Quantifying the Impacts of Shifting Residential Water Heating Loads

Experiments for Southern California Edison's SmartShift Rewards Program

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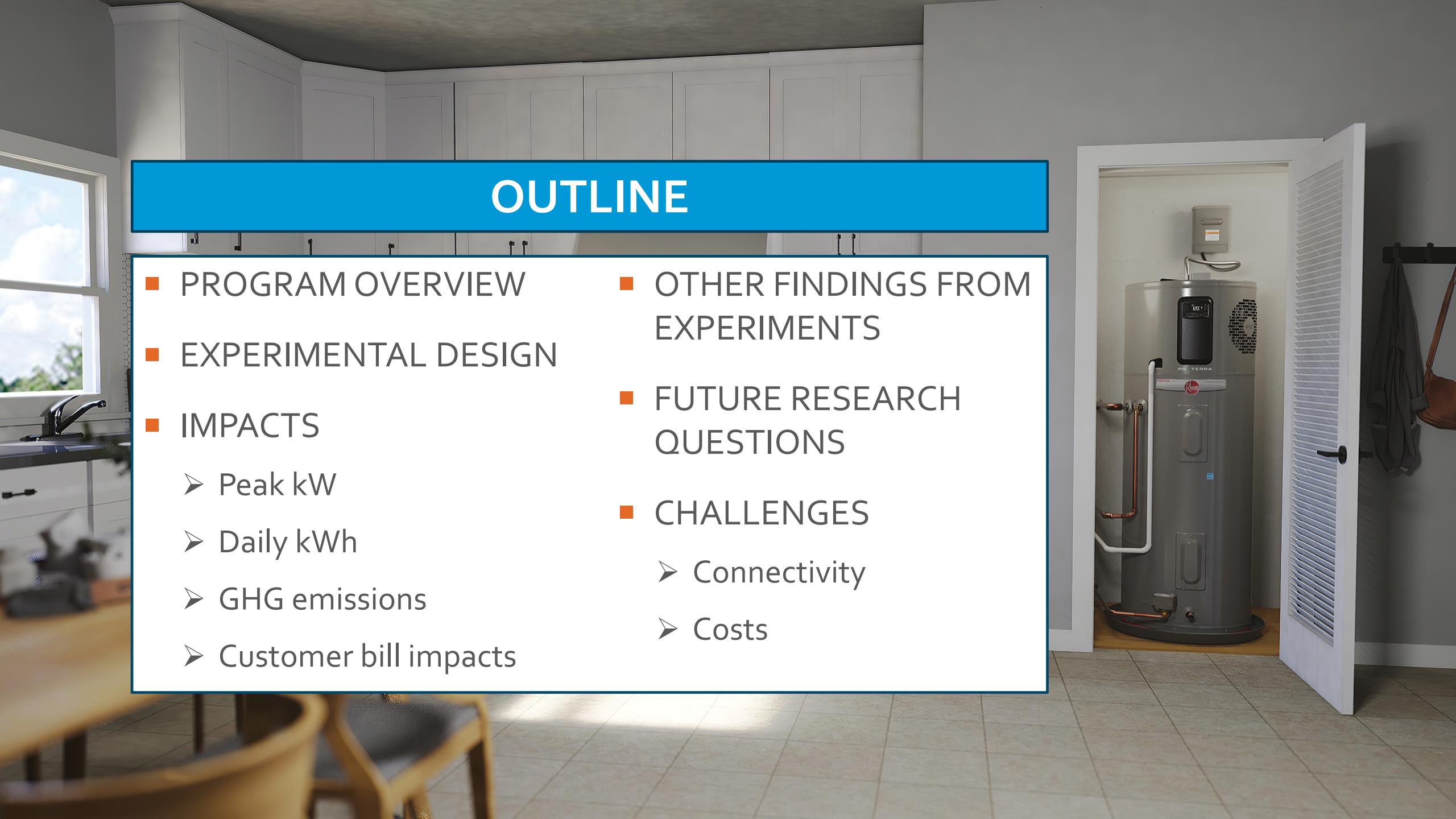

OUTLINE

- PROGRAM OVERVIEW
- EXPERIMENTAL DESIGN
- IMPACTS
  - Peak kW
  - Daily kWh
  - GHG emissions
  - Customer bill impacts
- OTHER FINDINGS FROM EXPERIMENTS
- FUTURE RESEARCH QUESTIONS
- CHALLENGES
  - Connectivity
  - Costs

SmartShift Rewards Hot Water

YOU CAN EARN REWARDS AND CAN AVOID PAYING THE HIGHEST PRICE TO HEAT YOUR WATER.

Learn More

Get Started

THE BENEFITS OF SMARTSHIFT REWARDS:

You can **avoid paying the highest electricity price** to heat your water

Provides you a one-time **$50 enrollment award**, and additional rewards for every month you participate

Helps **reduce greenhouse gas (GHG) emissions**, improve grid reliability and keep electricity cleaner for everyone

SMARTSHIFT AIMS TO REDUCE ELECTRIC USAGE 4-9 PM

- Designed to have:
  - **Advanced Load Up**: Raise set point 10° from 2-4 pm
  - **Shed**: Drop set point 10° below normal from 4-9 pm
- Any electric water heater is eligible
  - To date, all SHPWH's
  - Mostly recruited from TECH water heater program
  - External controller (CTA-2045) installed if needed
- 163 devices in our first experiment, now ~500 participants in the program
- Early focus has been on customers
  - Minimize impacts on comfort levels, emphasis on incentives + bill savings, etc.

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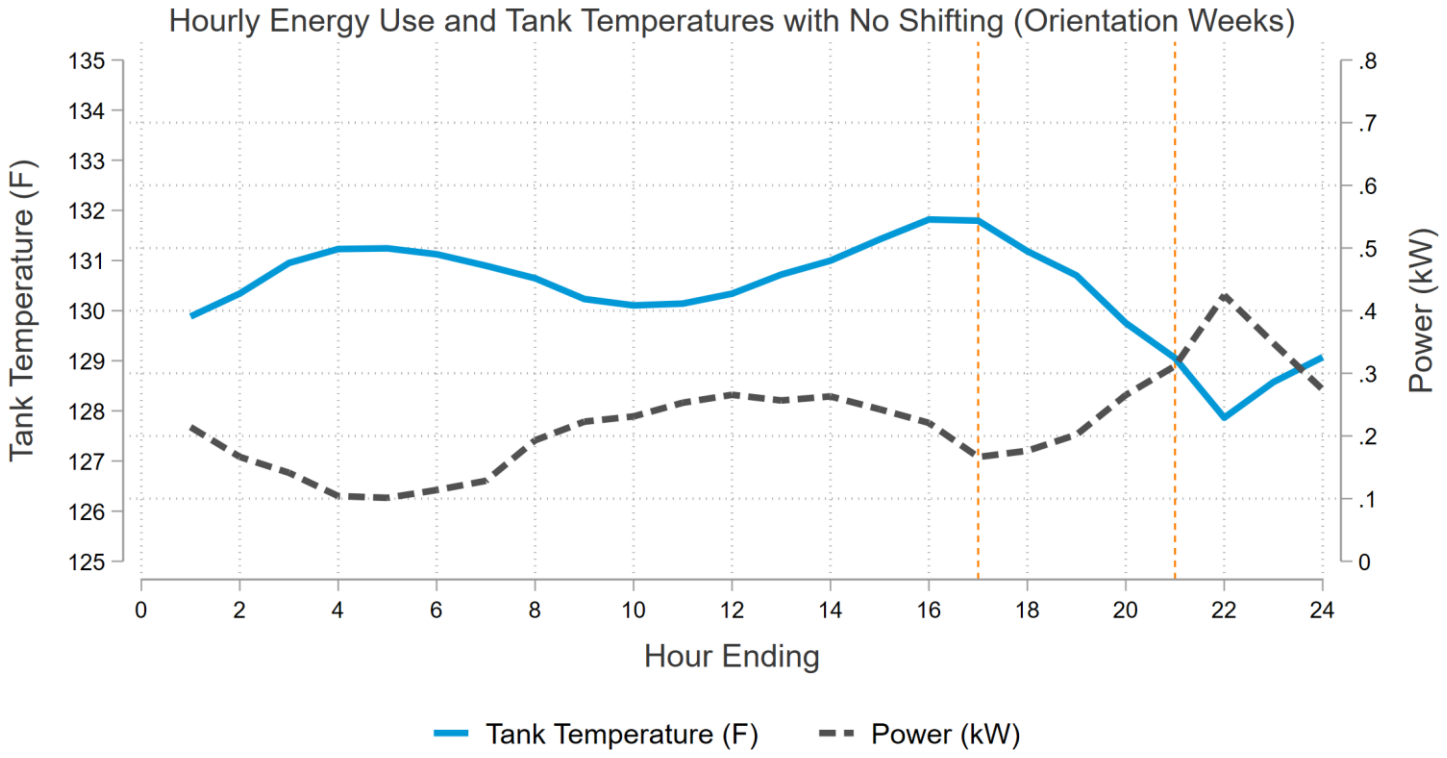
DSA HAS BEEN ANALYZING THE ENERGY & TEMPERATURE DATA FOR HPWHS THROUGHOUT 2025

- Devices analyzed to date have been Rheem 60 Gal. Smart HPWHs
  - Most installed by California's TECH program
- Ran experiment to estimate impacts April – June 2025
  - Additional data from before, after experiments
  - 2nd experiment from Sept. – Nov. 2025, 3rd experiment planned for Q1 2026
- We receive 5-minute reads for the water heaters:
  - kW
  - Tank temp
  - Set point



Data here is from the "Orientation Period" (before SmartShift's load shifting began)

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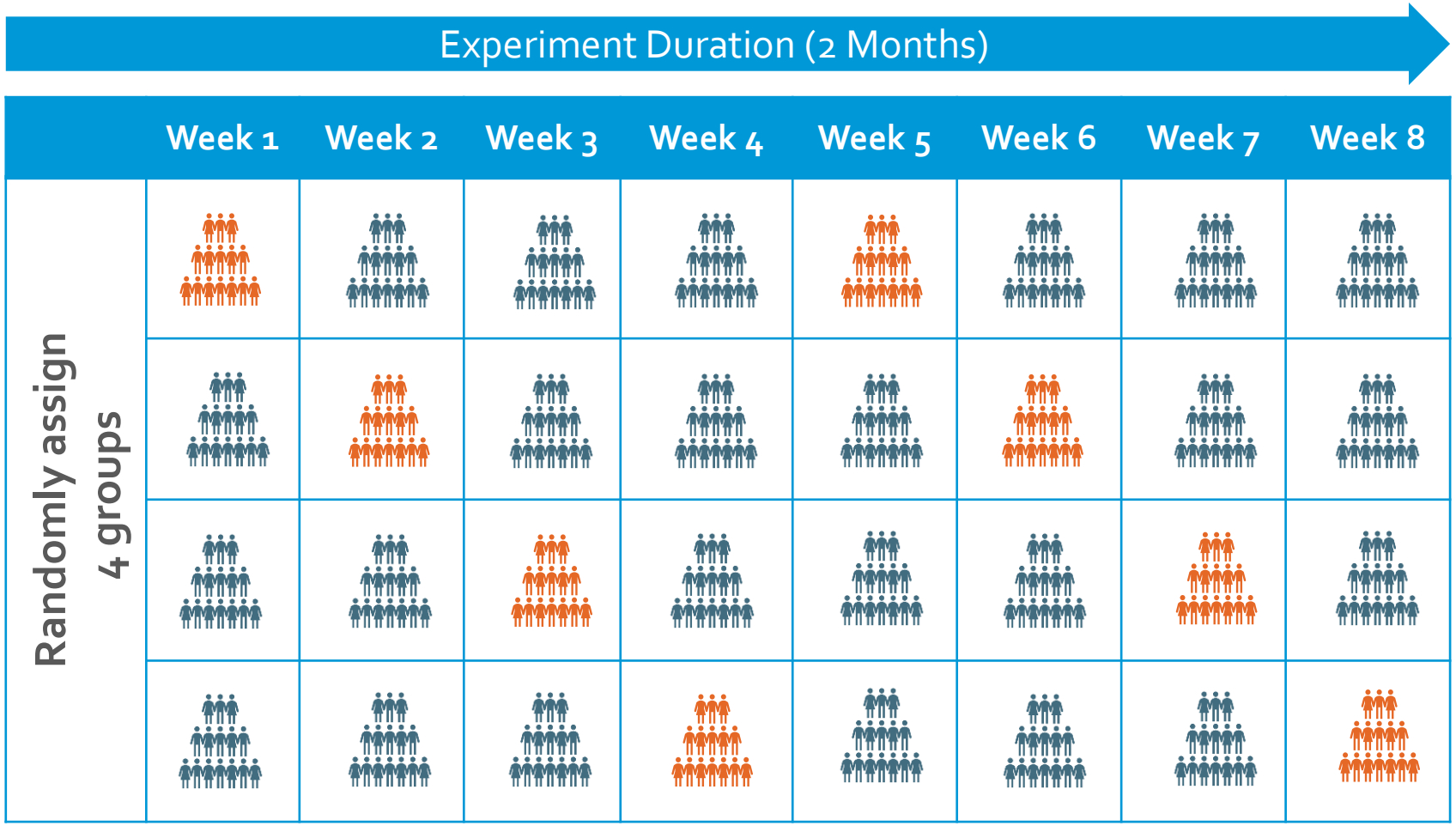
WE SET UP RANDOMIZED CONTROLLED TRIALS WITH ALTERNATING TREATMENT



- Each device experiences Treatment/ Control weeks over time
  - ***75% of time in shifting mode***: Preserve bill impacts for participants
- Customers don't know when the automated shifting is in effect
- On average:
  - Groups are similar since drawn randomly
  - Treatment & control days are similar

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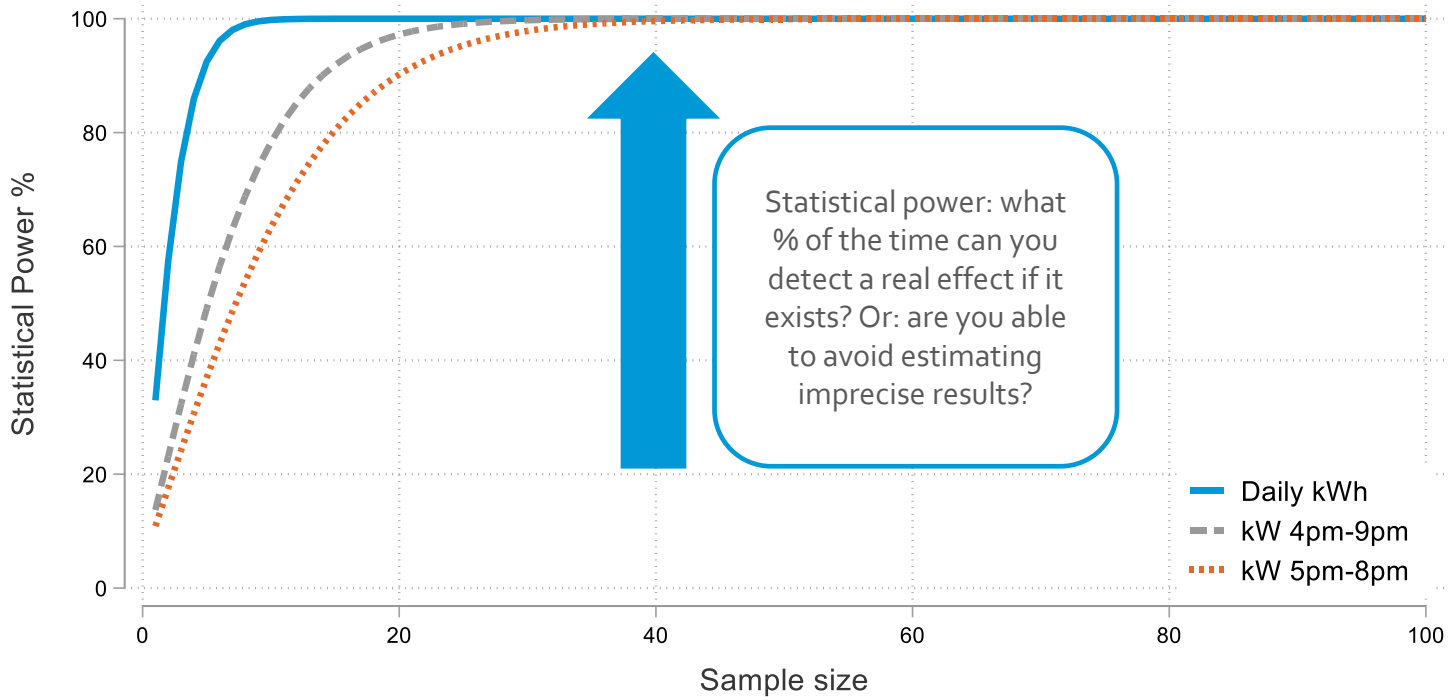
WE EXPECTED TO PICK UP EFFECTS WITH >40 HEAT PUMP WATER HEATERS

- Power analysis on SmartShift initial data completed in December '24-January '25
  - Suggested that, for expected effect size, methodology was highly precise with at least 40 participants in alternating treatment experiment for 1 month
- Enrollments increased, so ended up with 163 in 4 groups
  - Experiment ran for ~2 months



4-weeks with 4 groups, assuming 50% effect size and 90% confidence

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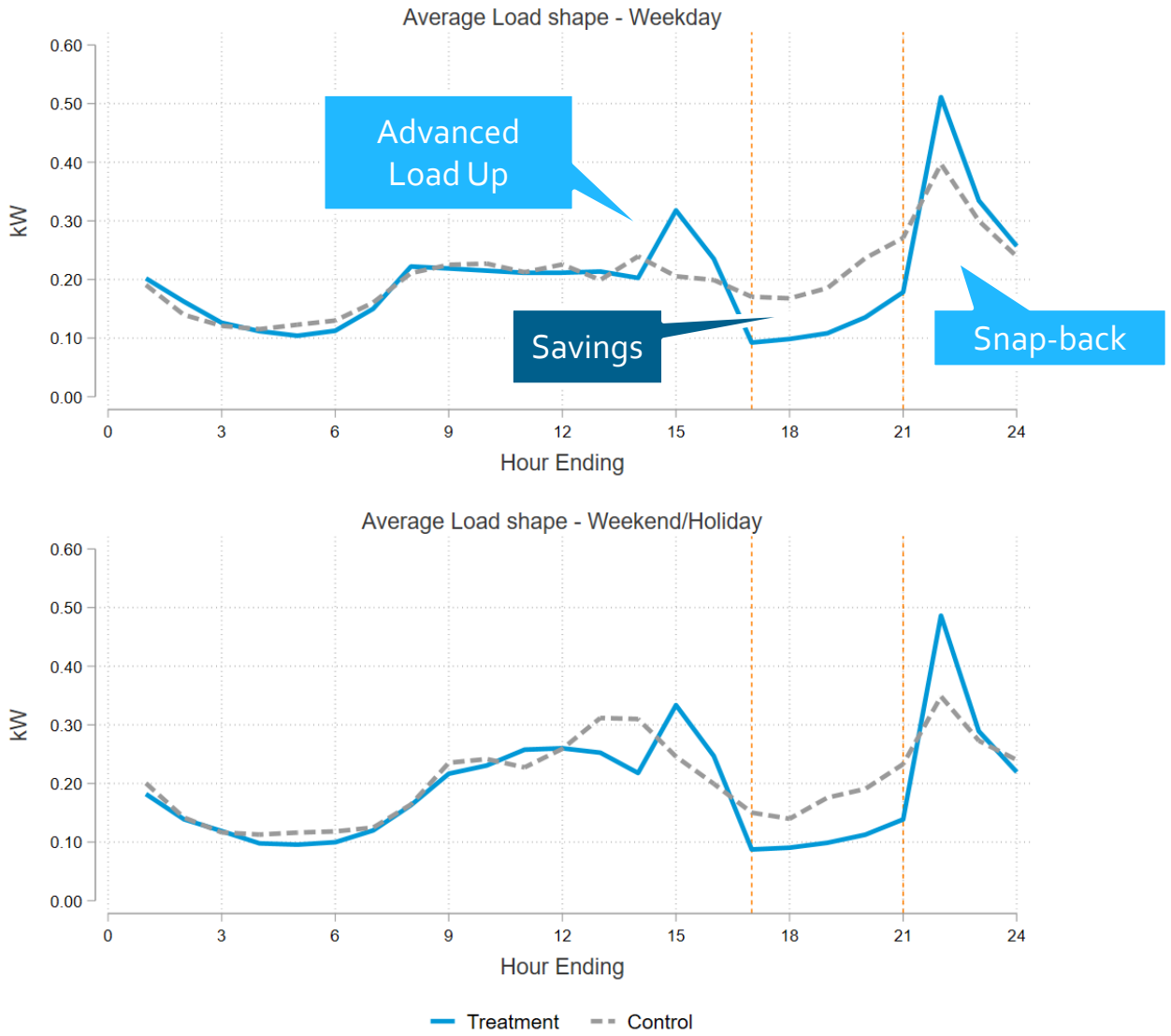
EXPERIMENTAL RESULTS: PEAK LOADS REDUCED BY ALMOST 30% (4-9 PM)

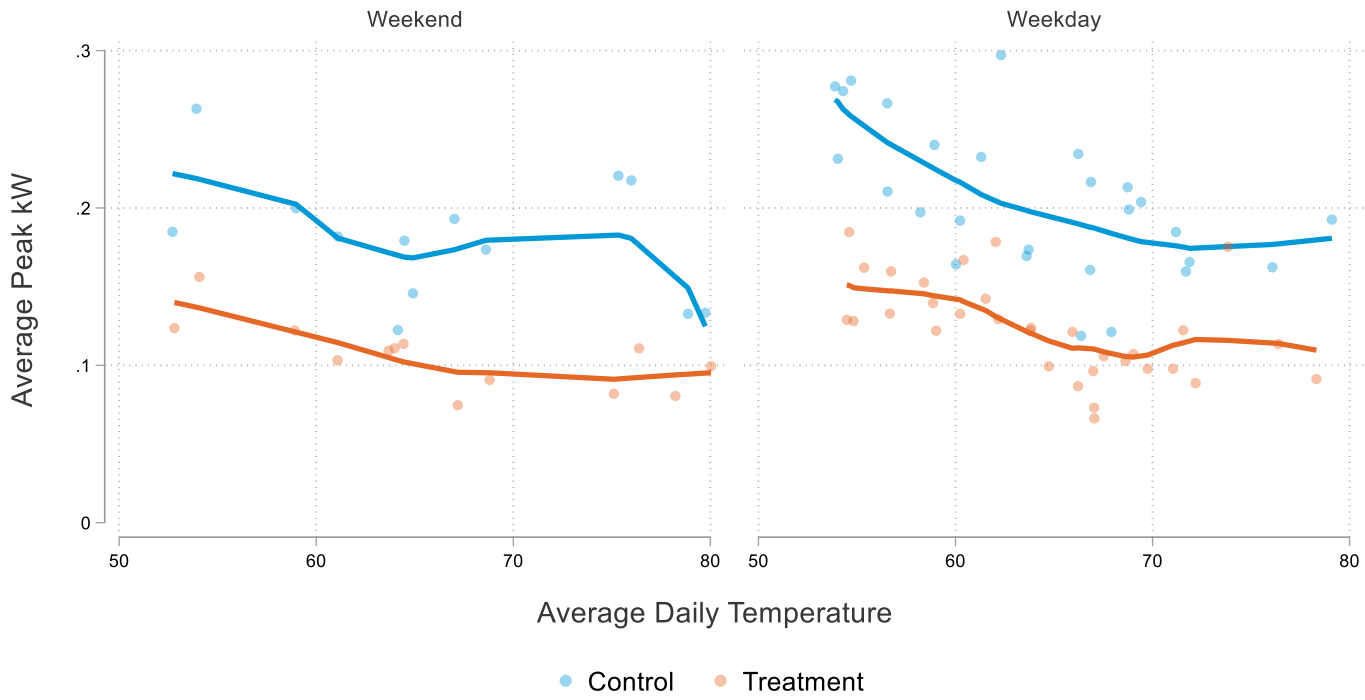


- **Peak load reduction:** 0.06 kW per device (statistically significant)
  - Baseline usage level from 4-9 pm: 0.197 kW (so 28.5% reduction)
- **Total daily kWh:** Increase of 0.07 kWh (not significant)
  - Essentially zero – no overall EE impacts
- **Customer bill** savings of about $20 per year from load shifting in conjunction with TOU rate window
- **GHG reductions** were small
  - Advanced load up used more power during low-emission hours (midday, lots of solar)
  - Snapback came during higher emission hours

PEAK SHIFTING DID NOT SHOW SENSITIVITY TO TEMPERATURE

- We want to test for effect of outdoor temperature on impacts for other evaluation activities
  - ➢ 8760 impacts useful for GHG impacts, bill impacts, etc.
- Tested for difference in impacts at different temperatures
  - ➢ No discernible trend in impacts by temperature in first experiment
    - Tested via regressions with interaction terms
  - ➢ We do see a higher peak kW in cooler weather, but ***impacts*** don't change

Average kW during Peak Hours: Treatment vs. Control Groups
(Experiment #1 – April through June 2025



1. Control group using more kW than Treatment (expected)

2. More usage by both groups in colder weather

3. No difference in gap between the lines (***impacts***) as temp. increases, though

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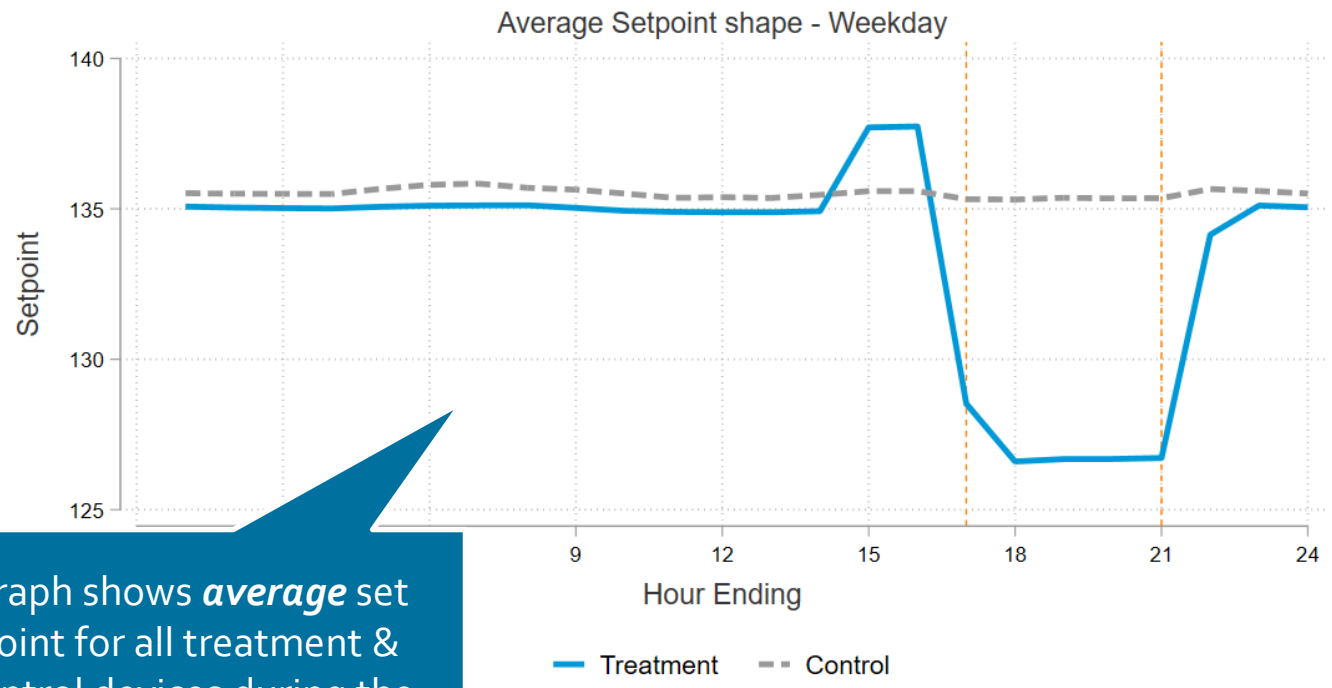
DURING LOAD UP, SET POINTS RAISED LESS THAN ANTICIPATED



Graph shows ***average*** set point for all treatment & control devices during the experiment

During advanced load up (2-4 pm), set point raised 3° on avg.

During load shed (4-9 pm): Set point dropped by 8° on avg.

Set point already at 140° for most devices, so less of an increase during advanced load up

Greater potential for demand savings if water heaters are set to 120° or 130°

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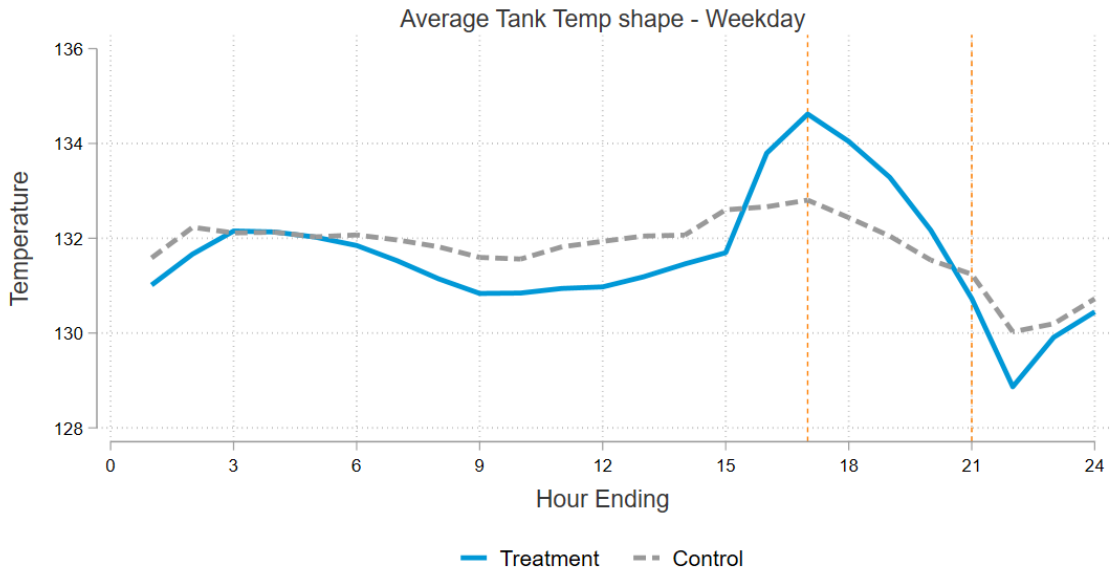
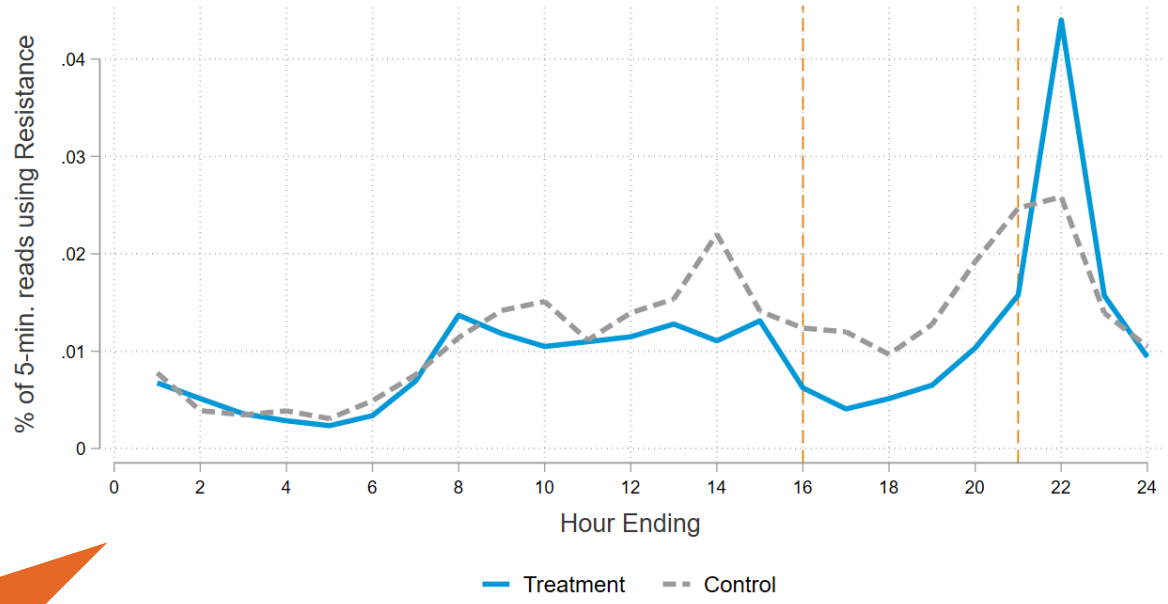
RESISTANCE HEAT CONTRIBUTES TO LARGE POST-PEAK POWER SPIKE

Tank temperatures in post-event hours are ~1° lower for SmartShift participants



The higher power in post-event hour is associated with more resistance heating



4 to 5% of 5-min. power reads from 9 – 10 pm show resistance heating (~4,000 to 5,000 Watts), but this adds significantly to energy usage since average draw is only ~200 Watts

In California, this reduces impacts on GHG emissions since there's no solar generation during the snap back

We're currently testing new algorithms to reduce this

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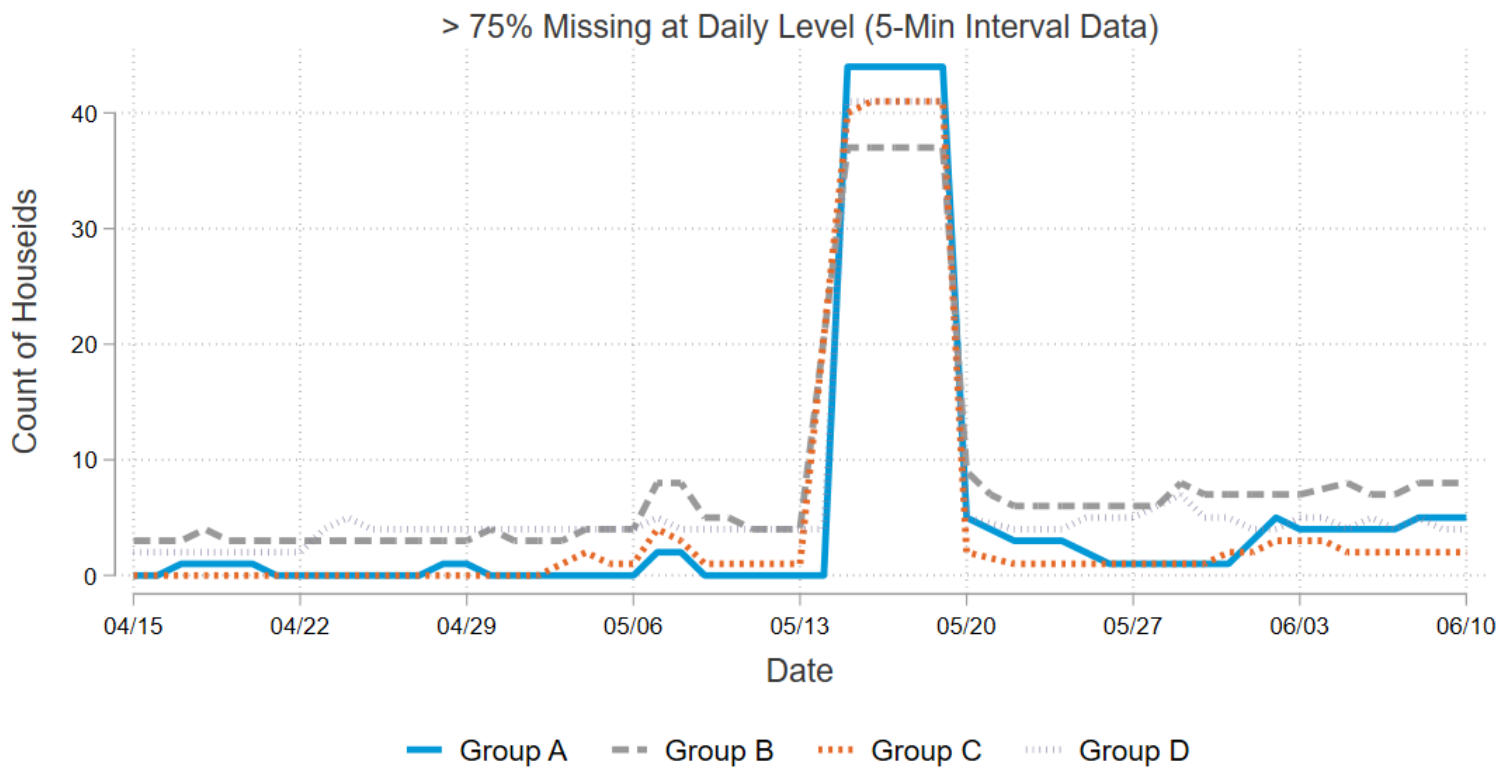
NEW SHIFTING ALGORITHMS TESTED IN EXPERIMENT #2

- **Algorithm 1:** No SmartShift (Control Group)
- **Algorithm 2:** Current SmartShift
  - Relative to #1: Are we seeing any new effects compared to last experiment?
- **Algorithm 3:** Current SmartShift, removing ability to do resistance heating in post-event period
  - Relative to #2: Do we see less post-event snap-back? Are there GHG savings or EE savings?
- **Algorithm 4:** Extra hour of Load Up/Advanced Load Up and removing ability to do resistance heating in post-event period
  - Relative to #2: Do we see less post-event snap-back? Are there GHG savings or EE savings?
  - Relative to #3: Are there ***more*** GHG/kWh savings? Do participant tank temperatures remain in a better range towards the end of the peak/in the post-peak period?

CHALLENGES FOR LOAD-SHIFTING PROGRAMS: CONNECTIVITY



- Graph shows days with > 75% of the expected data (5-min power reads) ***missing***
- Disconnections were balanced across groups, so they didn't bias impact estimates
- Some devices disconnected for most/all of experiment
  - This number was higher for experiment #2
- We've seen disconnections at several different levels
  - Large peak on graph was Rheem service outage
  - Wi-fi disconnection
  - Some evidence of better connections via CTA-2045, but this is costly

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CHALLENGES FOR LOAD-SHIFTING PROGRAMS: COSTS TO CONTROL DEVICES

- In California, the 60 Watt peak savings (every day) is worth ~ $25 per year per device
  - Potentially could get larger impacts, but unlikely to get more than 2x this level
- Operating the program at large scale could help reduce some costs
- But many costs are per device
  - OEMs, software, etc. to control WH's
  - Start-up costs
  - CTA-2045 controllers (if needed)
  - Incentives

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KEY TAKEAWAYS

1

~30% reduction in energy use during 4-9 pm peak hours, against a baseline of ~200 Watts. The loads are very controllable, but the devices are also very efficient.

2

Alternating treatment experiment generated precise, statistically significant impacts.

3

Set points: Some "advanced load up" before 4 pm, but this is limited since most HPWHs in the program are set to 140° (the program will not pre-heat water above 140°)

4

Resistance heating: Large "snap back" usage includes more use of resistance heating (all the devices are hybrid HPWHs)

5

Greenhouse gas reductions were largely erased by high energy use after 9 pm (the snap back).

Bill Savings: Participants save a modest amount on Time-of-Use rates, about $20/year

6

Challenges in expanding the program: Devices sometimes disconnected, costs per device to control the water heaters is high