Enhancing Participation in Residential Demand Response: Insights from Case Studies Conducted in Alaska and California

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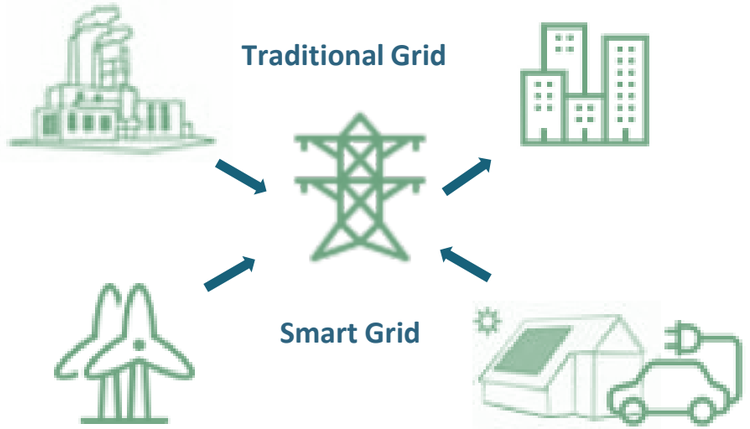
Agenda

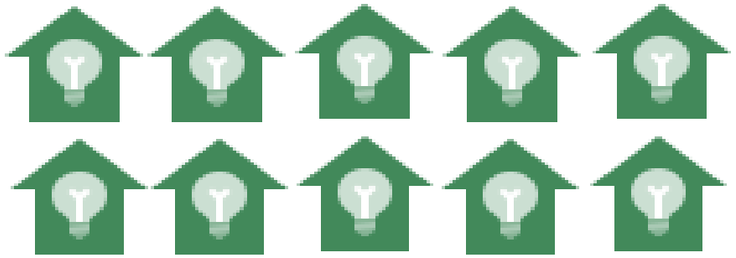
- Motivation
- Objectives
- Study description
- Findings
- Conclusions

Motivation

- Building energy use intensity will continue to increase
  - Uptake in air-conditioning
  - EV
  - Space and water heating electrification
- Renewable integration
- Supply-demand balancing



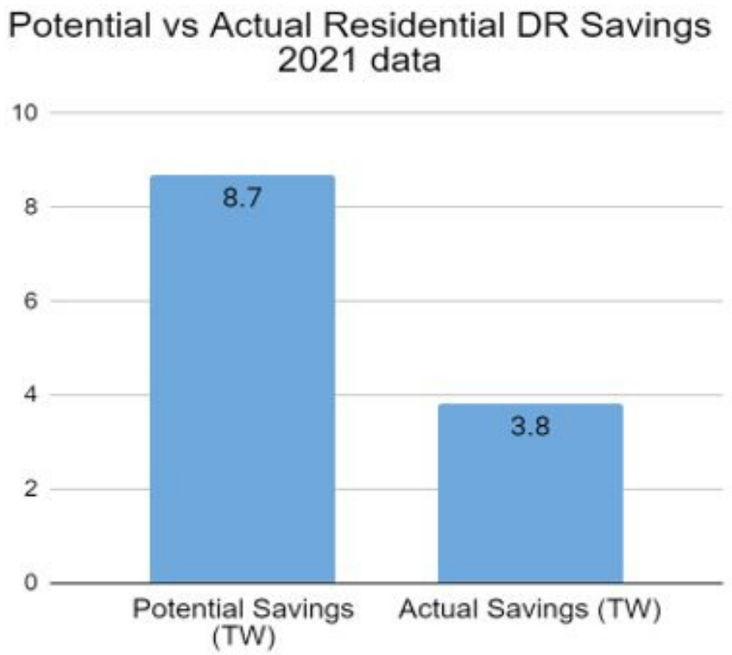
Demand flexibility



221 GWH: Annual Energy Use of ~ 20k U.S. Homes

Offset ~ 50 coal plants!

Demand Flexibility (DF): High potential… but low utilization



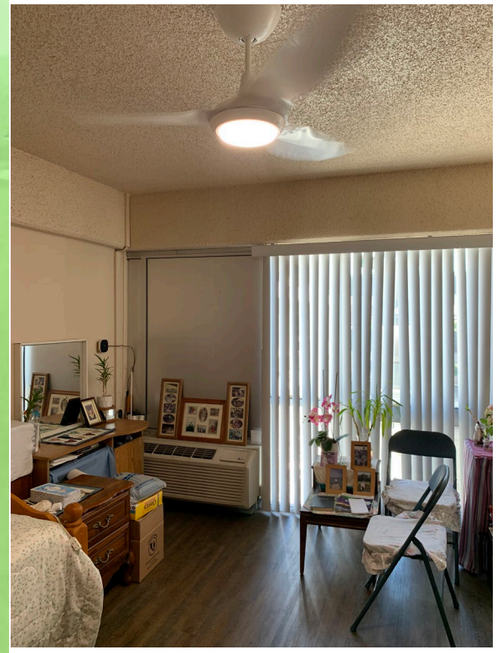
- 2021 - Utilization less than 50% of estimated potential
- Participation Rate ~ 7%

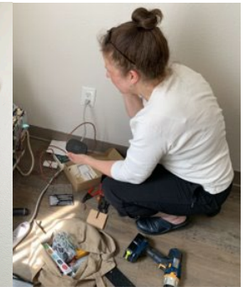
- Technological, Social, Economic barriers
- Initial enrollment barriers
- Persistent participation barriers
  - Household composition
  - Daily routines
  - Outdoor temperature
  - Thermal comfort preferences and flexibility to accept changes
- Gaps
  - Limited field data on comfort/indoor conditions (space heating/cooling DF)
  - Limited studies that address how comfort impacts persistent participation
  - Limited/no studies on winter DF.

Objectives

- Understand occupant response to space heating and cooling-based DF in residential settings
- Understand how changes in indoor environment impact:
  - thermal comfort → participation decisions
  - demand savings
- Method: Field Studies
  1. Summer DF test in Stockton, California
  2. Winter DF test in Cordova, Alaska

CoolFIT – Smart Thermostat + Ceiling Fan, Stockton, CA





- Senior housing center
- Five units – one & two bedrooms
- Cooling system - window A/C's ceiling fans
- Intervention- same A/C connected to ecobee smart thermostat. Old fan replaced with BigAss smart fans
- Summer Demand flexible testing – 6 weeks (08'23 – 10'23)

Ductless Heat pump Demand Flexibility, Cordova, AK

- Three detached single-family homes in rural fishing town
- Existing heating fuel-oil-based gas stoves
- Intervention- Mitsubishi heat pumps with CTA-2045 communication modules
- Winter Demand flexibility testing – 6 months (11’23 to 04’24)

Study Design

Pre-study

site survey

interviews

Study phase

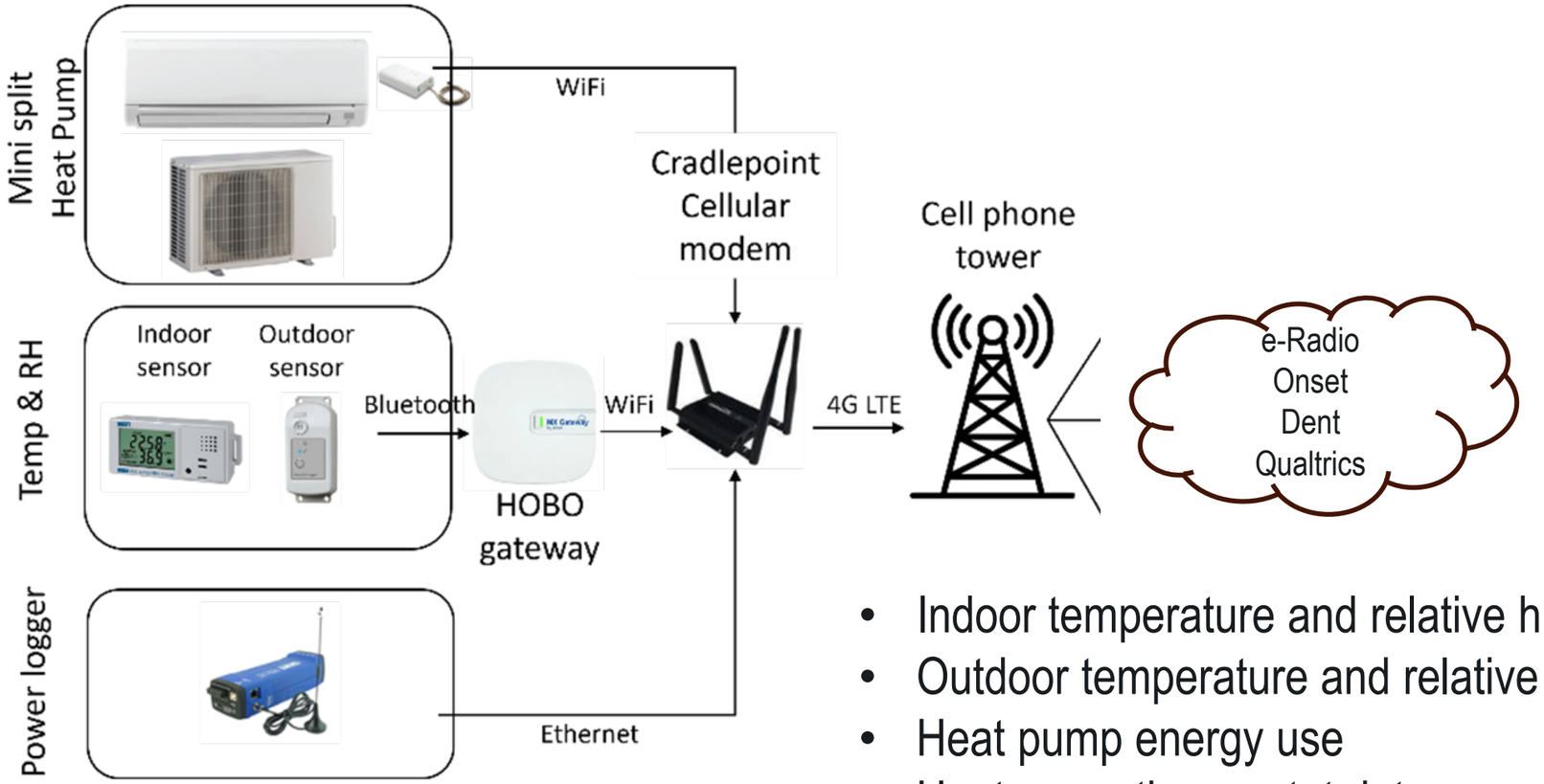
data monitoring

comfort survey

Post-study

interviews

Remote Data Collection & Automation Process



- Indoor temperature and relative humidity
- Outdoor temperature and relative humidity
- Heat pump energy use
- Heat pump thermostat data
- Monitoring devices borrowed from PG&E Tool lending library

Demand Flexibility Event Comfort Evaluation

Right-Now Comfort Surveys

Question 1: Right now, do you feel:

Response captures "Thermal sensation votes (TSV)" in Likert scale

Cold Cool Slightly-Cool Neutral Slightly-Warm Warm Hot

Question 2: Right now, would you prefer to be:

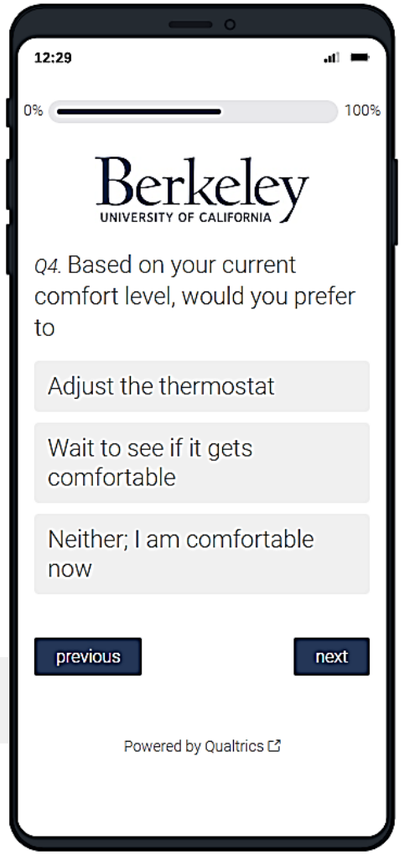
Response captures "Thermal preference votes (TPV)" in Likert scale

Cooler No change Warmer

Question 3: Based on your current comfort, would you prefer to:

Response captures potential near-time DR event behavior

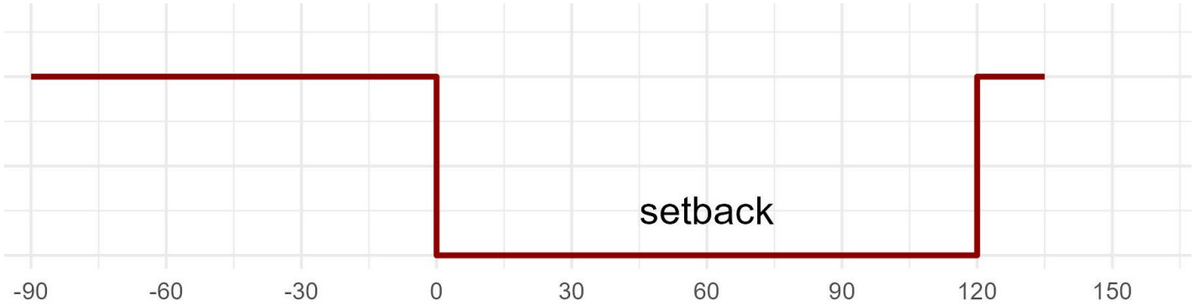
Adjust thermostat Wait to see if it gets comfortable Neither

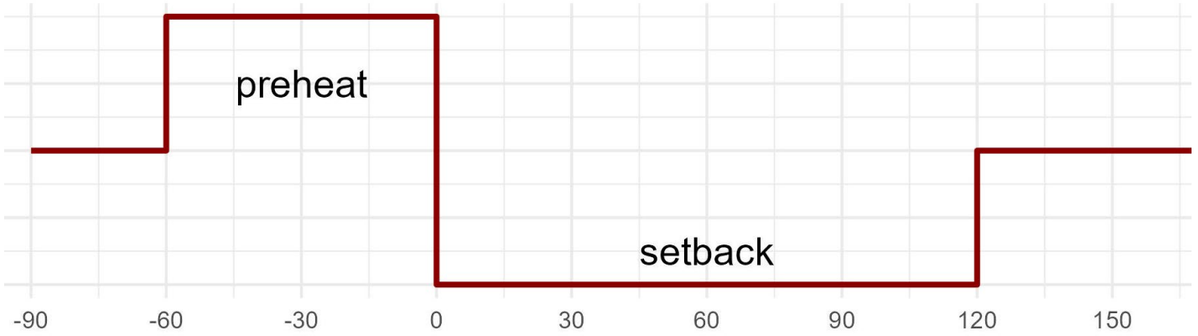


Demand Flexibility Event Testing

Demand flexibility event types:

- Thermostat offset
  - temperature offset (2°F to 6°F)
- Duration
  - duration (1 to 3 hours)
- Start time
  - occupants are typically home
  - pre-heat (DHP)/pre-cool (CoolFIT)
- Each event type repeated 3 times or more

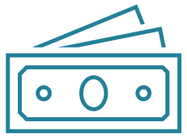




Findings: Pre-study Interview Thematic Analysis

Household energy-use behaviors – influential factors

comfort (85%)



cost (20%)

environment (20%)

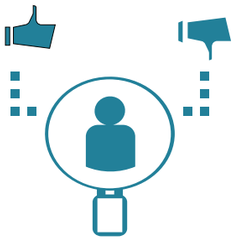
Comfort challenges

orientation

window placement

system inefficiencies

Comfort preferences



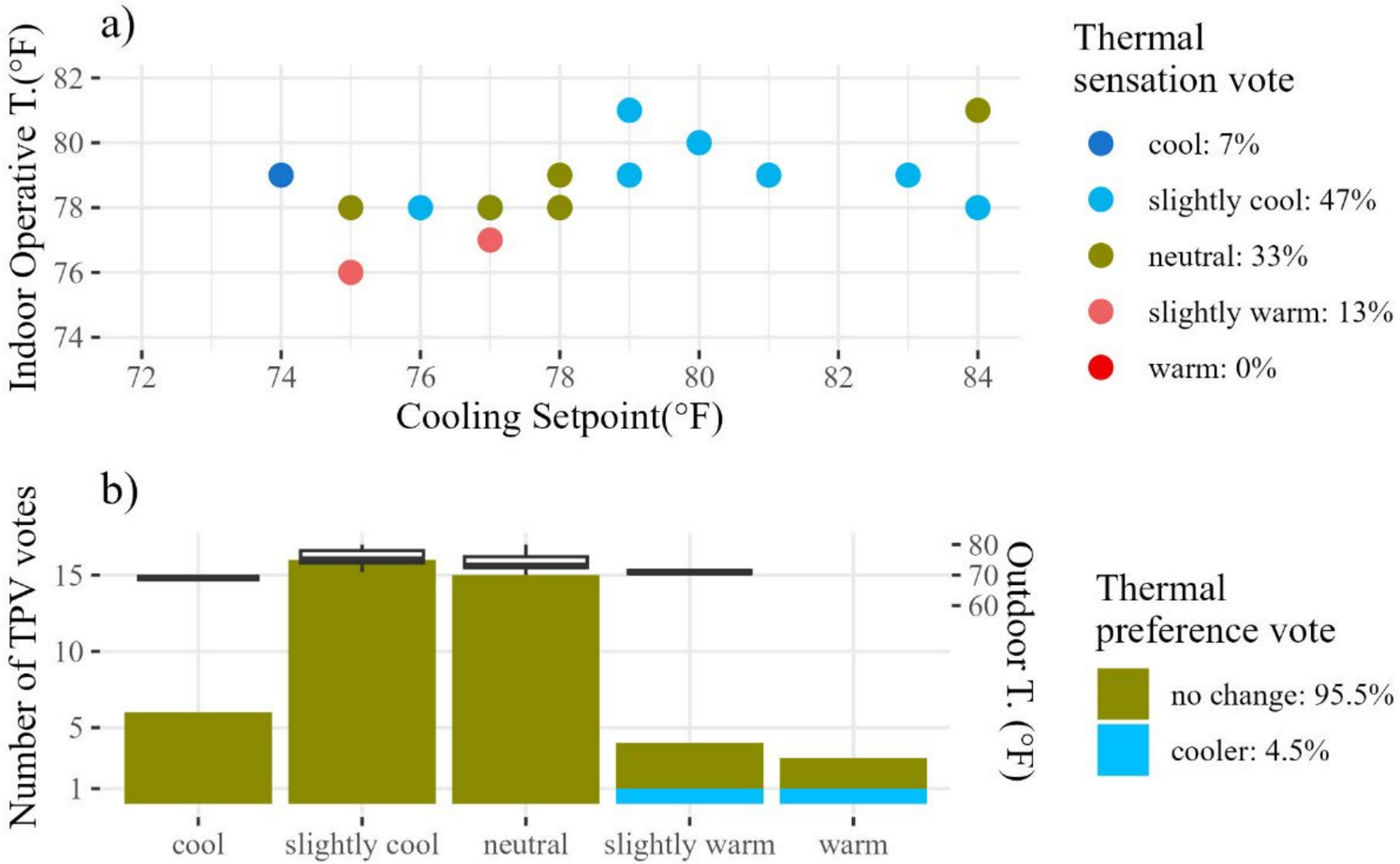
temperature acceptability limits

routines and flexibility

Other challenges

ease of use of enabling technology, communication

Findings: Summer DF Event Comfort Evaluation: CoolFIT, California

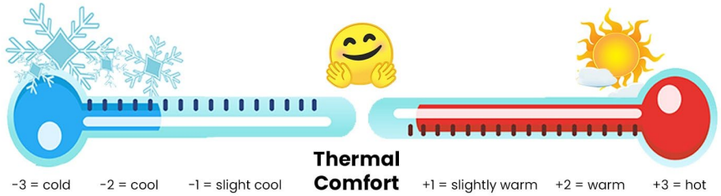


Thermal sensation vote

- cool: 7%
- slightly cool: 47%
- neutral: 33%
- slightly warm: 13%
- warm: 0%

Thermal preference vote

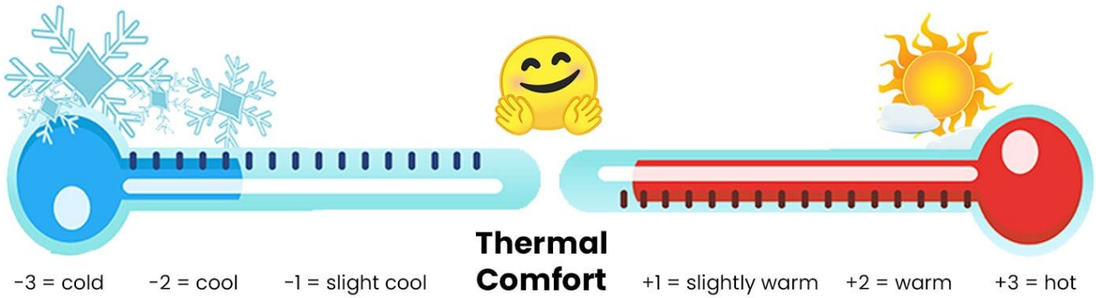
- no change: 95.5%
- cooler: 4.5%

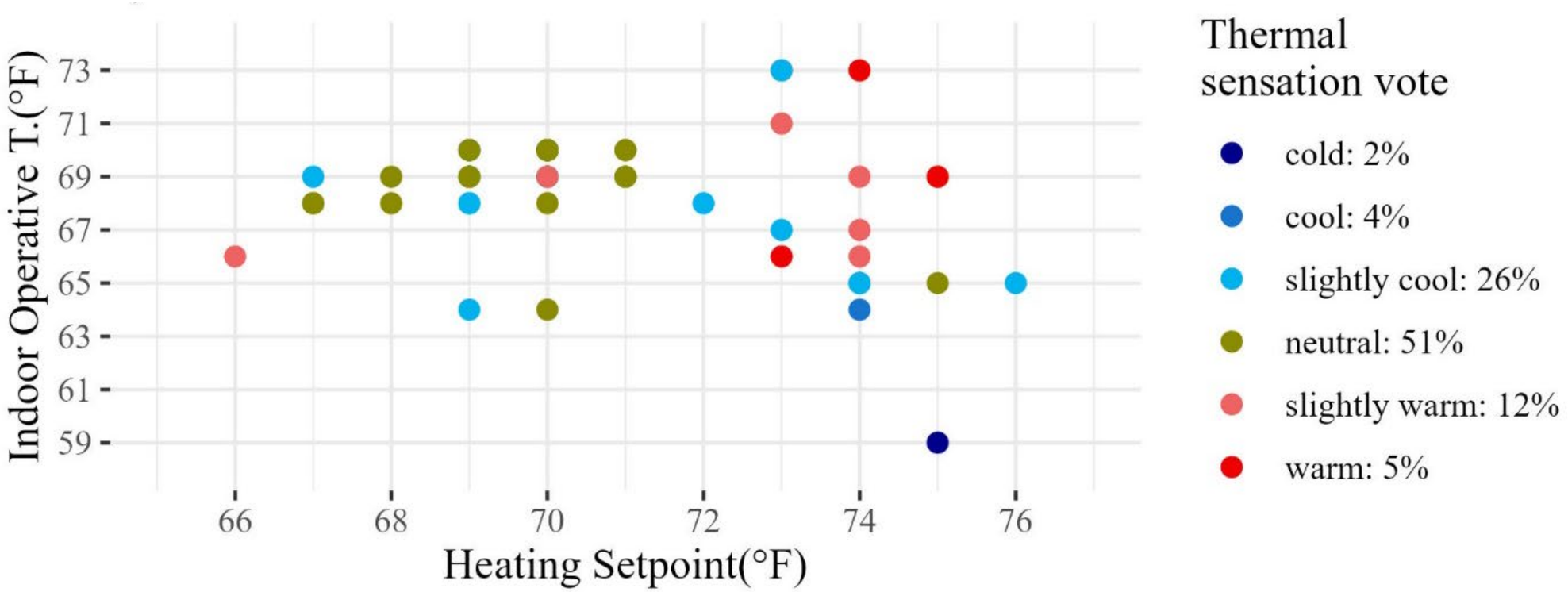


slightly cool and *neutral* responses:

- Indoor temperature range:
  - 78 to 81°F (25.5 to 27°C)
- Thermostat cooling setpoint range:
  - 74 to 84°F (23.3 to 29°C)

Findings: Winter DF Event Comfort Evaluation: DHP, Alaska





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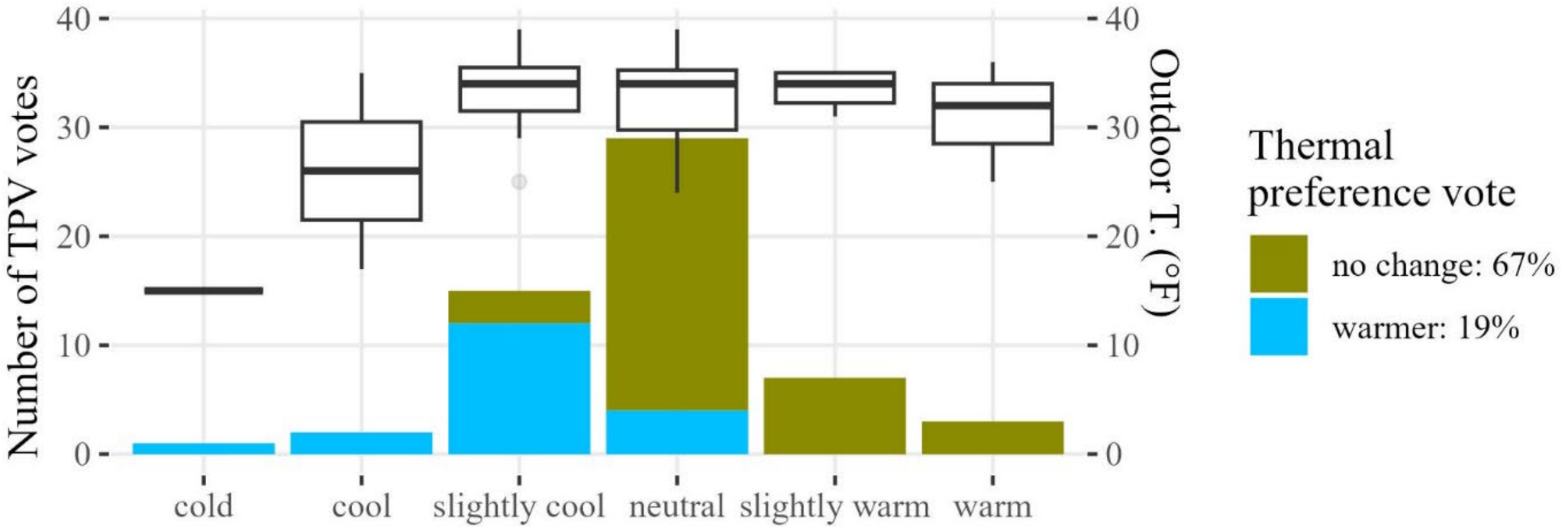
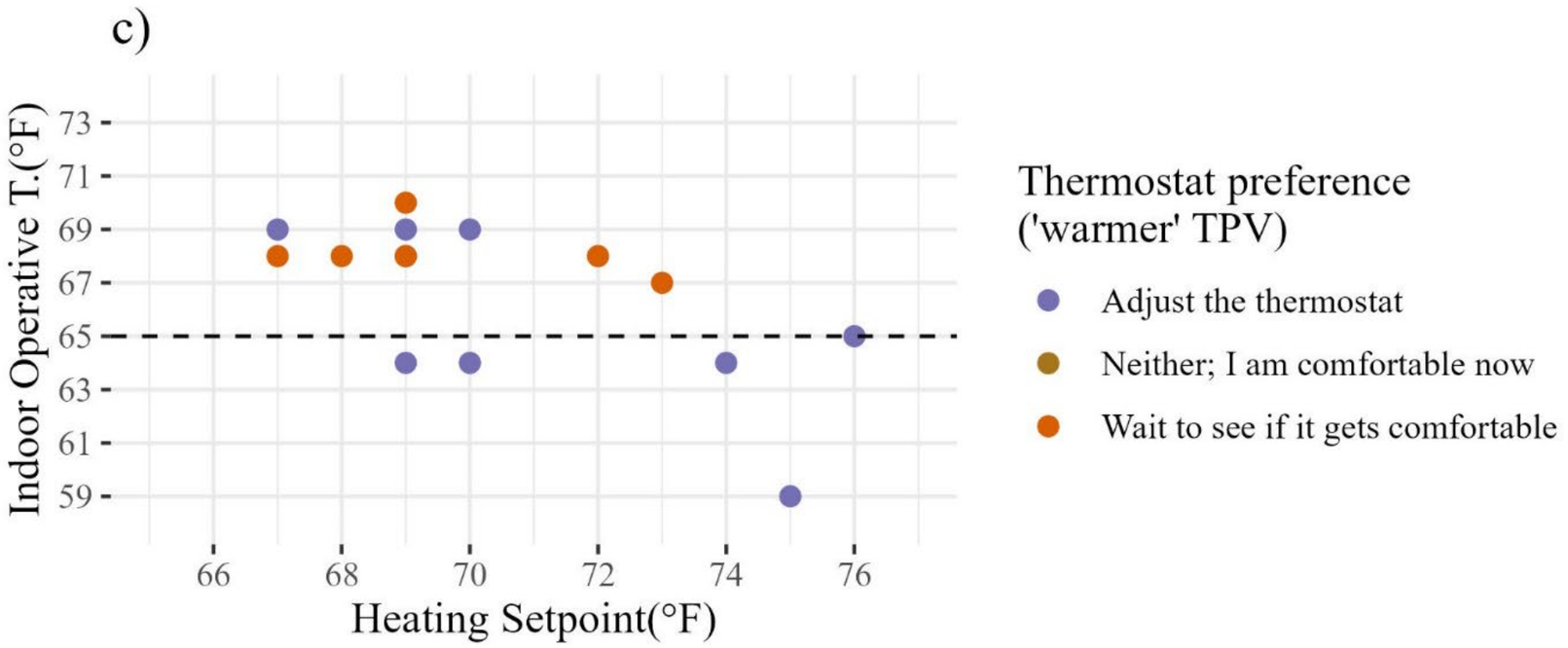


Thermal sensation: Cold Cool Slightly-Cool Neutral Slightly-Warm Warm Hot

Findings: Winter DF Event Comfort Evaluation: DHP, Alaska



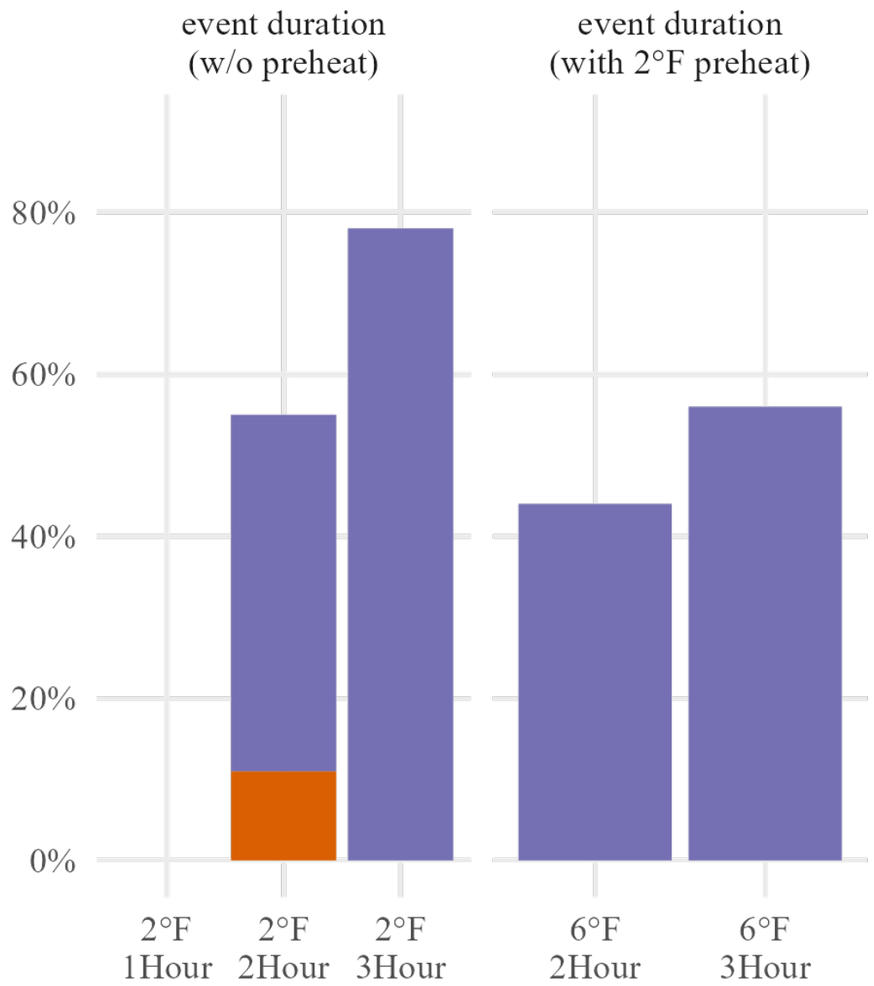
neutral responses:

- Indoor temperature range:
  - 67 to 71°F (19.4 to 22°C)
- Thermostat heating setpoint range:
  - 66 to 73°F (19 to 23°C)

Optimum range for DF

65 to 71°F (18 to 22°C)

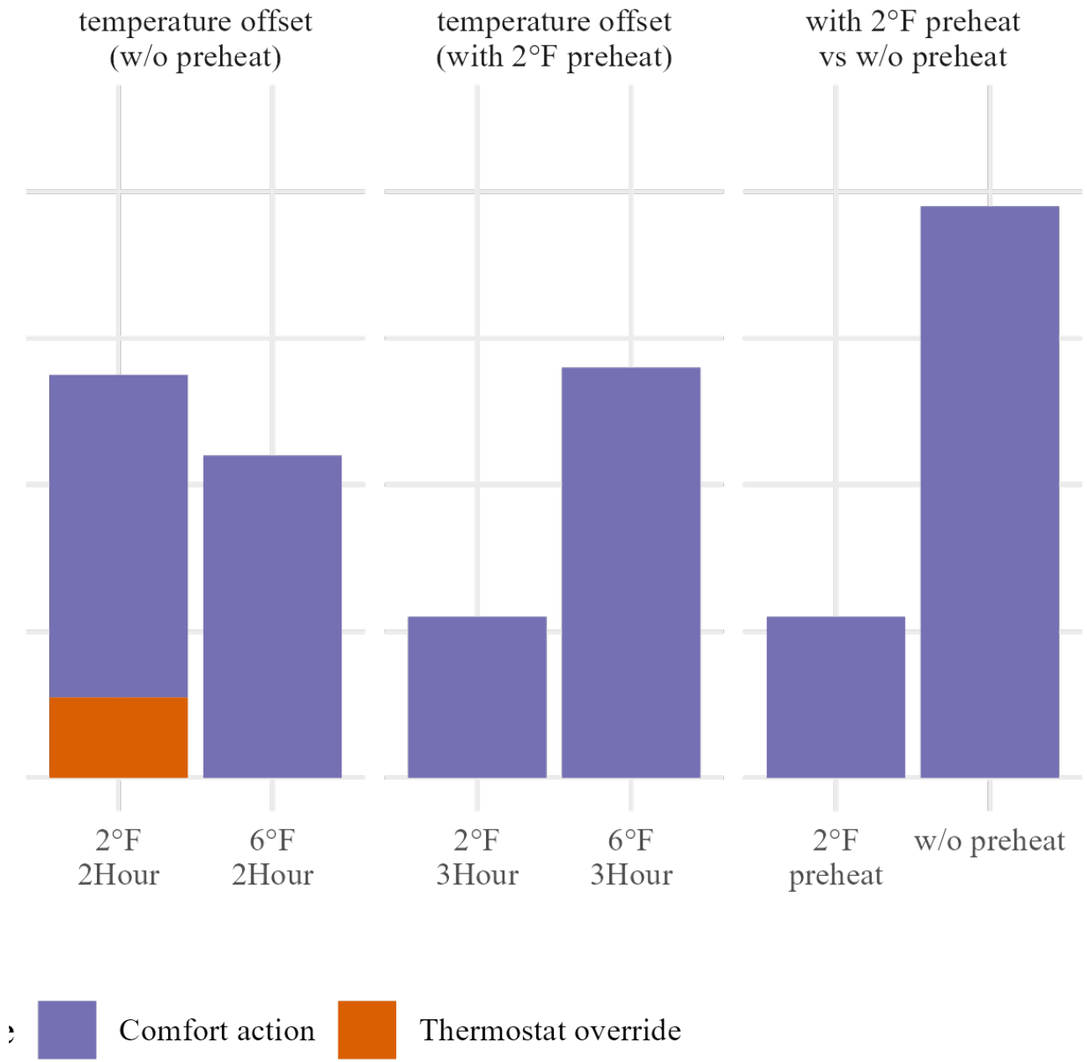
Findings: DF Event Comfort Action : DHP, Alaska



Impact of comfort on participation:

- Longer durations – increase likelihood of comfort action

Findings: DF Event Comfort Action : DHP, Alaska



Impact of comfort on participation:

- Impact of temperature offset- less pronounced than that of event duration
- Comfort action higher for events without preheat
- Outdoor temperature

Findings: Post-study Interviews

	CoolFIT	DHP
Thermal Comfort		
General satisfaction (during technology intervention and DF testing)	Satisfied: 3/5 Unsatisfied: 2/5	Satisfied: 2/3 Unsatisfied: 1/3
Positive influence on comfort (self-reported factors)	Performance of smart fan: 2/5 Improved HVAC control autonomy: 4/5	Response time: 1/3 General Effectiveness: 2/3 No (diesel) odor: 1/3
Negative influence on comfort (self-reported factors)	Complexity of new technology: 2/5 Perceptible changes during DF events: 1/5	Figuring out optimal settings: 3/3 Inability to meet heating needs in extremely cold days: 3/3
Future Participation		
Willingness to use DF enabled technology	Continue: 3/5 Unsure: 2/5 Discontinue: 0/5	Continue: 3/3
Factors that are likely to impact future DF program participation decisions	Comfort: 3/5 $ incentive: 0/5 Ability to override: 3/5 Environmental impact: 2/5	Supplementary heat: 3/3 Comfort: 3/3 Environmental impact: 2/3 Ability to override: 3/3 Utility cost reduction: 3/3

Conclusions

- Residential DF program success relies on proper understanding of limitations and flexibility potential of
  - DF technology,
  - DF strategy, and
  - Enrolled households
- Household energy use behaviors and thermal comfort preferences impact flexibility and participation decisions
- Flexibility potential, comfort – can vary by geography and season
  - Technology field studies can be great opportunities to collect comfort data
  - Can be done with low-cost sensors and survey instruments
- Region-specific comfort data can enable occupant-centric DF programs
  - More likely to succeed
  - Yield persistent savings

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