarbonization: Understanding Home Occupant Decision-Making Dynamics



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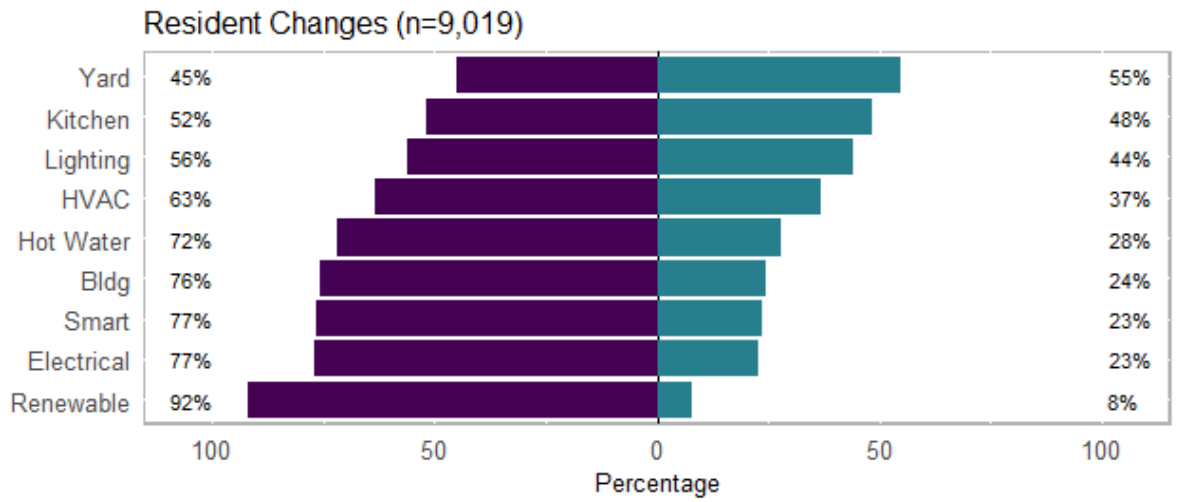
WBS # 3.4.6.73

# Project Summary

## Objective and outcome

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




## Team and Partners

PNNL Team (lead):

Chrissi Antonopoulos, PhD (PI), Building Scientist
Saurabh Biswas, PhD, Social Scientist
Tracy Fuentes, PhD, Terrestrial Ecologist
Adrienne Rackley, Economist
Kieren McCord, PhD, Post-doc, Data Scientist

Illume Advising (contractor):
60 min. semi-structured interviews in 121 homes in four states.
Additional Collaborators identified on Slide 21.

## Stats

Performance Period: FY2022-2023, and beyond

DOE budget: FY2022: $750k, FY2023: $400k

Milestone 1: Data-driven summary/lit review, 1/31/22
Milestone 2: IRB approval, subcontracting, 1/31/22
Milestone 3: Interview/survey data collection complete, 10/30/22
Milestone 4: Draft findings in journal and/or technical report, 3/23

# Problem

*Nearly **two-thirds** of residential homes in the U.S. were **constructed before 1992**, when DOE implemented conservation measures that were later formalized in codes. These homes **consume >21% of primary energy** and produce **20% of total GHGs**. Reducing energy use is a critical need to meet decarbonization goals, but **technology solutions alone will not ensure uptake**.*

Understanding household energy-related behaviors across socio-demographic groups is important, but we still know too little about how households make energy-related decisions. A large-scale social-science study focused on program enhancement can help address this gap.


*Transition from inefficient existing building stock*

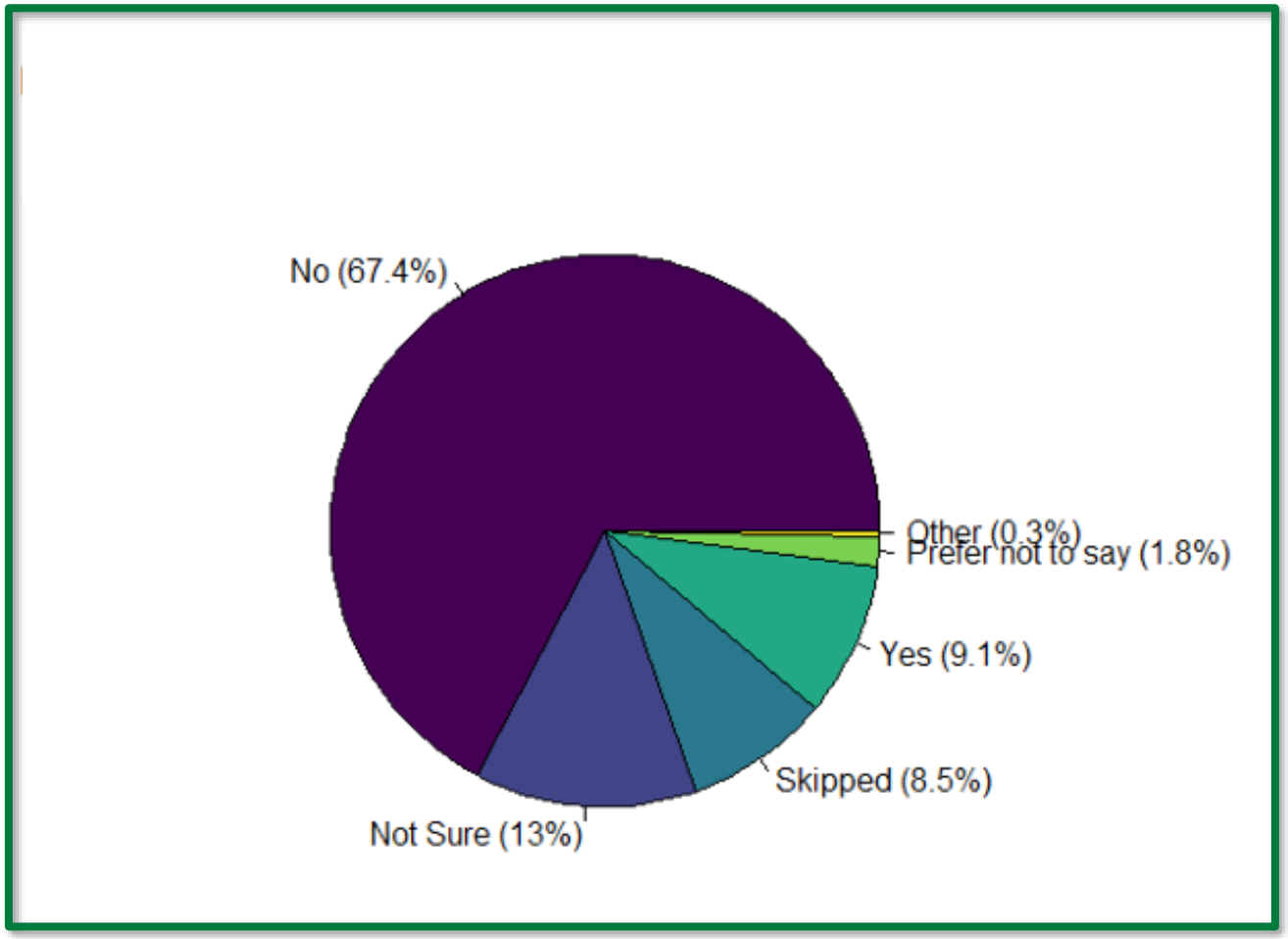
*To highly efficient or net zero energy performance retrofits*

# Alignment and Impact

Project goal aims to significantly advance decarbonization efforts in the residential sector by developing targeted information for decarbonization upgrades based on actionable information from the public (***target 20% increase in EE program success***).

Impact Activities:

- Conducted **largest-scale study** at the household level in the U.S.
- Quantify **decision-making considerations** made by low income and under-represented groups.
- Better **understand renter dynamics**, barriers and opportunities.
- Quantify impacts of increased technology adoption and **identify largest opportunities**.
- Publish and **disseminate findings**.
- Publish a publicly-available **dataset for future research**.



# Approach

U.S. Department of Energy's Building Technologies Office (BTO) 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 renovations and upgrades?

2. How do different residential stakeholders decide to buy and use key technologies relevant for residential electrification?

# Overall Research Approach

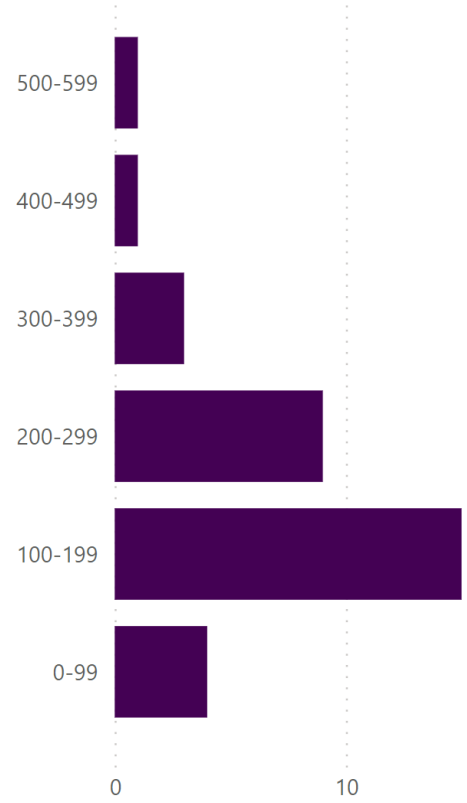
## Primary Research Activities:

- **HVAC manufacturer outreach** to learn about customer discovery and marketing.
- **Reviewed literature** to identify previous study findings.
- **Developed research protocols**, sampling strategy, participant criteria, analytical methods and gained *Institutional Review Board (IRB)* approval.
- **Conducted in-depth, semi-structured interviews** with 121 households to better understand purchasing decisions, use patterns and energy efficiency perceptions and behavior.
- **Executed national-scale survey** to 10,000 homeowners and renters, using questions developed from interview outcomes.
- **Assembled an international external advisory board**, comprised of experts in the field to inform methods and research protocol.
- **Synthesize results** from interviews and survey to inform decarbonization strategies.
- **Collaborate** with relevant stakeholders to enhance findings and expand decarbonization efforts.

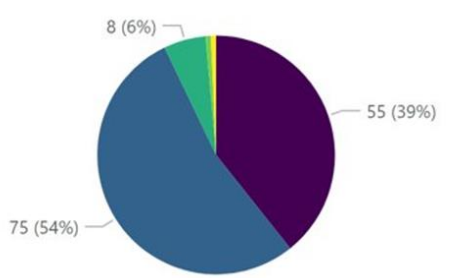
# Interview Approach

## Interview Methods:

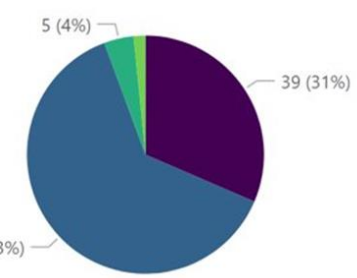
- **121 semi-structured interviews** with residents in warm climates (30 AZ, 31 GA) and cold climates (30 IL, 30 MA).
- Learn how **specific circumstances** (life stage, finances, personal relationships, preferences) interact with building characteristics, info availability, and market to **produce specific home decisions.**
- Use **qualitative and quantitative methods** to analyze interview transcripts – coding, keyword analysis, narrative analysis.

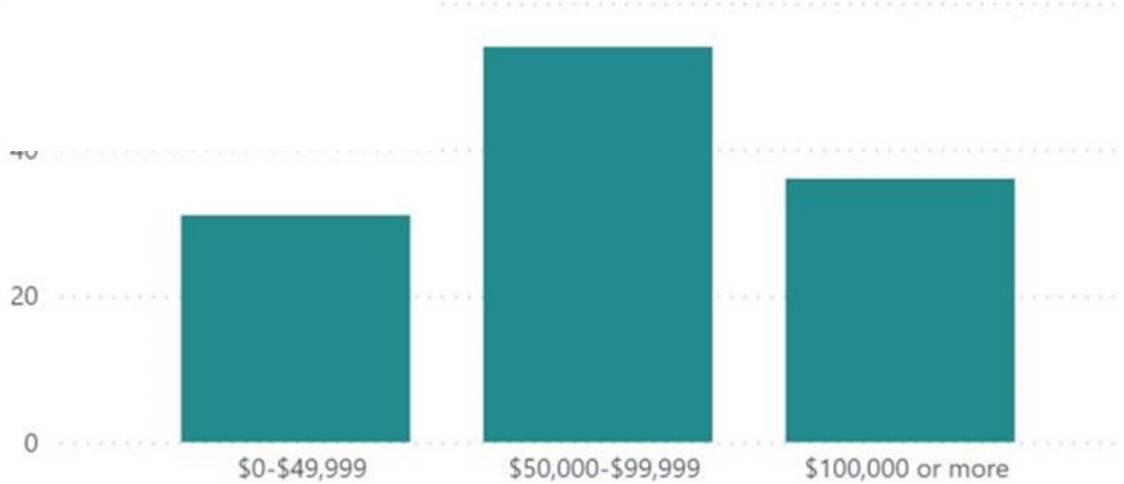


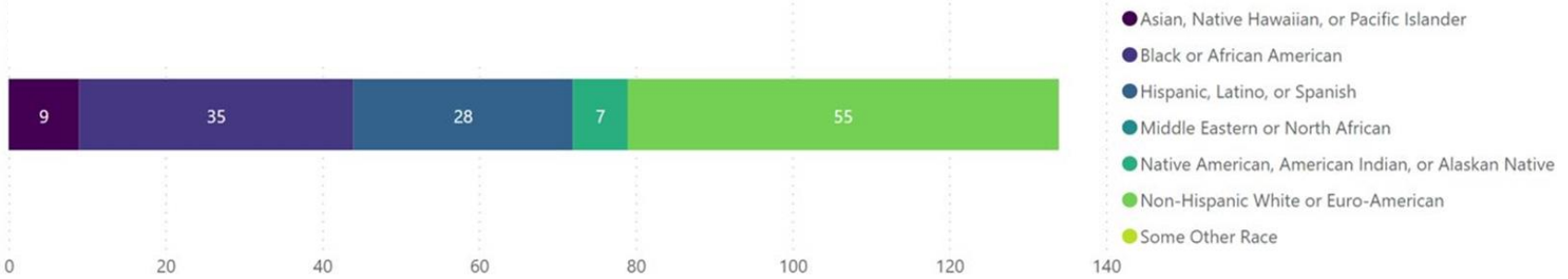

Space Heating Fuel




Water Heating Fuel



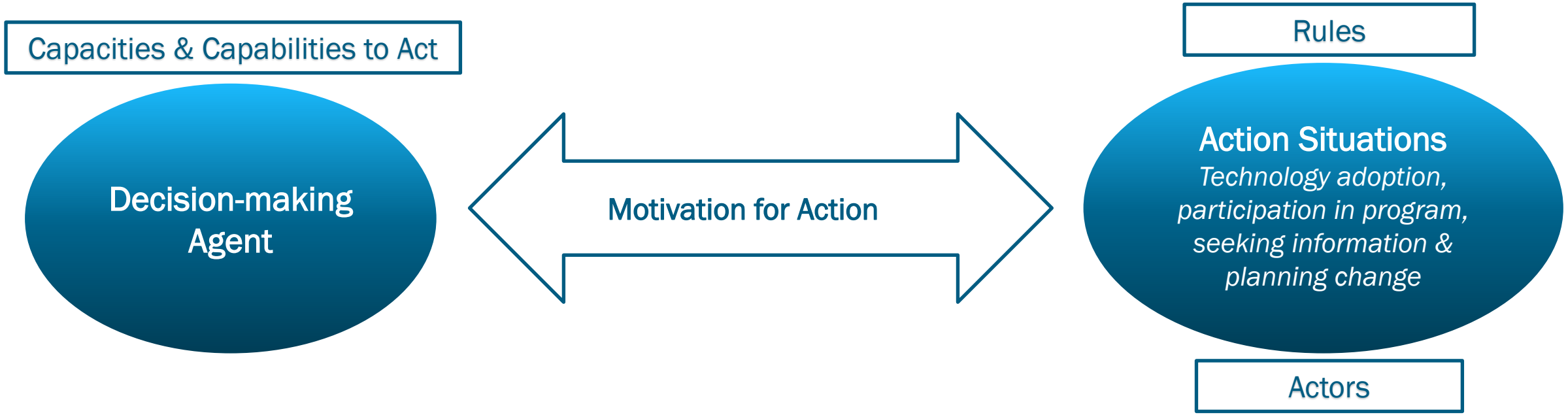



# Interview Approach

## Interview Framework:

Household decision-making has three interacting factors:

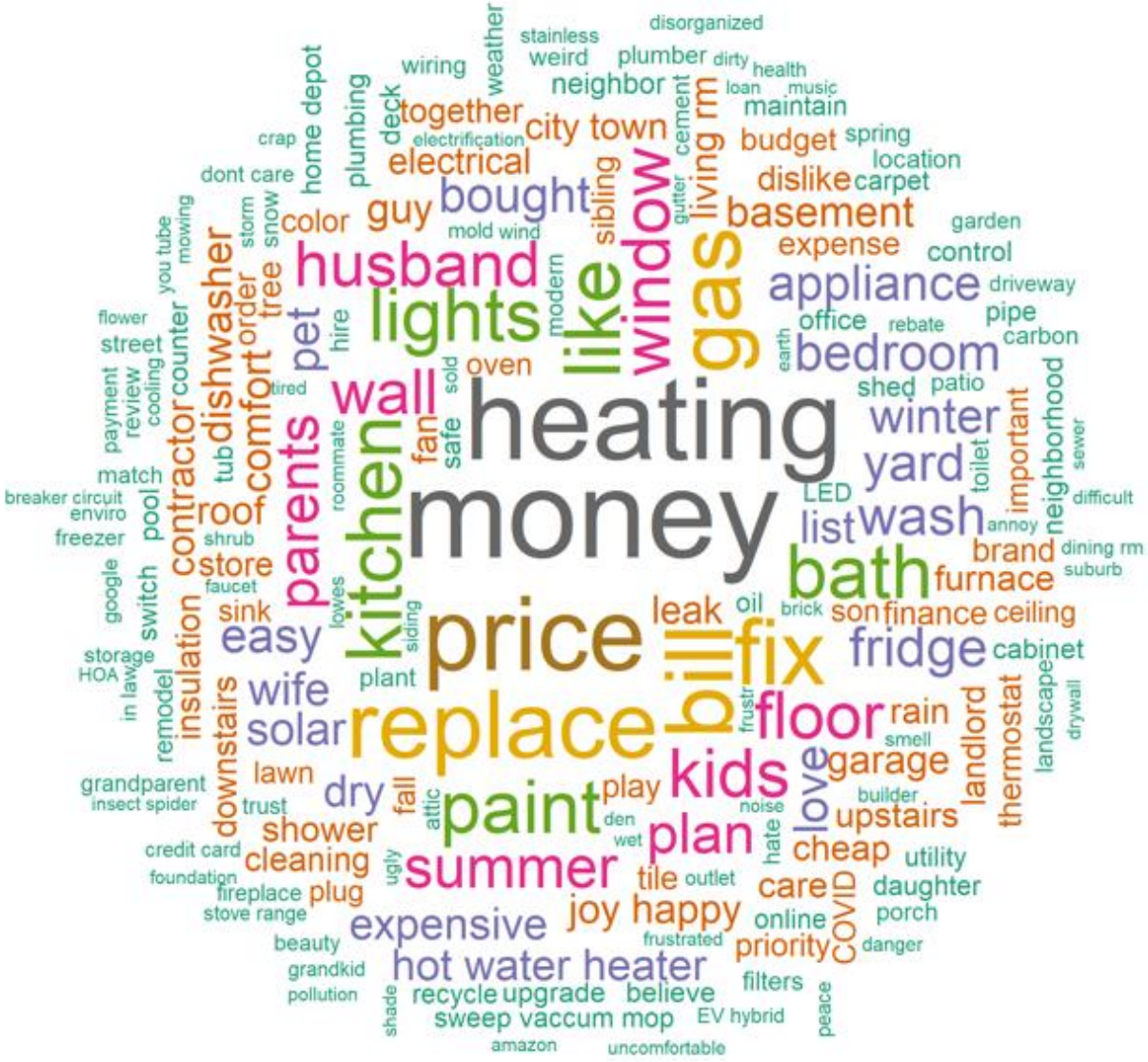
1. Decision-making agent, or the ability to act, with a myriad of factors that place conditions/constraints on agency
2. Placemaking dynamics, which translate agency to an action, also can be defined as the motivation for action.
3. A final action situation, where a concrete household decision is made, also defined as the outcome.



# Survey Approach

Survey Methods:

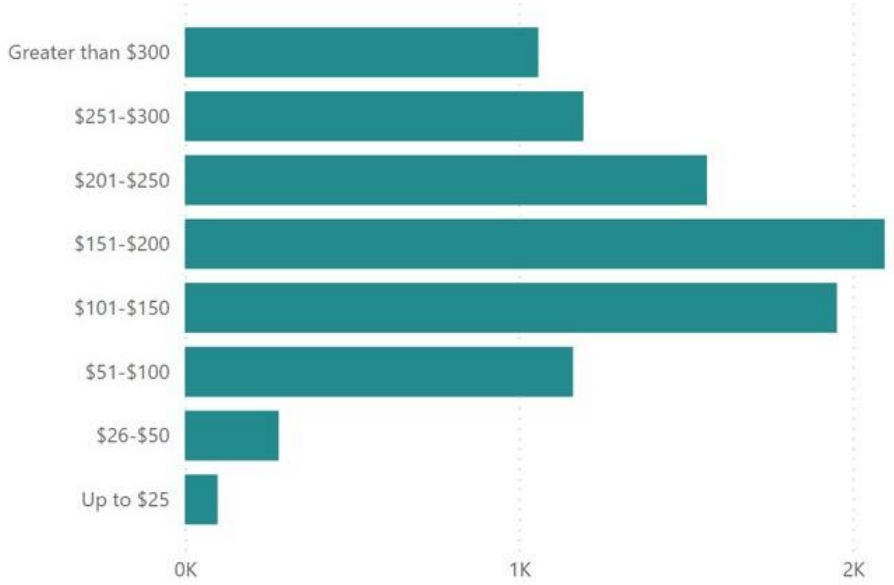
- Development of the national survey was informed by qualitative and quantitative analysis of a sample set of interview results.
- Homeowners and renters took slightly different surveys.
- ~50 multiple choice questions.
- Survey was released on August 12, 2022, and closed on October 17, 2022.
- Recruitment conducted by Qualtrics.
- 10,000 respondents distributed in all 50 states.
- Available online in English and Spanish.
- Partial survey responses not counted, though respondents could skip some questions.

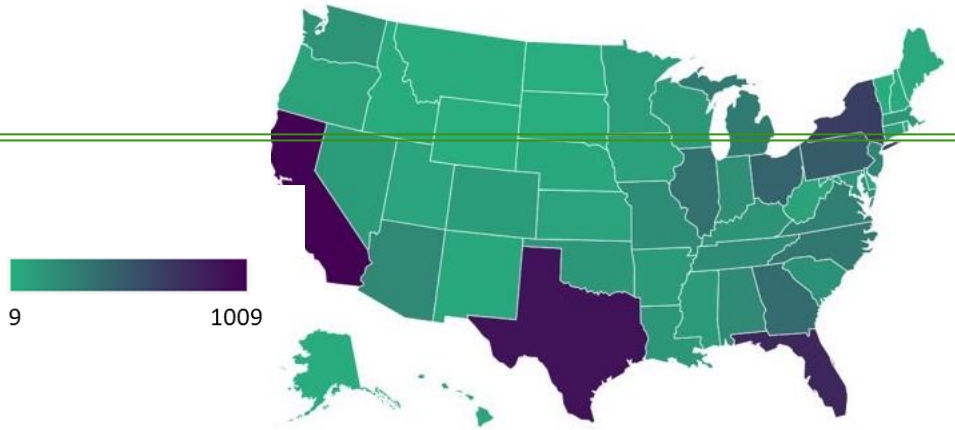


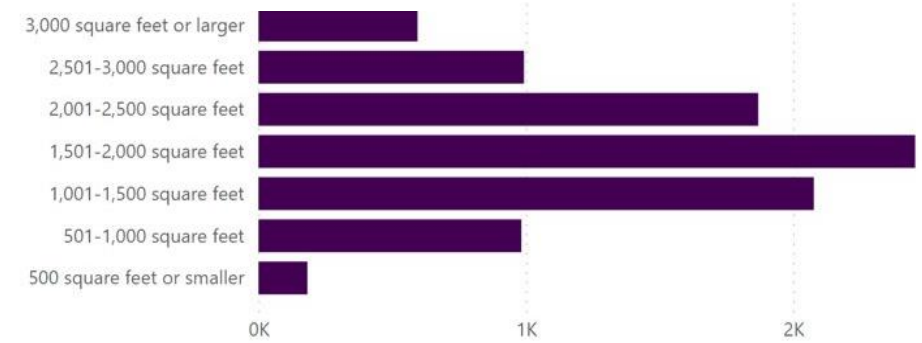
# Survey Approach

Survey demographic criteria were set to match US Census and BTO/EERE decarbonization goals

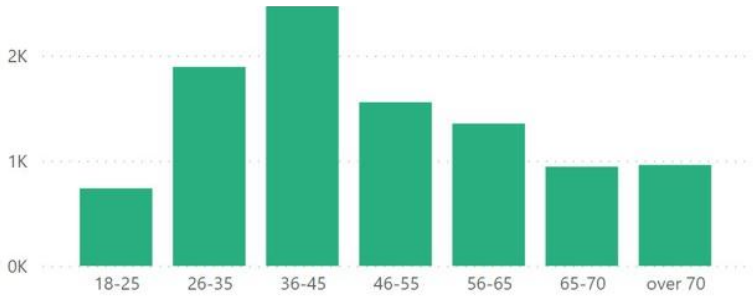
- 70% homeowners, 30% renters
- Even regional distribution throughout the US.
- Focus on higher response rates from low-income, non-white populations.



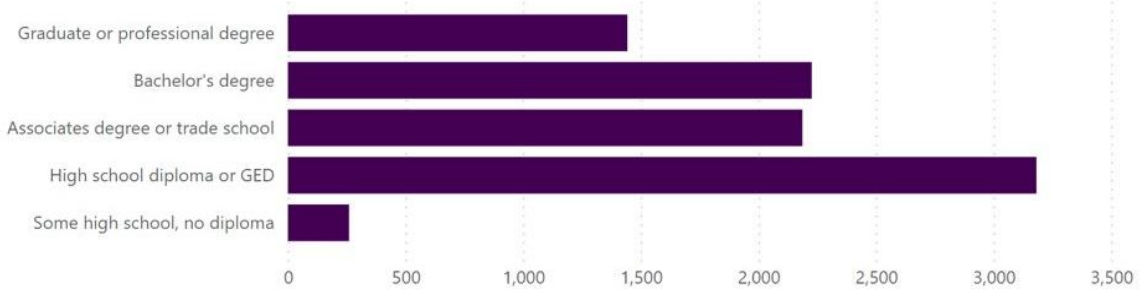




## Respondent Age




## Respondent Education



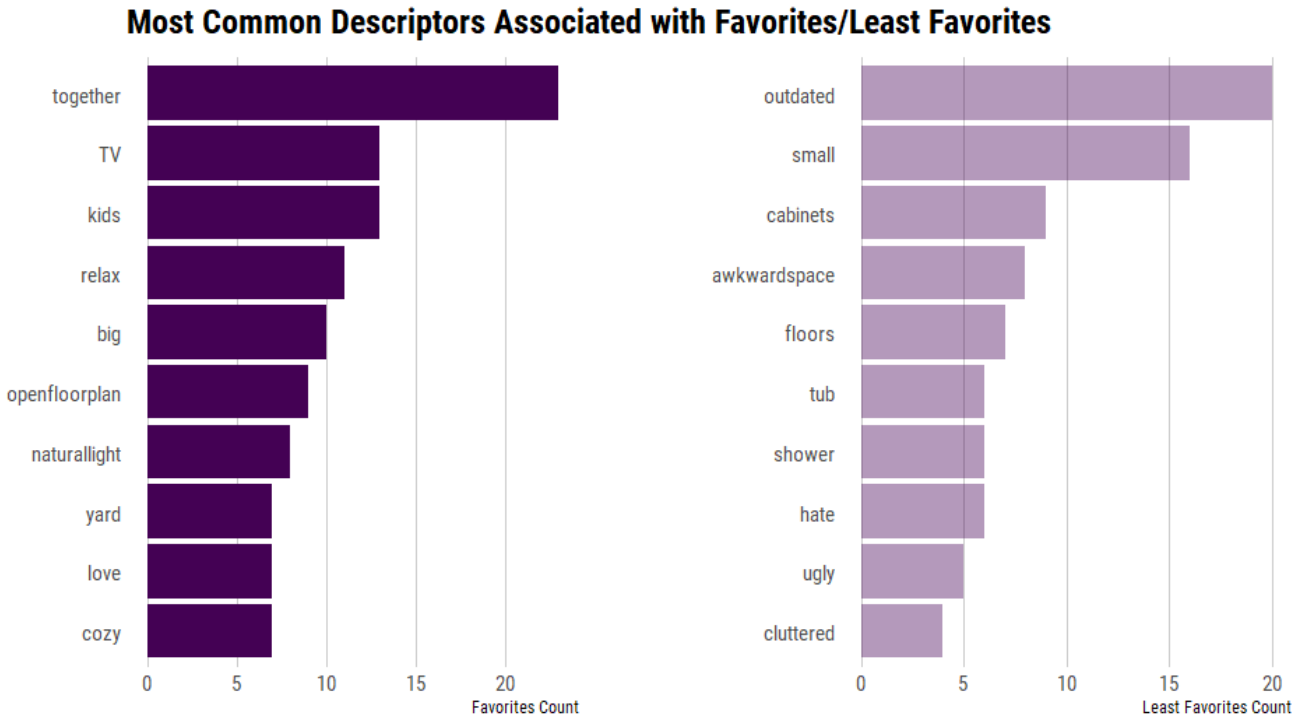
# Progress and Future Work

## Major Interview Findings:

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."

*- Respondent 237 (GA)*



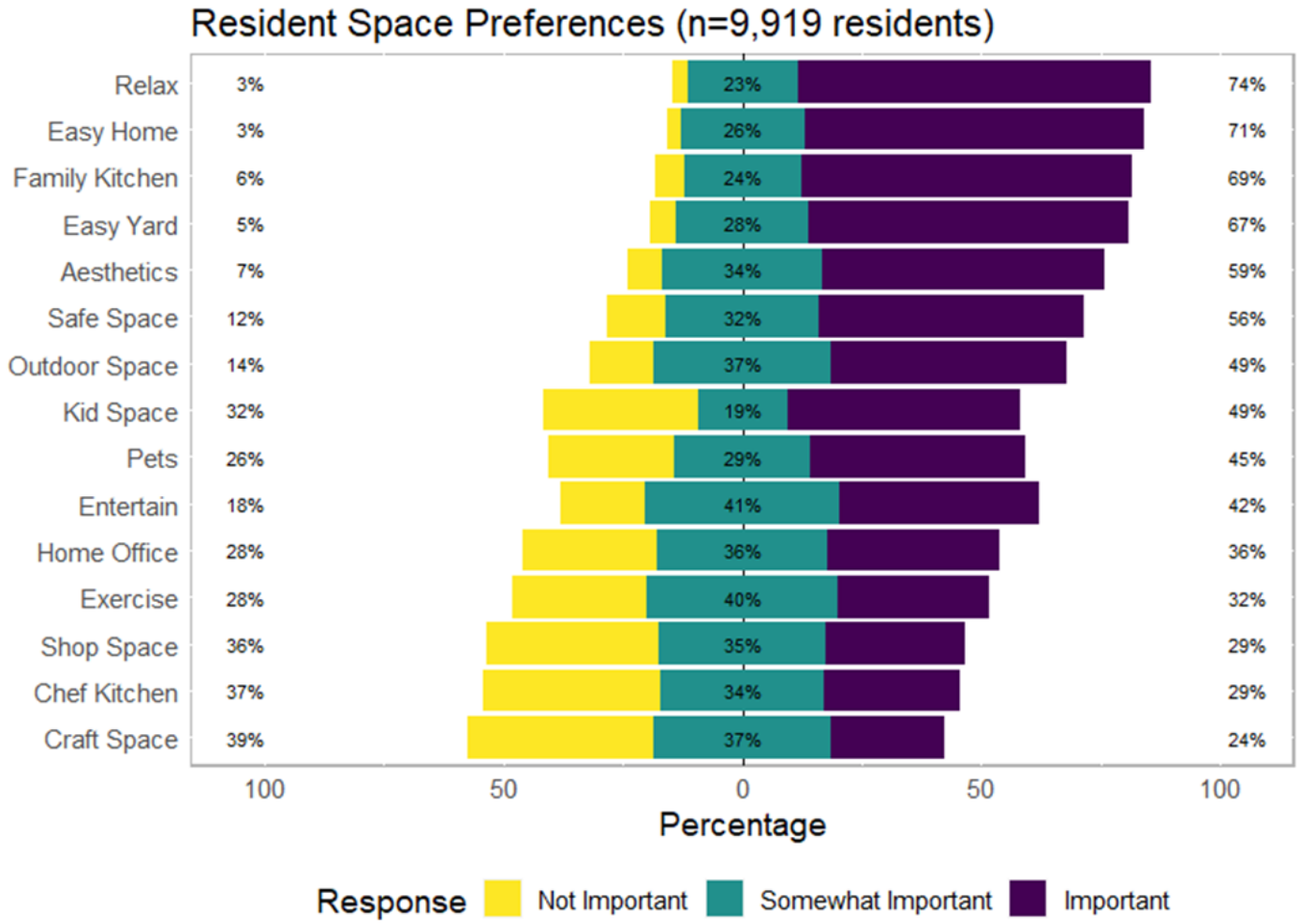

Frequency of most common words used to describe the favorite (dark purple) and least favorite (light purple) home themes.

# Progress and Future Work

## Major Survey Findings To Date:

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**: Homeowners highly value the look of their home (60%).
- **Noted**: Safety and access to outdoor space were noted by about 50% of respondents.

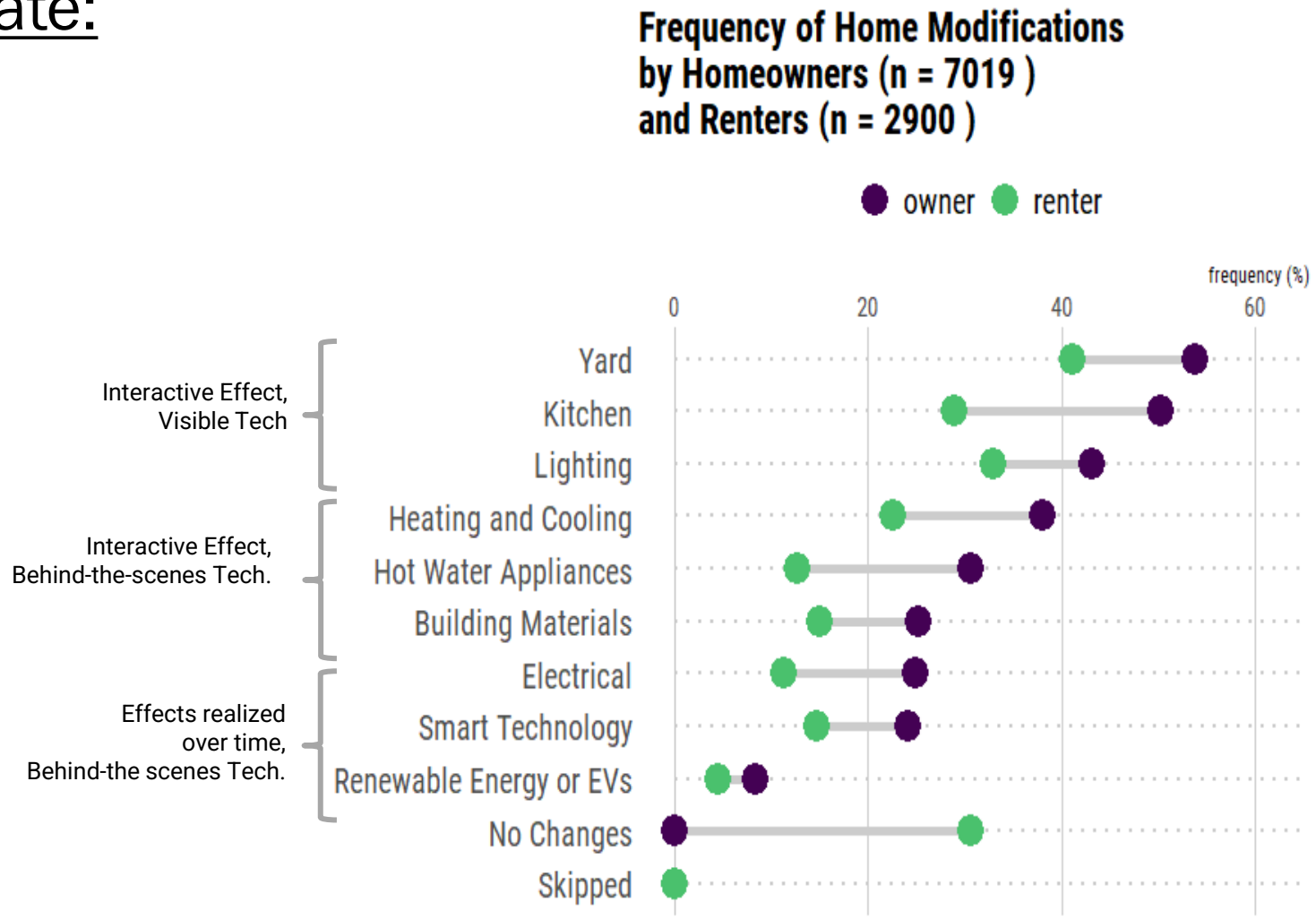


# Progress and Future Work

## Major Survey Findings To Date:

We asked about what types of modifications occupants have made:

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

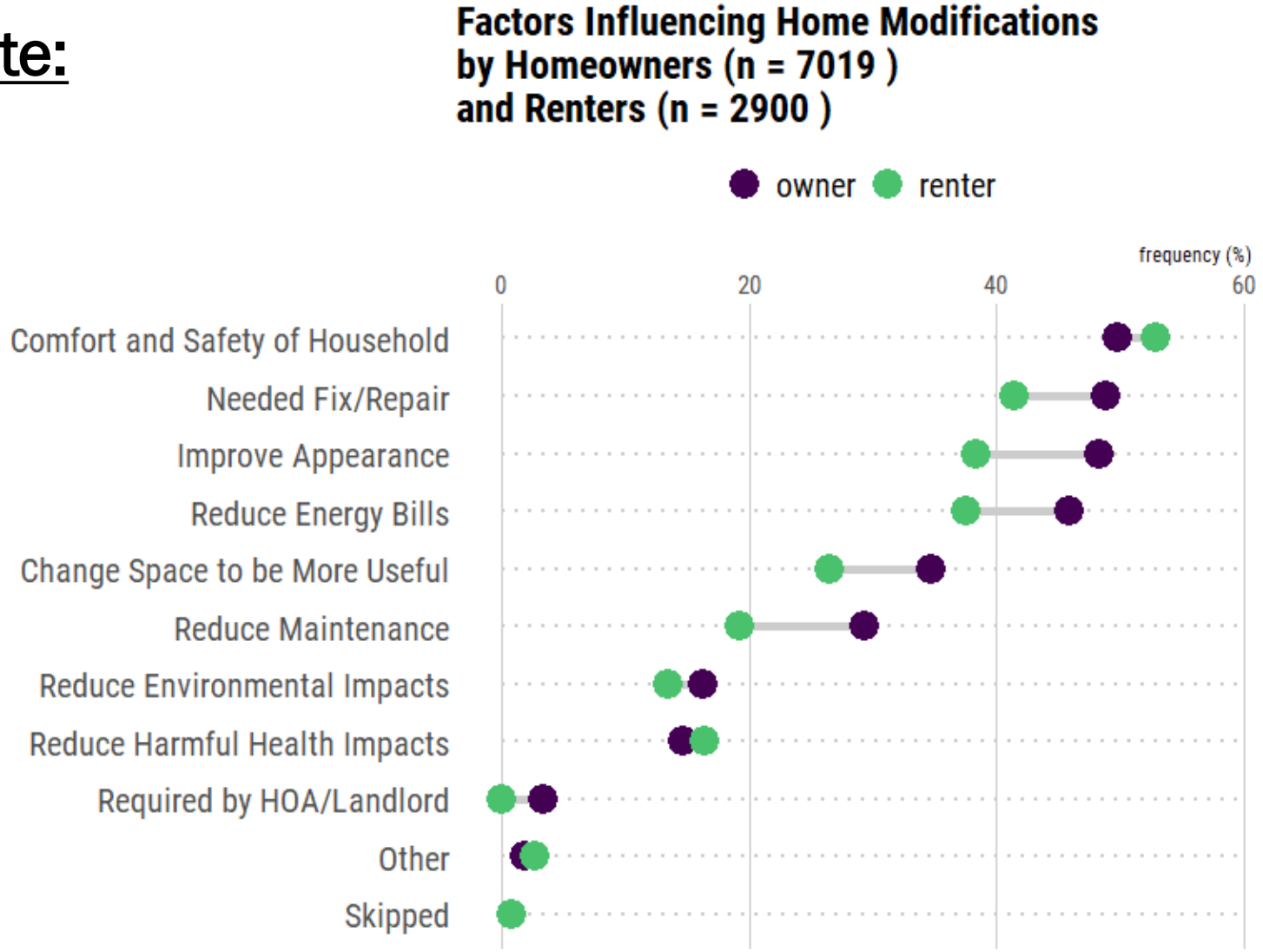


# Progress and Future Work

## Major Survey Findings To Date:

We asked what influences modifications:

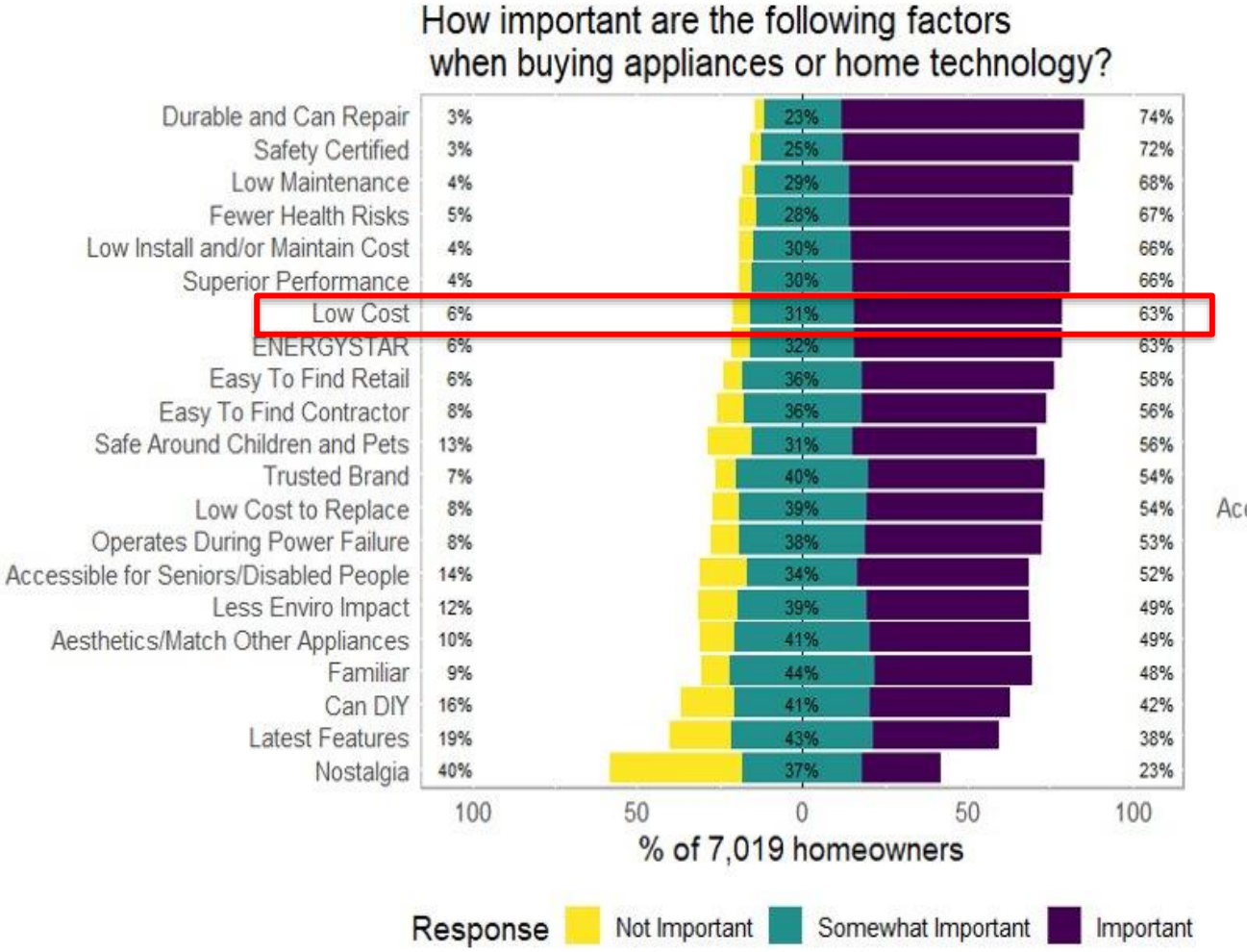
- **Comfort/safety for pets/children** is the most important decision-making factor for home modifications.
- **Repairing/replacing something broken** is second for both homeowners and renters.
- **Improving appearance** and **reducing energy bills** are also important.
- Reducing environmental impacts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



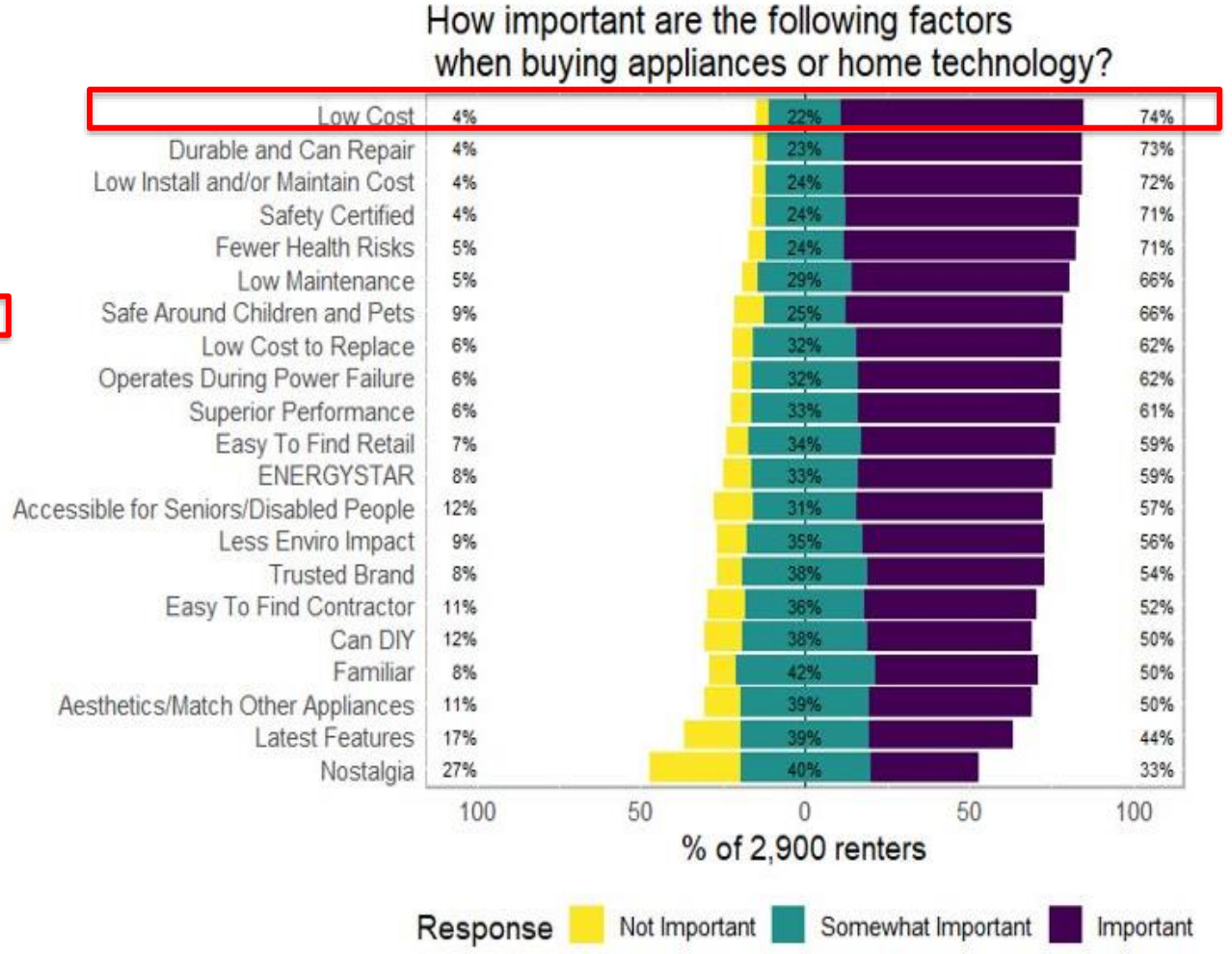
# Progress and Future Work

## Not all decisions are based on cost:

### Homeowners




### Renters

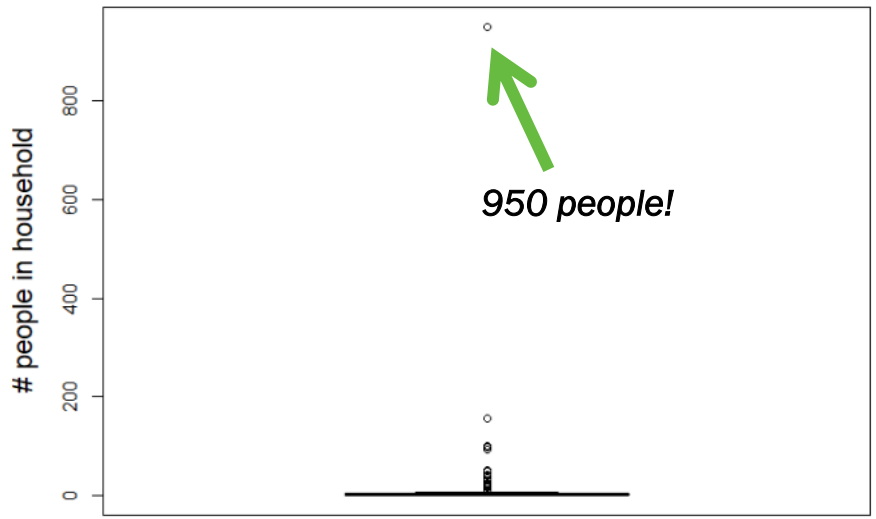


# Progress and Future Work

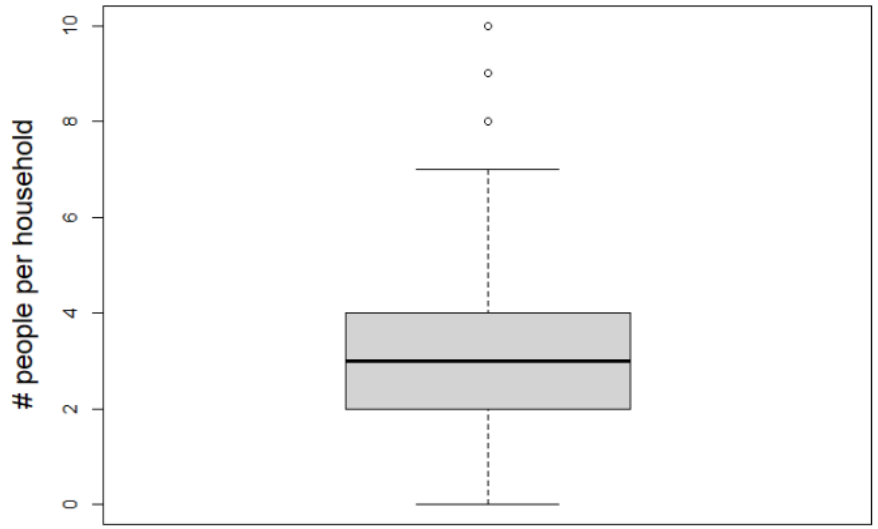
## Obstacles/Lessons Learned:

- 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 personally identifiable information (PII) while keeping a locator variable present both opportunities and drawbacks.
- Survey question design does not always yield data best suited to analyze easily with other questions.

Need to get from this:




To this:



# Progress and Future Work

Complete:

- Clean data, develop final dataset for sharing and publishing.
- Finalize framework for collaborative analysis of PNNL and LBNL survey instruments.

In Progress:

- Publish data as open source.
- Finalize interview results and submit manuscript.
- Finalize survey results and submit manuscript to Energy Research and Social Science.
- Synthesize both sets of results and publish as a PNNL Technical Report.
- Publish findings for collaborative PNNL/LBNL analysis.

Future Work:

- Help entities craft messaging for decarb programs.

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

# Thank You

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WBS # 3.4.6.73

# REFERENCE SLIDES

# Project Execution

| | FY2022 | | | | FY2023 | | | | FY2024 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Planned budget | $750k | | | | $450k | | | | TBD | | | |
| Spent budget | $750k | | | | $200k | | | | TBD | | | |
| | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| **Past Work** | | | | | | | | | | | | |
| Q1 Milestone: Data Collection Plan | ◆ | | | | | | | | | | | |
| Q2 Milestone: Data Driven Summary/Literature Review | | ◆ | | | | | | | | | | |
| Q2 Go/No-Go: IRB Approval/Subcontracts Placed | | ◆ | | | | | | | | | | |
| Q4 Milestone: Initial Data Complete | | | ◆ | ◆ | | | | | | | | |
| Q1 Milestone: High-Leve Initial Findings | | | | | ◆ | | | | | | | |
| **Current/Future Work** | | | | | | | | | | | | |
| Q2 Milestone: Assessment & Analysis: Journal Manuscript | | | | | | ◆ | | | | | | |
| Q2 Milestone: Collaboration Framework | | | | | | ◆ | | | | | | |
| Q3 Milestone: Communication Plan | | | | | | | ◆ | | | | | |
| Q3 Milestone: Draft Technical Report | | | | | | | | ◆ | | | | |

# Team

**Chrissi Antonopoulos, PhD**
Background: Building science, IAQ, Urban design & planning, Human factors, Data analysis, Methods
Roles: PI, Study design, PM, Formal analysis, Study dissemination, Writing

**Saurabh Biswas, PhD**
Background: Sociotechnical systems, energy transitions, human-centered research
Roles: Literature review, Research methods, Survey design, Formal analysis, Writing

**Tracy Fuentes, PhD**
Background: Ecology, Urban Design & Planning, Homeowner Decision Making
Roles: IRB Approval, Interview Questions, Survey Questions, Interview Memos & Coding, Interview and Survey Data Management and Analysis

**Adrienne Rackley**
Background: Socioeconomic impact assessment, financial & statistical modeling, affordable/public housing, equity & justice
Role: Literature review, manufacturer outreach, interview/survey development & testing, data analysis & visualization

**Kieren McCord, PhD**
Background: Architectural Engineering, Acoustics, Construction, Virtual Reality, Education
Roles: Survey Data Management and Analysis, Data Visualization

Collaborators:

- Illume Advising – Conducted 121 in-home 60 min. interviews
- Lawrence Berkeley National Laboratory – Residential Group – collaborating to compare LBNL contractor survey with PNNL occupant survey and to disseminate survey results.
- Harvard Joint Center for Housing Studies – collaboration to integrate survey results into JCHS research.

# Advisory Committee

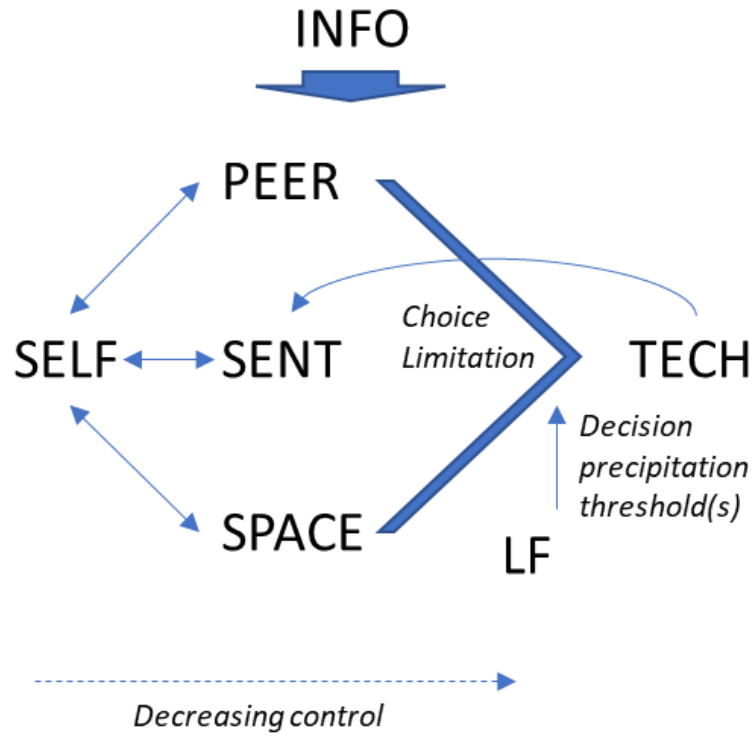
## Study Advisory Board:

| Name | Title | Affiliation | Sector |
|---|---|---|---|
| Timothy Echols | Vice-Chairman | Georgia Public Service Commission | Government - Regulation |
| KC Boyce | Vice President | Escalent | Consulting |
| Tracey Woods | Vice President | American Association of Blacks in Energy | Nonprofit |
| Alden Hathaway | Program Director | Pond | Engineering |
| Juliet Shavit | President | SmartMark Communications | Consulting |
| James Jackson | Director - Channel Development | Emerson | HVAC |
| Cory Fox | Partnership Manager | Ecobee | HVAC |
| Matthew Lipson | Consumer Insights Manager | Energy Systems Catapult (UK) | Consulting |
| Tom Hargreaves | Associate Professor | University of East Anglia (UK) | Academia |
| Mithra Moezzi | Air Pollution Specialist | California Energy Commission | Government - Regulation |
| Loren Lutzenhiser | Professor | Portland State University | Academia |
| Renee Guillory | Energy Innovation Program Consultant | Arizona Public Service | Utilities |
| Carlos Martin | Director, Remodeling Futures | Harvard University | Academia |
| Michelle Moore | CEO | Groundswell | Nonprofit |
| Emily Robichaux | SharePower Manager | Groundswell | Nonprofit |
| Joshua Loughman | Senior Analyst | Salt River Project | Utilities |
| Owen Howlett | Customer Experience Strategist | Sacramento Municipal Utility District | Utilities |
| Alexis Cureton | Clean Energy & Equity State Lead | Natural Resource Defense Council | Nonprofit |
| Lauren Bates | Senior Manager, Market Research | Northwest Energy Efficiency Alliance | Utilities |
| Monica Neukomm | Technology Manager – GEB | U.S. DOE | Government |
| Holly Carr | Solar Decathlon Director | U.S. DOE | Government |

# Interview Framework: Household energy choices are part of a resident's decisions to achieve emotional and functional wellbeing

Defining the agency and placemaking model:

- Personal preferences, values, DIY inclination and lifestyles **[SELF]** shapes decision-making style
- Family members, relatives and professional service providers **[PEER]** constitute a predominant form of influence on [SELF]
- Aesthetics, functional uses, accessibility and maintenance needs, protection from elements and infestations **[SPACE]** define desired characteristics of the inhabited space
- **[SENT]** Emotional fulfillment of achieving desired outcomes in [SPACE] and judgment of priorities for [SELF] and [PEER] moderates decisions and actions
- **[TECH]** Technologies, building fixtures, materials and fuels (existing and new) are viewed through the lens of [SENT]
- **[INFO]** Information from external sources constitute a secondary influence on [SENT]
- Limiting Factors **[LF]** including state of household finances, safety and health concerns, norms and rules in neighborhoods, and sociotechnical constraints precipitate [TECH] decision and determine final actions.




*Agency and Private Placemaking: A system dynamics model of home upgrades decision-making*