Electricity Centre

Unlocking Flexible Demand

Evidence from field experiments about getting flexibility to work

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Gent, Oct 2026

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Rethinking the role of demand

The electricity system of the past involved forecasting demand and dispatching supply;

the grid of the future will increasingly involve forecasting supply and dispatching demand.

— Jeff Nagle, Pacific Northwest National Laboratory

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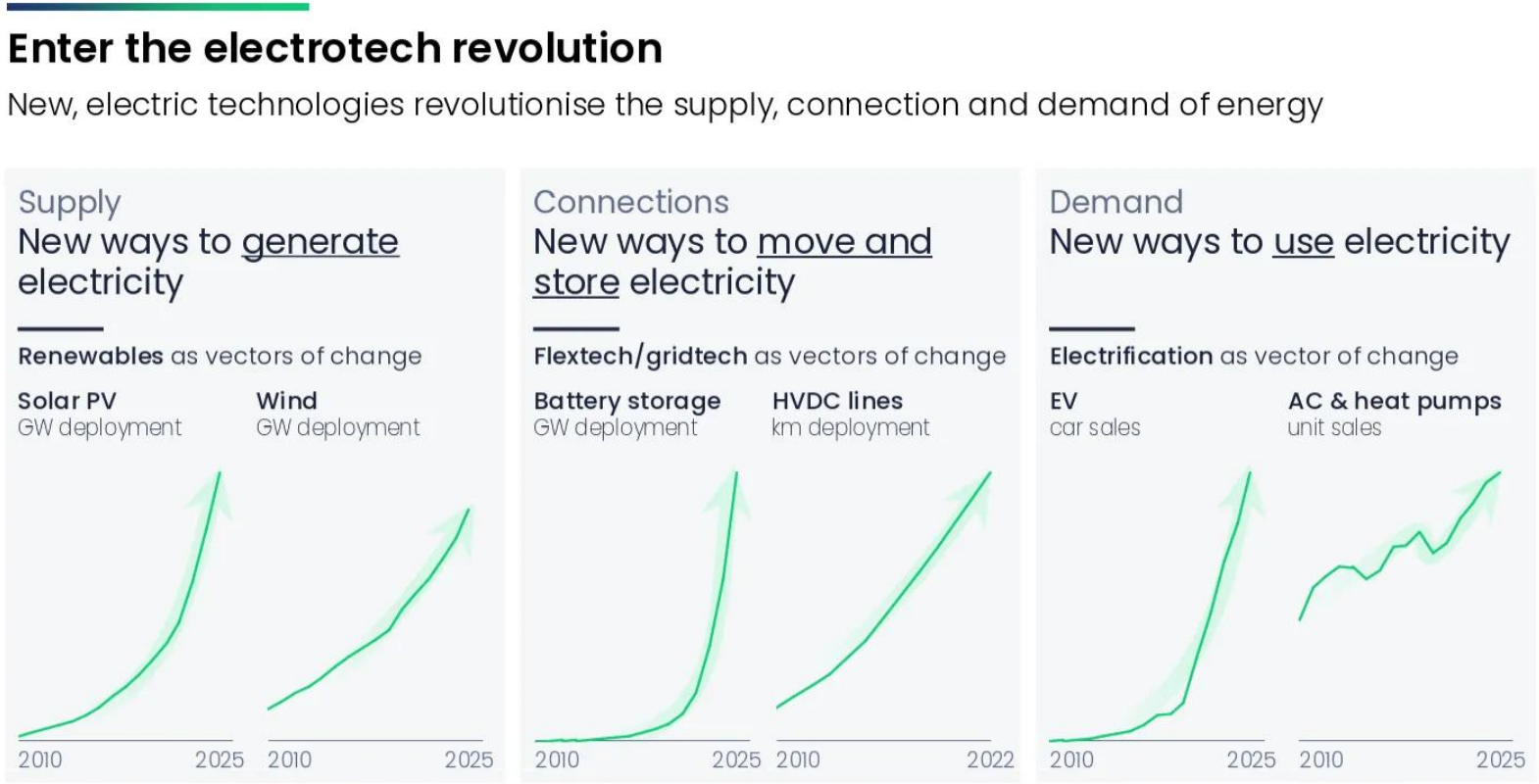
Electrification meets variable renewables



Source: Ember

Supply side

More wind and solar: supply is less dispatchable

Demand side

EVs, heat pumps and AC: bigger, newer loads

More demand flexibility is needed

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Why now? Need, potential, ability

1 Need

Higher shares of variable renewables mean less supply-side flexibility and more net demand variability.

Coincident peaks (the EV “rush hour”) add to it.

2 Potential

Growth of EVs and other electrification means a bigger magnitude of flexible load.

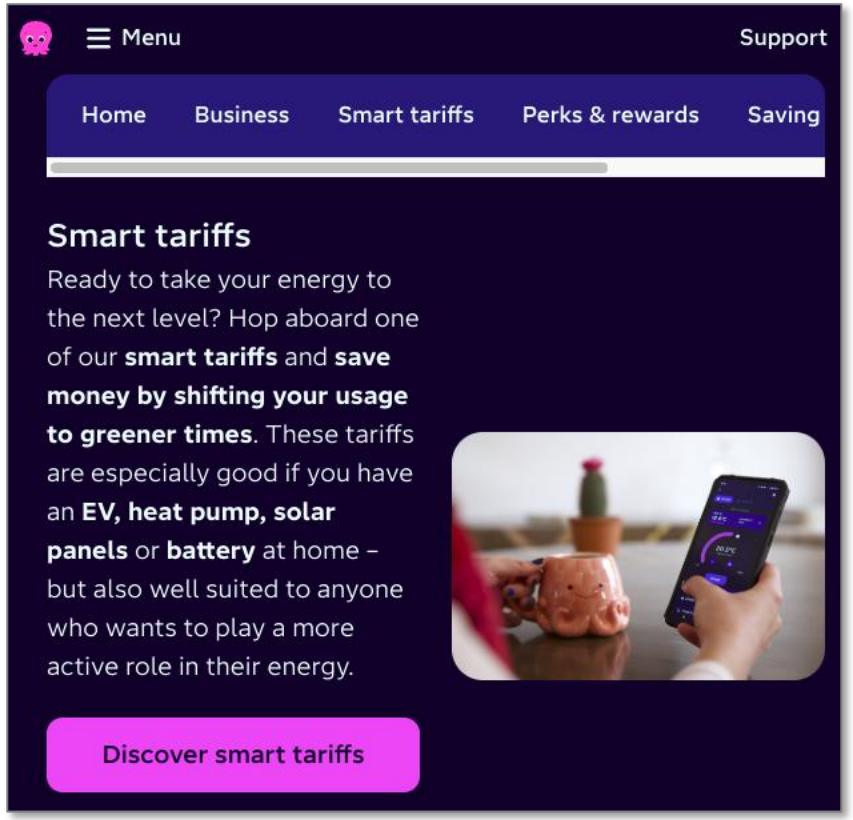
It also increases the need for flexibility.

3 Ability

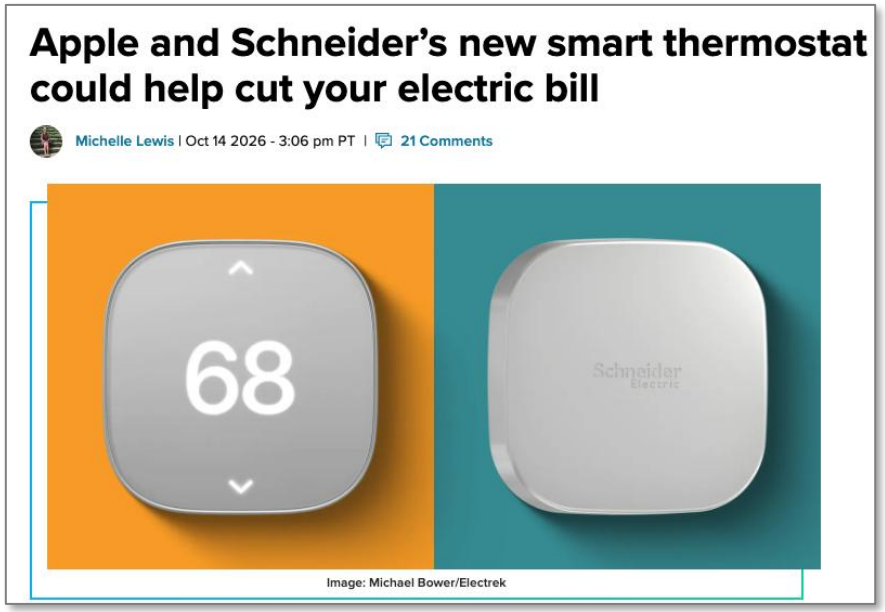
Control and telemetry technology is making it cheaper and easier to respond, including through automation.

Demand-side flexibility is now more valuable and more feasible

Flexible demand programs are growing







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But how do we unlock flexible demand?

Benefits are known	**Benefits of time-varying pricing are well known, and households do respond to time-varying rates** Boiteux (1960); Borenstein & Holland (2005); Harding & Sexton (2017), Bernard et al. (2026)
Barriers remain	**Adjustment and information acquisition costs, inattention, and difficulty understanding marginal prices** Fabra et al. (2021); Sallee (2014); Schneider & Sunstein (2017); Ito (2014); Shaffer (2020); Jacobsen et al. (2022)
Technology can help	**Technology should help, but it might not** Brandon et al. (2022)
Automation is key	**Automation can assist when combined with pricing** Bollinger & Hartmann (2020); Blonz et al. (2025); Metcalfe et al. (2026)

Three field experiments, three lessons

Leverage the benefits of Randomized Control Trial (RCT) research designs

1

EVs are different

Potential flexibility differs greatly across devices

ENMAX Study

2

Beware unintended consequences

Too much *uncoordinated* flexibility can overload distribution networks

Fortis Study

3

Automation is key

Effort is a barrier; automation overcomes the hurdle

Anonymous Canadian Utility

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Experiment 1.
EVs are different

Evidence from the ENMAX field experiment

Published as:

Bailey, Brown, Shaffer, & Wolak (2025)
Show Me the Money! A Field Experiment on Electric Vehicle Charge Timing
AEJ: Economic Policy

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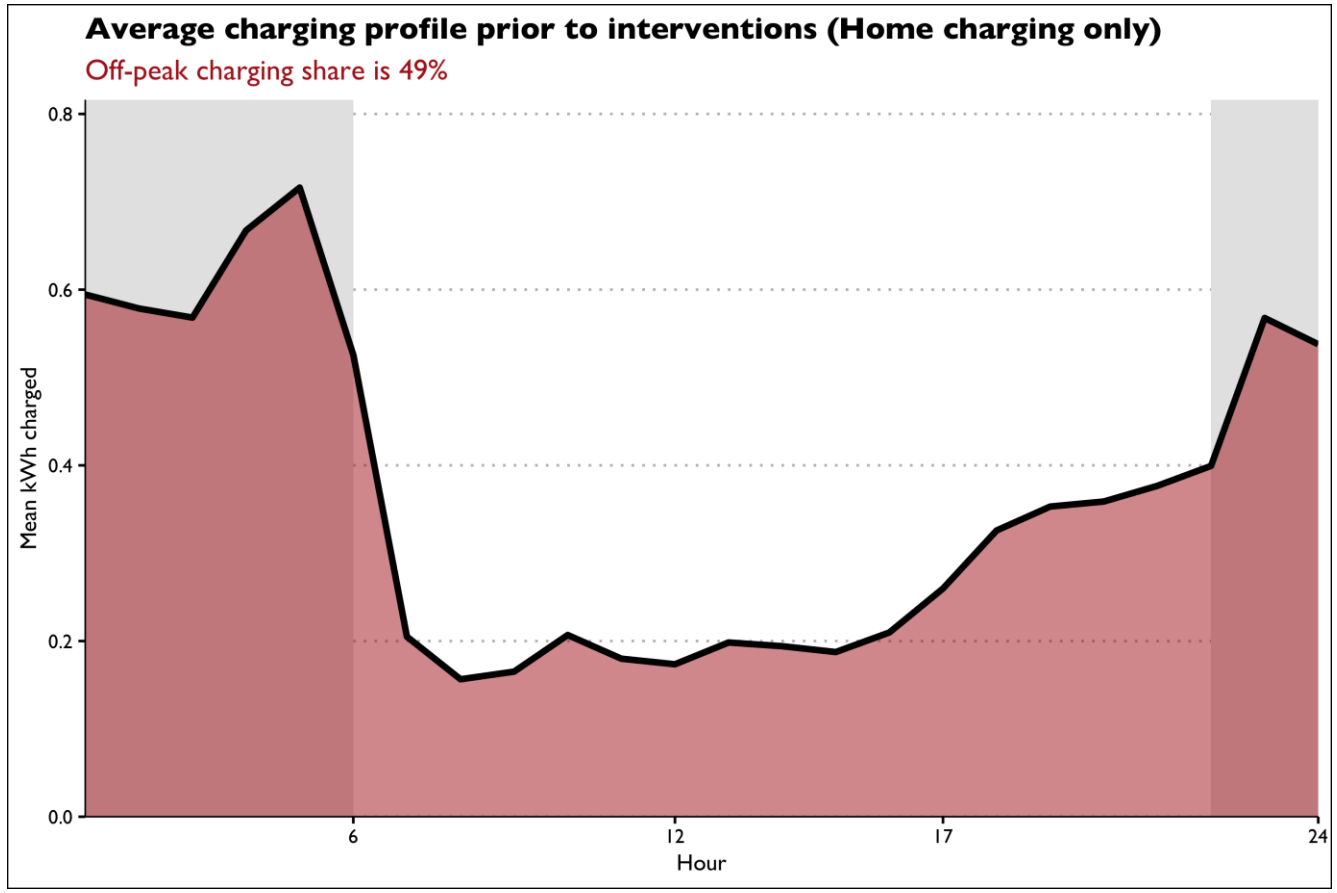
EVs are big, flexible loads

Average home charging profile, before any intervention



Power draw (kW)

Level 2 EV charger

5–12 kW

AC, dryer, oven

1–3 kW

49%

of home charging is already off-peak before any intervention

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The ENMAX experiment: What we do

~250 EVs recruited
from ENMAX Power customers (Calgary)

150 successful installs
of the on-board monitoring device

Lesson: requiring hardware to monitor charging reduced take-up

Rewards Group
3.5¢/kWh for all off-peak charging (10pm–6am)

n = 68

Information Group
Pro-social message on the grid benefits of off-peak charging

n = 45

Control Group
Baseline, no intervention

n = 37

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What participants received

Mar 31, 2022: Phase 1

Sept 1, 2022: Phase 2

Phase 1: Information group email

"Did you know that EV drivers often plug in at 5:00PM? This timing coincides with existing system load peaks and can lead utilities to upgrade wires and equipment ahead of schedule… charge between 10:00PM and 6:00AM when grid demand is low."

Phase 1: Rewards group; same text, plus:

"… effective immediately ENMAX will issue you a 3.5¢/kWh reward for charging that takes place between 10:00PM and 6:00AM. This reward will be paid monthly."

Phase 2: test for habit formation

The Rewards group is randomized into **Rewards-Stop** (payments end) and **Rewards-Continue**. Does off-peak charging persist once the money stops?

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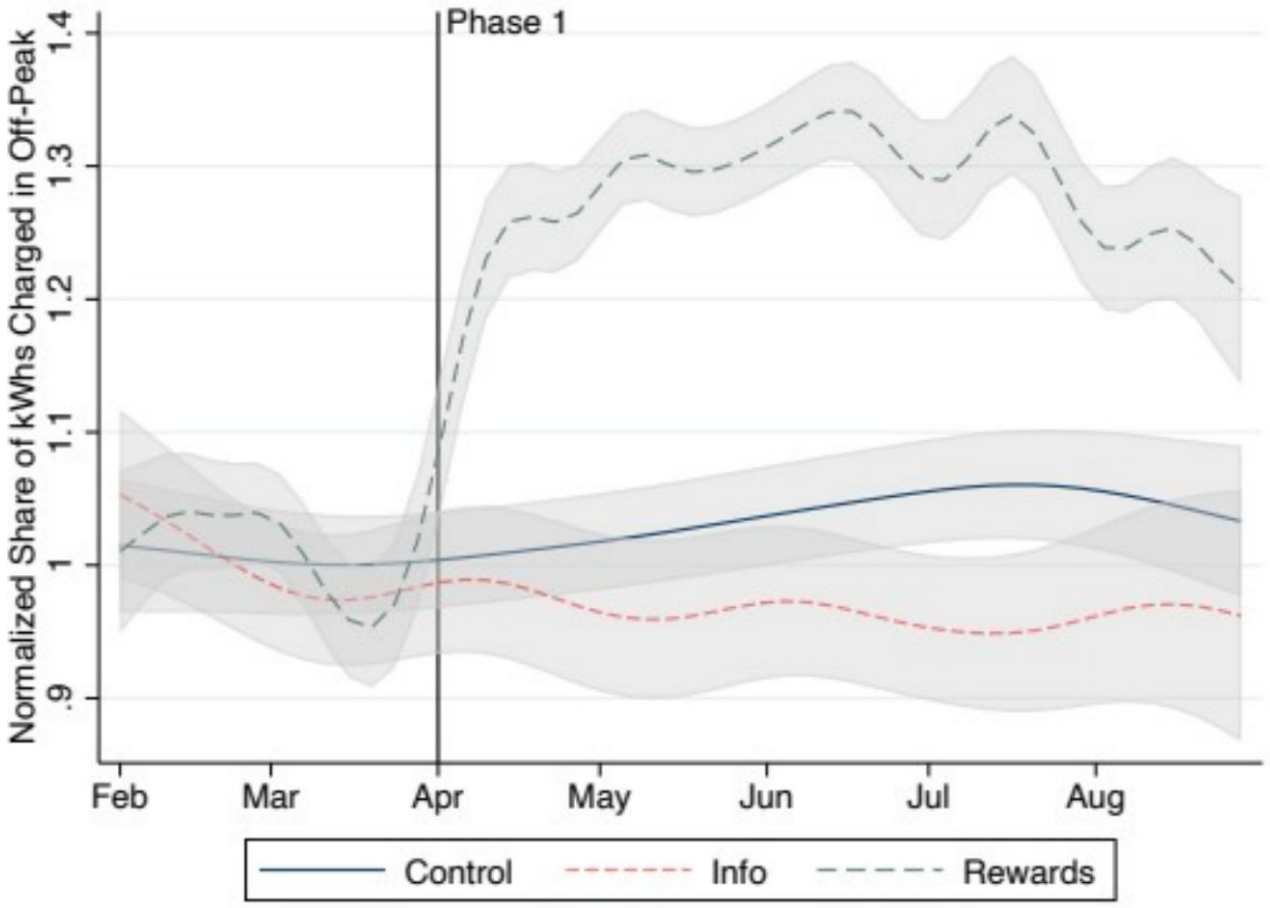
Rewards shift charging; information does not

ENMAX TOU EV study: share of kWh charged off-peak (normalized)



+30%

off-peak charging after a 3.5¢/kWh reward

No change

for the Information group

Treatment begins in April (Phase 1)

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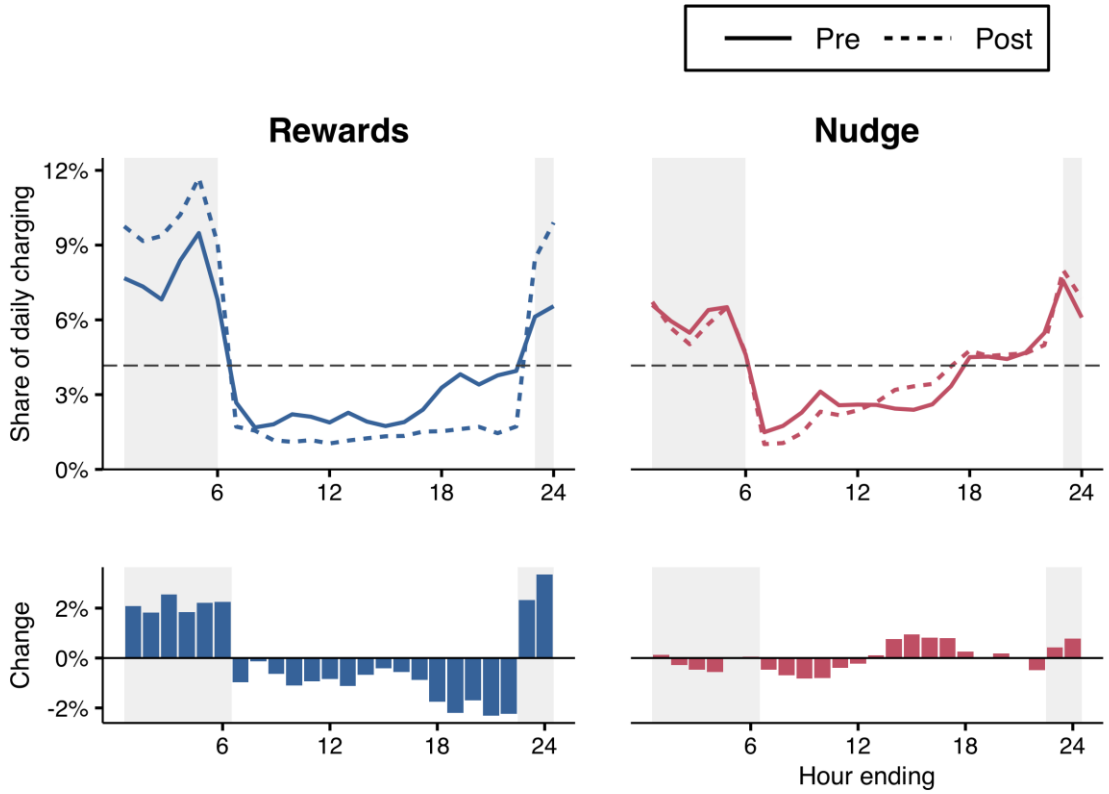
Rewards move charging into the overnight window

Share of daily charging by hour, pre vs post (top) and change (bottom)



- **Rewards:** more charging overnight, less during the day and evening
- **Nudge:** little change

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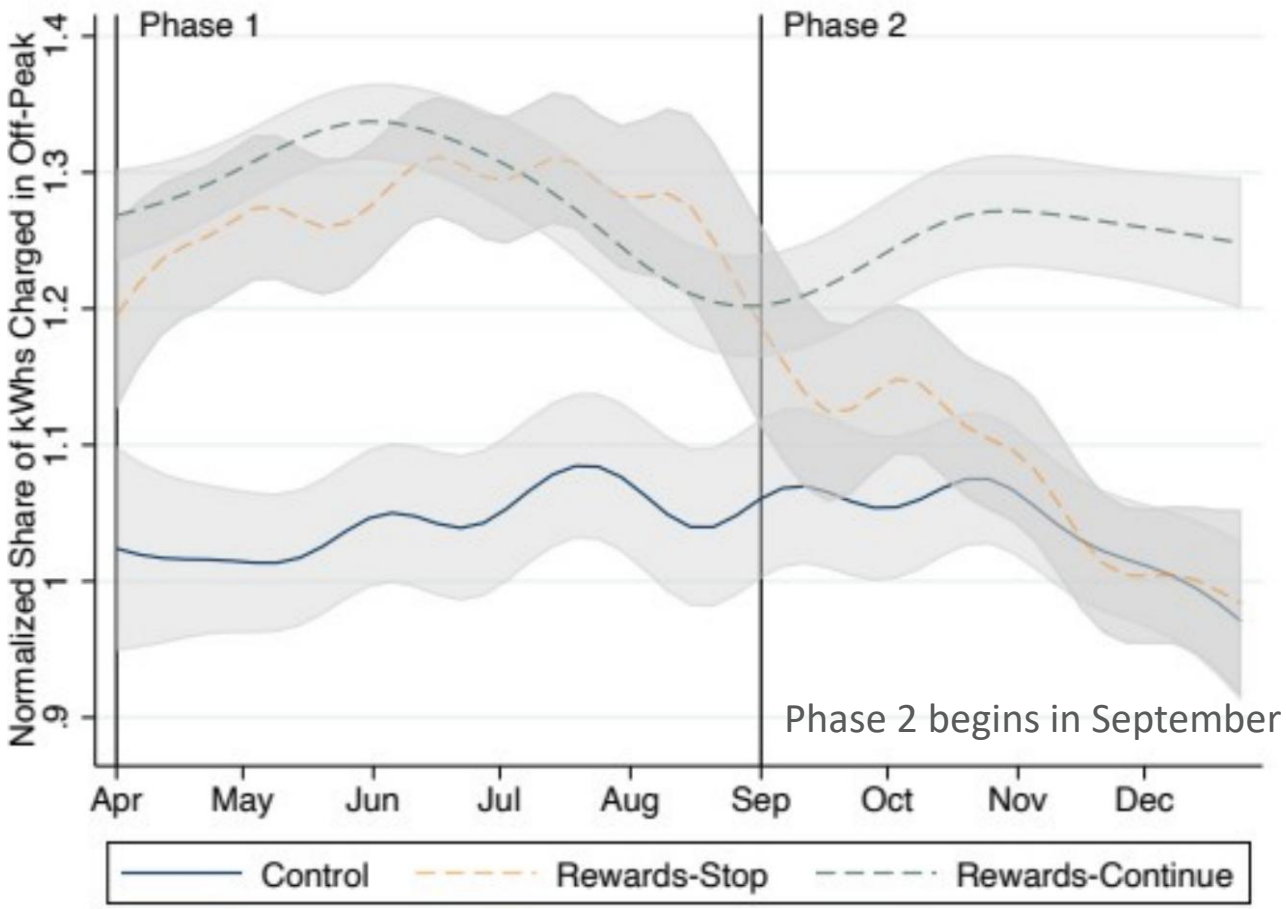
Money matters. Behavior reverts once payments stop.

Share of kWh charged off-peak (normalized), Phase 1 and Phase 2



Rewards-Continue

off-peak charging continues

Rewards-Stop

reverts to pre-intervention behaviour

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Price elasticity of demand is an *order of magnitude* larger

Off-peak EV charging, own-price elasticity



–1.6

Typical residential demand price elasticity



–0.1

Why? EV batteries separate the service (*driving*) from the power draw (*charging*).

In most situations, charging can move to an overnight hour without changing the service.

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Experiment 2.
Too flexible?

Unintended consequences of TOU rates with very flexible devices

Published as:

Bailey, Brown, Myers, Shaffer, & Wolak (2025)
Electric Vehicles and the Energy Transition: Unintended Consequences of Time-of Use Pricing
AER: Insights

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It’s not just about the bulk system

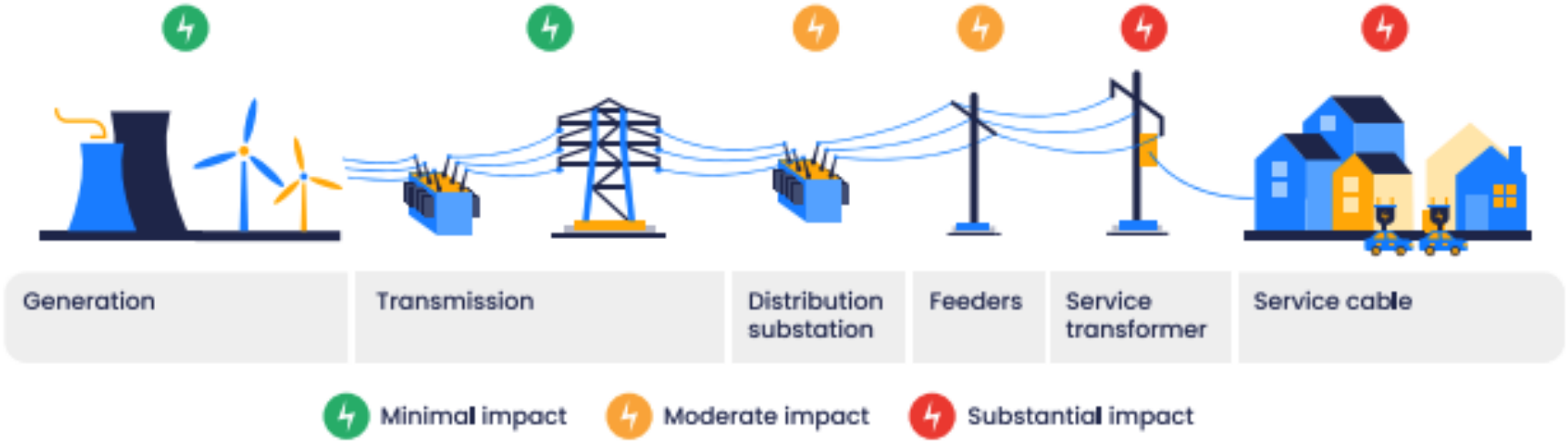

Image from EnergyHub

Bulk system

Many diverse households: aggregate load is smooth and predictable. EV charging mostly changes the level and timing of overall demand.

Local distribution

Fewer households per asset, less diversity, more granular load. EV charging stresses wires and transformers.

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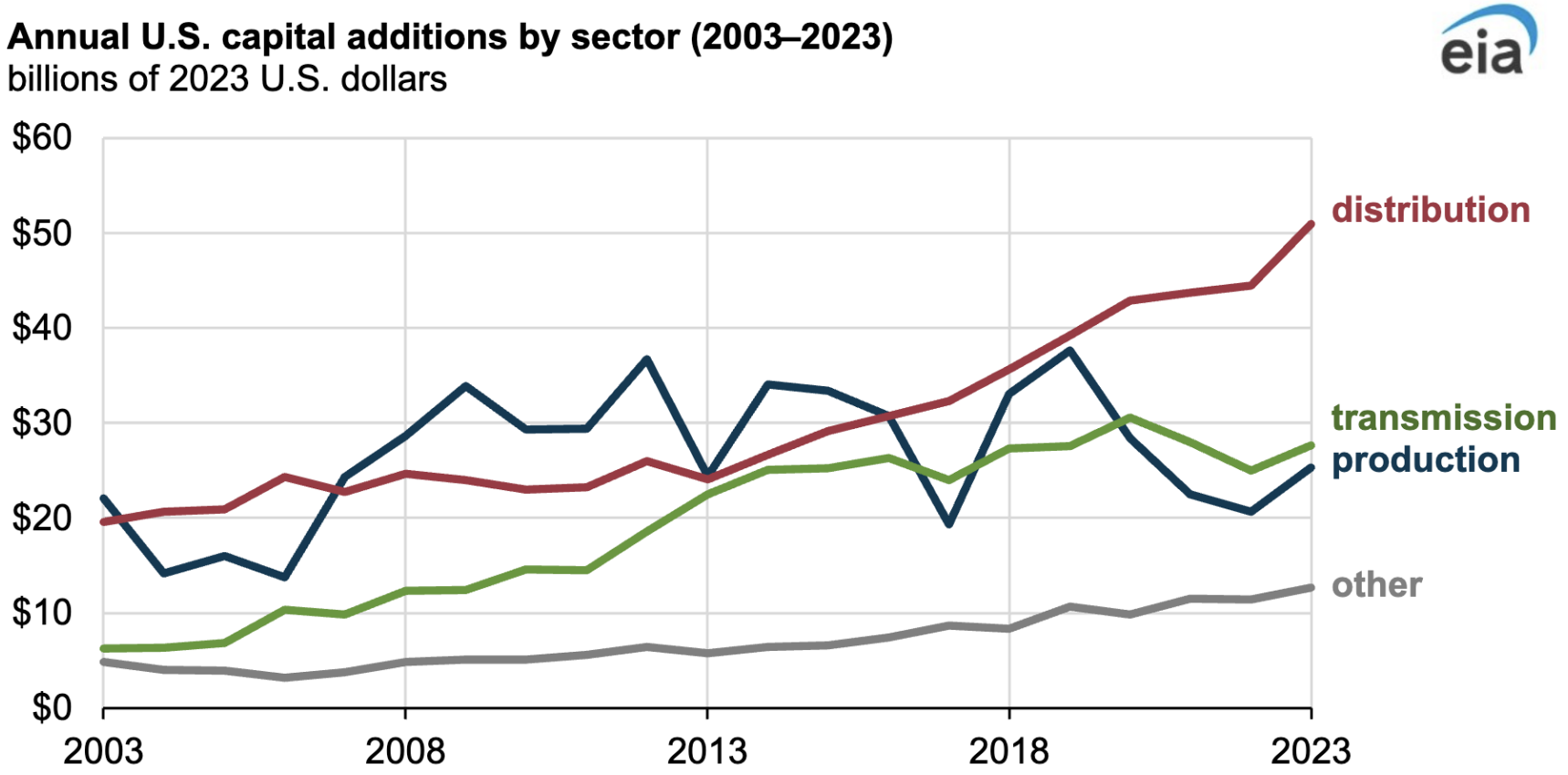
Distribution costs are rising



Data source: U.S. Energy Information Administration and Federal Energy Regulatory Commission (FERC) financial reports, as accessed by Ventyx Velocity Suite

Since 1990, real annual spending on the distribution system has more than doubled (EIA, 2023)

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The mighty transformer



~10 homes

served by a typical residential transformer, the last link before the customer

Strained

by larger loads, especially when they are geographically concentrated

~200%

increase in transformer capacity required by 2050 due to electrification (NREL, 2023)

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The Fortis experiment: What we do

FortisAlberta (rural and suburban Alberta) with Optiwatt (EV charging app); ~200 EVs, monitored then randomized

Control

No additional messaging

Time-of-Use

3.5¢/kWh reward for all off-peak charging (10am–2pm and 10pm–6am)

Managed Charging

3.5¢/kWh reward for all *managed charging* at home

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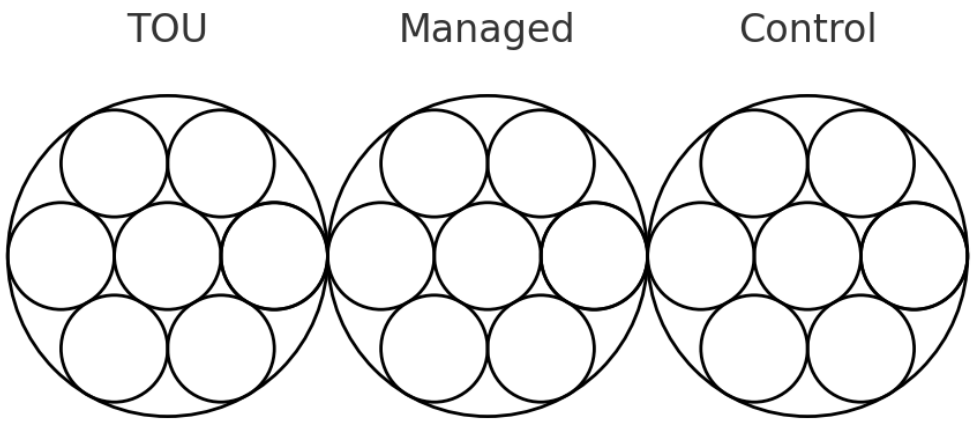
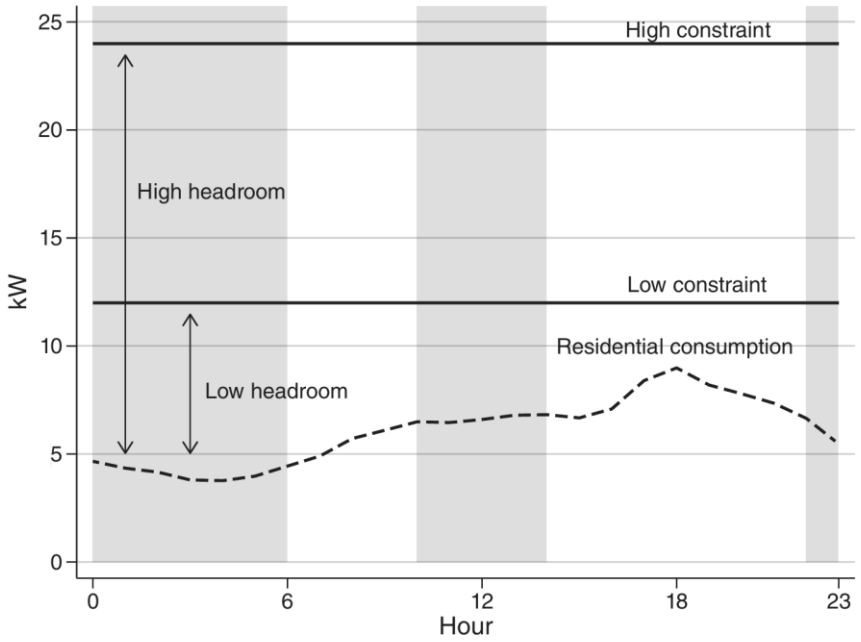
Managed charging: Going beyond individual behaviour



- **Virtual transformers:** groups of 10 EVs, with aggregate load monitored
- **Constraints** Consider a range of constraints; headroom is the constraint minus non-EV load
- **Key metric:** **violations of the transformer constraint**



Managed charging

Drivers set a target charge and departure time; the app sequences charging within the headroom. A "Boost" button lets drivers override.

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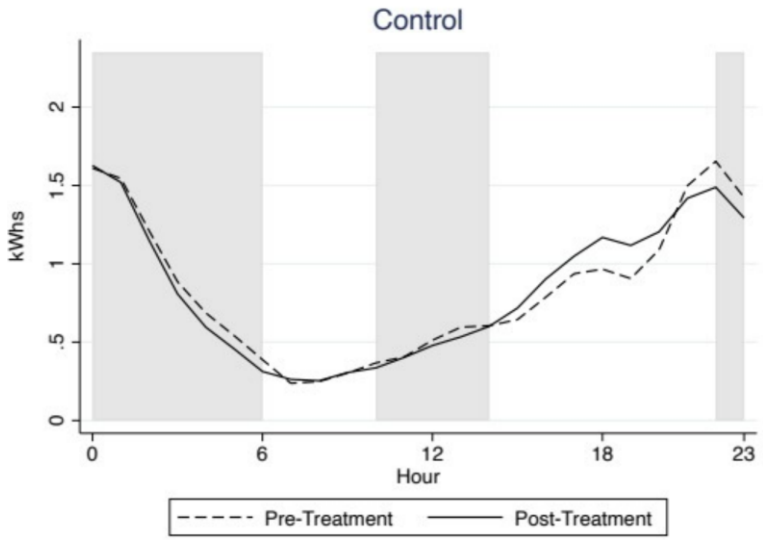
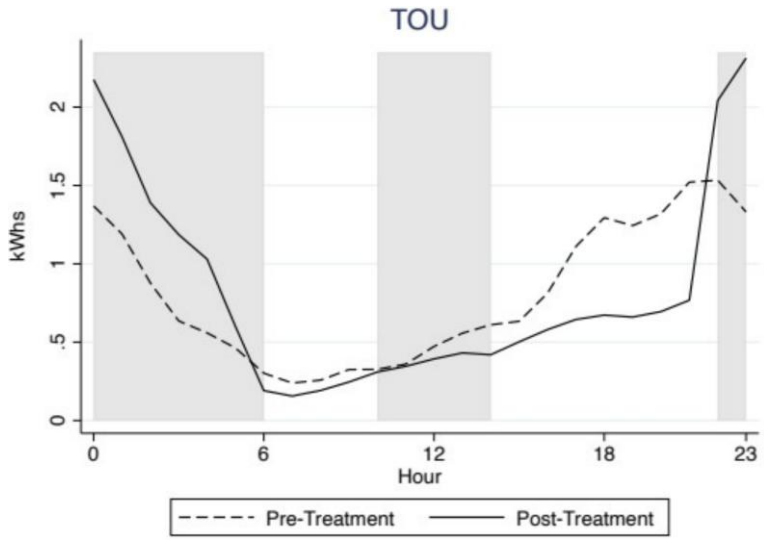
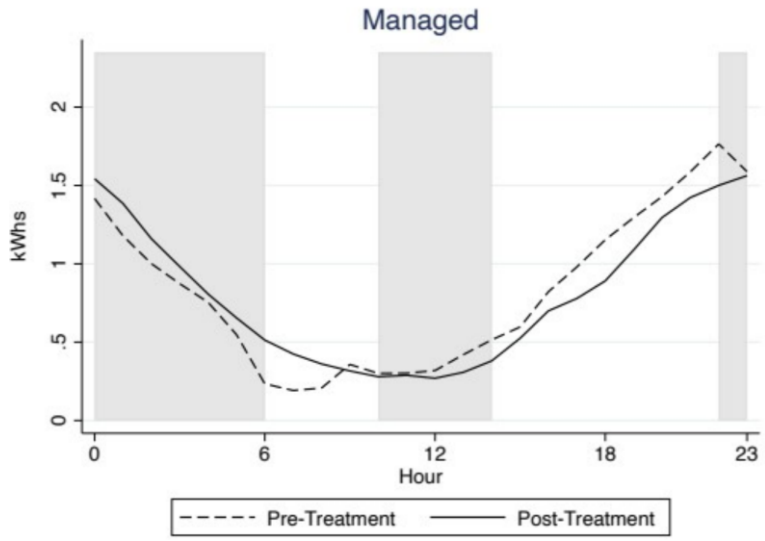
TOU shifts load into the cheap hours

Average hourly load per vehicle, pre vs post treatment (shaded = off-peak)







No change to Control

Large shift to the TOU shape

No change to Managed shape

TOU: peak charging −55%, off-peak charging +54%, concentrated at the start of the cheap window

Confirms ENMAX result: EV charge timing is very price elastic

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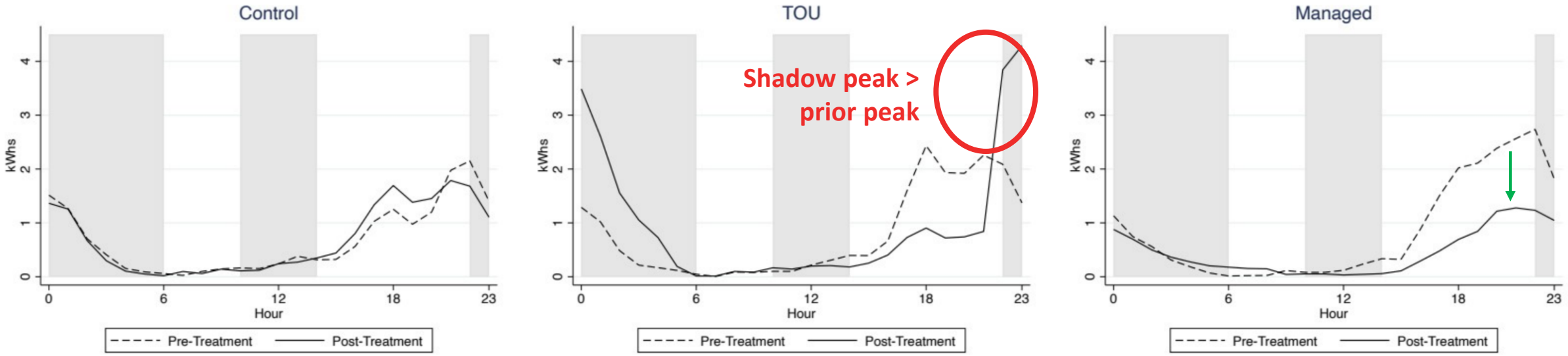
TOU rates can create a new “shadow peak”

Transformer constraint violation magnitude



No change to Control

Larger violations from TOU

Reduced violations from Managed

TOU makes the peak issue *worse*; managed charging smooths it.

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TOU shifts load, but managed charging smooths it

TOU

–55%
peak charging

+54%
off-peak charging

–85%
peak violations

+139%
off-peak violations

Managed charging

–79%
peak violations

–21%
off-peak violations

~1%
of managed events overridden

<1%
of charge-days overridden

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Will people accept managed charging?

44 of 5,743

managed charging events were overridden (~1%)

Similar attrition

in the TOU and Managed groups

34 of 35

control households offered managed charging chose to join ($0, $75 or $150 incentives)

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Why is TOU a problem with EVs, and what helps?

1 EVs are big and flexible

Big power draw that **moves easily**.

Household peaks become more correlated under TOU

2 Demand charges can help

$ per kW based on peak demand encourages lower-draw “Level 1” charging

3 Managed charging resolves the problem

But will people accept it?

More research needed on take-up

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Experiment 3.
Automation is key

Evidence from a residential demand response field experiment

Published as:

Bailey, Brown, Shaffer, & Wolak (2026)
Take the Load Off: Effort and Technology as Determinants of Electricity Demand Response
NBER Working Paper

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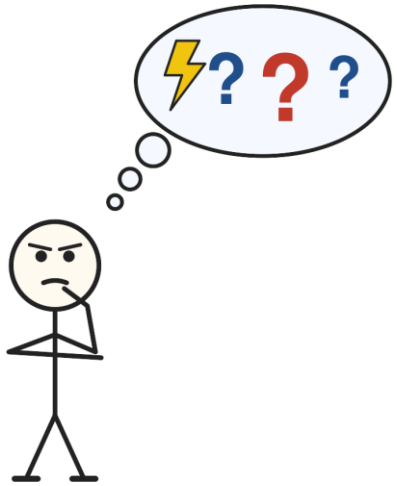
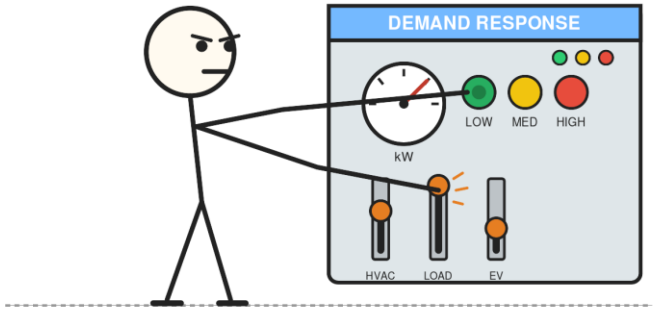
Two stages of consumer response

1. ***Should I respond to this event?***



Should I respond?

2. ***Conditional on responding, by how much?***



How much should I respond?

Overall demand reduction = (likelihood of responding) × (magnitude | responding)

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In this experiment we ask:

- Do households respond to price incentives to reduce demand?
- What is the role of **technology** in boosting demand response?
- What is the role of **automation**?

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Step 1: Assign to 3 Demand Response Programs

Manual Program

Active response req'd

Notified of a peak event; respond yourself

Tech Program

Active + enabling technology

Notified of a peak event; opt in on App to respond

Central Program

Passive (automated)

Centralized load control by default; opt out of events

Manual vs Tech: effect of enabling **technology**

Tech vs Central: passive vs active response (**automation**)

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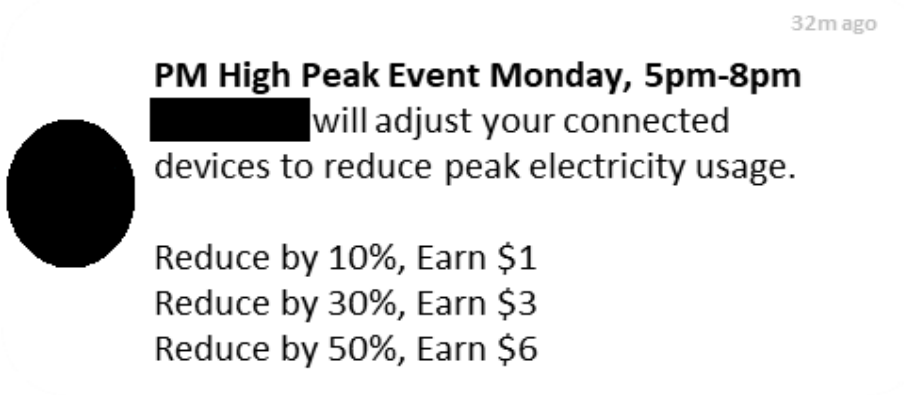
Step 2: Randomized “peak events”

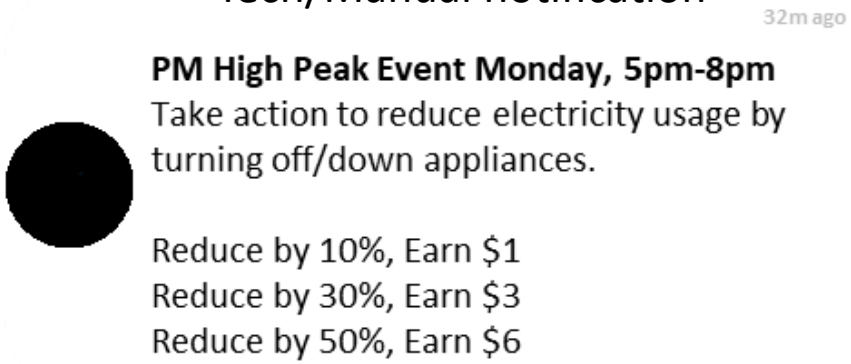
Participants receive randomized encouragements to reduce consumption for 3-hour periods

- ~ 3 events per month
- Over 17 months
- Morning (7-10am) or Evening (5-8pm)
- Regular (C$1-3) or High (C$1-6) pricing

Central Program notification



Tech/Manual notification



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Individual randomization gives us more information

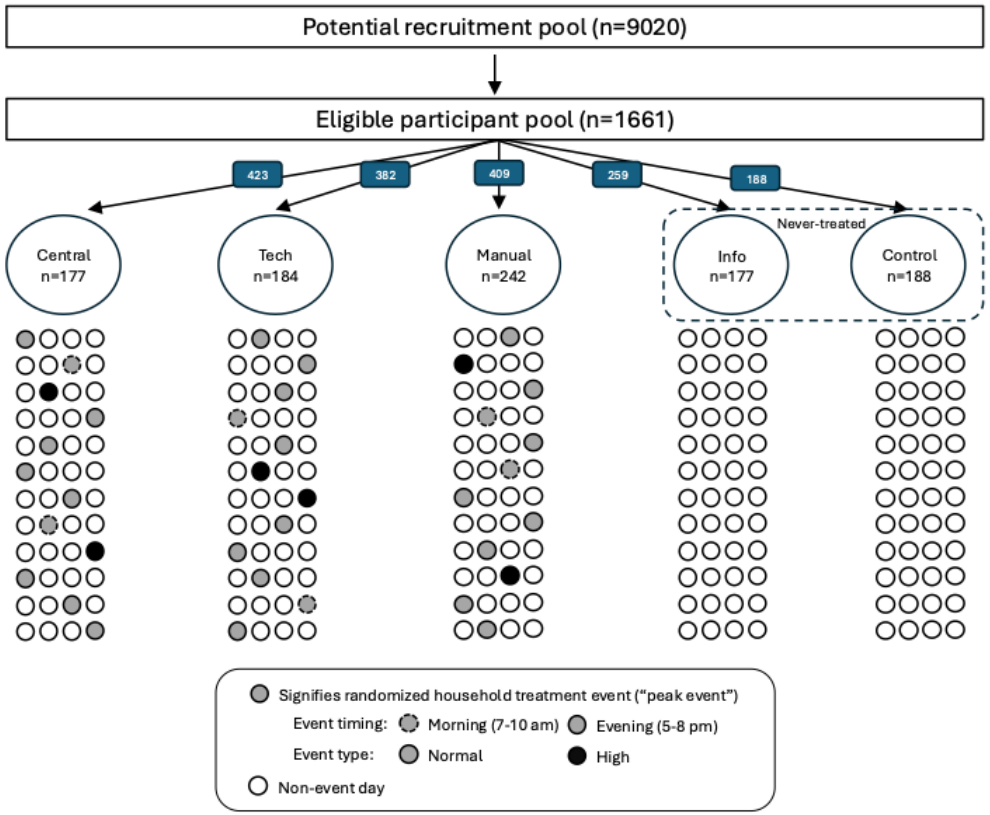
Every participant gets a different schedule

Gives us variation both *within* and *across* subjects. Benefits of this method:

1. Estimate full **distribution** of household treatment effects

2. Examine **heterogeneity** and how performance correlates with household attributes and behavior

3. Boosts **statistical power**!



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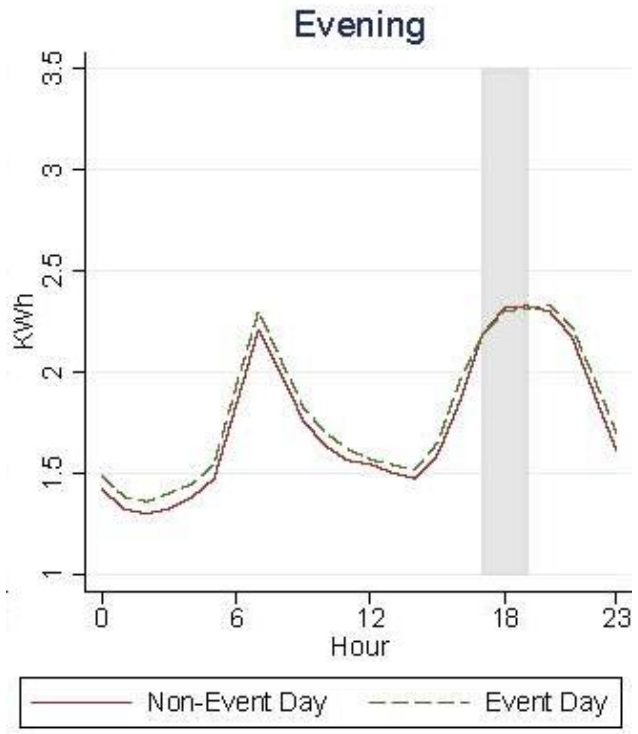
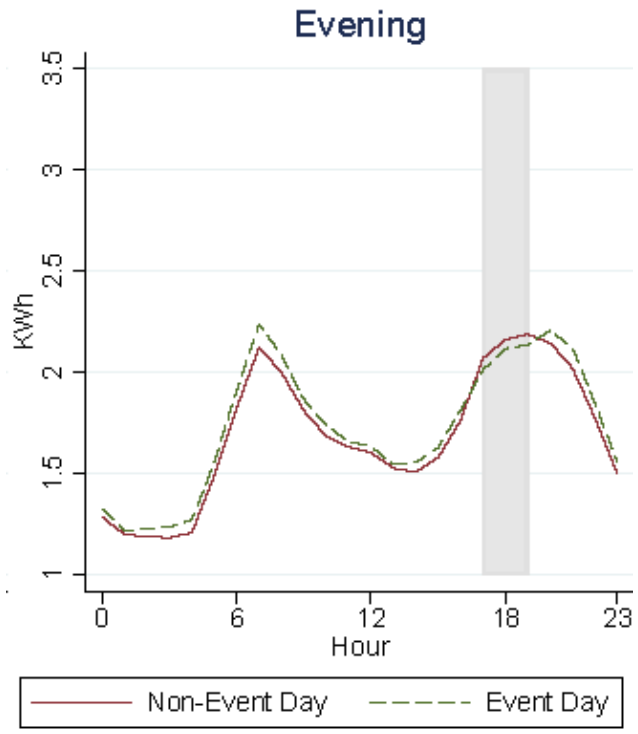
Results: Event days vs non-event days

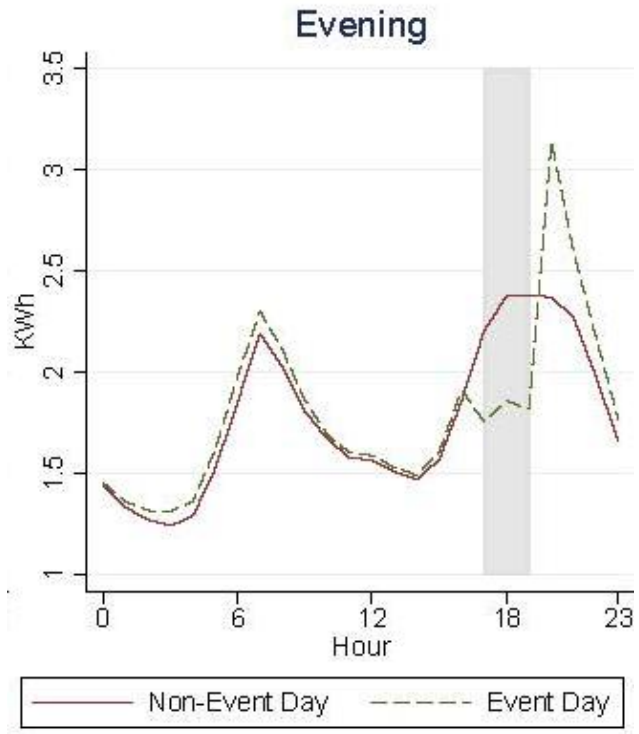
Evening events: average household consumption by hour (shaded = event window)



Manual: minimal difference



Tech: minimal difference



Central: big cut, then snapback

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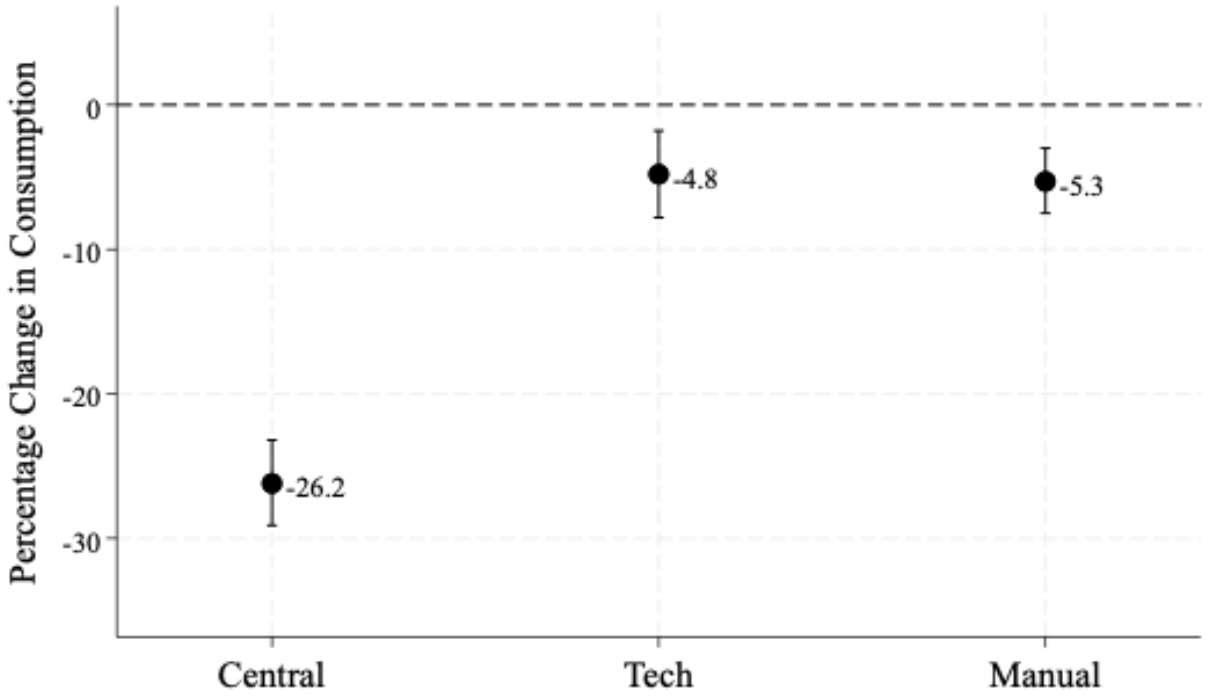
Central control performs 5x better

Change in consumption during events, by program



–26.2%
Central (automated)

–4.8%
Tech, no better than Manual

–5.3%
Manual

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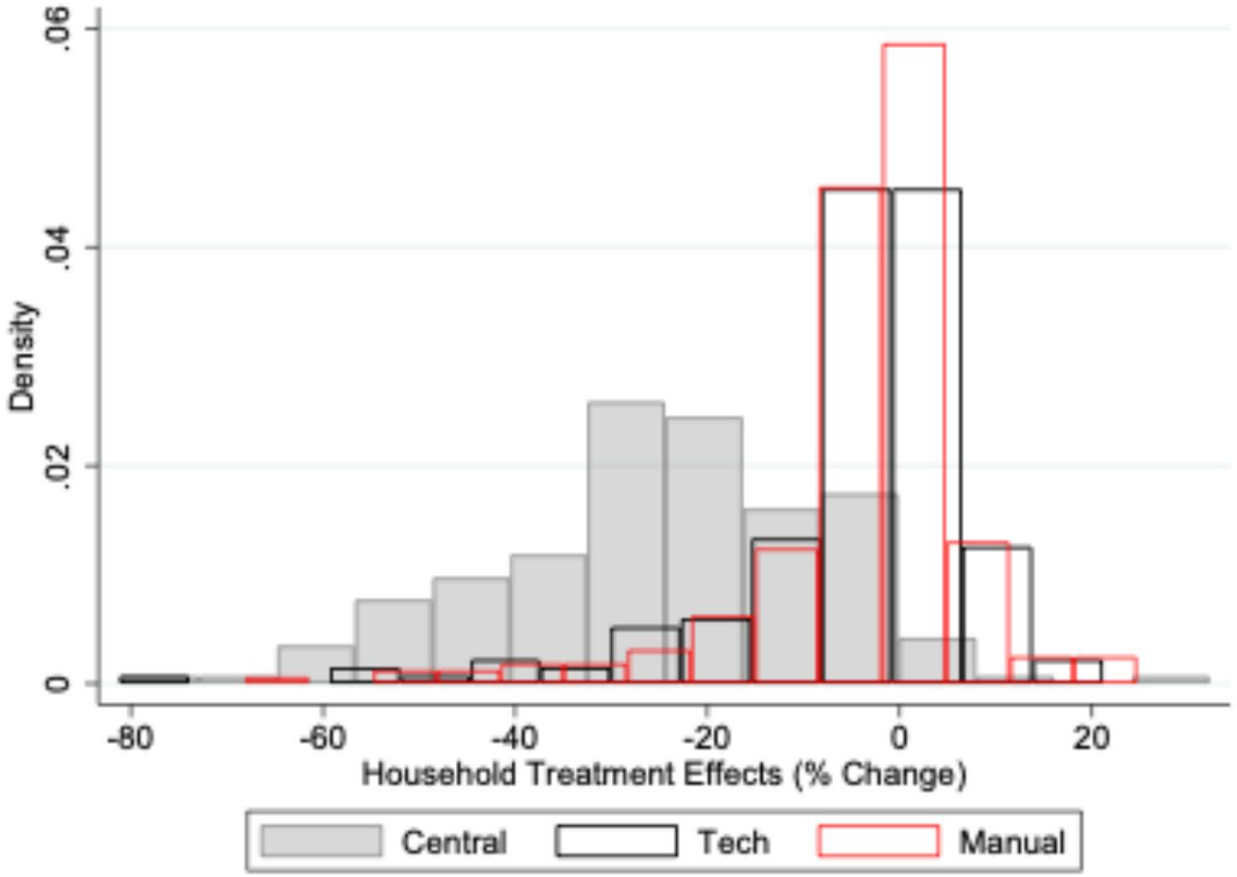
Household-level estimates



Tech and Manual

- Modal response near 0
- Mean response 4.6% and 4%
- Some large responders
- 20% of estimates significant

Central

- Mean response 24%
- 80% of estimates significant

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Central lifts both stages of response

	1. Likelihood of responding		2. Magnitude (%), when responding	= Overall reduction
Central	80%	×	−0.31	−24.8%
Tech	20%	×	−0.27	−5.4%
Manual	18%	×	−0.23	−4.1%

Responders: significantly negative household effect ($p < 0.05$). Magnitude. % Change in consumption.

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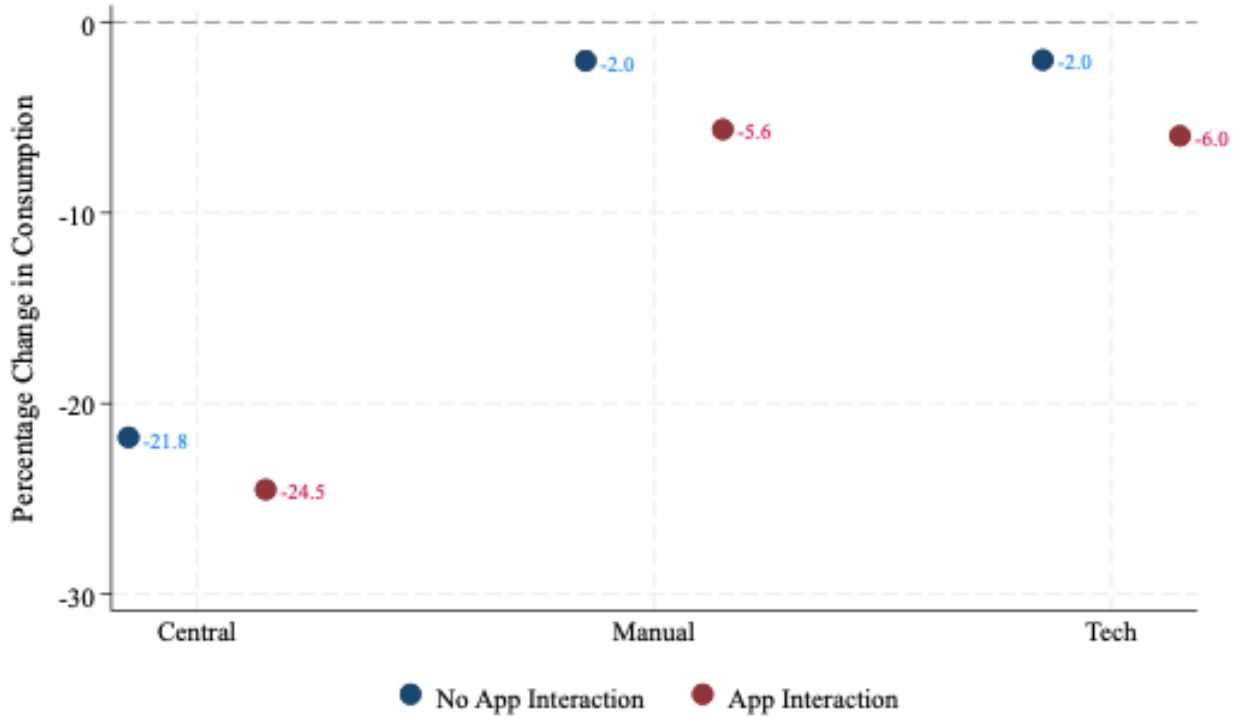
Effort and attention: interacting with the app

Consumption reduction, with and without app interaction



–2% to –6%

Tech and Manual respond more when households interact with the app

–22%

Central has a head start, even with no app interaction

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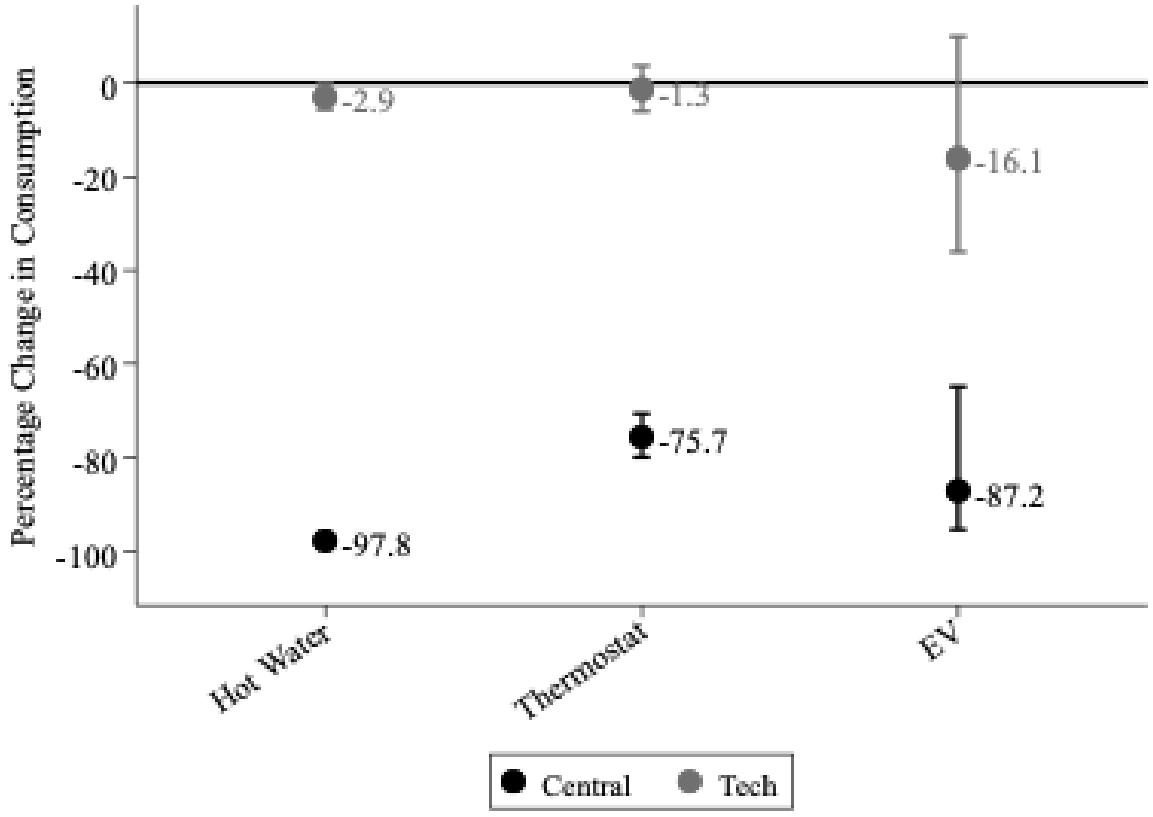
Which devices respond?

Change in consumption by device composition (Central vs Tech)



Water heaters

biggest beneficiary of automation

EVs

respond somewhat even without central control

More devices

means more response

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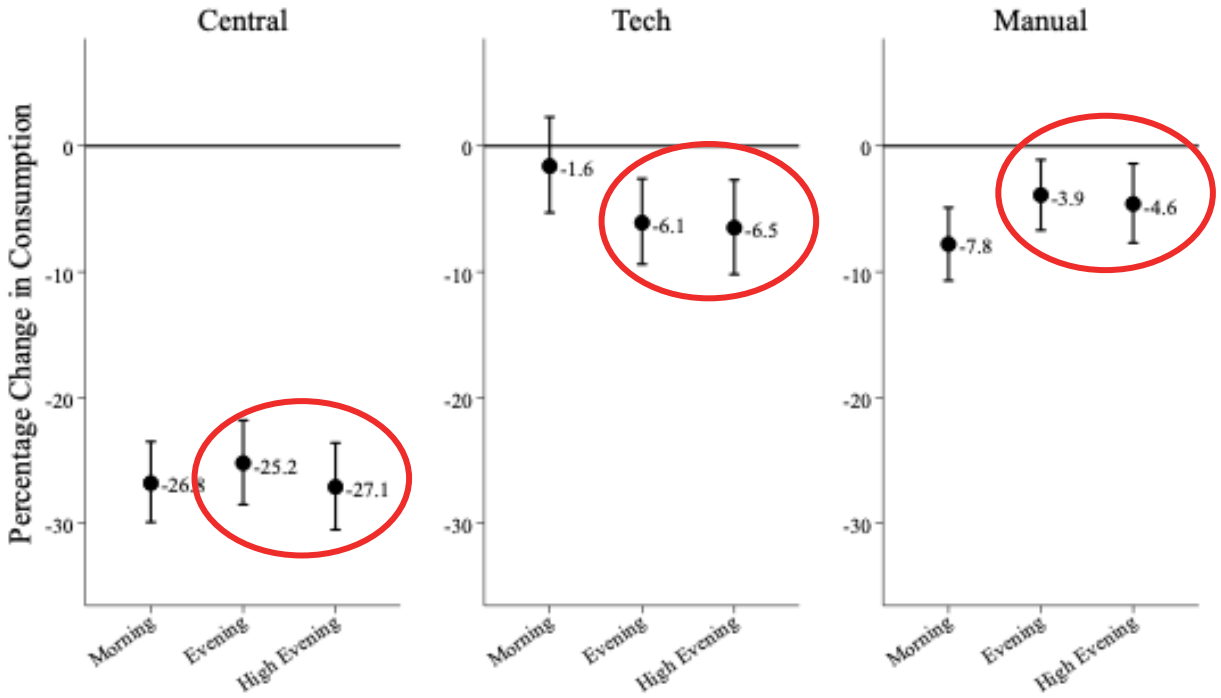
More money does not buy more response

Change in consumption by event type (morning, evening, high-incentive evening)



Higher rewards do not raise responsiveness in Tech or Manual (consistent with Prest, 2020)

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Others find that automation is key

Automation, not information or price alone, delivers the response & defaults are important

Smart meters and dynamic pricing

Bollinger & Hartmann (2020)

Management Science, 290–314

- Only automation technology yields the short-run price elasticity needed to justify real-time pricing
- Information alone does not

Smart thermostats, RCT

Blonz et al. (2025)

Blonz, Palmer, Wichman & Wietelman. AEJ: Applied 17(1): 90–125

- Automated AC reduction at peak prices
- Customers rarely override it
- They accept small discomfort for savings

Norway, default enrolment

Garnache, Hernæs & Imenes (2025)

JAERE 12(2): 257–283

- Critical peak pricing with default enrolment
- Peak consumption down 15.3%, similar across income groups
- Majority of users defaulted-in stayed

What this suggests

Automate

Passive (default) response, with an opt-out

Cut the effort

Reduce effort costs for repeated, small-stakes rewards: “picking up pennies”

Tech and money are not enough

Technology and financial rewards may be ineffective without automation

Next question

Willingness to hand over control?

Key takeaways

Effort is a barrier to performance

Automation is key

Not all devices are equal

EVs are a big source of flexibility

Beware uncoordinated flexibility

Unmanaged response can create new peaks

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Thank you!

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apps.ualberta.ca/directory/person/dpbrown

ucalgary.ca/electricity-centre

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Backup

Extra slides for questions

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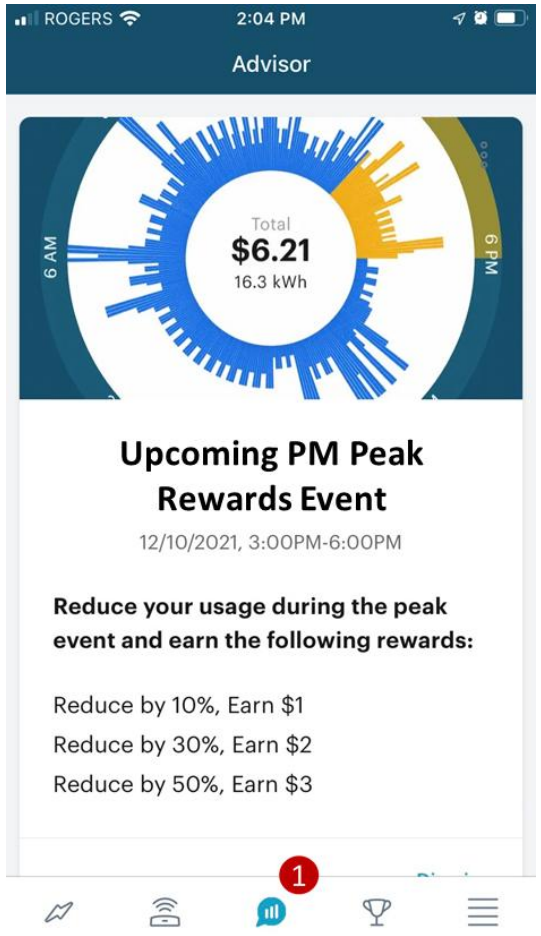
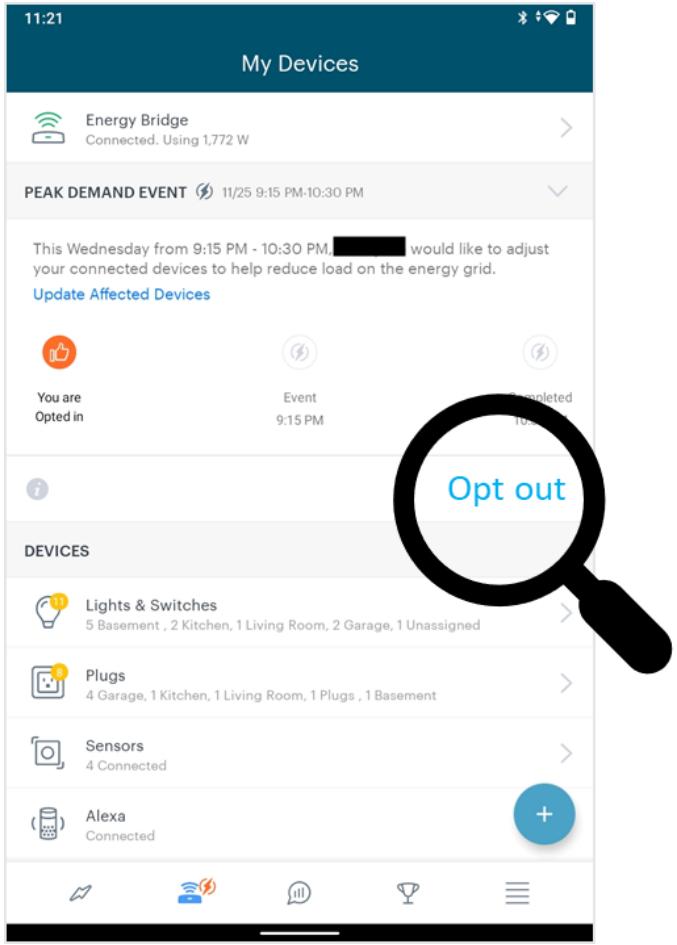
In-app notification and Central opt-out



In-app notification



Central opt-out

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Program acceptance

	Central	Tech	Manual	Info	Control
Invited	423	382	409	259	188
Accepted	177	184	242	177	188
Rate	42%	48%	59%	68%	100%

Central and Tech take-up rates are roughly similar; the Manual take-up rate is higher.