Electric Vehicle Charging at the Workplace: Experimental Evidence on Incentives and Environmental Nudges

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Timing of EV charging

Timing of EV charging impacts carbon emissions from cars: Assumptions

Petrol car:

CO_2 **emissions: 5.06Mt**

EV charged at night:

CO_2 **emissions: 1.14Mt**

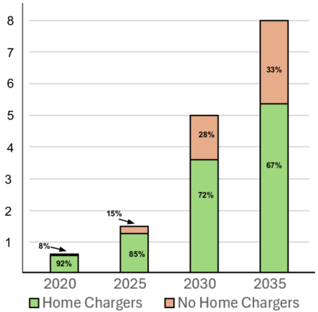
EV charged at midday:

CO_2 **emissions: .16Mt**

Location of EV charging

Shift to workplace EV charging:

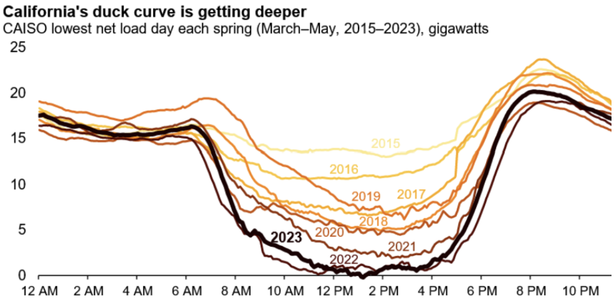
1. Substantial decline in access to home charging through 2035
2. Expected increase of EV fleet to 8 mil. in California



Timing of solar generation

Timing of EV charging could reshape California's "duck curve":

1. Timing of EV charging could shift net demand (consumption minus solar production) back toward midday
   - → Avoid curtailment of renewables
   - → As transportation electrifies and grids decarbonize, timing EV charging becomes critical



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2. **Timing of charging:**
   → We measure the effect of interventions on temporal shifts in workplace charging
   → Derive three mechanisms that explain temporal shifts

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   → We build an experimental basis for workplace EV research
2. **Timing of charging:**
   → We measure the effect of interventions on temporal shifts in workplace charging
   → Derive three mechanisms that explain temporal shifts
3. **Policy implications:**
   → We derive charging policy strategies that align with sustainability objectives

Preview of results

Empirical findings:

- No significant effect on total charging behavior
- Interventions induced opposite temporal shifts:
  - → Environmental nudges induced a transition from early to later morning
  - → Discounts prompted a shift from daytime to overnight and early morning charging

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Mechanisms:

- Quality of the charging network
  - → Garages with high network utilization and low glitch rates
- Experimental incentive structure
  - → Incentive-induced scarcity concerns
- Driver demographics
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Policy implications:

- Environmental nudges would reduce cost of CO_2 emission by $16.1 mil.
- First and second financial discount would increase cost of CO_2 emissions by $13.2 mil. and $7.5 mil.

Literature review

This work speaks to two strands of literature:

1. Home charging experiments
   1.1 **Temporal shifts in home charging** (Bailey *et al.* 2023)
   1.2 Effect on total charging behavior:
      - Pricing strategies (Motoaki & Shirk, 2017; Davis & Bradley, 2012; Langbroek *et al.*, 2019; Kacperski *et al.*,, 2022), financial penalties (Asensio *et al.*, 2016), and prizes and auctions (Fetene *et al.* 2017)
      - Information on cost savings (Nicolson *et al.*,, 2017), charging sourced from renewable energy (Nienhueser & Qui, 2016), and tailored at point of charge (Asensio *et al.* 2021)

2. Workplace EV networks
   2.1 Efficiency of charging policy strategies (Caperello *et al.* 2013; Bonges *et al.* 2016)
   → Public messaging systems (Sutton *et al.* 2022), and policies on unplugging (Wolbertus & van den Hoed, 2017)

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- Promote daytime workplace charging - *where* and *when* people charge

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1. Environmental nudges about the climate benefits of daytime charging
   → Run over 18 days from October 4–23
2. Financial discounts for workplace charging (irrespective of time)
   → Two phases of financial treatment run over 26 days from October 24 to November 19
3. Follow-up experiment on scarcity concerns
   → Run over 13 days from February 5-17

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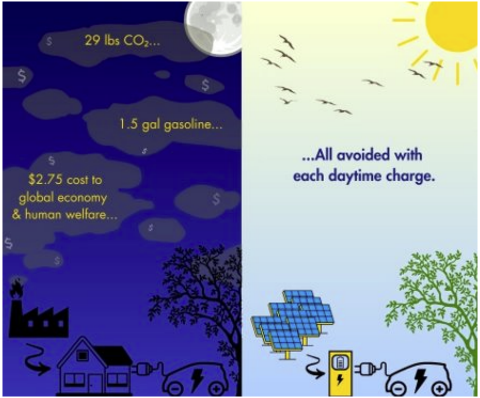
Experimental setting:

- We conducted the field experiment at UCSD in coordination with
  → Campus administrators responsible for campus charging policy and pricing
  → Two leading charging vendors, ChargePoint and PowerFlex, who collect and share charge session data
- We created a campus club for EV drivers — the "Triton Chargers" — open to UCSD affiliates
  → Drivers opt-in, consent to research, answer surveys, and receive discounts on campus charging

Design of informational intervention

Informational nudges:

- Stating the climate benefits of daytime compared to nighttime charging in an email, delivered three times (once per week)
  - → Benefits are reported as avoided CO_2 emissions, equivalent unburned gasoline, and prevented global environmental damages



Design of financial intervention

First phase of financial intervention: Financial prompt 1

- One-third of participants receive a small discount (\$.16/kWh) — 50% off the base campus rate
  - → Effective small-discount rate (\$.14/kWh) is slightly less than cheapest overnight home charging rate of the local electric utility (SDG&E)
- Two-thirds receive a large discount (\$.23/kWh) — 75% off the base campus rate
  - → Large-discount rate (\$.07/kWh) equals locational marginal price of wholesale electricity, corresponding to the plausible lowest cost that drivers would pay for charging

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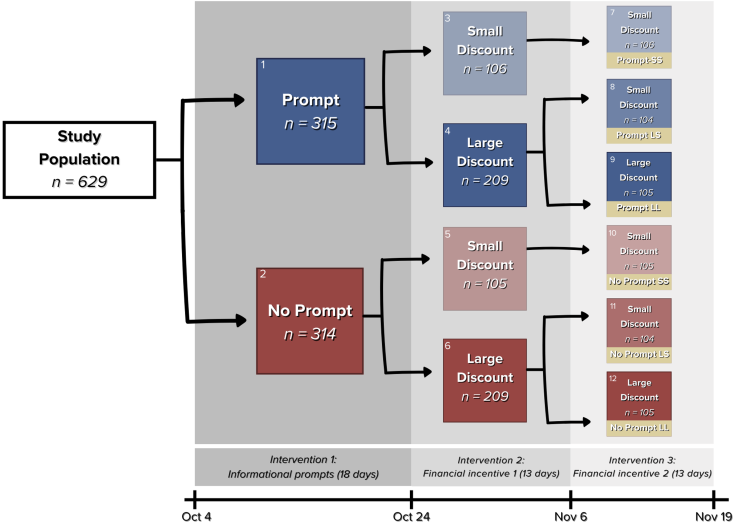
Second phase of financial intervention: Financial prompt 2

- Three treatment arms—LL (Large-Large), LS (Large-Small), and SS (Small-Small) discounts
  - → Test for the presence of habit formation when financial discounts are reduced

Experimental design



Experimental schedule

Datasets

We combine various data sources for our experiment (October 4–November 19):

1. **Charging network data** Parking stalls Parking features
   - → 331 Level-2 charging ports: 249 from ChargePoint, 72 from PowerFlex
   - → Session data (session duration, charging duration, idle duration, energy consumed)
   - → Sample restrictions:
     - Sessions that indicate an initiation error (i.e., $< .5$ kWh or < 5 minutes)
     - Flout campus parking rules (i.e., exceed 16 hours)

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2. **Driver data**
   - → Triton Chargers EV club members provide information on
     - Demographics (age, gender, income, living arrangement, university affiliation, and education)
     - Vehicle (year, make, model, type)
     - Charging behaviors (access to charging alternatives, fraction of charging done by location)
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3. **Other data**
   - → Home charging rates set by the local utility (SDG&E) Charging rates
   - → Emission factors from California Air Resources Board Emission factors

Participant characteristics and charging behaviors

	Mean	Std. dev.	Min	Max	Obs.
A.Demographics					
Age	38.25	12.88	22	80	629
Share male (%)	0.53	0.50	0	1	629
Income ($ '000)	135.73	66.58	25	200	557
Years of education	17.18	3.09	11	21	629
Days on campus per week	3.26	1.75	0	6	629
B.Vehicle attributes					
Vehicle age (years)	2.38	2.59	0	22	629
Battery electric (%)	0.76	0.43	0	1	629
Odometer reading (miles)	29153.09	28770.26	28	205,069	422
C.Commuting and charging habits					
Daily mileage (miles)	39.95	40.83	0	491	318
Home charger (%)	0.59	0.49	0	1	629
Charging price ($ per kWh)	0.18	0.12	0	1	382
D.Outcome variables					
Share of charging on campus	30.70	34.60	0	100	313
Weekly charging sessions	0.89	1.21	0	9	629
Energy consumed (kWh)	18.72	12.32	1	67	401
Session costs ($)	5.35	3.53	0	18	401
Session duration (min)	312.33	170.62	23	792	401
Charging duration (min)	228.53	136.92	21	749	401
Idle duration (min)	83.79	102.51	0	614	401

Supplementary statistics

Estimating equations

Effect of interventions on charging behavior:

$$y_i = \beta Info_i + \delta Reward_{1i} + \eta(Info_i \cdot Reward_{1i}) + \gamma X_i + \alpha_j + \eta_t + \varepsilon_i \quad (1)$$

- y_i : Charging outcome variable of interest
- $Info_i$: 1 if the individual received the informational prompts
- $Reward_{1i}$: 1 if the individual received the large discount in the first financial treatment
- X_i : Demographics, vehicle and charging characteristics, and motivation about charging
- η_t : Dummy variable for UCSD's "Clean Air Day" (campus advertised charging discounts of 50%)
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Coefficients of interest:

- β : Response to informational treatment
- δ : Response to first financial treatment
- η : Interaction effect between information and financial treatment

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Second financial treatment:

- $Reward_{2i}$: 1 if the individual received the large discount in the second financial treatment

Balance

Charging outcome of interest

Total charging behavior:

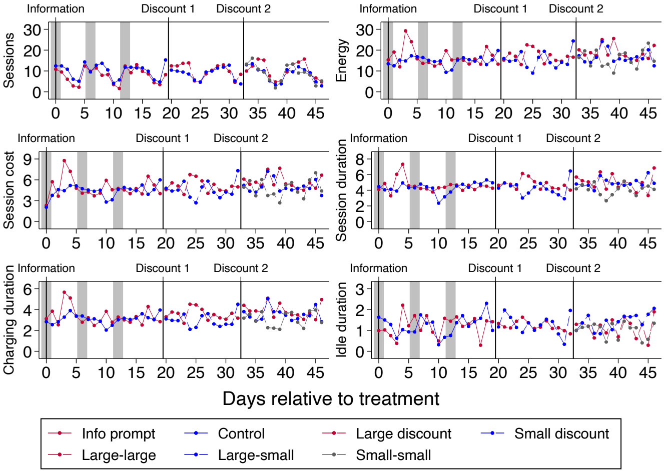
1. Share of charging done on campus
   → Total energy consumed from campus charging divided by the expected energy consumed from total driving)
2. Number of sessions initiated
3. Energy consumed
4. Session cost
5. Session duration
6. Charging duration
7. Idle duration

Timing of charging behavior:

1. Overnight (21:00–4:59)
   → Low network utilization
2. Early morning (5:00–6:59)
   → Early morning commuters and low utilization
3. Morning (7:00–9:59)
   → Arrival of most regular commuters and a rapid surge
4. Midday (10:00–15:59)
   → High utilization and maximal solar generation
5. Evening (16:00–20:59)
   → Departing commuters, arrival of nighttime workers, and waning solar generation

Total charging behavior by day

Total charging activity for six measures of campus charging:



Effect on total charging behavior

	Total charging behavior						
	(1) Share	(2) Sessions	(3) Energy	(4) Cost	(5) Duration	(6) Charge time	(7) Idle time
A. Informational prompt	.501	-.002	-1.471	-.589	-47.084	-18.950	-28.159
	(3.673)	(.269)	(5.365)	(1.485)	(101.501)	(69.166)	(48.349)
Mean Dep. Var.	30.37	2.47	42.67	11.89	784.07	547.62	236.43
B. Financial incentive 1	-.170	-.040	5.349	1.546	46.346	53.400	-7.051
	(4.029)	(.199)	(3.917)	(1.133)	(68.710)	(49.377)	(29.872)
Mean Dep. Var.	34.67	1.71	30.84	8.91	549.03	390.56	158.48
C. Financial incentive 2	1.824	.313	5.127	1.537	89.069	62.649	26.454
	(4.821)	(.251)	(5.551)	(1.616)	(91.692)	(67.101)	(39.365)
Mean Dep. Var.	31.89	1.73	31.6	9.17	560.06	391.2	168.85
D. Information x large discount	-2.195	-.070	.601	.119	-94.626	-34.872	-59.771
	(3.732)	(.461)	(8.775)	(2.464)	(166.376)	(112.816)	(82.161)
Observation	350	629	629	629	629	629	629

Between group-substitution

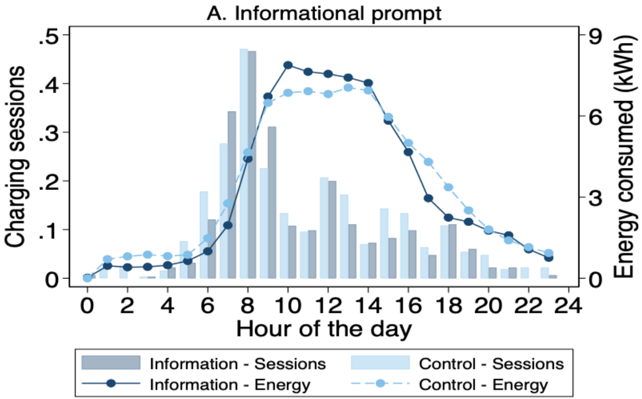
Substitution among commuter groups:

- Shift in charging sessions from high- to medium-utilization garages during the informational treatment Charging utilization
- Increase in campus charging by commuters who experience low glitch rates during the second financial discount Charging glitches
  - → Larger campus charging responses from workplace charging facilities characterized by lower congestion and greater reliability
- Substitution in total charging behavior from infrequent to frequent commuters Charging commute frequency
  - → Larger campus charging responses from commuters with greater flexibility

Effect on the timing of charging behavior

Charging sessions and energy consumed by hour of the day:

- Information shifts initiated charging sessions from morning to midday



Effect on the timing of charging behavior

Charging sessions and energy consumed by hour of the day:

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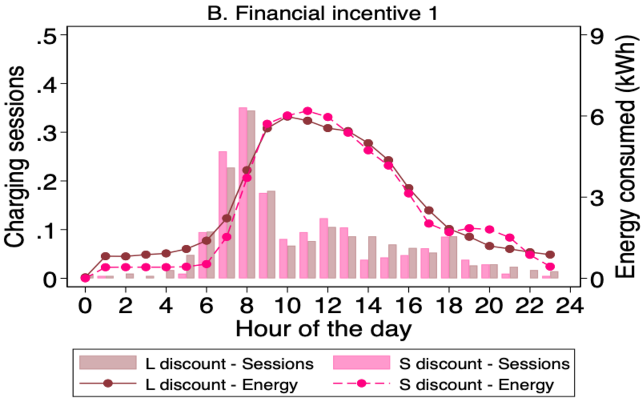

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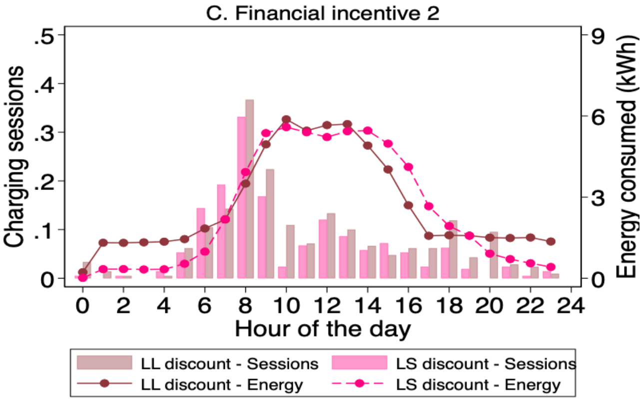

Effect on the timing of charging behavior

	Timing of initiated charging session				
	(1) 21-5	(2) 5-7	(3) 7-10	(4) 10-16	(5) 16-21
A. Informational prompt	-.048	-.124*	.202	-.049	.017
	(.044)	(.072)	(.176)	(.137)	(.083)
Mean Dep. Var.	.09	.2	1.05	.75	.37
B. Financial incentive 1	.061**	.084*	-.076	-.043	-.046
	(.030)	(.049)	(.130)	(.092)	(.062)
Mean Dep. Var.	.07	.13	.76	.49	.26
C. Financial incentive 2	.040	-.061	-.002	.194*	.205**
	(.062)	(.082)	(.140)	(.121)	(.093)
Mean Dep. Var.	.07	.19	.71	.63	.26
D. Information x large discount	-.045	-.146	.106	.011	.003
	(.077)	(.115)	(.313)	(.215)	(.144)
Observation	629	629	629	629	629

Main mechanisms

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Implications:

- Predict temporal shifts in charging behavior
- Target interventions toward the most responsive socio-demographic groups.

Network utilization

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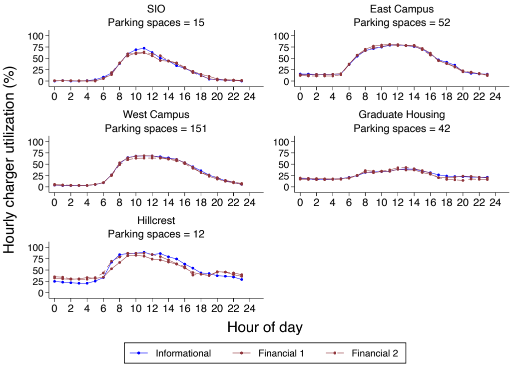
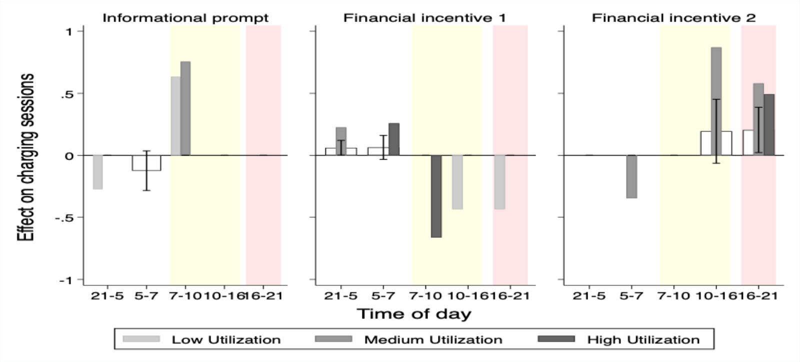
- EV drivers at UCSD have reported difficulty finding an available charger as a primary barrier to charging on campus
- Network utilization of 80-90% at the two largest campus zones by 9 am Parking zones
  - → Excludes chargers that are temporarily non-operational or out-of-service Network operation Designation share
  - → Includes stalls that are occupied by non-charging vehicles



Effect of network utilization

Network utilization: Energy - Utilization

- Temporal shifts from informational prompts are exclusively from low-utilization garages
  - → Drivers are more responsive to information when they perceive no charger scarcity
- Temporal shifts from discounts are from medium- and high-utilization garages.
  - → Drivers shift to periods with lower utilization to guarantee they receive a charge
  - → Temporal shifts are in campus zones with high network utilization Charging by location



Charger unreliability

Session glitch rates:

- Perceived unreliability of chargers may impede EV charging (Rempel, 2022)
- 15 to 20% of charging sessions fail to deliver a meaningful energy (i.e., "glitch") Session glitch rate
- Drivers who fail to plug in successfully on their first attempt are less likely to receive a charge during successive attempt

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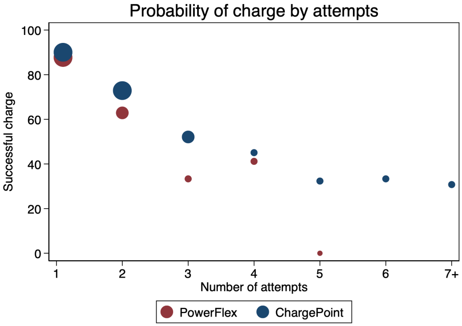

Effect of charger unreliability

Session glitch rates: Energy - Charger reliability

- Drivers are more willing to shift their charging behavior when chargers are reliable (i.e., low-glitch-rate garages)
- Temporal shifts are mostly associated with the less-glitch-prone ChargePoint stations Charging by operator

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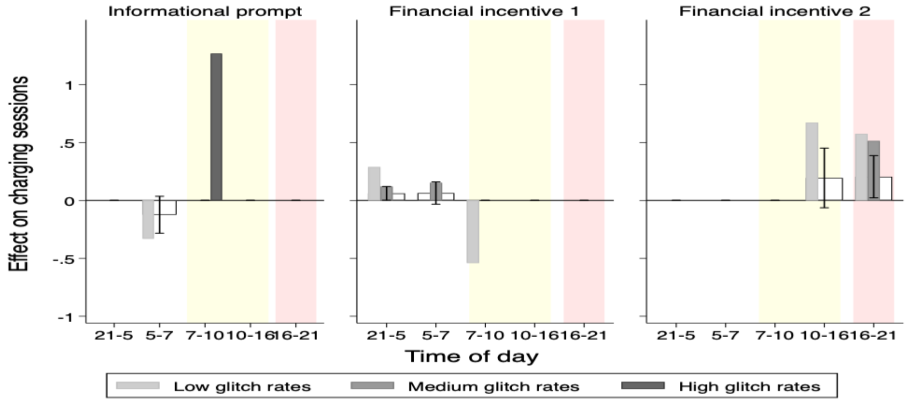

Experimental incentive structure

Scarcity concerns:

- Discounts could induce perceptions of charger scarcity
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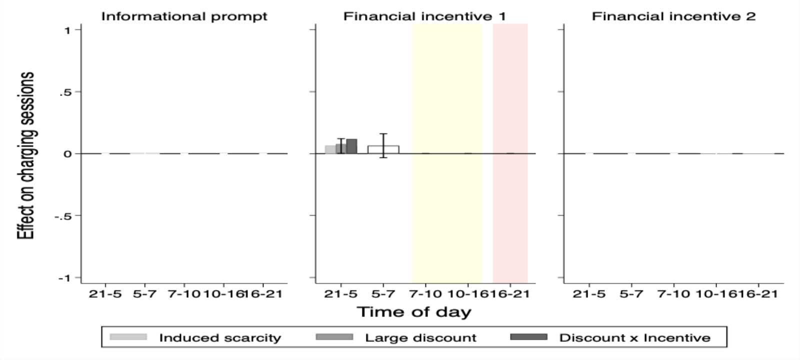
Scarcity results: Energy - Scarcity

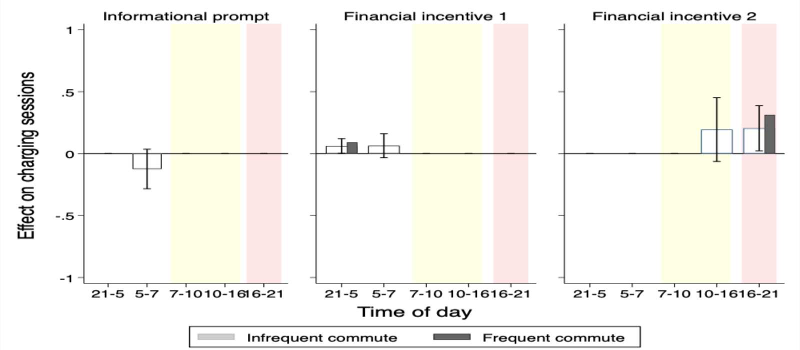
- Expectations of incentive-induced scarcity resulted in shifts to overnight charging sessions



Driver characteristics

Flexibility of commuters: Energy - Commute frequency

- Commuters with greater flexibility may be better able to adapt their commuting schedules
- Compare commuters with different commute frequency



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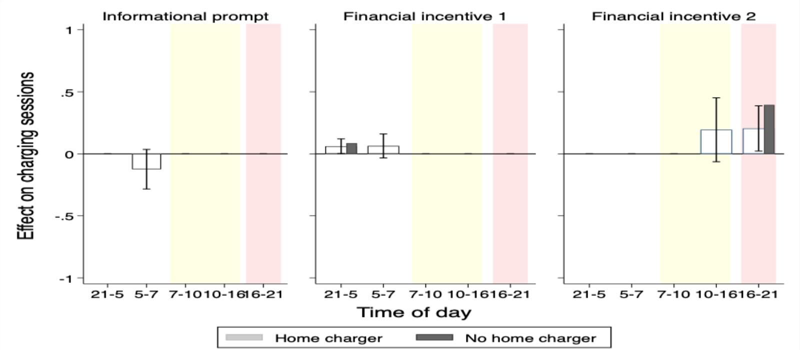
Convenience of home charging: Home charging access | Energy - Home charger

- Access to private home charging makes home charging more convenient
- Compare commuters with/without access to private home charging



Welfare effects

Net welfare $\triangle W$ per driver annually:

$$\triangle W = \underbrace{\triangle CO_2}_{Global\ \ pollutant} + \underbrace{\triangle LCFS}_{Local\ \ benefit} - \underbrace{\triangle Costs}_{Local\ \ costs} \tag{2}$$

- $\triangle CO_2$: Change in CO_2 emissions from temporal shifts in charging
- $\triangle LCFS$: Revenues earned through CA's Low Carbon Fuel Standard (LCFS) program
- $\triangle Costs$: Cost for financial discounts

Assumptions:

- Convert treatment effects over the experiment to annual effects.
- Welfare effects of intertemporal substitution
- Welfare effects are per driver and from the institution's perspective

Avoided CO_2 emission damages

Carbon emission changes for each hour h of the day:

$$\triangle CO_2 = \sum_{h=1}^{24} (\underbrace{\beta_h^{kWh} \cdot CI_h}_{Information} + \underbrace{\delta_{1h}^{kWh} \cdot CI_h}_{Discount\ 1} + \underbrace{\delta_{2h}^{kWh} \cdot CI_h}_{Discount\ 2}) \cdot SCC. \quad (3)$$

- β_h^{kWh},δ_{1h}^{kWh}, and δ_{2h}^{kWh}: Response to informational, first, and second treatment on hourly energy consumption
- CI_h: Hourly carbon intensity (gCO_2/MJ) Emission factors
- SCC: Social cost of carbon (210 $\frac{\$}{tCO_2}$)

Avoided CO_2 emission damages

Carbon emission changes for each hour *h* of the day:

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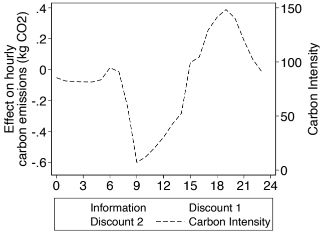

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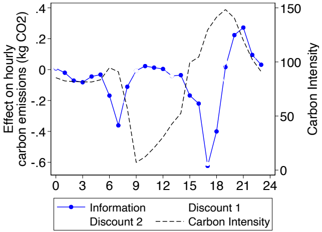

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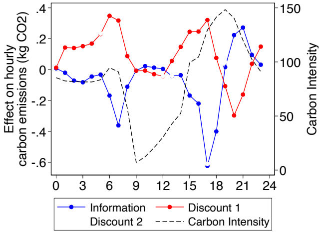

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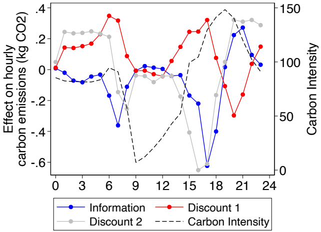

LCFS revenues

LCFS revenue changes for each hour h of the day:

$$\triangle LCFS = \sum_{h=1}^{24}(CI_{standard} - CI_h/3.4) \cdot (\beta_h^{kWh} + \delta_{1h}^{kWh} + \delta_{2h}^{kWh}) \cdot \bar{P} \cdot 3.4. \quad (4)$$

$CI_{standard}$: Carbon intensity from gasoline-powered cars (89.5 gCO_2/MJ)

- $\bar{P}$: LCFS credit price per ton (64.51 $\$/t$)
  - → Multiply by Energy Economy Ratio (3.4)

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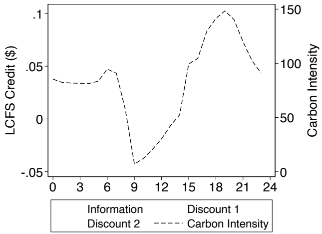

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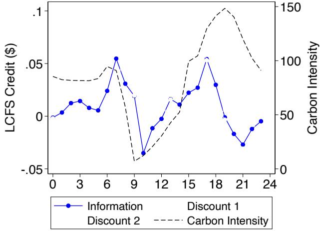

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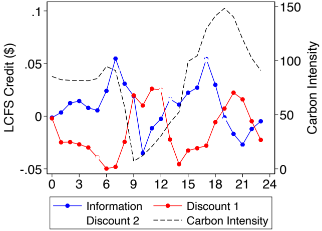

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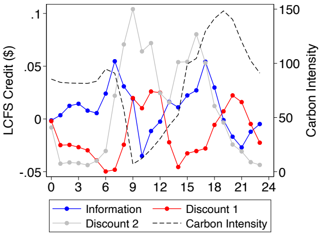

Cost of incentives

Financial costs of discounts:

$$\triangle Costs = \underbrace{(E_l \cdot \$.23/kWh)}_{Large\ \ discount} + \underbrace{E_s \cdot \$.16/kWh)}_{Small\ \ discount} \tag{5}$$

- E_l, E_s: Energy consumption of the large and small discount group
- $\$.16/kWh$: Size of small discount
- $\$.23/kWh$: Size of large discount

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- $\$.16/kWh$: Size of small discount
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Cost of incentives:

- First financial treatment: \$7.43 for the large and \$4.48 for the small discount
- Second financial treatment: \$8.59 for the large and \$4.59 for the small discount

Welfare effect decomposition

Effect on all Triton Charger EV club members:

- Treating intervention costs as transfers (i.e., omitting intervention costs)
- Informational prompts increased welfare by $13,913
- First and second financial discounts decreased welfare by $11,259 and $3,126

EV owners in California (currently 1.29 million vehicles):

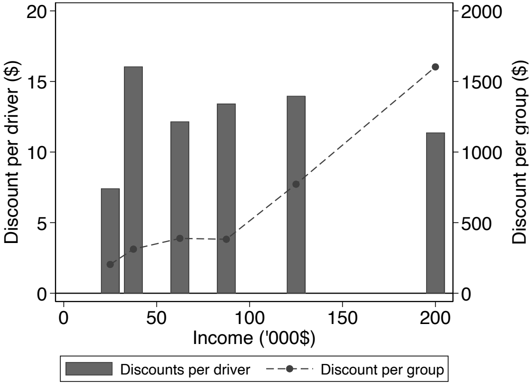
- Informational treatment reduces CO_2 emissions equal to $16.1 mil.
- First and second financial discount increase CO_2 emissions by $13.2 mil. and $7.5 mil.

	Intervention per driver ($)		
	Information	Discount 1	Discount 2
Avoided CO_2 damages ($\triangle CO_2$)	12.51	−10.23	−5.8
LCFS revenues ($\triangle LCFS$)	9.61	−7.67	.83
Intervention costs ($\triangle Costs$)		−328.48	−368.66
Welfare effects ($\triangle W$)	**22.12**	**-346.38**	**-373.64**

Distributional effects

Strong regressive effects:

- Lowest and highest income group received \$216 and \$1,667 in discounts
  - → Given that current EV drivers are wealthier, providing financial incentives to shift these individual's charging sessions to the workplace is a highly regressive policy tool.



Conclusion

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- Shift charging behavior toward daytime hours with abundant solar energy

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Empirical findings:

- Interventions induce opposite temporal shifts
  - → Environmental nudges induced a transition from early to later morning charging
  - → Discounts prompted a shift from daytime to overnight and early morning charging
  - → Mechanisms: Quality of the charging network, incentive-induced scarcity concerns, and driver demographics

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Policy implications:

- Calculate annual welfare effects from avoided CO_2, LCFS, and incentive costs per driver
  - → Environmental nudges yield net welfare benefit of $22.12
  - → First and second financial treatments reduce welfare by $18 and $4.97

Outlook

Timing of solar generation:

- Grid operations strongly favor temporally shifting EV charging toward midday in solar-dominated grids

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Benefits of daytime charging:

- California EV stock (currently 1.29 million vehicles) would decrease annual emissions by 1.2 $MMtCO_2$
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Policy implications:

- As more EVs are on the road and renewable energy capacity increases, policies should encourage a shift to daytime charging to optimize power usage

Carbon emission calculations

	Vehicle type		
	Petrol car	EV charged at night	EV charged at midday
Annual miles	11,500	11,500	11,500
Fuel per mile	.05	.33	.33
Fuel per year	575 gallons	3795 kWh	3795 kWh
Carbon intensity ($kgCO_2$ / gallon)	8.8	.3	.04
Annual CO_2 emissions (Mt)	5.06	1.14	.16

Carbon emission damages from cars

Financial prompt 1

Research participants were notified about financial discounts via email. On October 23, ahead of the first financial treatment, the following messages were sent to the large and small discount treatment arms:

- [Large discount group]: **From October 24 through November 5**, we will offer a >**75%** discount on all Level-2 charging you do on campus. We are providing a **$0.23/kWh** discount on the base campus price of $0.30/kWh. That means you pay just **$0.07/kWh**. After November 5, these discounts will continue, but they may change in size. We will tell you of all changes ahead of time.
- [Small discount group]: **From October 24 through November 5**, we will offer a >**50%** discount on all Level-2 charging you do on campus. We are providing a **$0.16/kWh** discount on the base campus price of $0.30/kWh. That means you pay just **$0.14/kWh**. After November 5, these discounts will continue, but they may change in size. We will tell you of all changes ahead of time.

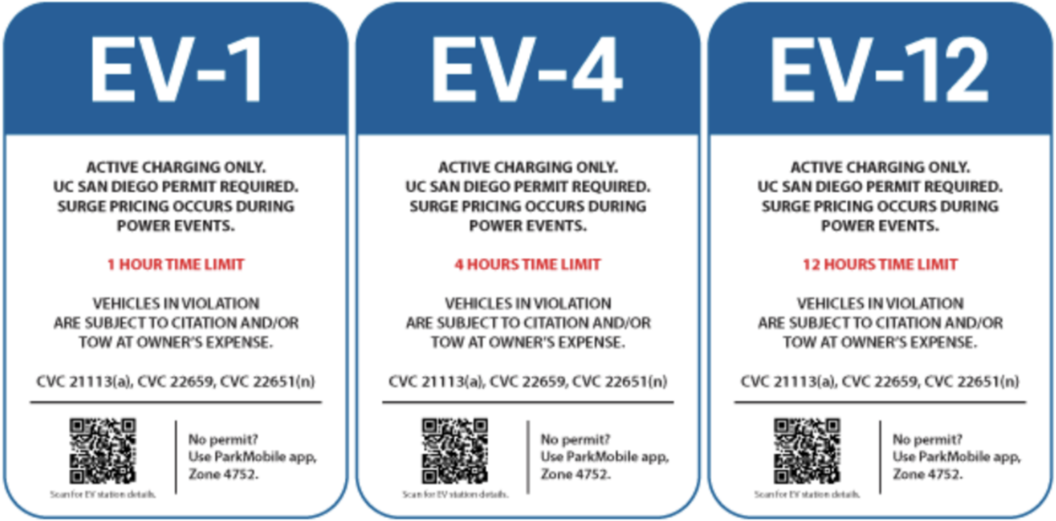
Design of financial intervention

Financial prompt 2

On November 5, ahead of the second financial treatment, the following messages were sent to the large–large, large–small, and small–small discount treatment arms:

- [Large - large discount group]: In October, we announced discounted campus charging through November 5. **From November 6 through November 19, your discount will remain the same.** The Triton Chargers research team will continue to provide a >**75%** discount ($0.23/kWh) off the base campus price of $0.30/kWh. That means you will continue paying just **$0.07/kWh**. After November 19, these discounts will continue, but they may change in size. We will tell you of all changes ahead of time.
- [Large - small discount group]: In October, we announced discounted campus charging through November 5. **From November 6 through November 19, your discount will now be smaller.** It will decrease from about 75% to **50%** off the campus's base price of $0.30/kWh. That means you will now pay just **$0.14/kWh**. After November 19, these discounts will continue, but they may change in size. We will tell you of all changes ahead of time.
- [Small - small discount group]: In October, we announced discounted campus charging through November 5. **From November 6 through November 19, your discount will remain the same.** The Triton Chargers research team will continue to provide a >**50%** discount ($0.16/kWh) off the base campus price of $0.30/kWh. That means you will continue paying just **$0.14/kWh**. After November 19, these discounts will continue, but they may change in size. We will tell you of all changes ahead of time.

Parking stalls



Datasets

Parking features

	Tariff		
	EV -1	EV -4	EV 12
Limit	1 hour	4 hours	12 hours
Ports	1	2	1
Power	50–125 kW	6.6 kW	1.2–6.6 kW
Range	75-–185 mi per half hour	21 mi per hour	21 mi per hour
Plugs	CHAdeMO, CCS	J1772	J1772
Energy minimum	None	7 kWh	10 kWh
Flex charging	No	No	Yes

Datasets

SDG&E charging rates

	Price (\$/kWh)					
	Summer (Jun-Oct)			Winter (Nov-May)		
Tariff	Super-Off-Peak	Off-peak	On-peak	Super-Off-Peak	Off-peak	On-peak
EV -TOU	.285	.497	.832	.276	.464	.527
EV -TOU-2	.285	.497	.832	.276	.464	.527
EV -TOU-5	.154	.481	.816	.145	.448	.511

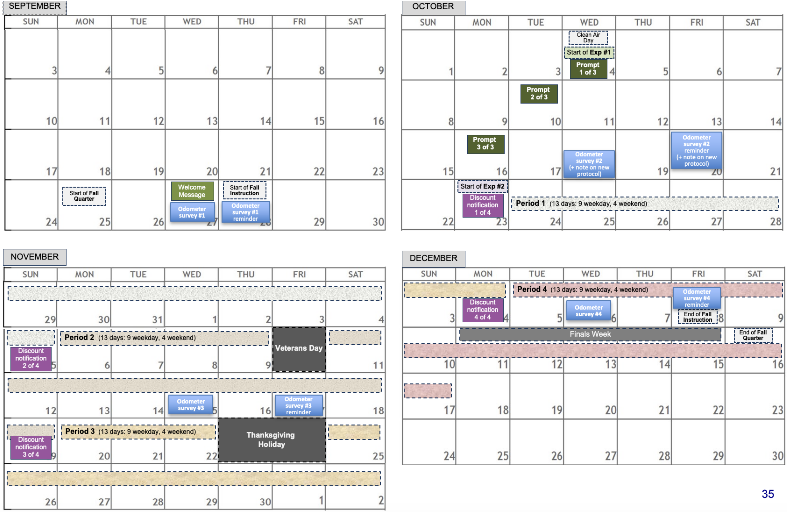
Datasets

Average carbon intensity of the California power grid

	Season			
Time	2022-Q1	2022-Q2	2022-Q3	2022-Q4
12:01 - 01:00	81.66	82.48	85.43	90.97
01:01 - 02:00	81.62	80.68	82.43	87.1
02:01 - 03:00	81.62	80.64	81.82	84.95
03:01 - 04:00	81.62	80.61	81.59	84.52
04:01 - 05:00	81.62	81.79	81.47	86.37
05:01 - 06:00	87.03	90.14	83.5	97.52
06:01 - 07:00	108.88	88.8	94.67	119.41
07:01 - 08:00	107.18	28.24	90.9	118
08:01 - 09:00	63.59	2.28	57.31	97.07
09:01 - 10:00	29.08	1.68	7.05	38.86
10:01 - 11:00	0.41	3	12.26	31.13
11:01 - 12:00	0	47.2	20.61	7.57
12:01 - 13:00	0	50.24	30.4	9.03
13:01 - 14:00	0	52.09	42.67	11.27
14:01 - 15:00	0	55.64	52.49	40.08
15:01 - 16:00	28.52	60.37	99.35	74.02
16:01 - 17:00	63.34	26	104.51	123.7
17:01 - 18:00	105.37	30,.28	129.55	144.16
18:01 - 19:00	136.85	75.05	141.37	147.13
19:01 - 20:00	131.9	146.13	148.42	143.16
20:01 - 21:00	121.95	147.19	140.49	136.57
21:01 - 22:00	101.6	124.86	119.97	122.34
22:01 - 23:00	87.84	94.26	102.34	108.95
23:01 - 24:00	82.13	84.41	91.01	95.2

Datasets Avoided emission damages

Experimental schedule



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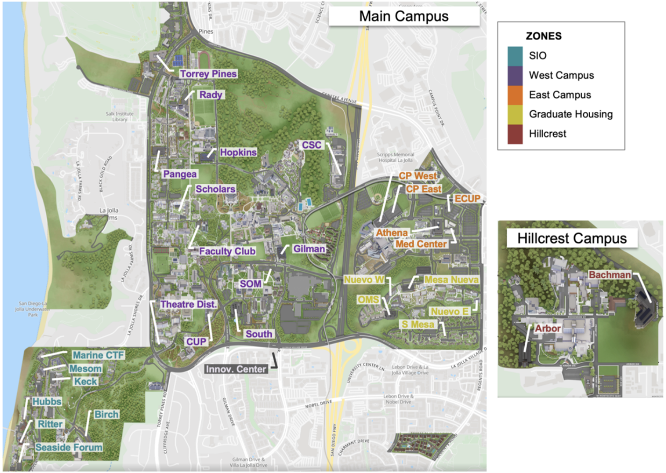
Experimental design

Supplementary statistics

A. Demographics							
	(1) Staff	(2) Faculty	(3) Undergraduate	(4) Graduate	(5) Other		
Affiliation	49.13	20.67	17.8	11.45	.95		
	(1) Own House	(2) Rent off-campus	(3) Own condo	(4) Rent house	(5) On-campus	(6) Other	
Living Arrangement	42.61	24.17	10.33	9.7	9.7	9.7	
B. Charging Characteristics							
	(1) Campus	(2) Residence	(3) Other	(4) Neighborhood	(5) Destination	(6) Other Home	
Charging Location (%)	42.58	38.68	7.81	5.24	4.95	.74	
	(1) Night	(2) Morning	(3) Afternoon	(4) Evening			
Charging Time (%)	39.33	26.54	19.33	14.8			
	(1) Low Prices	(2) Activities	(3) Find Charger	(4) Campus	(5) Parking	(6) Fast Charger	(7) Environment
Charging Motivation (%)	35.55	17.21	16.51	11.8	9.52	7.31	2.1
	(1) Close Office	(2) Open Stall	(3) Long Dwell	(4) Short Time	(5) Environment		
On-campus Charging (%)	38.93	30.82	23.82	4.72	1.71		

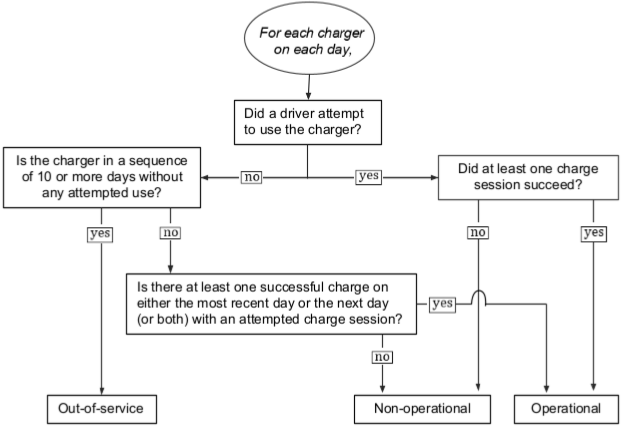
Participant characteristics and charging behaviors

Parking zones



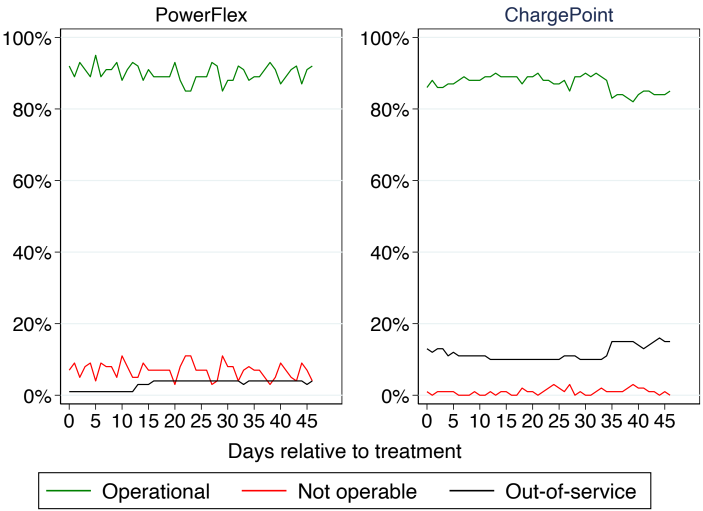
Network utilization

UCSD EV network operation



Network utilization

Designation share



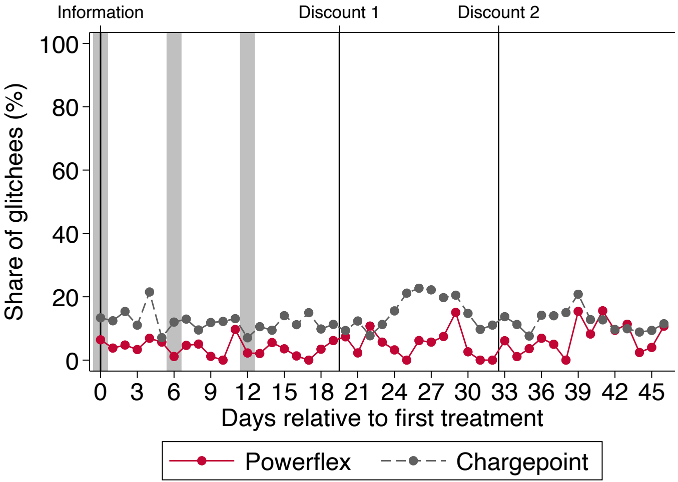
Network utilization

Balance table

	Information		Discount 1		Discount 2	
	Treated	Control	Large	Small	Large-large	Large-small
A.Demographics						
Age	38.58	37.92	38.48	37.79	38.35	38.61
	(13.33)	(12.43)	(12.65)	(13.34)	(12.36)	(12.36)
	[.42]		[.4]		[.04]	
Share male (%)	0.50	0.57	0.58	0.45	0.55	0.61
	(.5)	(.5)	(.49)	(.5)	(.5)	(.5)
	[3.55]		[9.79]		[1.45]	
Income ($ '000)	138.39	133.03	136.69	133.82	137.09	136.28
	(66.21)	(66.97)	(66.94)	(66)	(66.45)	(66.45)
	[.9]		[.23]		[.01]	
Years of education	17.32	17.04	17.40	16.74	17.47	17.33
	(3.14)	(3.04)	(3.06)	(3.11)	(3.17)	(3.17)
	[1.36]		[6.34]		[.21]	
Days on campus per week	3.23	3.29	3.28	3.22	3.28	3.27
	(1.75)	(1.76)	(1.76)	(1.74)	(1.76)	(1.76)
	[.16]		[.13]		[0]	
B.Vehicle attributes						
Vehicle age (years)	2.40	2.37	2.44	2.27	2.50	2.39
	(2.87)	(2.29)	(2.69)	(2.4)	(2.68)	(2.68)
	[.02]		[.67]		[.15]	
Battery electric (%)	0.76	0.77	0.75	0.80	0.79	0.70
	(.43)	(.42)	(.44)	(.4)	(.41)	(.41)
	[.2]		[1.92]		[4.35]	
Odometer reading ('000 miles)	31.56	30.59	31.77	29.79	32.56	30.93
	(31.5)	(27.17)	(28.9)	(30.34)	(27.87)	(27.87)
	[.12]		[.46]		[.23]	
C.Commuting and charging habits						
Daily mileage (miles)	34.27	38.38	36.53	35.93	37.74	35.10
	(27.81)	(30.28)	(26.94)	(32.66)	(29.53)	(29.53)
	[1.79]		[.03]		[.55]	
Home charger (%)	0.59	0.58	0.59	0.58	0.59	0.60
	(.49)	(.49)	(.49)	(.5)	(.49)	(.49)
	[.08]		[.13]		[.01]	
Charging price ($ per kWh)	0.18	0.18	0.18	0.19	0.17	0.19
	(.12)	(.12)	(.12)	(.12)	(.12)	(.12)
	[.35]		[.65]		[1.78]	
Number of Observation	315	314	418	211	210	208

Estimating equations

Session glitch rate

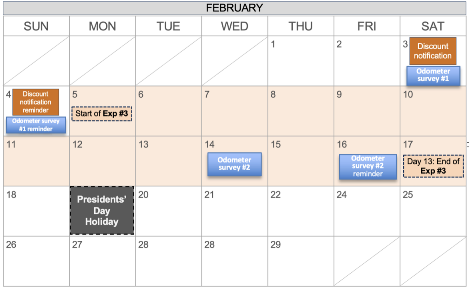


Charger unreliability

Charger scarcity experiment

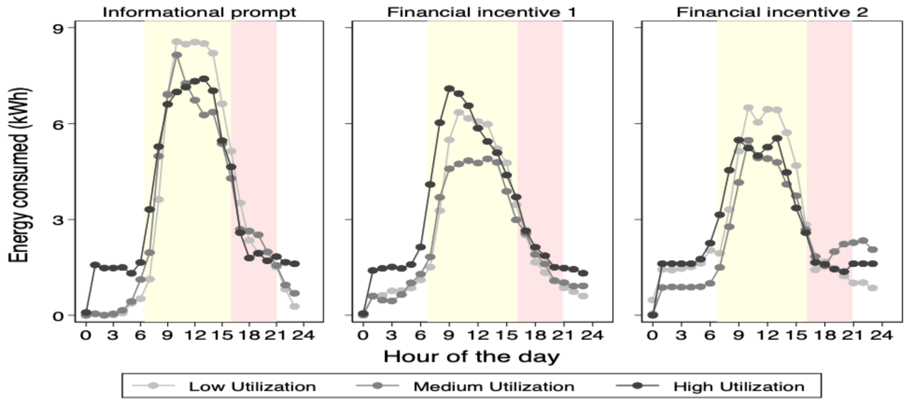
Charger scarcity experiment:

- [High scarcity]: Starting tomorrow, and for the next two weeks, you will receive an extra discount on campus charging for being a member of the Triton Chargers EV club. During these two weeks, **we are making discounts available to you and fellow Triton Chargers.**
- [Low scarcity]: Starting tomorrow, and for the next two weeks, you will receive an extra discount on campus charging for being a member of the Triton Chargers EV club. During these two weeks, **you and no more than 33% of Triton Chargers will receive this discount.**



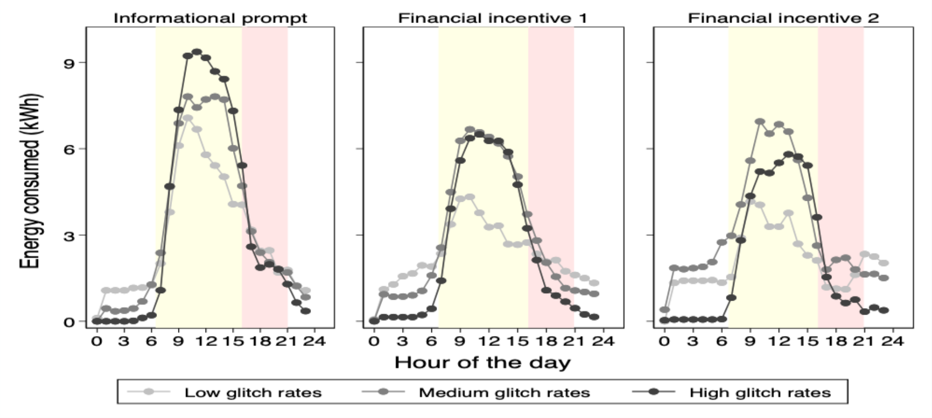
Experimental incentive structure

Energy consumed by hour of the day - Utilization



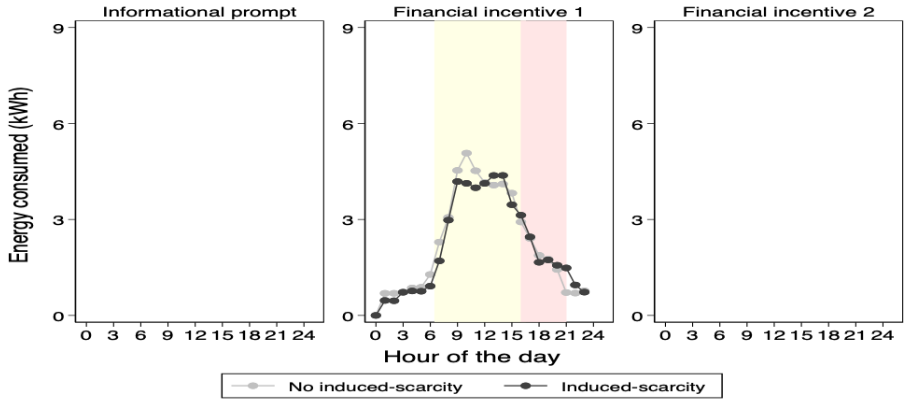
Effect of network utilization

Energy consumed by hour of the day - Charger reliability



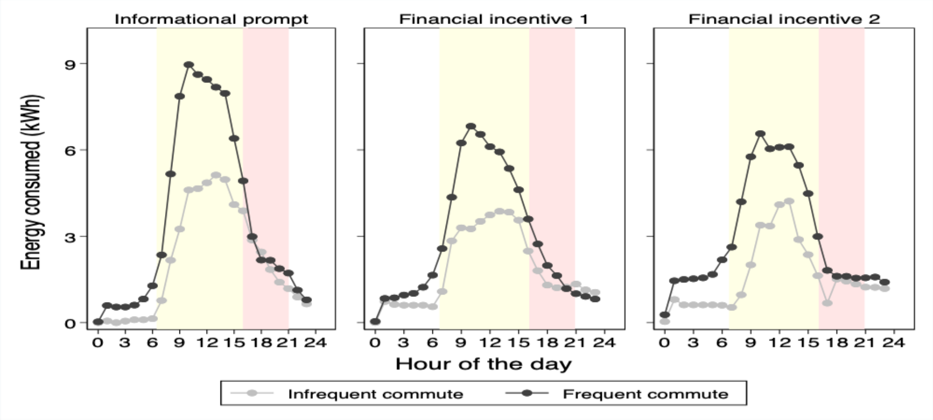
Effect of charger unreliability

Energy consumed by hour of the day - Scarcity



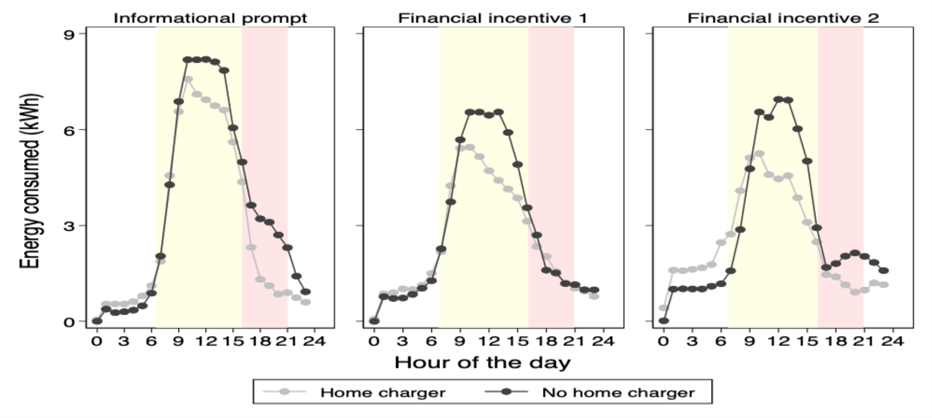
Experimental incentive structure

Energy consumed by hour of the day - Commute frequency



Driver characteristics

Energy consumed by hour of the day - Home charger



Driver characteristics

Effect on total charging behavior by utilization

	Total charging behavior						
	(1) Share	(2) Sessions	(3) Energy	(4) Cost	(5) Duration	(6) Charge Time	(7) Idle Time
A.Informational prompt							
Low Network Utilization	-1.319	-.229	4.571	1.063	-87.606	-2.212	-85.403
	(7.955)	(.590)	(9.940)	(2.833)	(183.386)	(119.599)	(92.013)
Medium Network Utilization	7.224	1.206**	9.158	2.092	111.227	210.312	-99.126
	(9.142)	(.603)	(10.896)	(2.996)	(202.102)	(156.149)	(90.094)
High Network Utilization	-4.173	-1.309**	-19.919	-5.683*	-277.204	-324.391*	47.097
	(7.912)	(.603)	(12.085)	(3.325)	(264.719)	(172.222)	(140.101)
B.Financial incentive 1							
Low Network Utilization	-5.215	-.797**	3.279	.860	-117.011	-31.206	-85.816
	(7.089)	(.404)	(7.584)	(2.239)	(140.612)	(87.690)	(75.932)
Medium Network Utilization	-5.625	.065	6.663	2.025	-3.249	86.436	-89.627
	(8.308)	(.394)	(7.552)	(2.220)	(131.433)	(98.911)	(57.523)
High Network Utilization	1.948	-.241	9.697	2.872	195.697	96.351	99.301
	(8.695)	(.440)	(9.585)	(2.752)	(196.711)	(136.429)	(97.569)
C.Financial incentive 2							
Low Network Utilization	-5.561	-.065	1.542	.481	-81.509	-76.659	-4.806
	(6.935)	(.471)	(10.184)	(3.006)	(153.182)	(112.541)	(75.547)
Medium Network Utilization	-2.621	1.207**	3.989	1.595	91.244	148.070	-56.747
	(10.083)	(.606)	(9.391)	(2.835)	(180.086)	(125.214)	(89.462)
High Network Utilization	8.096	.343	8.051	2.451	284.576	202.654	81.981
	(9.103)	(.542)	(15.814)	(4.570)	(271.780)	(208.393)	(104.334)

Charging substitution

Effect on total charging behavior by reliability

	Total charging behavior						
	(1) Share	(2) Sessions	(3) Energy	(4) Cost	(5) Duration	(6) Charge Time	(7) Idle Time
A.Informational prompt							
Low Glitch Rate	-16.232	-.882	-11.418	-2.953	-347.024	-170.931	-176.073
	(10.445)	(.736)	(13.085)	(3.668)	(251.577)	(172.206)	(126.466)
Medium Glitch Rate	.886	-.293	-7.865	-2.333	-163.103	-154.478	-8.693
	(5.977)	(.457)	(7.873)	(2.255)	(156.081)	(100.775)	(84.122)
High Glitch Rate	14.316	1.114	27.719*	6.599	399.831	442.235*	-42.438
	(11.025)	(.832)	(16.774)	(4.501)	(294.593)	(230.931)	(116.585)
B.Financial incentive 1							
Low Glitch Rate	-9.222	-.555	-.031	.161	-94.038	-2.828	-91.204
	(9.971)	(.474)	(8.555)	(2.516)	(179.482)	(108.936)	(102.898)
Medium Glitch Rate	.069	-.293	7.658	2.224	31.908	44.220	-12.313
	(6.377)	(.319)	(6.997)	(2.040)	(121.077)	(86.695)	(55.666)
High Glitch Rate	-6.471	-.527	6.894	1.780	-3.794	60.024	-63.812
	(10.552)	(.645)	(11.125)	(3.208)	(200.953)	(160.479)	(80.958)
C.Financial incentive 2							
Low Glitch Rate	-2.927	.891*	3.525	1.112	-58.957	42.950	-101.868
	(9.295)	(.485)	(13.452)	(3.931)	(225.931)	(152.935)	(103.593)
Medium Glitch Rate	1.268	.566	6.578	2.221	119.085	106.236	12.869
	(7.310)	(.465)	(9.944)	(2.909)	(164.604)	(127.049)	(68.893)
High Glitch Rate	-7.943	-.612	-1.804	-.433	-34.588	-86.109	51.679
	(10.853)	(.528)	(11.243)	(3.298)	(215.403)	(145.771)	(116.189)

Charging substitution

Effect on total charging behavior by commute frequency

	Total charging behavior						
	(1) Share	(2) Sessions	(3) Energy	(4) Cost	(5) Duration	(6) Charge Time	(7) Idle Time
A.Informational prompt							
Infrequent Commute	-5.847	.021	-5.316	-1.459	-180.663	-76.156	-104.519**
	(6.256)	(.362)	(6.834)	(1.892)	(121.883)	(85.478)	(52.442)
Frequent Commute	2.679	-.013	.367	-.172	16.773	8.397	8.345
	(4.778)	(.339)	(6.637)	(1.840)	(125.149)	(84.545)	(60.067)
B.Financial incentive 1							
Infrequent Commute	-1.536	-.147	-2.875	-.916	-94.435	-55.247	-39.174
	(6.032)	(.247)	(5.234)	(1.513)	(87.589)	(64.274)	(35.244)
Frequent Commute	-1.899	.016	9.624*	2.826*	119.536	109.884	9.649
	(5.499)	(.251)	(5.112)	(1.494)	(90.478)	(67.347)	(37.833)
C.Financial incentive 2							
Infrequent Commute	-16.281**	-.061	-7.989	-2.378	-43.946	-77.764	33.823
	(6.684)	(.326)	(6.310)	(1.880)	(101.390)	(74.869)	(42.588)
Frequent Commute	6.269	.494	11.495	3.438	153.660	130.831	22.877
	(6.168)	(.307)	(7.787)	(2.279)	(124.054)	(92.348)	(52.162)

Charging substitution

Effect on total charging behavior by location

	Total charging behavior					
	(1) Sessions	(2) Energy	(3) Cost	(4) Duration	(5) Charge Time	(6) Idle Time
A.Informational prompt						
SIO	.033	.404	.269	9.006	9.185	-.180
	(.069)	(.841)	(.428)	(18.334)	(15.356)	(3.659)
West Campus	.101	.146	-.290	18.412	32.588	-14.177
	(.224)	(4.257)	(1.934)	(119.942)	(87.748)	(50.258)
East Campus	-.003	-1.445	-1.176	-116.159	-90.511	-25.648
	(.151)	(3.622)	(1.847)	(145.214)	(92.523)	(69.111)
Graduate Housing	-.121	-1.600	-.922	-76.622	-32.538	-44.085
	(.101)	(2.390)	(1.360)	(74.342)	(48.680)	(30.843)
B.Financial incentive 1						
SIO	-.142**	-2.246**	-1.152*	-46.530*	-37.130*	-9.400
	(.069)	(1.081)	(.664)	(27.121)	(22.448)	(6.232)
West Campus	-.043	2.083	.378	-73.509	-27.367	-46.141
	(.171)	(3.148)	(1.734)	(110.968)	(80.432)	(49.228)
East Campus	.125	4.167*	1.910	75.593	82.619	-7.026
	(.084)	(2.252)	(1.390)	(95.253)	(65.957)	(42.431)
Graduate Housing	-.046	.128	.010	-16.046	-8.585	-7.462
	(.082)	(2.088)	(1.366)	(61.909)	(47.246)	(23.170)
C.Financial incentive 2						
SIO	.016	.217	.017	1.032	.383	.649
	(.026)	(.493)	(.300)	(12.238)	(10.143)	(3.701)
West Campus	.038	-.561	-1.262	-102.791	-47.679	-55.113
	(.223)	(3.545)	(1.893)	(111.924)	(75.846)	(56.258)
East Campus	.065	1.903	.314	-9.775	22.534	-32.309
	(.108)	(2.967)	(1.581)	(122.744)	(81.660)	(57.001)
Graduate Housing	.144	3.996	1.627	76.625	44.860	31.764*
	(.088)	(3.361)	(1.629)	(64.308)	(54.802)	(18.853)

Effect of network utilization

Effect on total charging behavior by operator

	Timing of initiated charging session				
	(1) 21-5	(2) 5-7	(3) 7-10	(4) 10-16	(5) 16-21
A.Informational prompt					
PowerFlex	-.018	-.051	.151	.045	.035
	(.015)	(.055)	(.137)	(.035)	(.030)
ChargePoint	-.030	-.073	.052	-.094	-.018
	(.043)	(.064)	(.121)	(.130)	(.078)
B.Financial incentive 1					
PowerFlex	-.001	.036	-.023	.008	.003
	(.013)	(.036)	(.092)	(.021)	(.018)
ChargePoint	.062**	.028	-.053	-.051	-.049
	(.028)	(.036)	(.101)	(.088)	(.059)
C.Financial incentive 2					
PowerFlex	.008	-.052	.055	.023	.036
	(.010)	(.062)	(.091)	(.030)	(.032)
ChargePoint	.032	-.009	-.057	.171	.169*
	(.061)	(.054)	(.112)	(.125)	(.089)

Effect of charger unreliability

Effect on total charging behavior by home charging access

	Total charging behavior						
	(1) Share	(2) Sessions	(3) Energy	(4) Cost	(5) Duration	(6) Charge Time	(7) Idle Time
A.Informational prompt							
Home Charger	1.956	-.198	-7.118	-2.275	-107.906	-51.950	-55.960
	(4.667)	(.341)	(6.800)	(1.871)	(133.845)	(84.035)	(69.192)
No Home Charger	-4.151	.295	7.092	1.968	45.146	31.091	13.999
	(7.721)	(.464)	(8.830)	(2.468)	(154.945)	(118.734)	(58.587)
B.Financial incentive 1							
Home Charger	-.399	-.007	6.250	1.752	9.996	49.083	-39.090
	(5.054)	(.236)	(4.666)	(1.353)	(88.086)	(57.728)	(43.799)
No Home Charger	-4.091	-.084	4.095	1.260	96.917	59.406	37.520
	(7.585)	(.361)	(6.702)	(1.946)	(114.641)	(88.730)	(42.706)
C.Financial incentive 2							
Home Charger	-.834	.145	4.448	1.444	47.175	51.465	-4.263
	(5.885)	(.272)	(7.303)	(2.136)	(112.531)	(80.926)	(48.251)
No Home Charger	-2.224	.558	6.118	1.671	150.305	78.997	71.353
	(8.828)	(.420)	(8.121)	(2.386)	(138.505)	(106.828)	(57.916)

Driver characteristics