Centre for Net Zero

Critical peak rewards

Can paying households to cut peak demand buy reliable capacity at national scale?

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Next in Flex

Flexible demand matters more as grids electrify

The problem: Reliable electricity supply is becoming harder. The 2021–22 price crisis exacerbated underlying challenges from rising demand and changes to supply.

More electrified demand

Heat pumps and EVs add load that can be timed, if households are willing.

Weather-dependent supply

Supply that follows wind and sun needs demand that can follow it back.

No national-scale evidence

Smaller evaluations exist. Causal evidence on a nationwide programme did not.

Britain is where this was tried at national scale.

Pricing is well studied; rewards at scale are not

Pricing: charge more at the peak

Customers can end up worse off.

Earlier work: peak-time and critical-peak pricing, interruptible contracts. Mostly small scale.

Closest study: Fowlie et al. (2021) randomised opt-in versus opt-out pricing for 174,000 households in Sacramento. About 20% signed up.

Rewards: pay for cuts at the peak

Nobody can end up worse off, so retailers can advertise events widely.

Closest study: Bailey et al. (2025) compare utility-managed, manual and app-controlled arms in a Canadian programme.

Nationwide: no causal evidence on any critical peak reduction programme.

> This paper: critical peak rewards, tested nationwide with randomised invitations.

How Britain's Demand Flexibility Service works

System operator

NESO pays providers £150 to £6,000 per MWh. The average accepted bid was £3,100 per MWh.

Retailer or aggregator

Decides how much to pass on. In our events households were offered £1.75 to £4 per kWh.

Household

Signs up once, then opts in to each event. Paid for cutting below a baseline from recent smart-meter data.

NESO is Britain's National Energy System Operator. The service began as an emergency measure in winter 2022 to 2023 and became a regular market service in 2024 to 2025.

Four questions

Does paying households to cut peak demand work?

Is there a scale / voltage tradeoff?

When is that capacity worth its cost?

How generalisable are the results?

Largest natural field experiment on energy demand

2.7M

customers in the experiment, every eligible household and small business

15

events across winter 2023 to 2024

22%

of Britain's household electricity market served by our partner utility

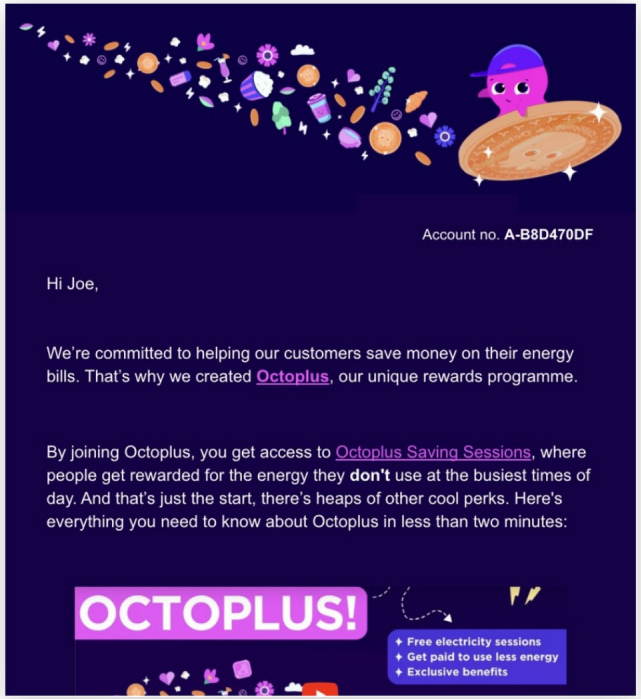
119,999

households in the no-invitation control group

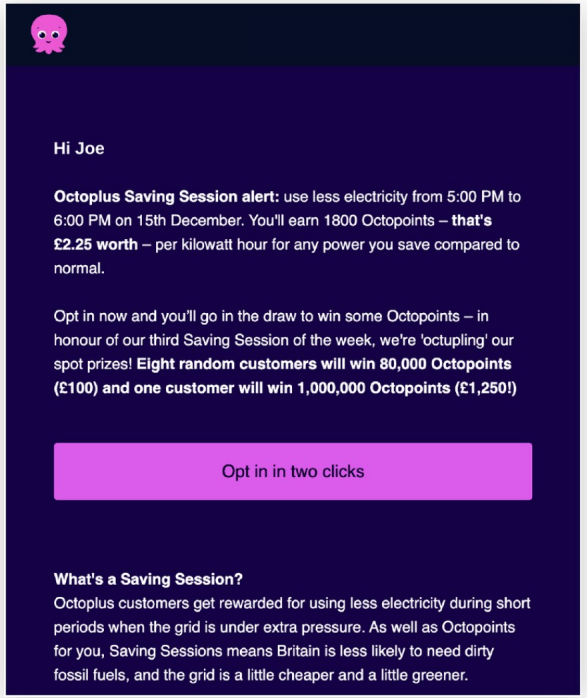
Within the utility we worked with:

- 1.5m households signed up to the programme
- Average opt-in rate of 37%
- 15 events were held; we excluded 2 from analysis due to problems sending notifications in those events

The two emails households received



Step 1, sign up: the encouragement email we randomised, inviting households to join Octoplus and take part in DFS events.

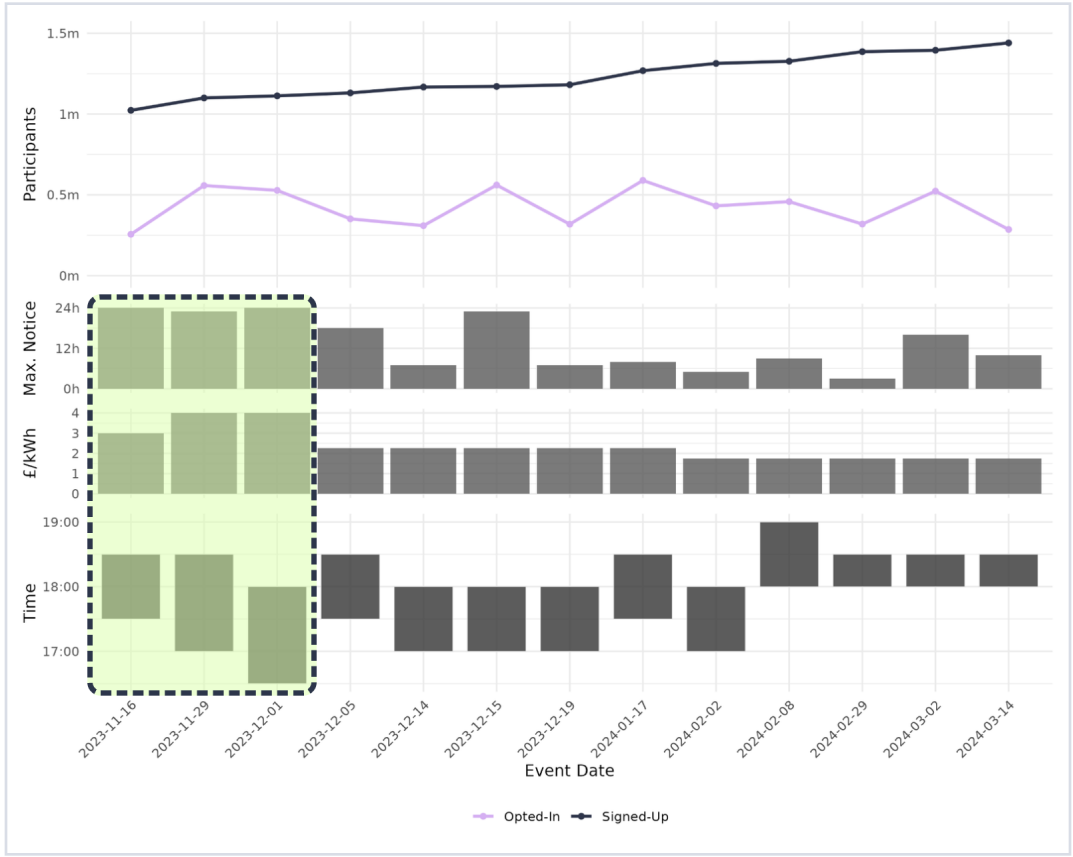


Step 2, opt in: the email to signed-up customers before each event, with the reward on offer.

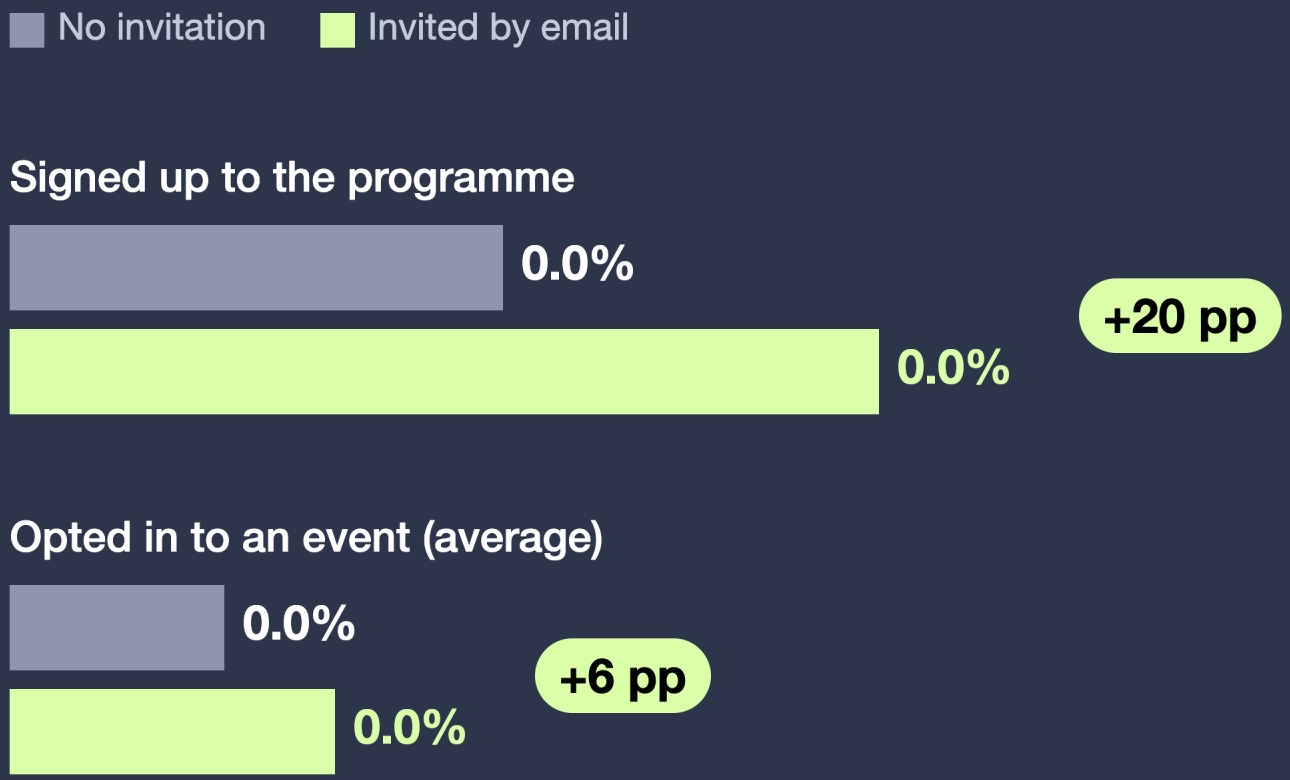
Earlier events tended to be longer, have longer notice periods, and have higher remuneration

In the 13 events we analyzed:

- Notice period varied from day-ahead (24h) to within-day short notice (3h)
- Event length varied between 30 min and 1h30min
- Events were always during UK peak (4:30pm to 7pm)
- Incentives varied from £1.75 to £4 per kWh reduction



The encouragement email was successful in creating a wedge between control and treatment



Everyone eligible was in the sample. Control households could still sign up on their own.

Many did: about 26% of the control group signed up anyway.

40,000 control households were invited late, to test for fatigue.

The events substantially decreased electricity consumption

Invitations were assigned at random, so invited and not-invited households are alike. Any difference in demand is caused by the invitation.



Everyone we invited
Invited versus not invited households, including the many who never act.

-1.4%
ITT

Signed up because invited
Households that joined because of the invitation. They skip many events.

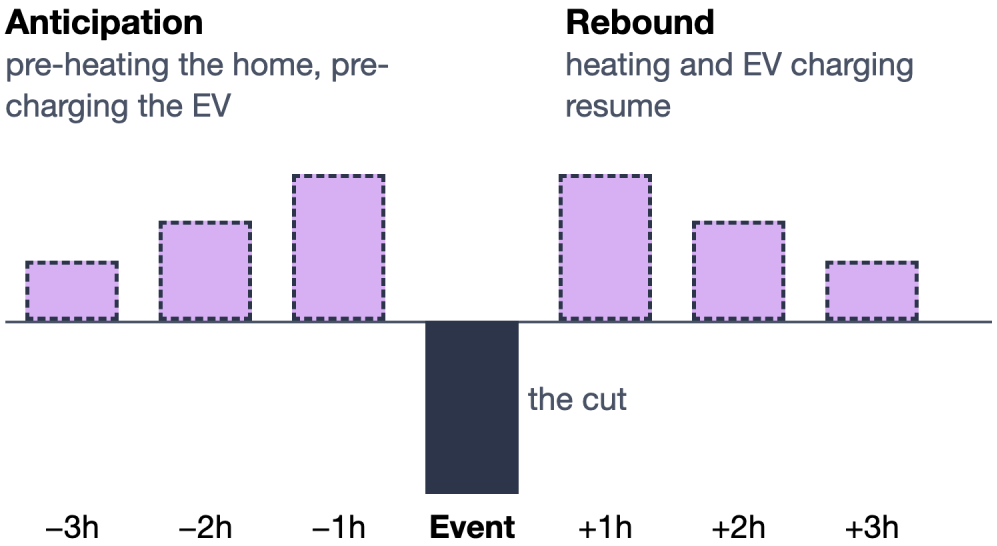
-6.8%
LATE on sign-up

Opted in to an event because invited
Households that said yes to an event because of the invitation, measured during it.

-23.1%
LATE on opt-in

What we expected, and what we saw

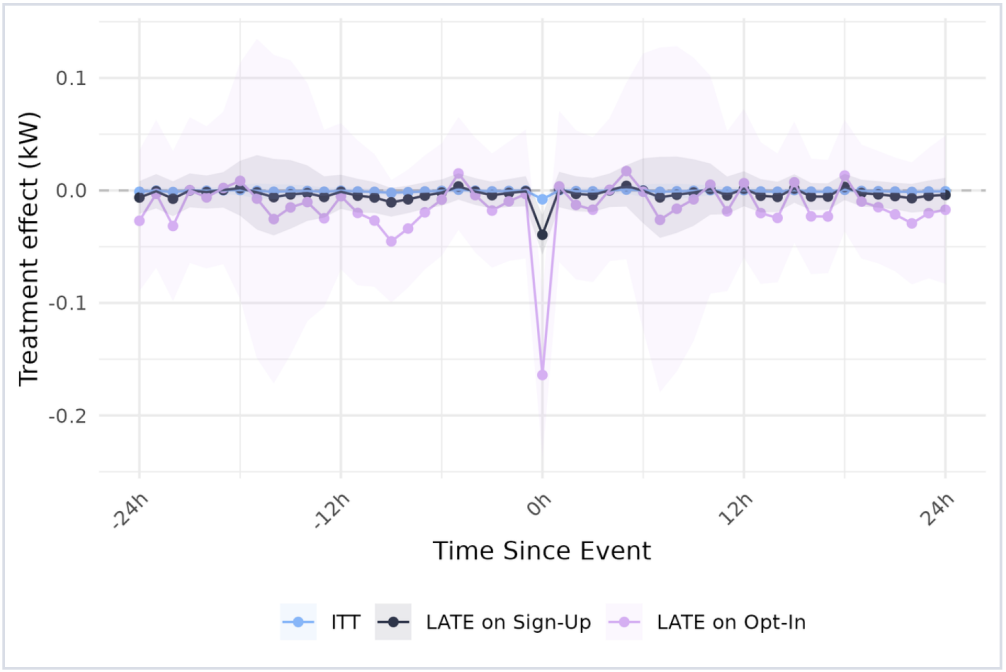
What we would expect if households shifted use



Schematic of the expected pattern, not data

Extra use before the event (anticipation) and after it (rebound).

What we saw: treatment effects around the events (kW)



Neither: no increase before or after, across seven non-overlapping events.

Why we saw no anticipation or rebound

What households told us

15,000 households surveyed in three surveys; **4,278** responded (29%); **3,234** of them took part in an event. Answers below are from the 3,234.



- **Avoided use only** (switched off appliances or left home)
- **Shifted only** (ran appliances before or after)
- **Both**
- **Other or unclear**

Why there is nothing to anticipate or rebound

A manual response

Most households switched things off or left home. That destroys load rather than moving it.

Little heating, no cooling

Winter evenings leave no cooling load. Only 8.4% of households in England and Wales heat with electricity (2021 Census).

No automation

Few households have an EV, a heat pump or a battery: the loads that can be pre-charged or resume after an event.

What we can rule out: large anticipation or rebound in any single hour. Pooling the hours around each event, the smallest effect we could detect is smaller still.

There were no habits, no fatigue, no spillovers

Non-event days

No change in peak-time use

Tariffs and suppliers

No change in time-of-use adoption or switching

Over the winter

No evidence of fatigue as events accumulated

Baselines

No evidence of gaming





Reach was broad and size followed demand

Bigger homes cut more kW

Households with above-average annual use cut roughly twice the average, but by a similar share.

Few differences elsewhere

No meaningful gaps by prior experience, efficiency, dwelling type, tenure, metering, prior supplier or geography.

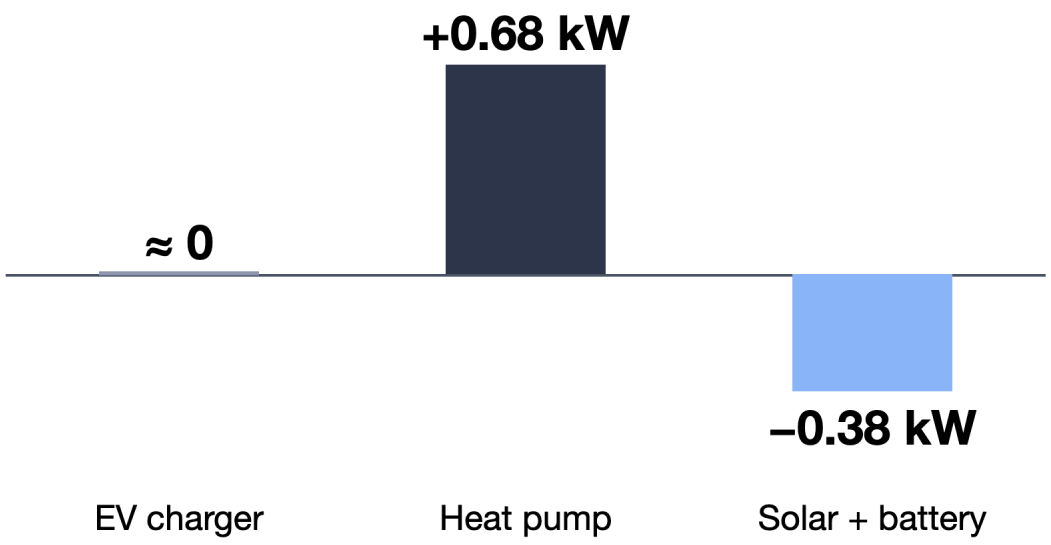
Inclusion is cheap

Renters and prepayment customers respond like everyone else, so including them costs little in efficiency.

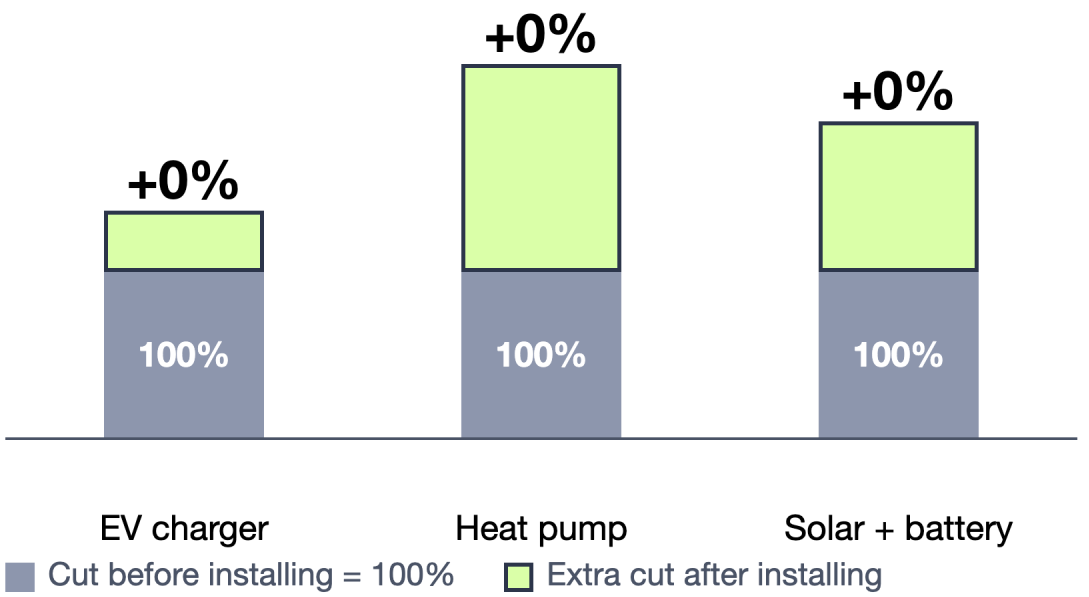
Heat pumps and batteries roughly doubled response

1. What installing does to evening consumption

kW per household during events, without opting in



2. Extra cut when opting in, as % of the cut before installing



Difference-in-differences among technology adopters: the 17,085 signed-up households that installed after the first event, compared before and after installing with households that had not yet installed.

Three ways to scale up

Widen participation

Reminders, late invitations, higher payments and invitations to small businesses all raised take-up.

Raise kW per household

High-use and technology-owning households, where each enrolment delivers more.

Make automation easy

Automation lifts response per signed-up household, but costs effort: requiring an app reduced joining in Bailey et al. (2025)

Enrolment effort should aim at take-up, not at finding better responders.

Valuing it: the marginal value of public funds

MVPF = benefits to society ÷ net cost to government

Consumer surplus

Value of the payments households receive

Both cases

Utility surplus

Share of the payment kept by the retailer

Both cases

Carbon abatement

CO2 saved, valued by HM Treasury

Base case

Lost load avoided

Blackouts avoided, valued at £6,000 per MWh

Scarcity case

divided by

Payment to the system operator

What NESO pays for the reductions

Both cases

Avoided balancing cost

Balancing actions no longer needed

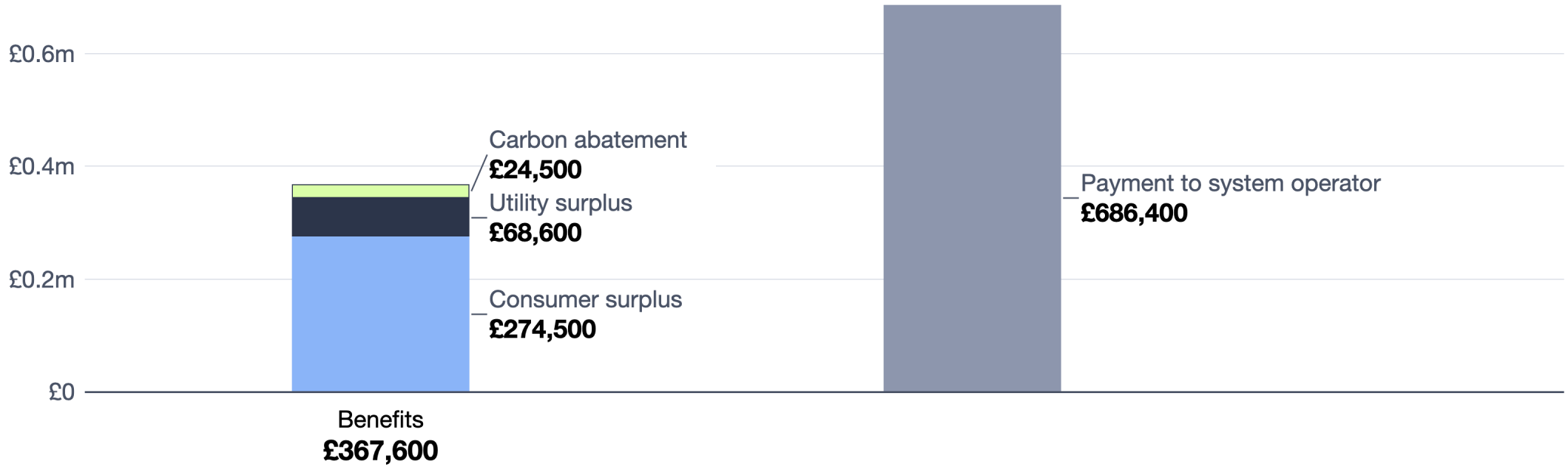
Base case

Base case replaces routine balancing

Scarcity case avoids involuntary disconnection

Base case: the programme replaced routine balancing

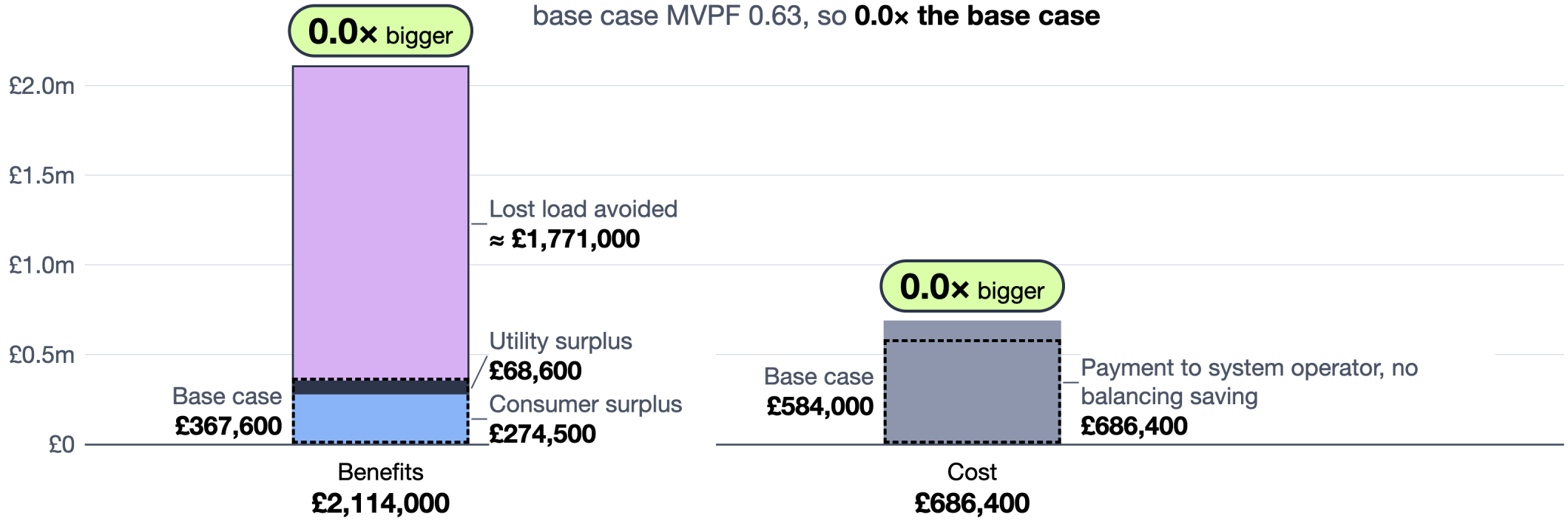
£367,600 ÷ £584,000 = MVPF 0.00



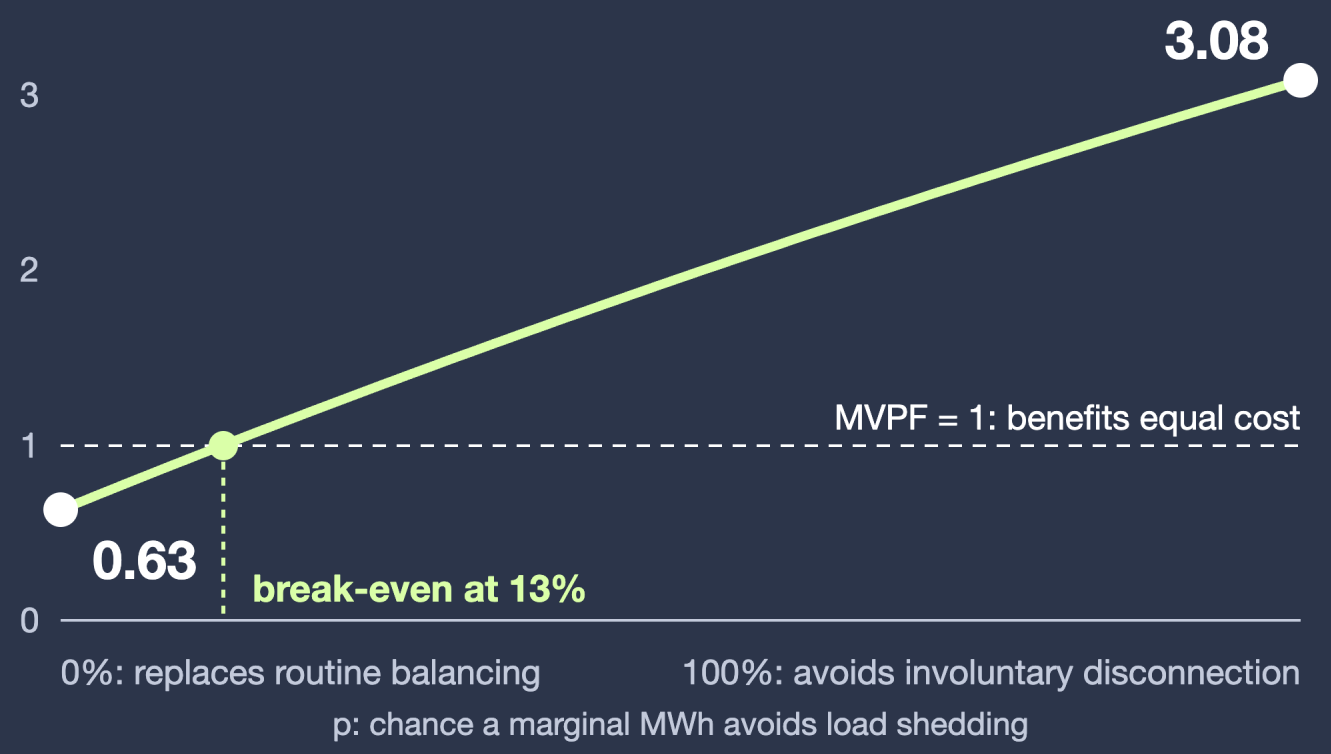
Scarcity case: it would have avoided disconnection

£2,114,000 ÷ £686,400 = MVPF 0.00

base case MVPF 0.63, so **0.0× the base case**



What it was worth depended on what it displaced



0.63 when it replaces routine balancing.

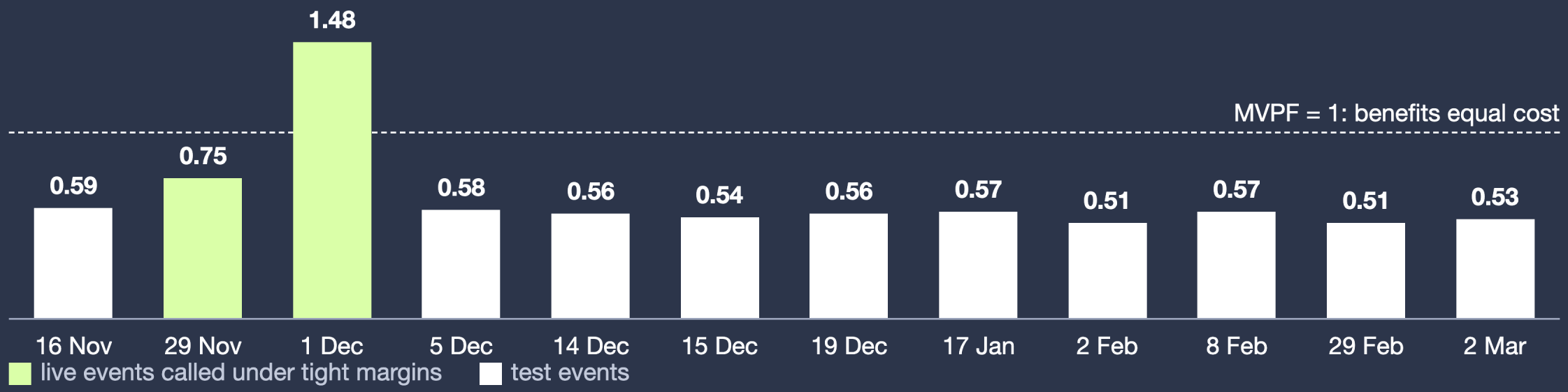
3.08 when it avoids involuntary disconnection.

It breaks even if a marginal MWh has a 13% chance of avoiding load shedding.

Curve reconstructed from the paper's campaign totals.

Base case: highest when the system was stretched

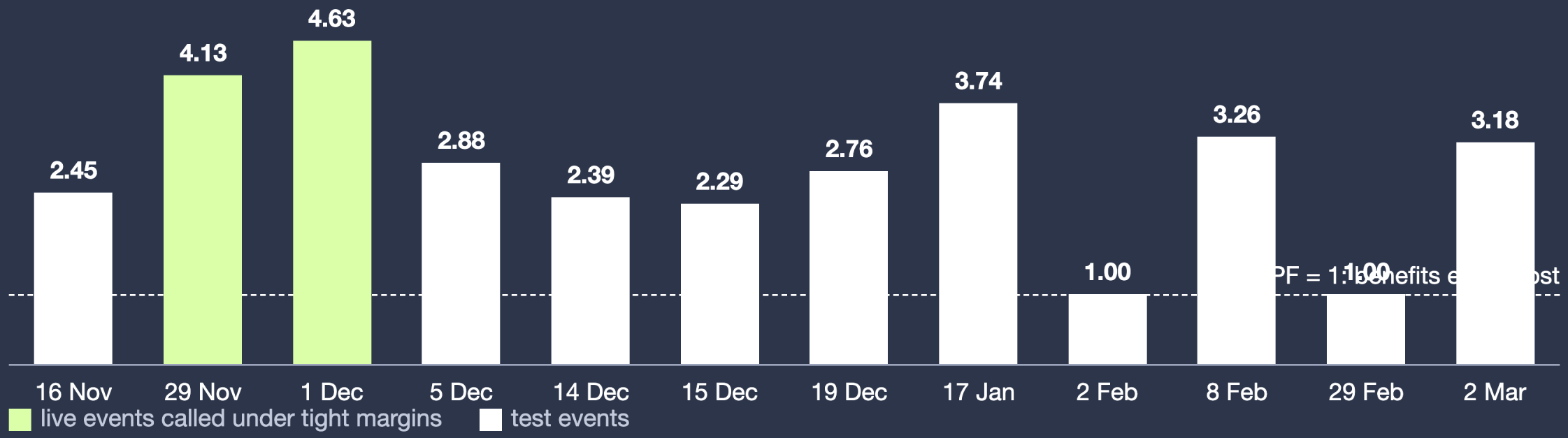
MVPF by event, base case: the programme replaces routine balancing



Live events (29 Nov and 1 Dec 2023) were called under tight margins: 1.5 and 2.5 GW against 9.2 GW on average. Pooled base-case MVPF for the two live events: 0.94.

Scarcity case: every event would have broken even

MVPF by event, scarcity case: the programme avoids involuntary disconnection



If each MWh avoided involuntary disconnection, valued at £6,000 per MWh, the live events reach 4.13 and 4.63. No loss of load occurred, so this is a counterfactual.

First time at this scale: critical peak rewards worked as we expected, with no voltage drop, even in the two events when the system was most stretched

- Households delivered substantial, durable demand reduction at scale (23% per opt-in across 2.6M households)
- No fatigue, no rebound, broad response across customer segments
- Adoption of 1) EV, and particularly 2) heat pumps and 3) solar + battery amplified flexibility.
- Welfare impacts depend on context:
  - Under normal winter conditions: expensive compared to routine balancing (MVPF ≈ 0.63).
  - Under scarcity: valuable as reliability insurance (MVPF ≈ 3.08 at VoLL)

Thank you

Contact details

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Backup: randomisation balance

Variable	Control	Invited	p-value
House (%)	87.17	87.28	0.30
EPC score	65.39	65.37	0.71
Property value (£)	371,491	370,393	0.22
Owner occupied (%)	85.37	85.38	0.91
Urban (%)	77.85	77.76	0.49
IMD score	17.85	17.88	0.54
Estimated annual consumption (kWh)	4,130	4,129	0.89
Returning participant (%)	25.79	25.89	0.49

Backup: features of the events

Feature	Range
Events held / analysed / in welfare analysis	15 / 13 / 12
Notice period	3 hours to 1 day
Household reward	£1.75 to £4 per kWh
Typical event window	16:30 to 18:00 (peak 16:00 to 19:00)
Temperature	-0.6 to 10.8 °C
England and Wales peak demand	33.5 to 40.7 GW
Households signed up (partner)	1.0 to 1.4 million
Average opt-in per event	37.4% of signed-up households

Backup: low-carbon technology specification

$$Y(it) = b0 \cdot Installed + b1 \cdot OptedIn + b2 \cdot OptedIn \times Installed + b3 \cdot HDD + event\ effects + household\ effects$$

What the coefficients mean

b0: direct effect of the technology.
b1: opt-in effect before installation.
b2: extra flexibility unlocked by installing.

Assumptions

Parallel trends and no anticipation. Installation timing unrelated to events. Opt-in response does not depend on opt-in propensity. Homogeneous effects across cohorts. We call it a candidate channel, not a formally identified mediator.

Backup: compliers against always-takers

Compliers

0.177 kW cut per opted-in household, 23.1% of control demand. Used for all welfare calculations.

Always-takers

About 0.23 kW cut per opted-in household. Opted in without any encouragement.

Reweighted average

0.2146 kW (28.1%) per opted-in household. Exploratory: assumes both groups respond as estimated.

The welfare analysis uses 295.21 MWh from compliers. Including always-takers in treatment and control, total reduction was about 1,450 MWh.