How millions of households actually flex demand

Lessons from Britain's biggest flexibility trials

Centre for Net Zero



Centre for Net Zero is a research institute founded by the Octopus Energy Group

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I am CNZ's Director of Trials and Analysis.



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1. LOW-CARBON TECHNOLOGIES

What are the impacts of people adopting and using new low-carbon technologies?

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1. LOW-CARBON TECHNOLOGIES

What are the impacts of people adopting and using new low-carbon technologies?

2. DEMAND FLEXIBILITY

Are people willing to flex? What impact do incentives have?

Heat pumps



Decarbonizing Heat: The Impact of Heat Pumps and a Time-of-Use Heat Pump Tariff on Energy Demand
NBER Working Paper 33036

Octopus Energy data allowed us to quantify the impact of heat pumps and time-of-use pricing

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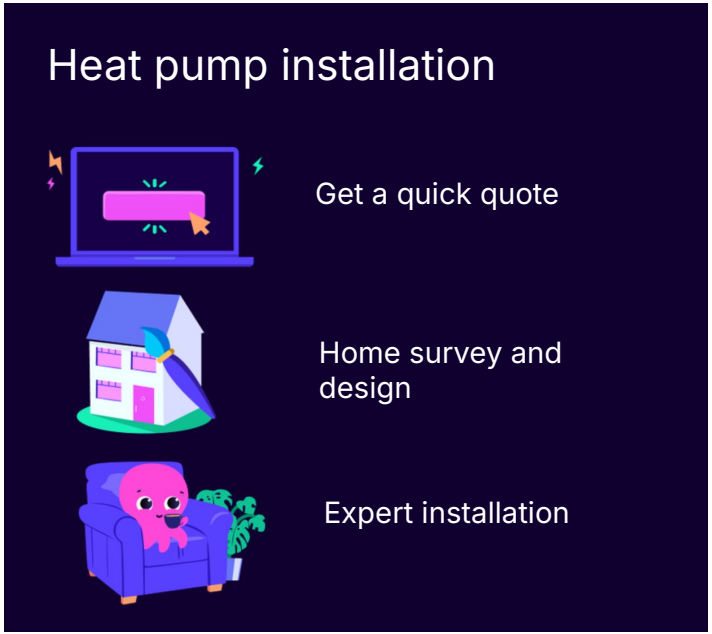
Octopus Energy is a major installer of air source heat pumps in homes



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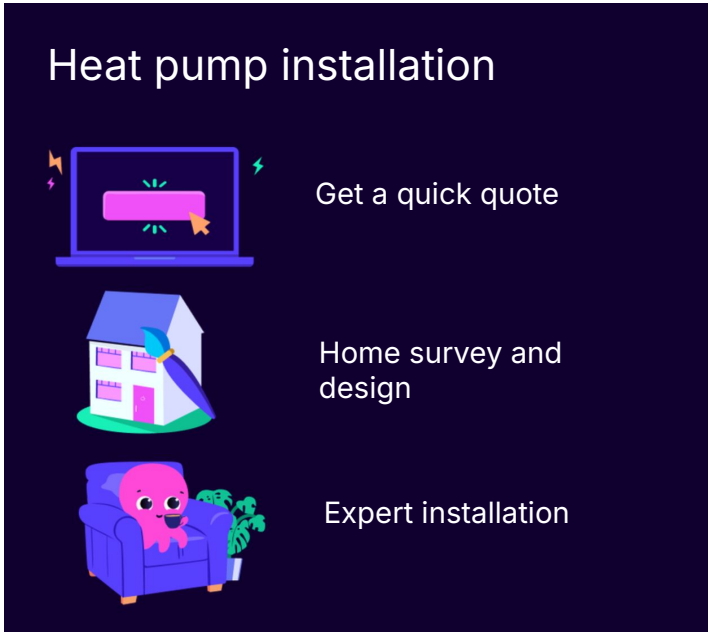
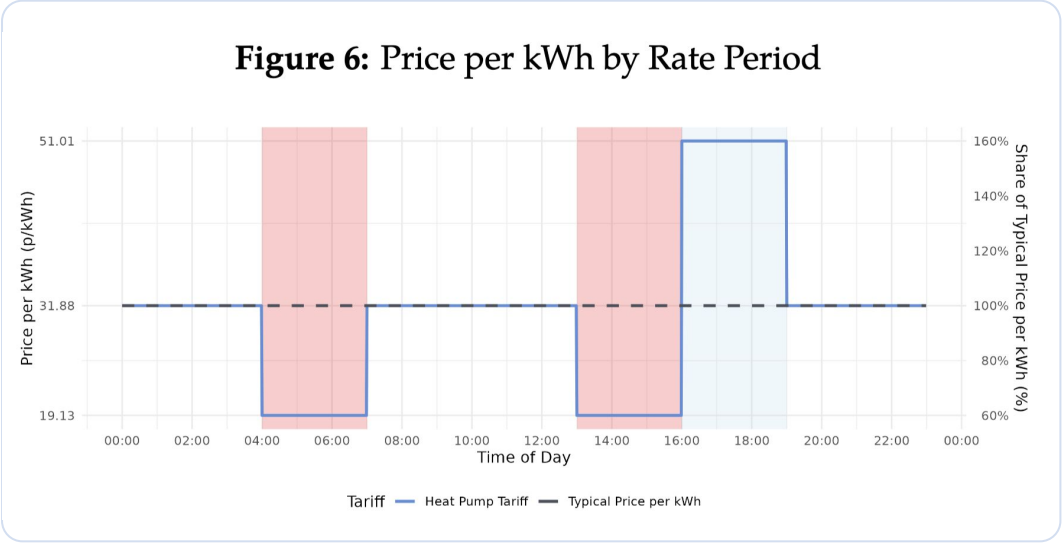


***They also have a* time-of-use tariff** for heat pump owners that encourages pre-heating when electricity is cheap, and reduced consumption during peak periods.



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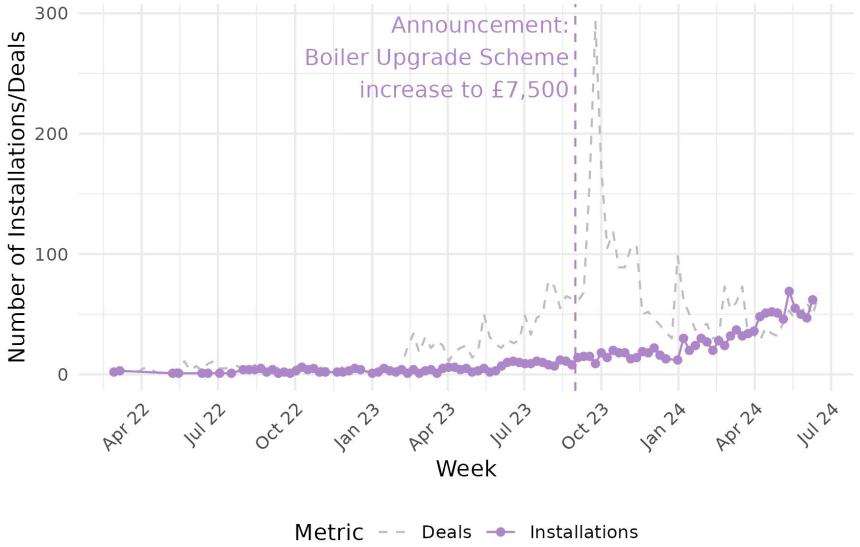
1,308 Octopus customers adopting air source heat pumps



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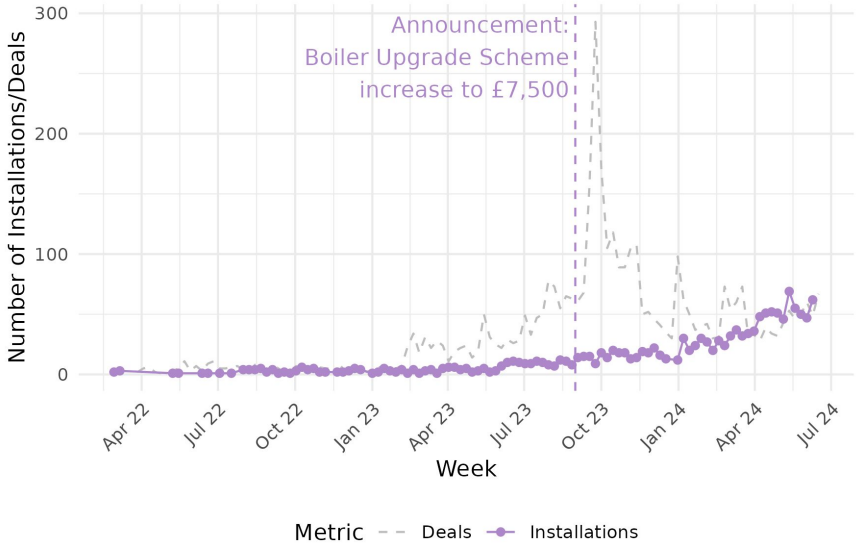
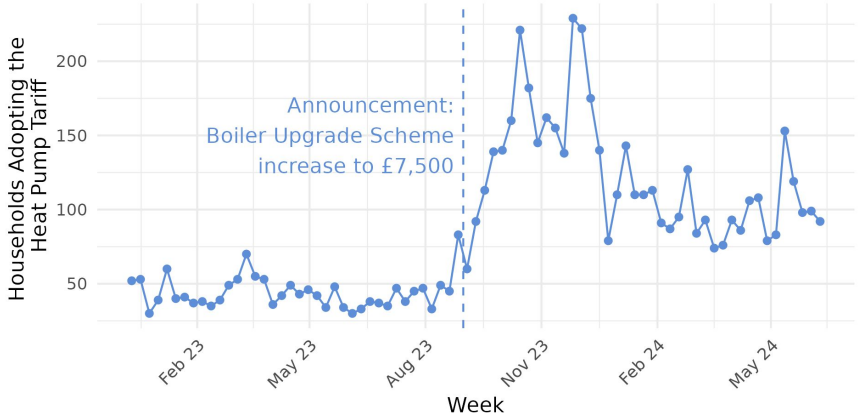
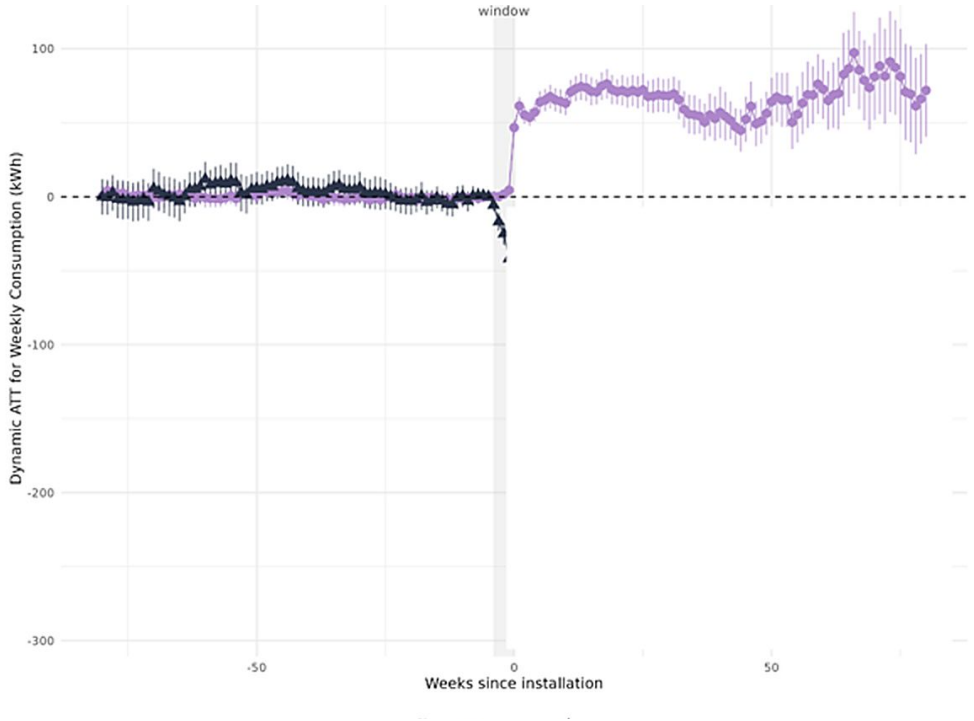


6,631 Octopus customers adopting the heat pump tariff



Heat pumps significantly increased electricity demand

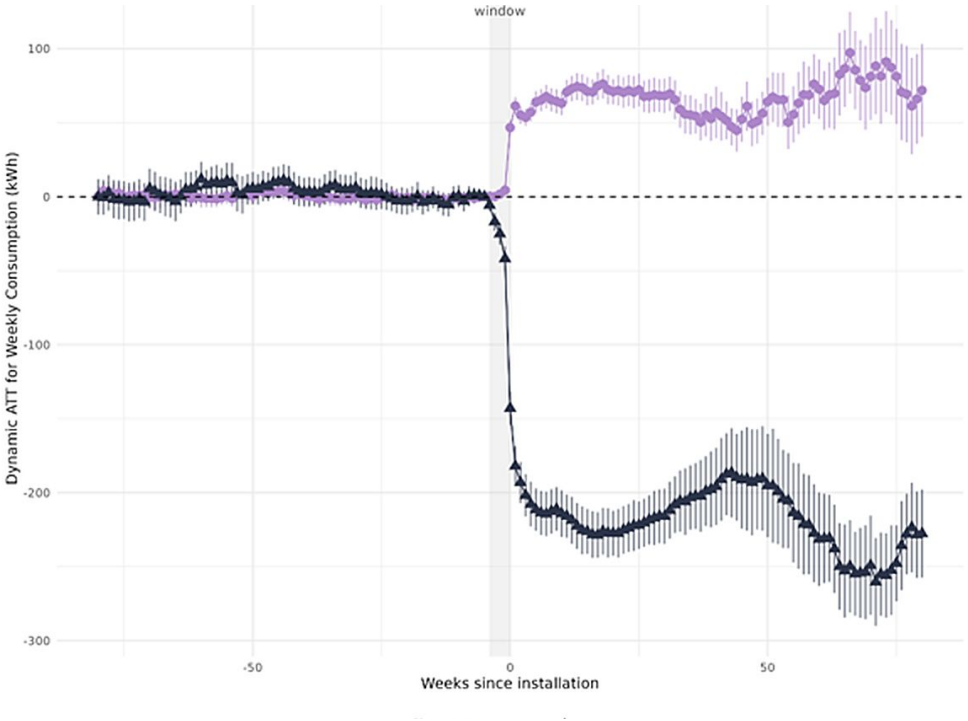
Impact on overall electricity and gas consumption of heat pump adoption



→ 50% increase in electricity (2,551 kWh p.a.)

Heat pumps significantly decreased gas demand

Impact on overall electricity and gas consumption of heat pump adoption



→ 50% increase in electricity (2,551 kWh p.a.)

→ 98% decrease in gas (8,744 kWh p.a.)

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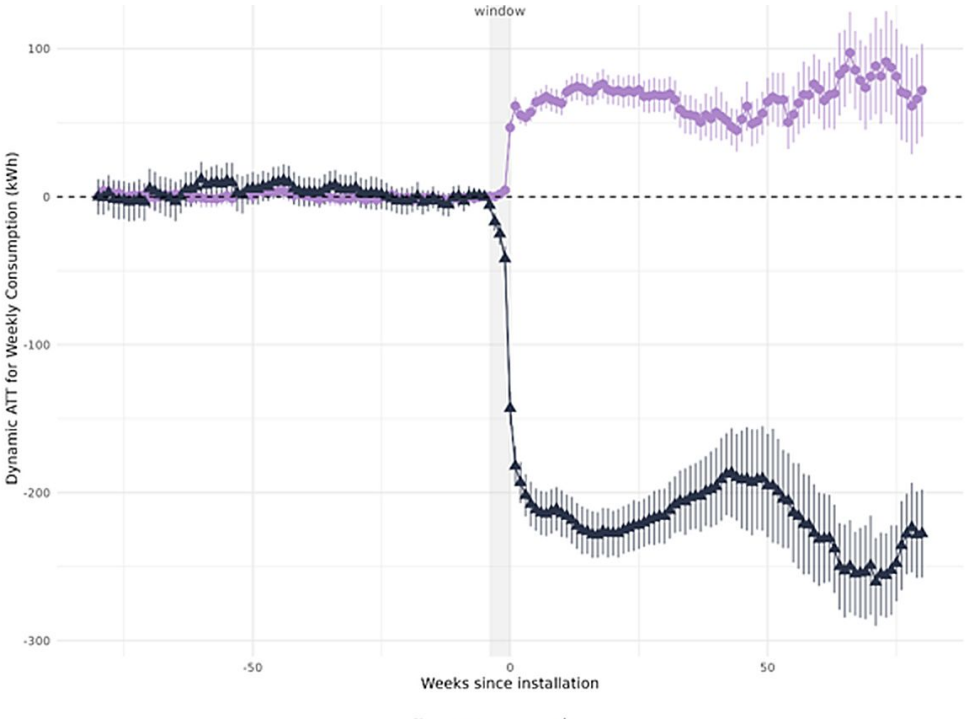


→ 50% increase in electricity (2,551 kWh p.a.)

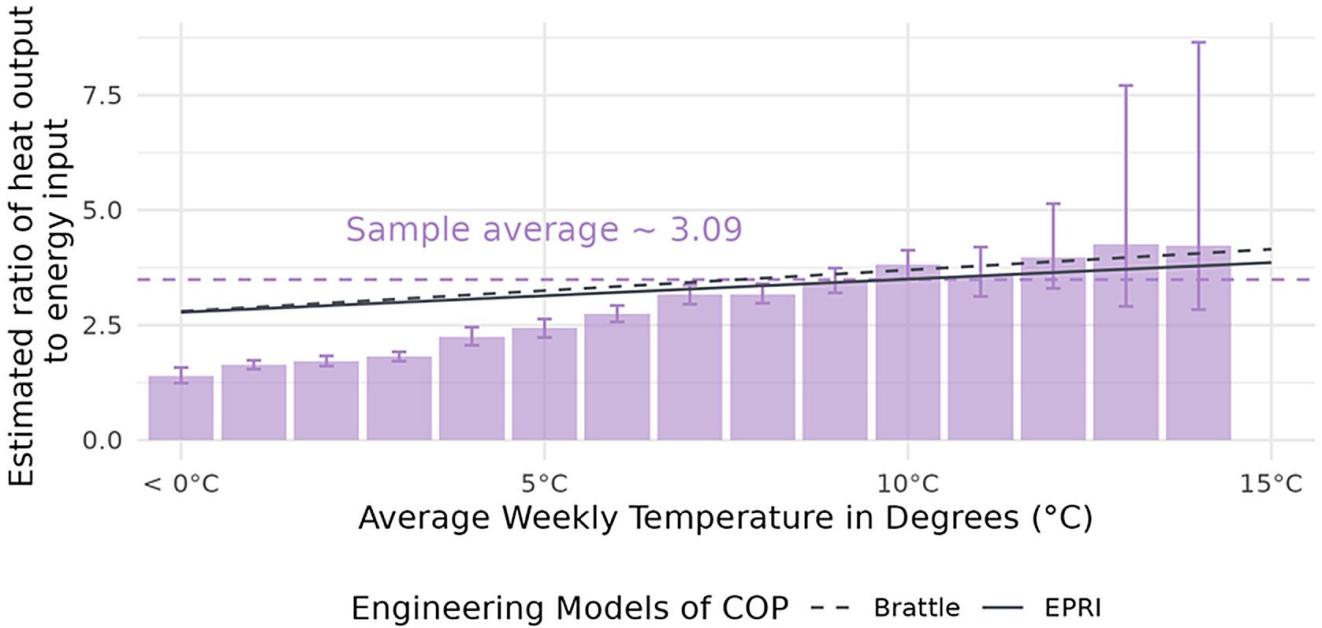
NET CHANGE

Decrease of 1.16 tonnes of CO_2 p.a. (39% decrease in carbon emissions in the first year; 72% over the 20-year lifetime of the heat pump)

→ 98% decrease in gas (8,744 kWh p.a.)

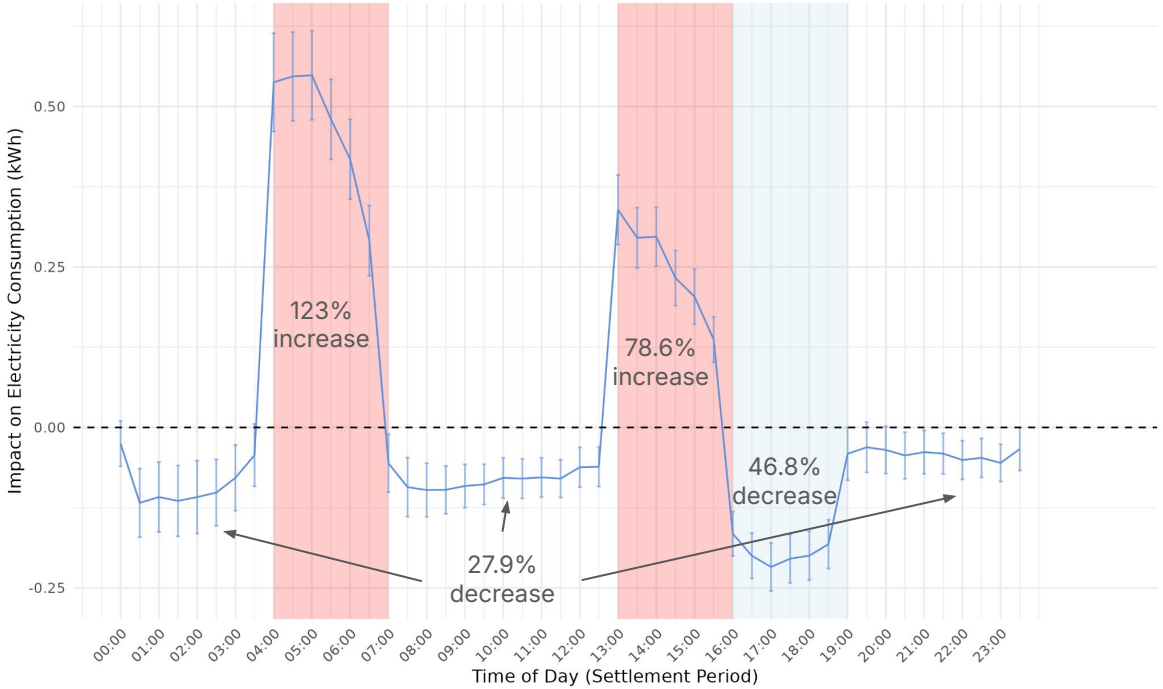
Empirical heat pump efficiency was in line with engineering estimates on average

Impact on overall electricity and gas consumption of heat pump adoption across temperature



Time-of-use pricing for heat pumps shifted demand from peak periods

Impact on consumption of heat pump tariff (blue line)



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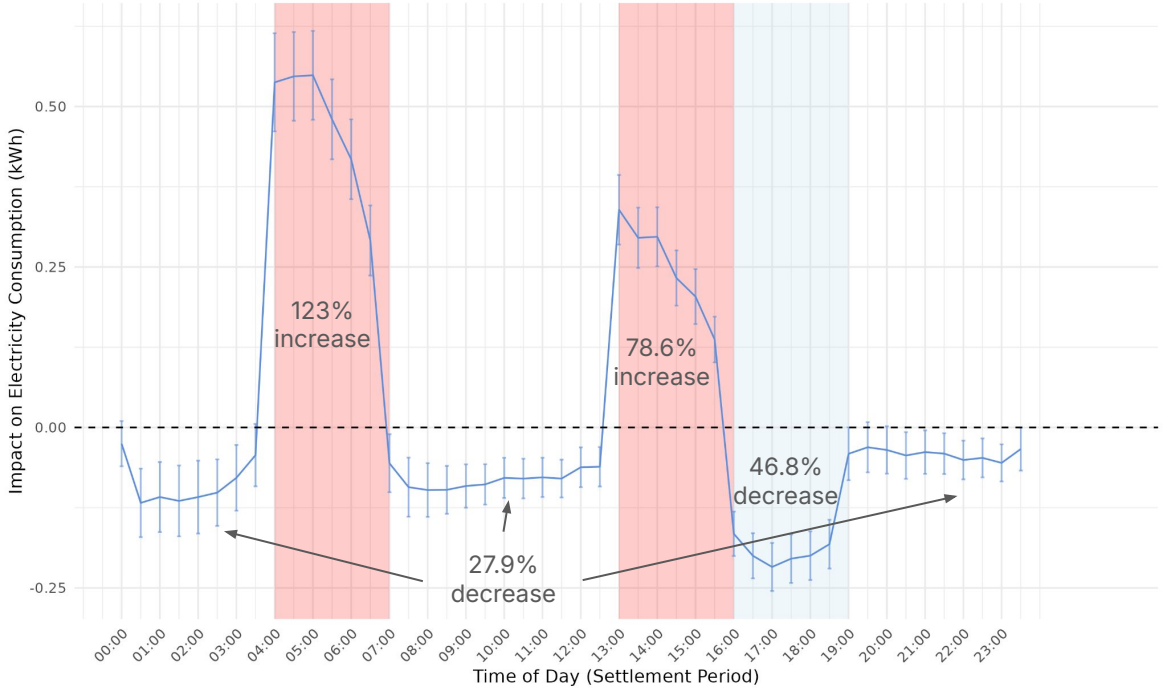

FOR THE CONSUMER

£345

saved per year, about 18% of energy bills, compared with the standard tariff

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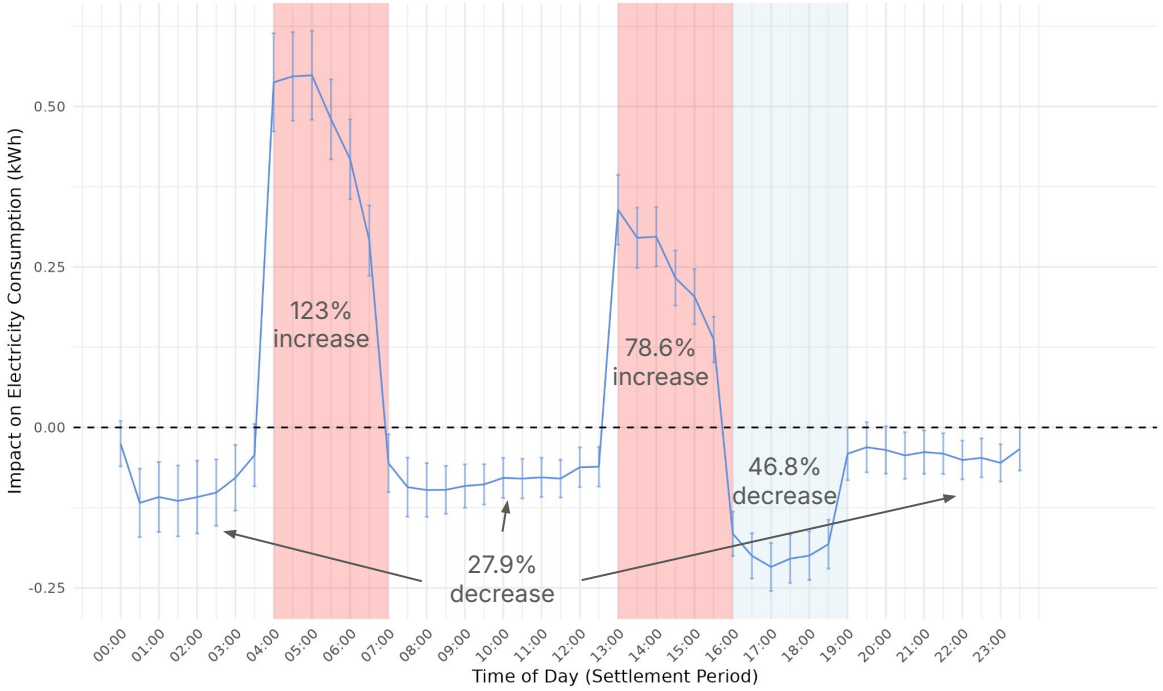

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23%

structural

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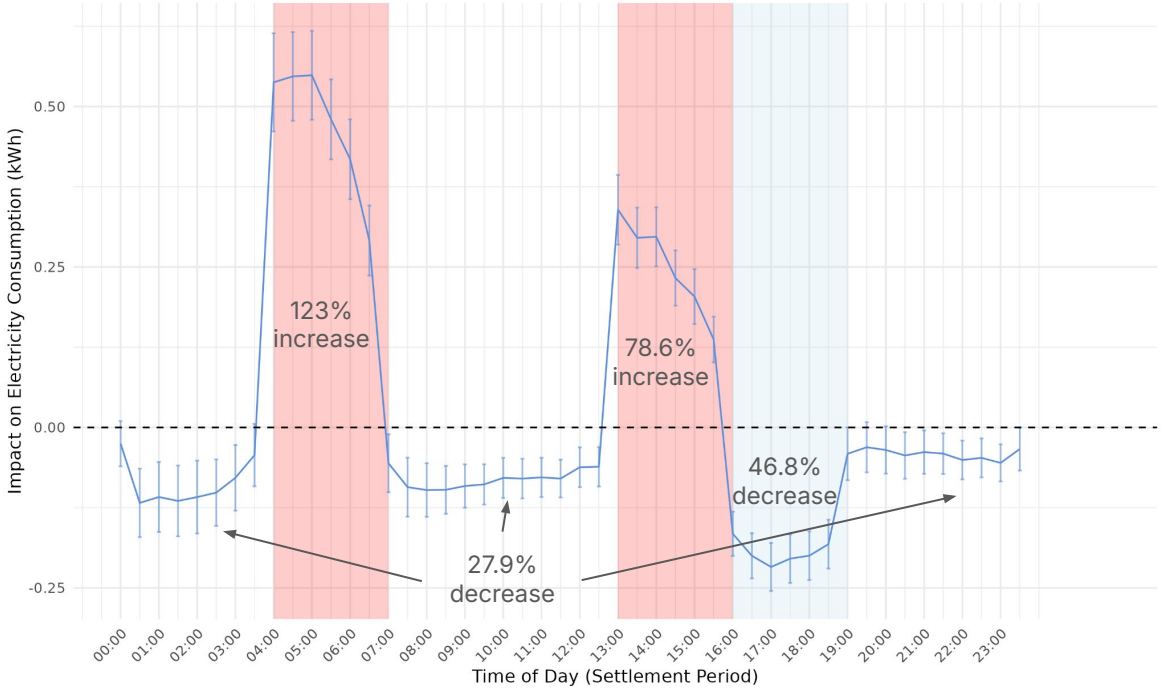

FOR THE CONSUMER

£345

saved per year, about 18% of energy bills, compared with the standard tariff

23%	77%
structural	active shifting

But policy headwinds make it difficult for heat pumps to reduce operating costs for households, despite reducing *total* energy consumption

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Scenario	◀ Heat pump saving / Penalty ▶ £ per year	Gas price (£/kWh)	Electricity price (£/kWh)
(1a) Govt estimated prices	£186	£0.08	£0.35
(1b) Govt estimated prices, no gas standing charge	£79	£0.08	£0.35
(1c) Utility prices	£97	£0.06	£0.24
(1d) Utility prices, no gas standing charge	−£10	£0.06	£0.24

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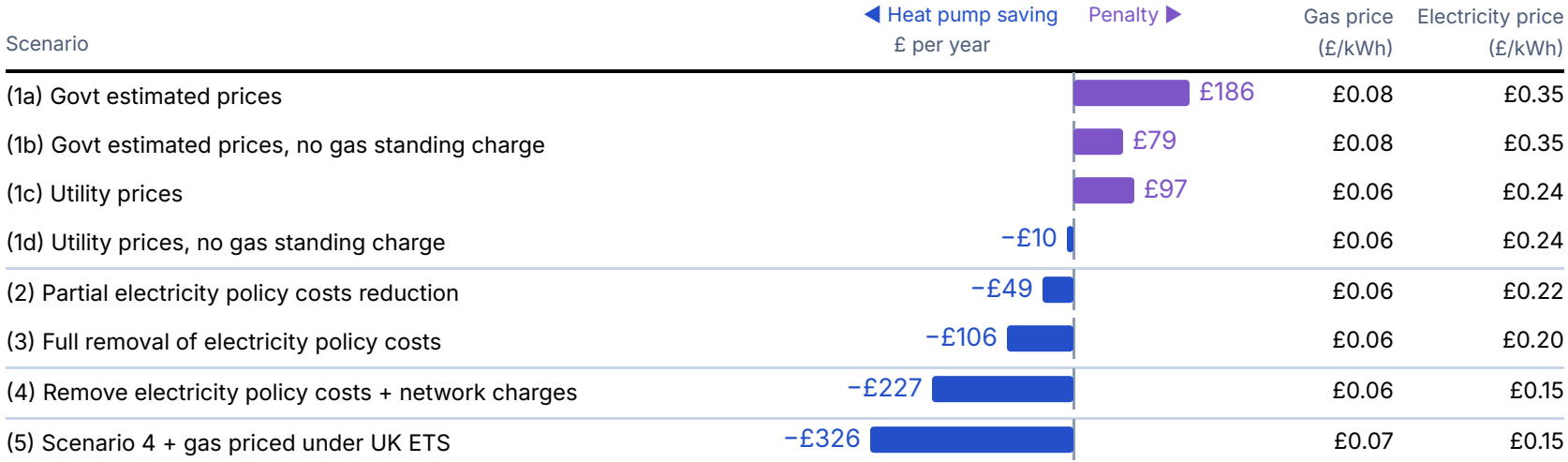
(4) Remove electricity policy costs + network charges	−£227	£0.06	£0.15

But policy headwinds make it difficult for heat pumps to reduce operating costs for households, despite reducing *total* energy consumption



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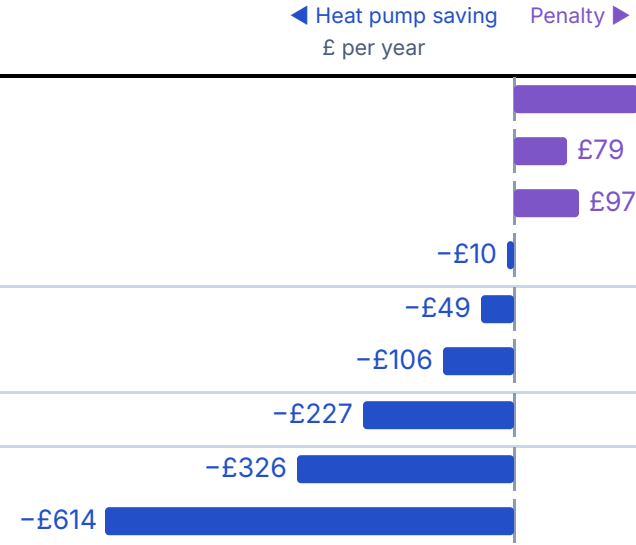
(3) Full removal of electricity policy costs	£0.06	£0.20
(4) Remove electricity policy costs + network charges	£0.06	£0.15
(5) Scenario 4 + gas priced under UK ETS	£0.07	£0.15

But policy headwinds make it difficult for heat pumps to reduce operating costs for households, despite reducing *total* energy consumption



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(2) Partial electricity policy costs reduction	£0.06	£0.22
(3) Full removal of electricity policy costs	£0.06	£0.20
(4) Remove electricity policy costs + network charges	£0.06	£0.15
(5) Scenario 4 + gas priced under UK ETS	£0.07	£0.15
(6) MSC: Scenario 4 + both fuels priced at SCC	£0.12	£0.20

02 / 04

Electric vehicles

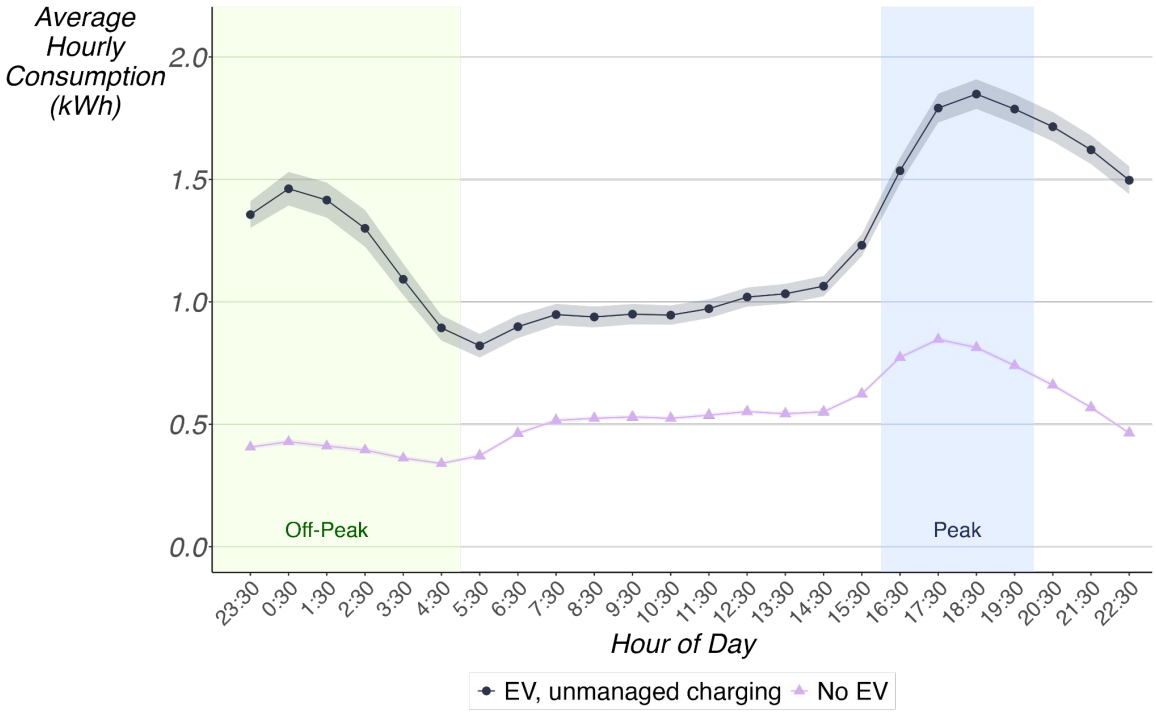
In the home



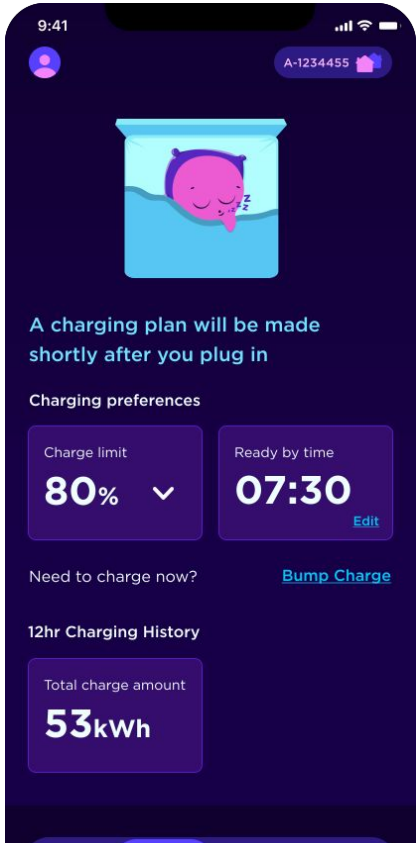
AI in Charge: Large-Scale Experimental Evidence on Electric Vehicle Charging Demand
NBER Working Paper 34709

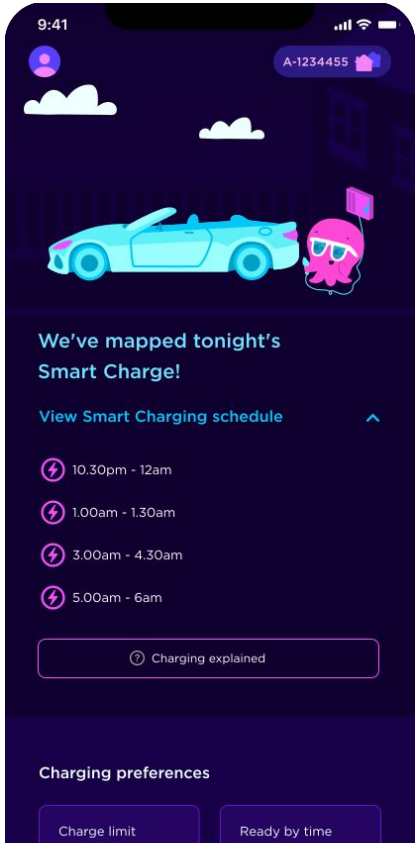
Mass EV adoption risks overwhelming electricity networks, increasing system costs and grid instability

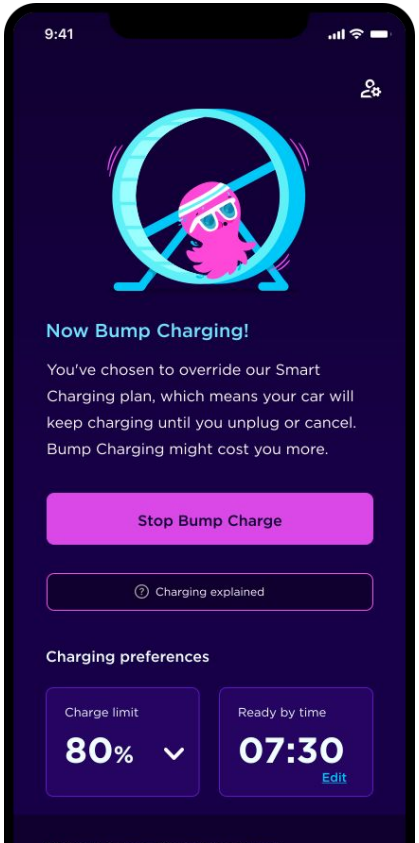
Hourly consumption for a sample of Octopus customers with unmanaged EV charging compared to customers without EVs, January 2024



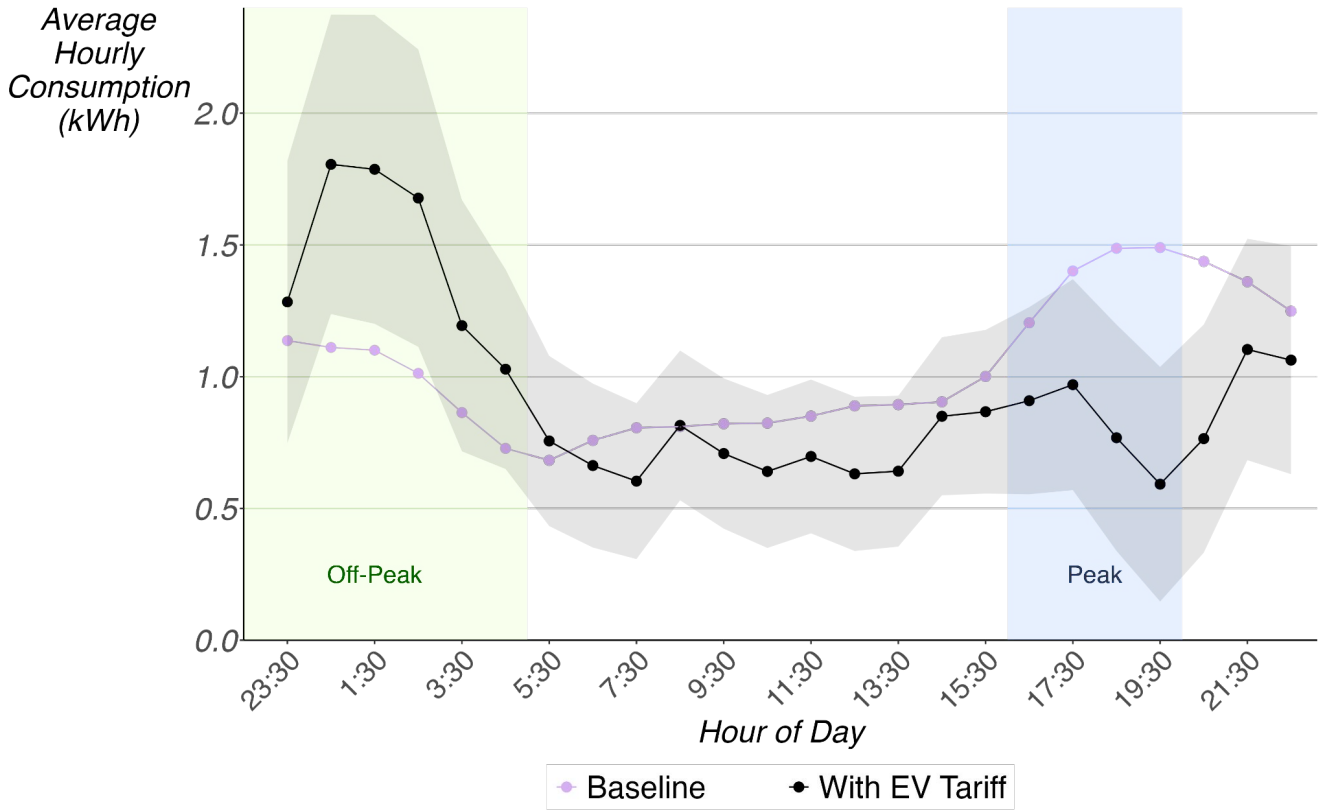
So we looked at the impact of the UK's most popular managed charging service







Managed charging caused a large shift in consumption from peak to off-peak hours; no change in total consumption



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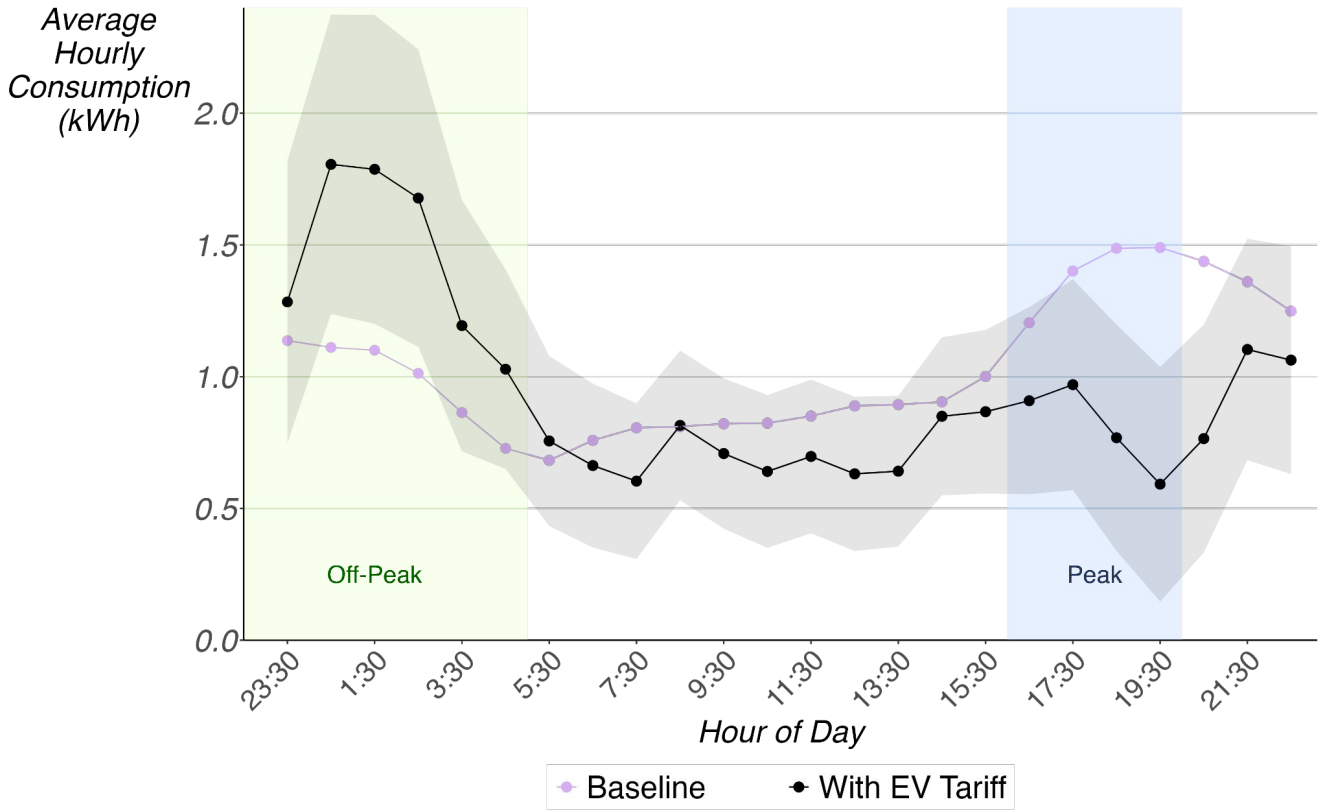
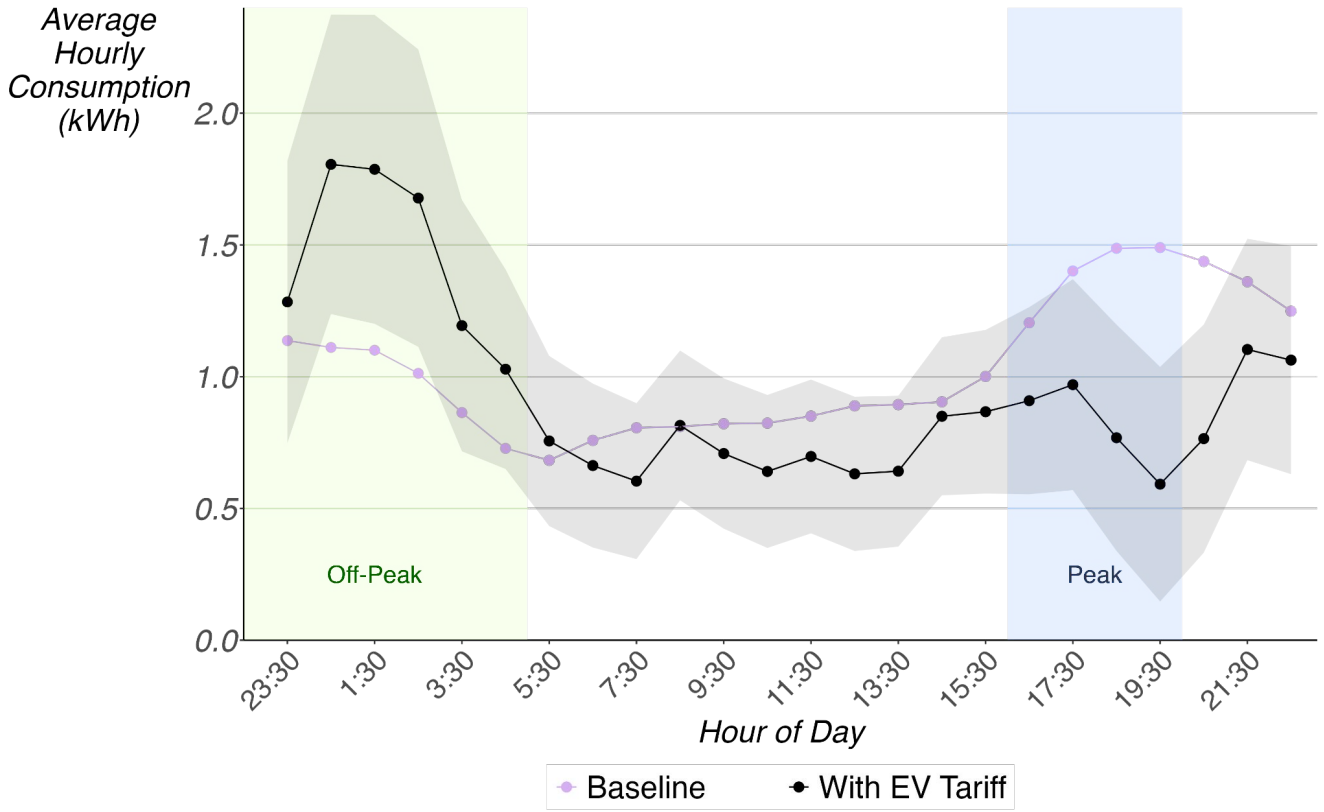


42%

lower household peak demand

Managed charging caused a large shift in consumption from peak to off-peak hours; no change in total consumption



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lower household peak demand

~100%

of EV charging moved off-peak

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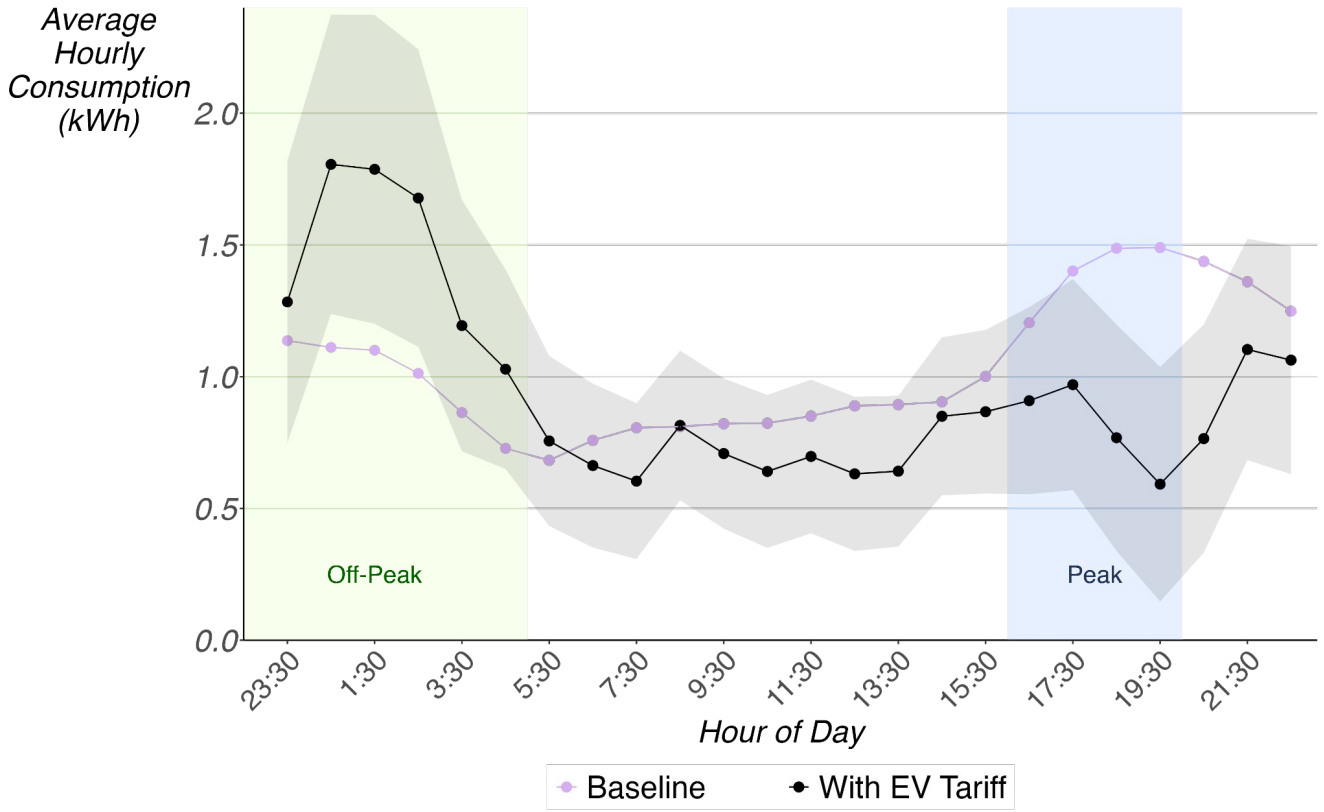


42%

lower household peak demand

~100%

of EV charging moved off-peak

£350

saved a year (£650 vs a flat tariff)

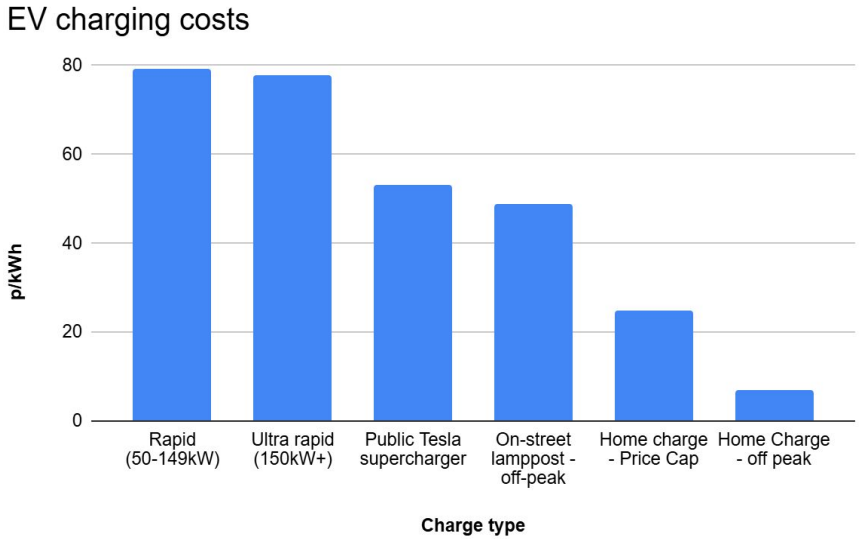
Electric vehicles

Public charging



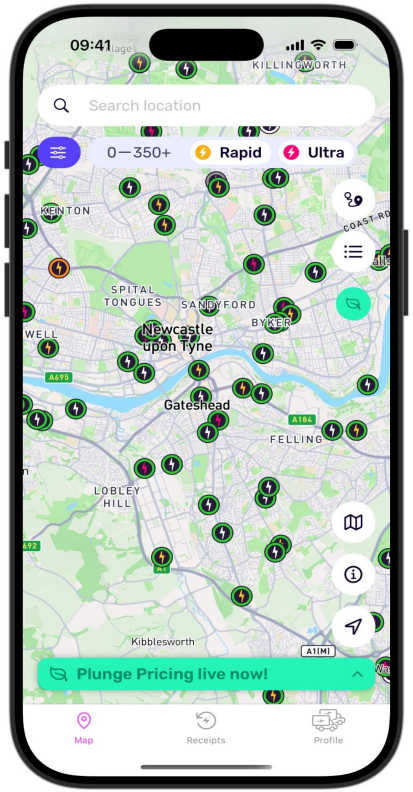
The Impact of Dynamic Prices on Electric Vehicle Public Charging Demand
NBER Working Paper 34600

Public charging costs and speed are the next major barriers for EV adoption



RAC Charger Watch – cost data (2024); McKinsey – survey (2024)

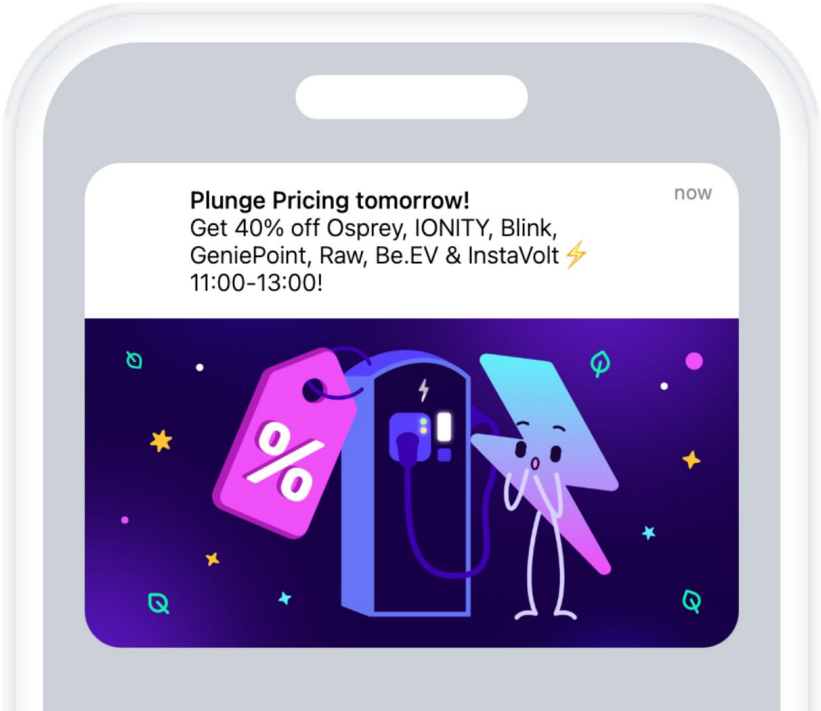
So we worked with a leading public EV charging platform to evaluate dynamic pricing events



110k
EV drivers in the trial

12k
participating chargers

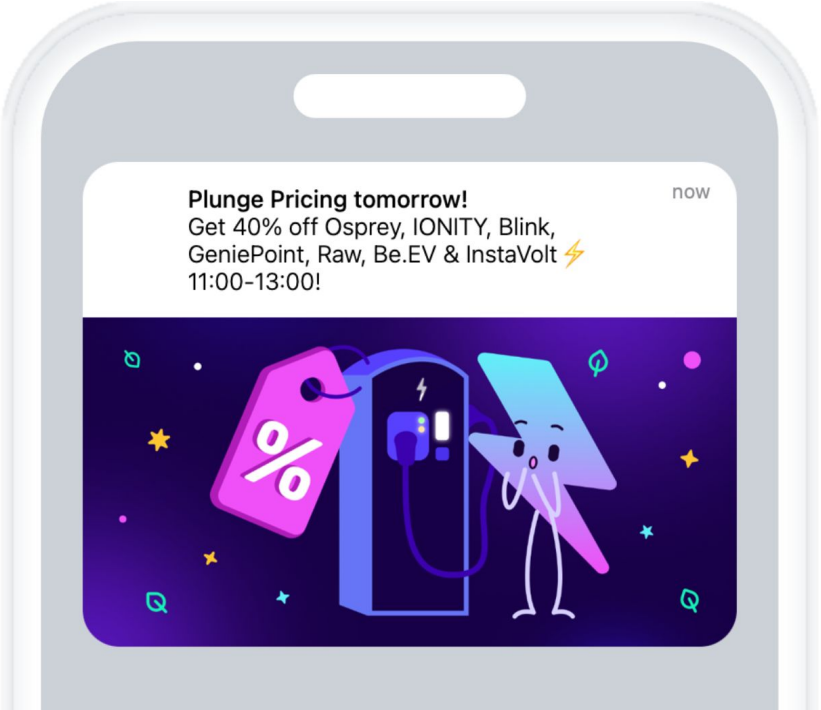
11
weeks of dynamic pricing



And tried to find out what incentives have the most impact

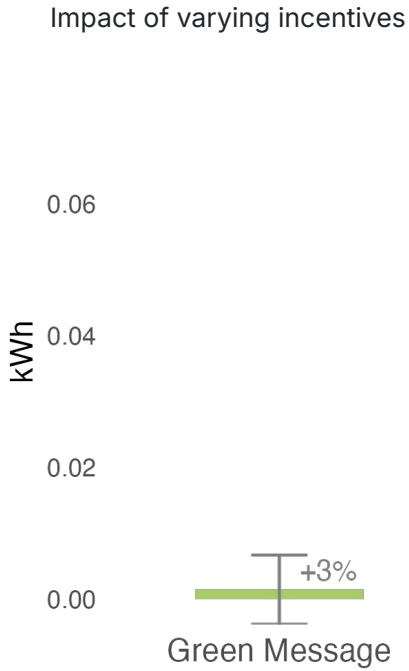
We exposed the 110k customers to four different treatments:

1. **Control group**: no notification
2. **Green message** highlighting that the grid was “green”
3. **15%** price decrease app notification
4. **40%** price decrease app notification



EV drivers were highly responsive to price signals in public charging

Non-price “green” message: no statistically significant impact.



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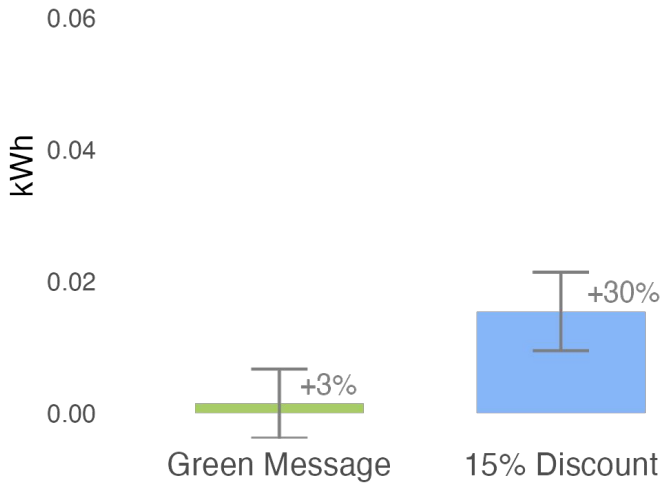
15% discount: 30% increase (elasticity of −2).

Impact of varying incentives on charging demand during events



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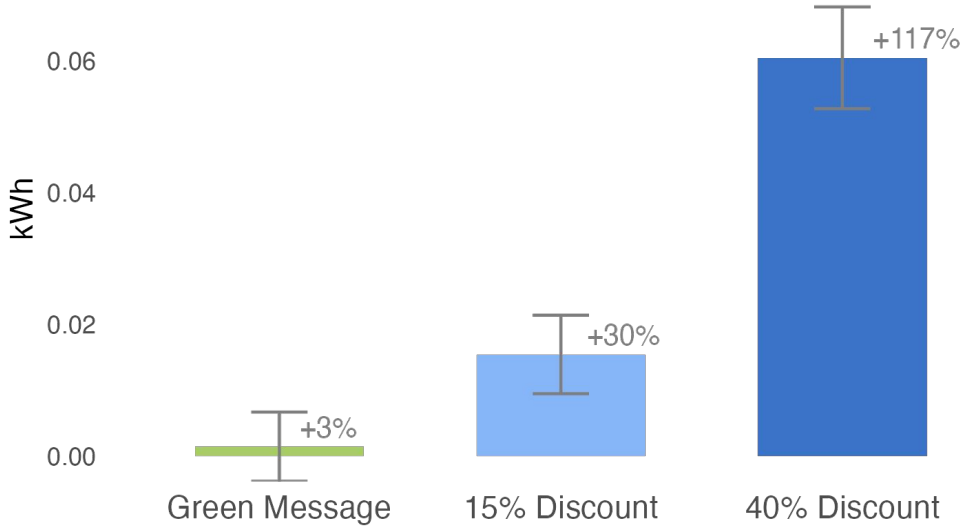
Non-price “green” message: no statistically significant impact.

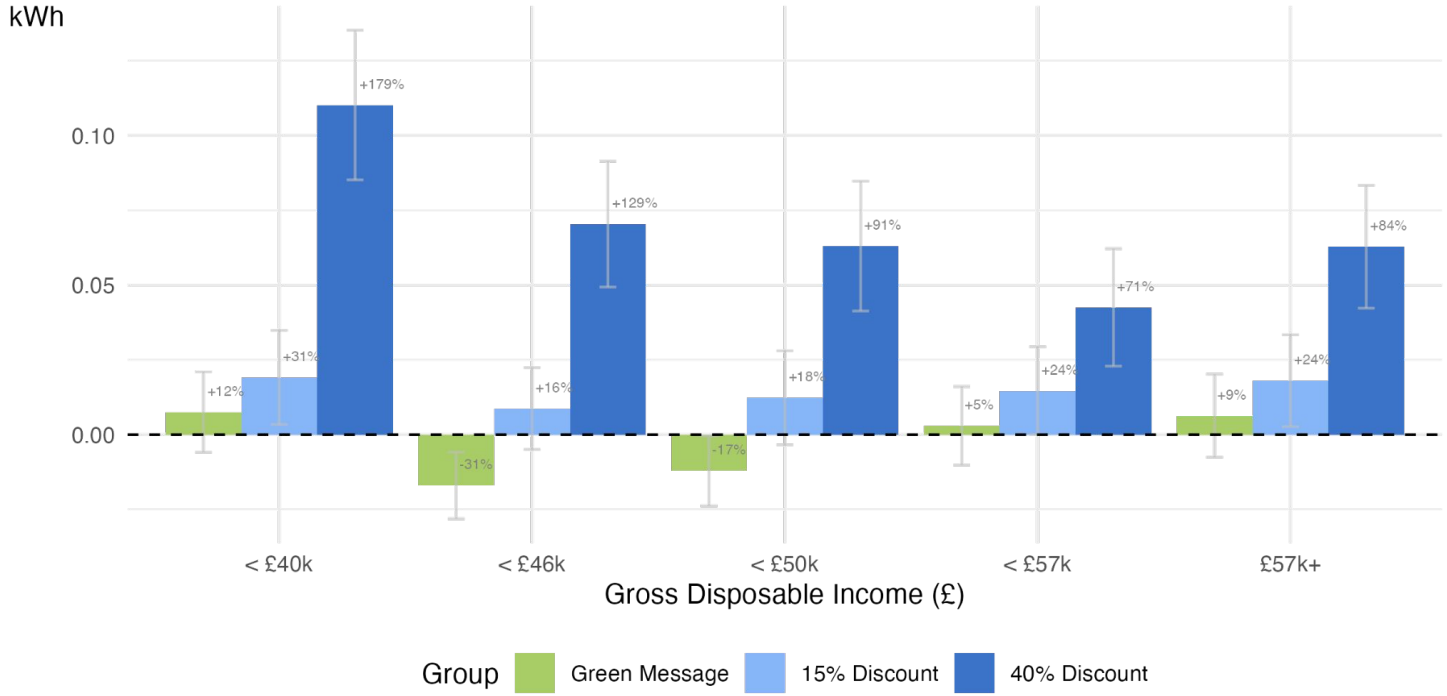
15% discount: 30% increase (elasticity of −2).

40% discount: 117% increase across the whole network (an elasticity of −2.9).

Impact of varying incentives on charging demand during events



Drivers in low-income areas had a greater response



Consumer response (kWh) by local authority gross disposable income (£); bars show absolute increase in demand, percentage labels show treatment effect estimate

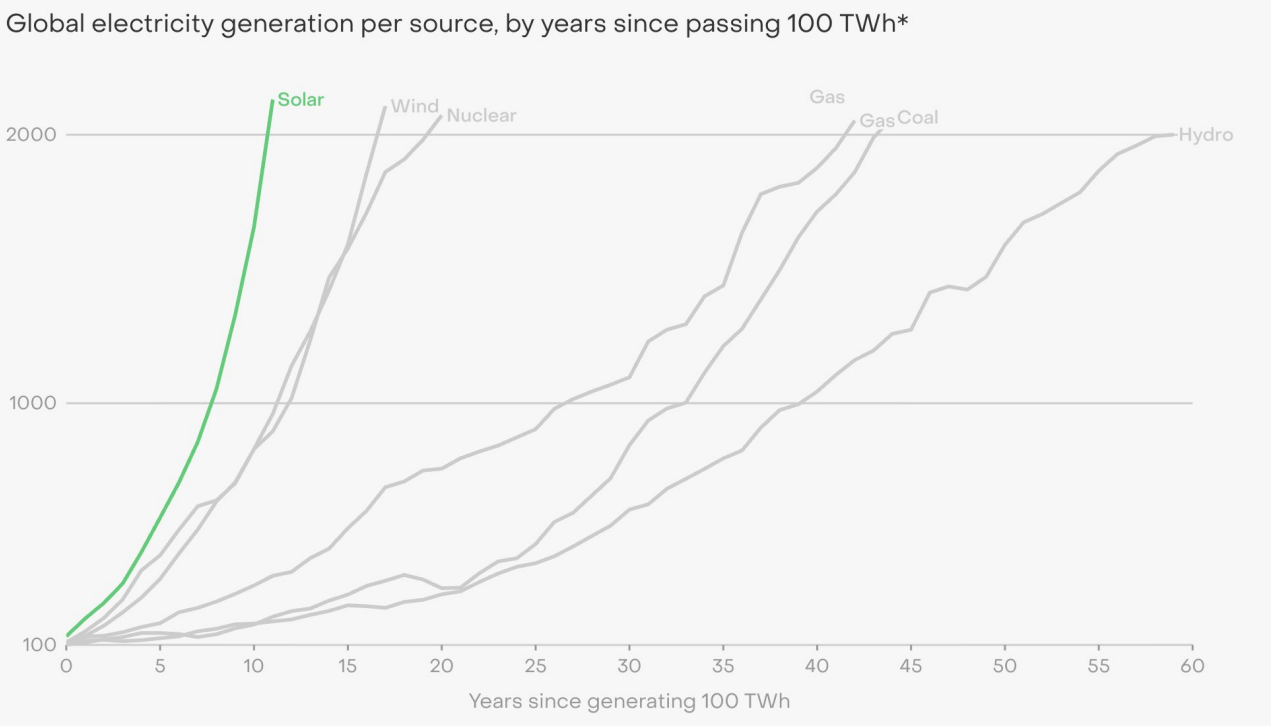
03 / 04

Solar and battery



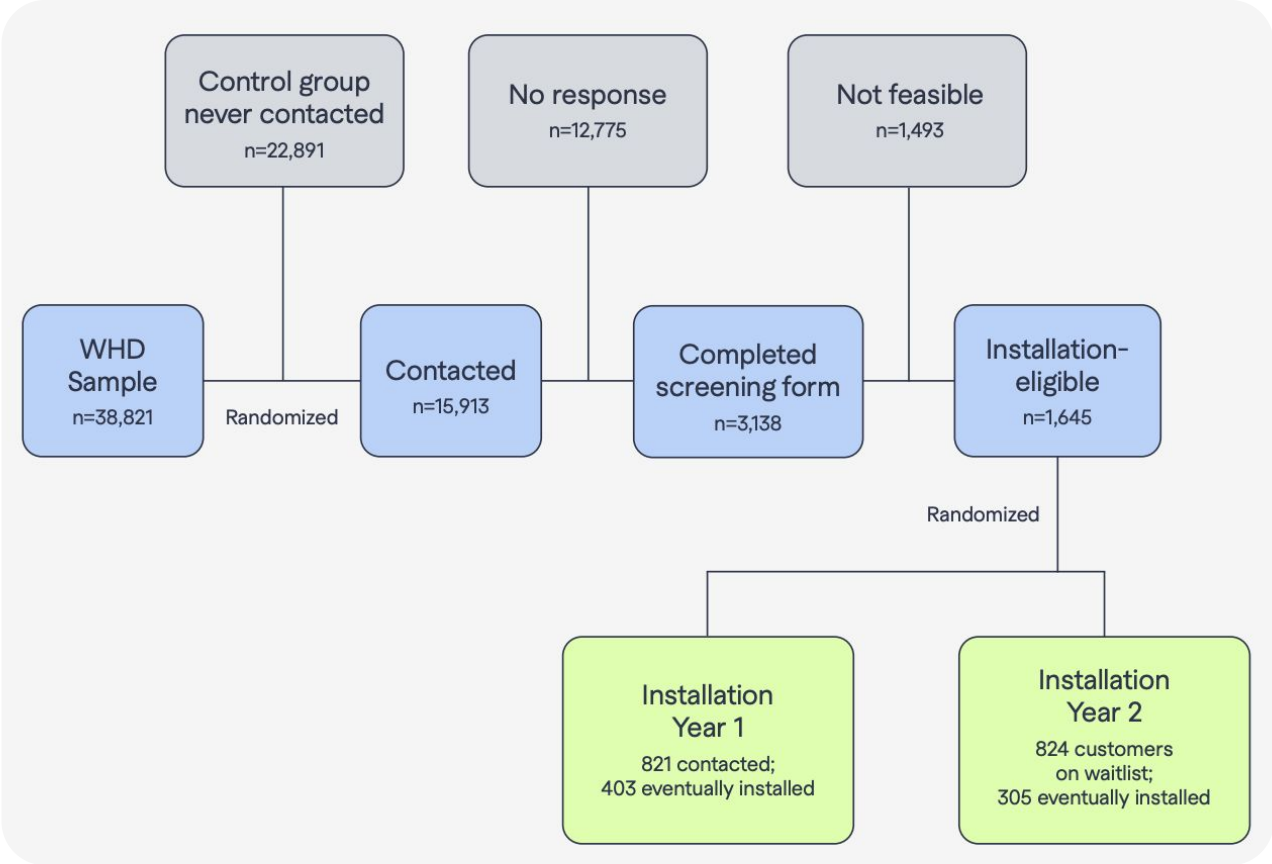
The Impact of Residential Solar and Battery on Energy Demand and the Grid
CNZ Working Paper

Solar PV is the fastest-growing source of electricity in history

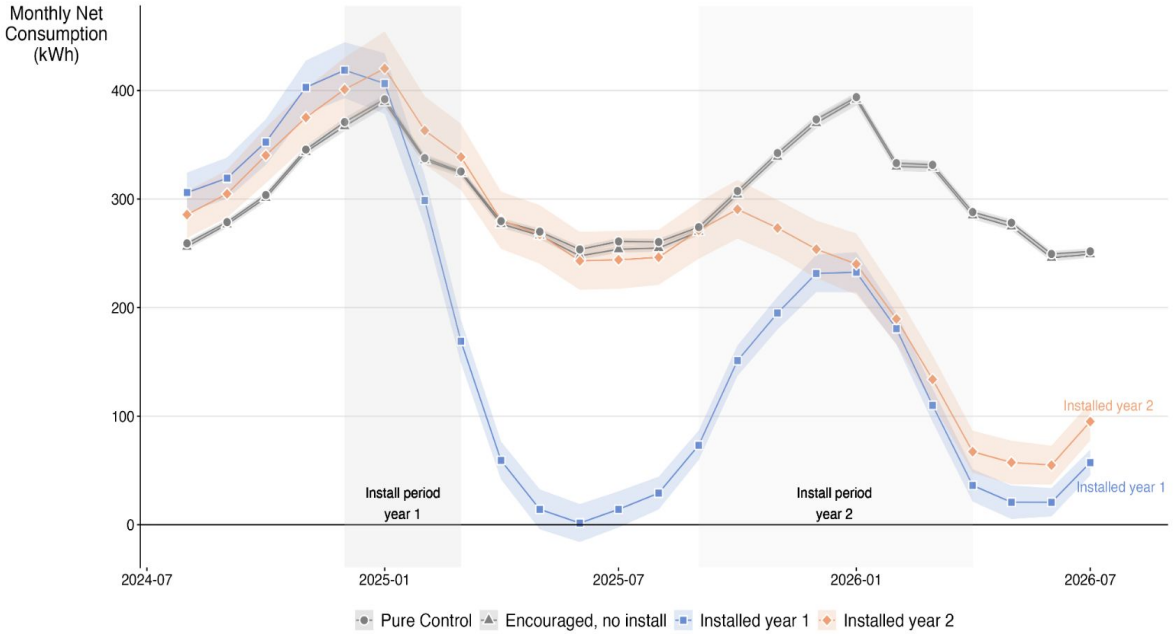


Ember, based on their yearly electricity data. Nuclear, gas, coal and hydro data from Pinto et al. (2023)

Our trial: large-scale randomised controlled trial installing solar and battery for customers facing fuel poverty



Solar and batteries cut net grid imports by 77%



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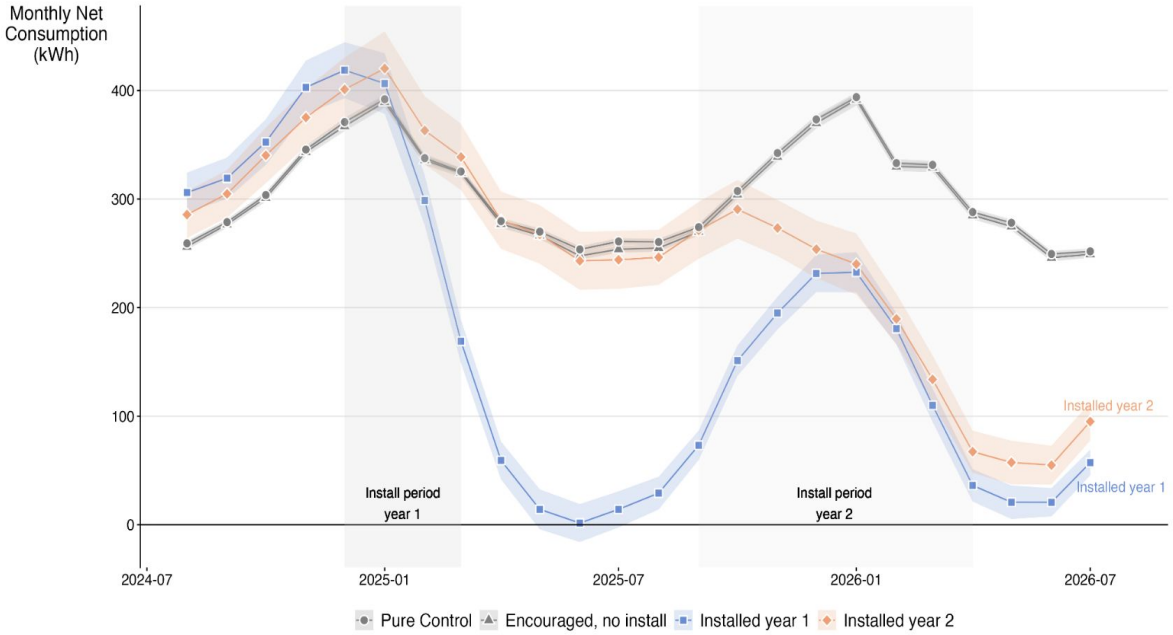

1. **Grid electricity imports fell 38%**, or 1,528 kWh a year

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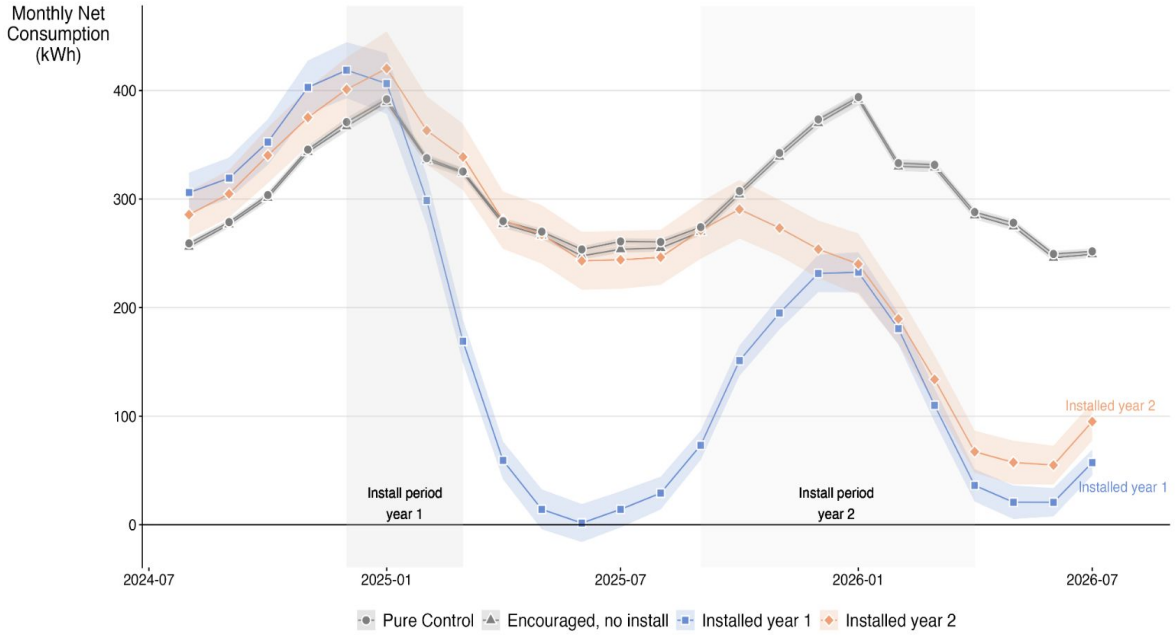
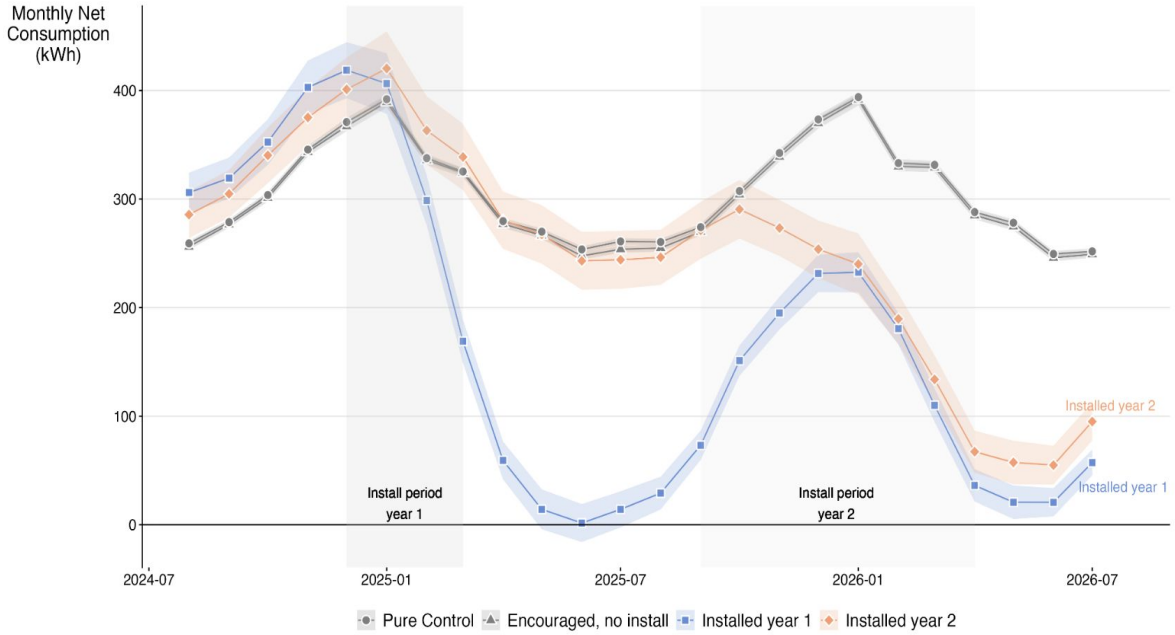


1. **Grid electricity imports fell 38%**, or 1,528 kWh a year

2. After accounting for exports, **net imports fell 77%**, or 3,062 kWh

Solar and batteries cut net grid imports by 77%



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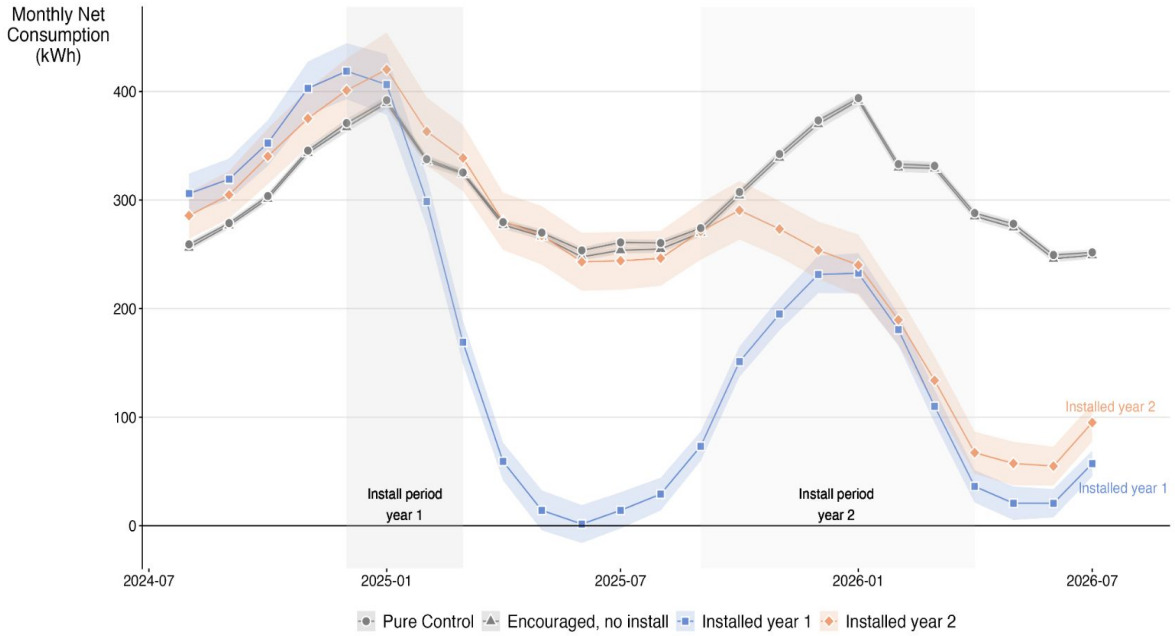

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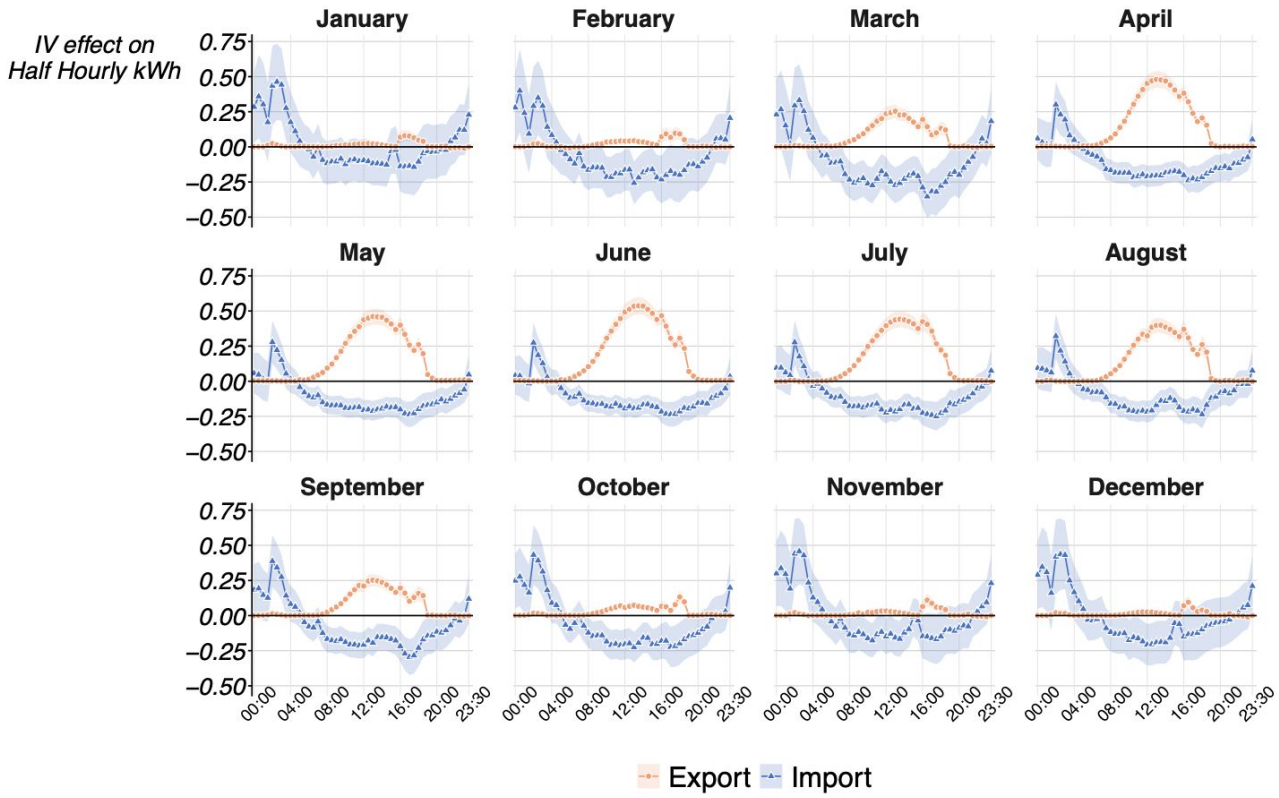
4. **£681 annual saving** against a baseline electricity bill of £1,092

Export patterns were seasonal, but load-shifting was year-round



Flexibility events

Critical Peak Rewards: Evidence from a Nationwide Demand Response Program
NBER Working Paper 35485

A Demand-Side Alternative to Renewable Curtailment: Natural Field Experimental Evidence from Two Countries
NBER Working Paper 35530



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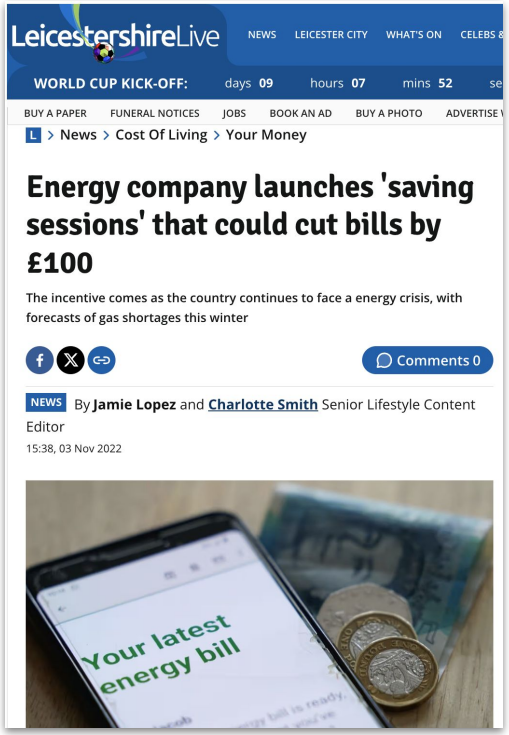
By Jessica Sheldon

Published: 29/11/2023 - 09:22 | Updated: 29/11/2023 - 11:05



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Energy company launches 'saving sessions' that could cut bills by £100

The incentive comes as the country continues to face a energy crisis, with forecasts of gas shortages this winter

Comments 0

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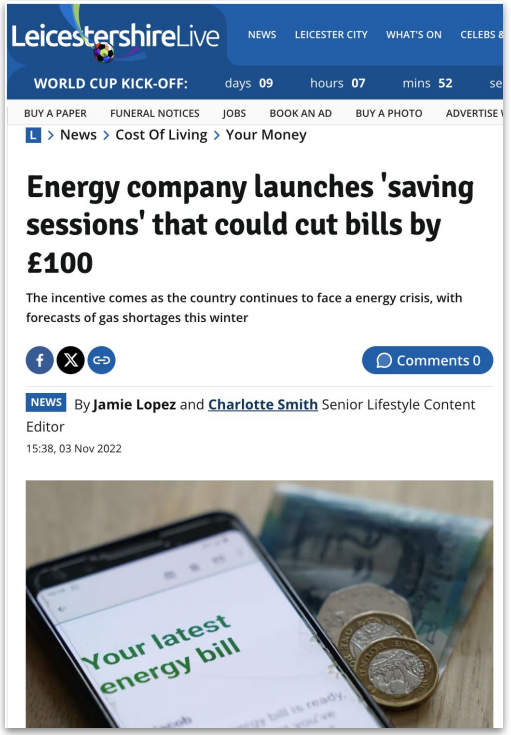

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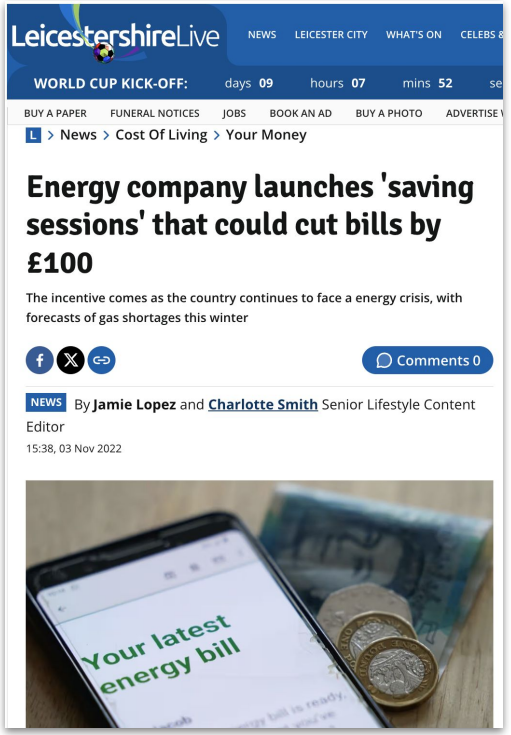

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Scale: 16 events, 2.7m customers.



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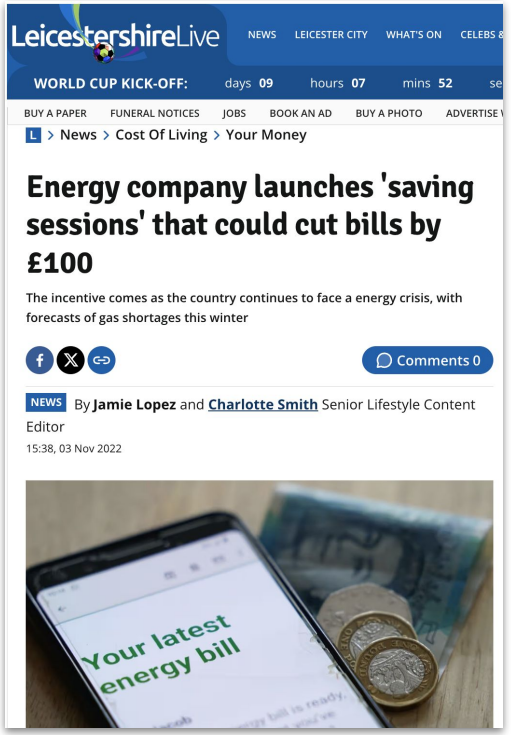

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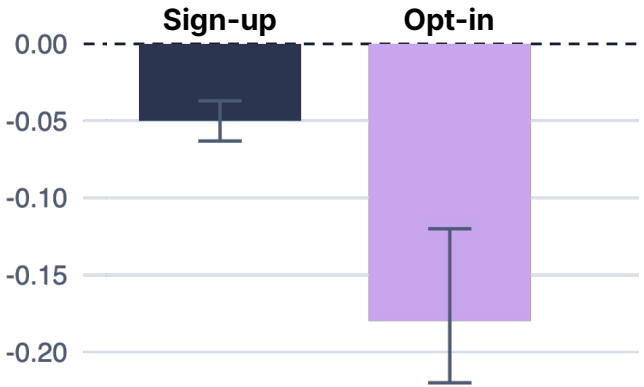
Treatment effects during the events (kW)



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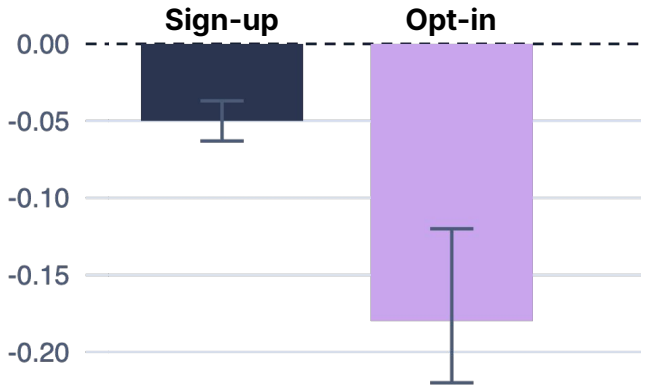

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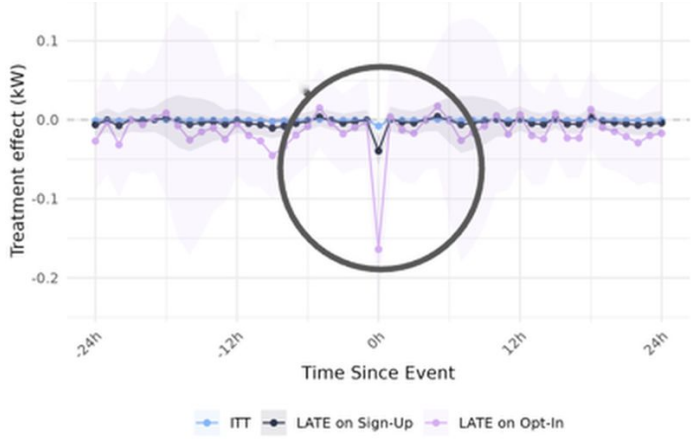
2. We saw **no secondary peak**.

Treatment effects around the events (kW)



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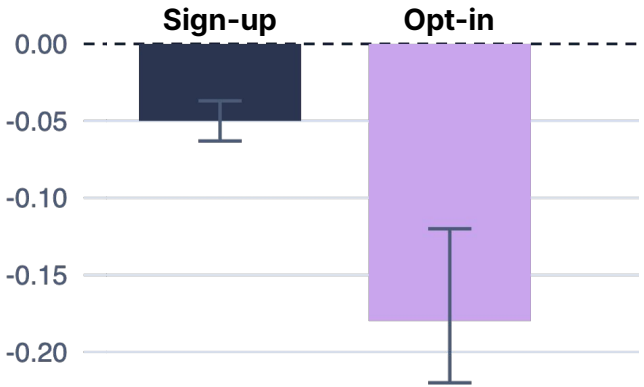
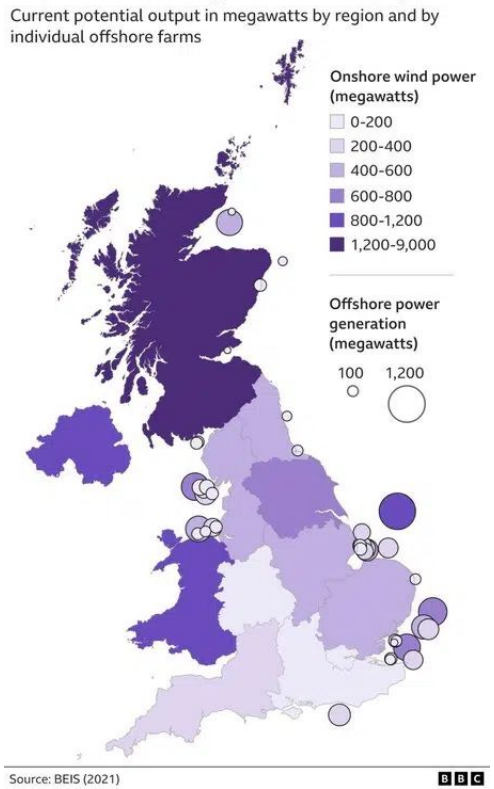


1. The events **substantially decreased electricity consumption** among compliers at peak time.
2. We saw **no secondary peak**.
3. **No sign of fatigue** in later events.

Turn-up events offered households cheap, free or negative prices when renewables were abundant

Context: Renewables make electricity cheap, but low prices rarely reach households. Policymakers want to know how to fix this.



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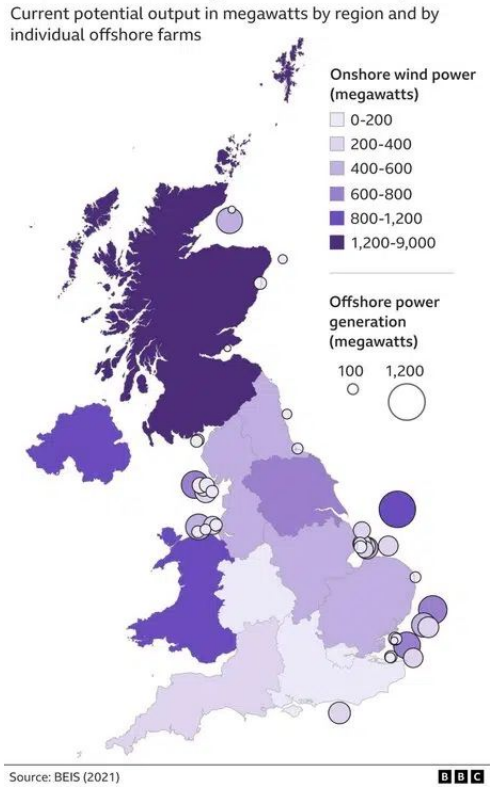

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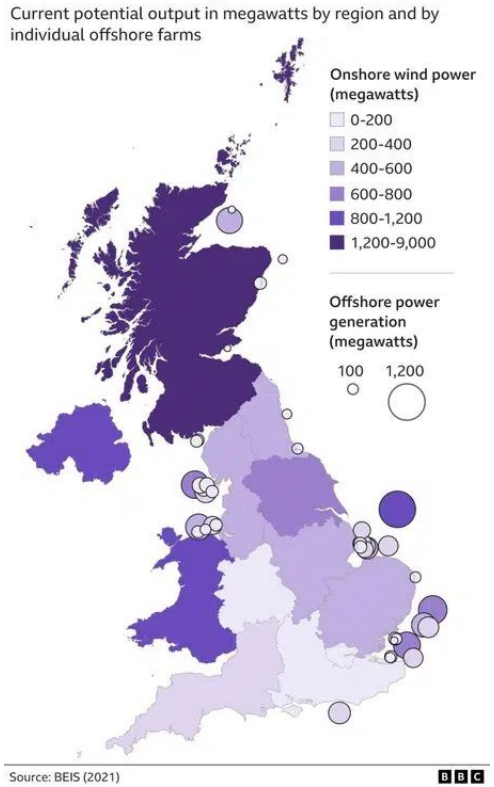

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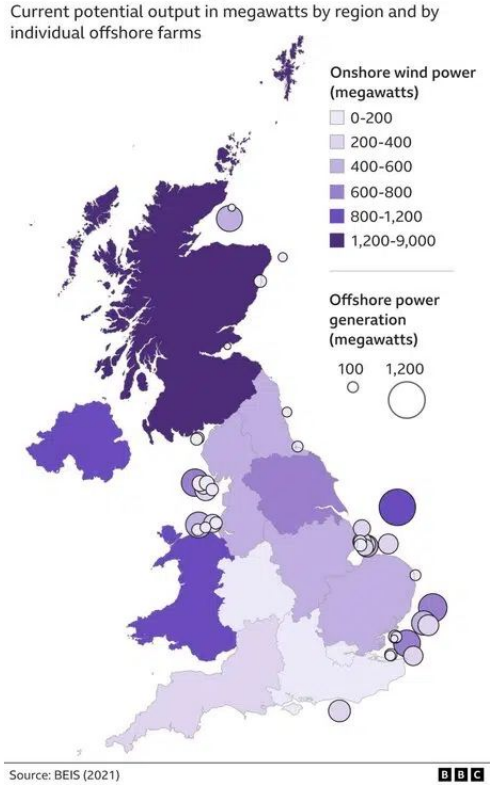
Scale: 5 events and 60k customers per country.



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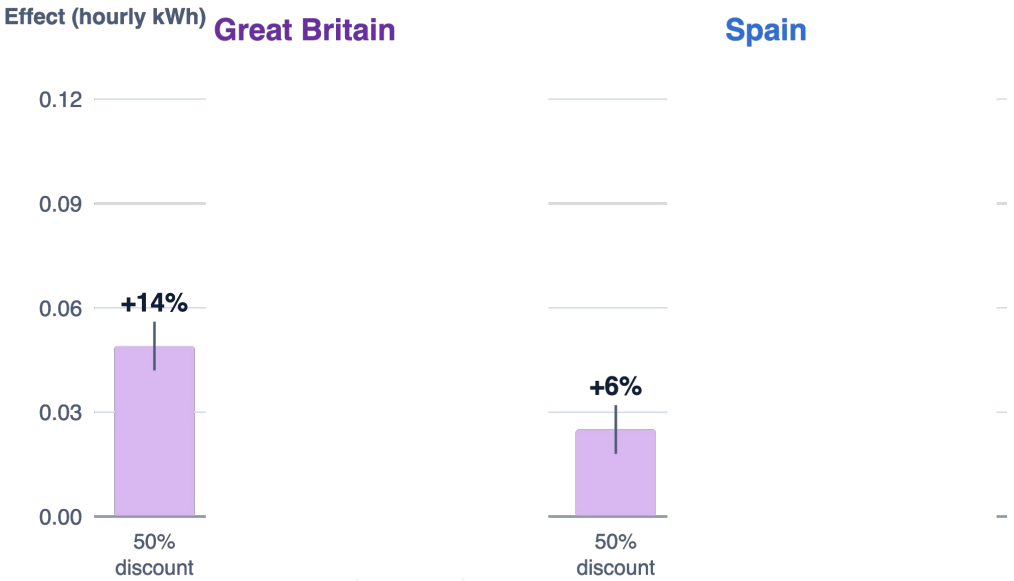

Control group mean during events: 0.34 kWh per hour in GB and 0.40 in Spain

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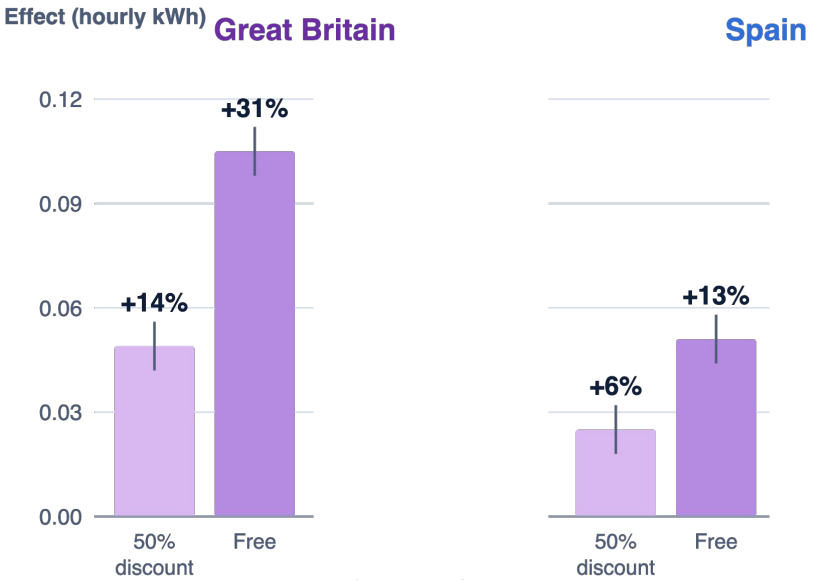

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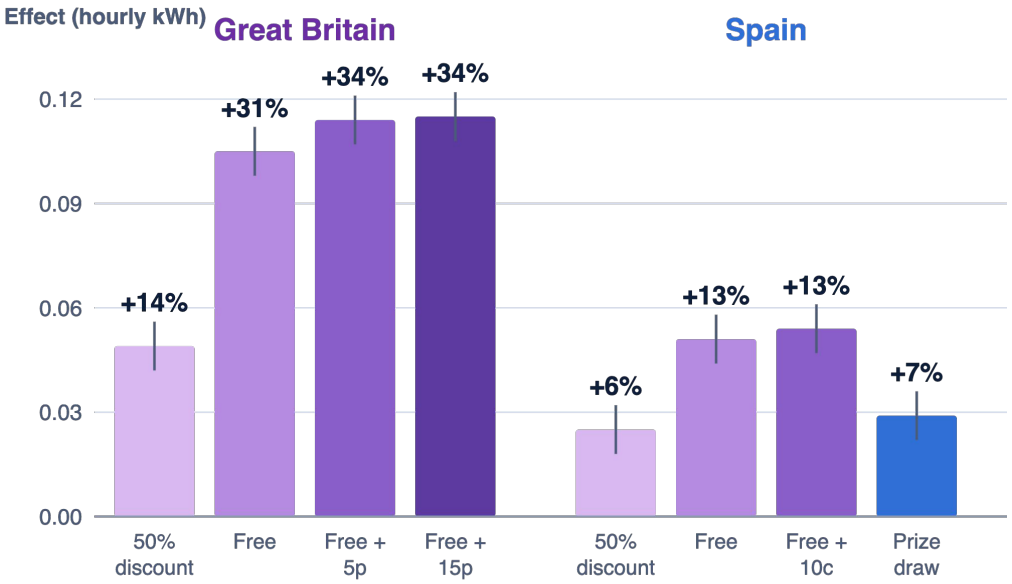

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2. Offering **free electricity doubled** the effects from the 50% discount group.

3. **Negative prices** increased responses by a small margin beyond what offering free electricity achieved.

Lessons learned

And future research questions



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They respond to prices

...as long as the design and mechanism are right.

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04

They turn up more than down

Flex responses were large, but especially upward flex.



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QUESTION 01

What is flexibility worth once everyone has it?

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QUESTION 04

How far can automation take demand flexibility?



Thank you

Contact details
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www.centrefornetzero.org

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