# Charging Uncertainty: Real-Time Charging Data and Electric Vehicle Adoption

Omar Asensio
Georgia Tech and HBS

Elaine Buckberg
Harvard

Cassandra Cole
Harvard

Luke Heeney
MIT

Christopher Knittel
MIT and NBER

James H. Stock
Harvard and NBER

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# Motivation: Why real-time data?

- Electric vehicle adoption crucial for meeting EPA greenhouse gas emissions standards and broader US climate goals.
- Prior literature finds charging infrastructure is key in drivers' vehicle choice (Springel 2021; Sommer and Vance 2021; Li et al 2017; Zhou and Li 2018, Xing, Leard, and Li 2021) and money spent on charging infrastructure has greater impact than money spent on vehicle subsidies (Cole et al 2023).
- But charging experiences are poor: Rempel et al 2022 (72.5% of Bay Area chargers functional), Asensio et al 2020 (almost half of public charging reviews are negative), Asensio & Liu 2024 (78% average reliability score nationwide).
- Real-time data has significant potential to save drivers time *and ease range anxiety*, especially on long trips far from home.

**What is the current state of real-time data on highway DC fast chargers?**

# Motivation: Why real-time data?

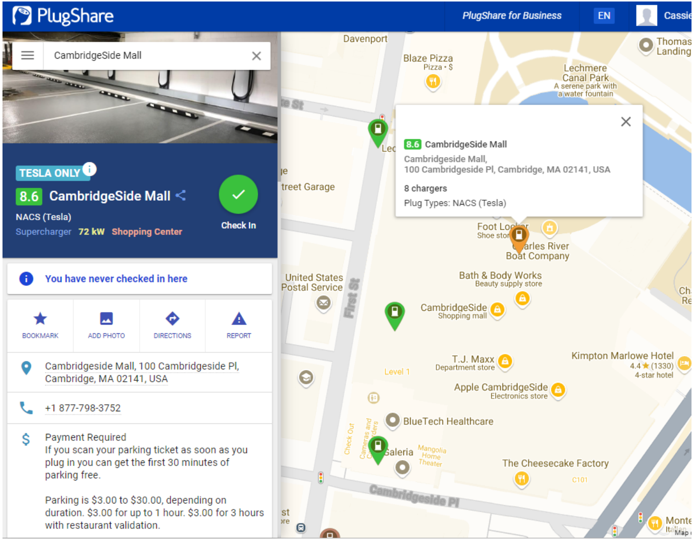
- **Our definition of real-time data**: real-time information on charger status and price available alongside charger location and type *in a central app(s)*
- Precedent for requiring real-time data: mandated for all NEVI-funded chargers
- CPOs (charge point operators) may not want to share data:
  concerns about business-stealing, revealing downtime or utilization, forgoing potential monetization

**What would be the impact on EV adoption of requiring real-time data reporting at all public highway fast chargers?**

# Outline

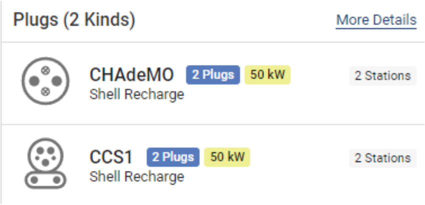
1. Two novel data sources: scraped data from PlugShare.com and survey evidence
2. Current status of real-time data
3. Two-sided model of EV industry
   - Consumer vehicle choice, accounting for variability in charging experience
   - Charging station supply
4. Results: impact of real-time data on EV adoption, carbon emissions

# Data on real-time data: PlugShare.com

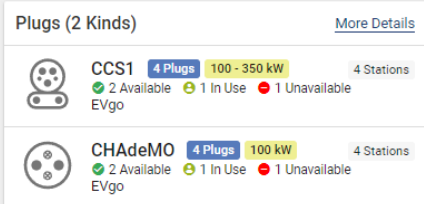


# Data on real-time data: PlugShare.com

**No Real-Time Data**




**Real-Time Data**




**Data collection:** regular scraping of details of public DC fast chargers ($\geq$ 50kW) within two miles of exits on 6 interstates covering 40 states (I-5, I-10, I-75, I-80, I-90, I-95) between March and August 2024

# Data on driver beliefs: Survey evidence

Real-time data accelerating EV transition relies on drivers' beliefs about station reliability, conditional on having real-time data or not

- Surveyed 908 prospective car buyers and 813 current EV drivers
- Asked to assess probability of successfully charging at:
    1. Charger with real-time data reporting at least one plug working and available
    2. Charger with real-time data reporting at least one plug working but none available
    3. Charger without real-time data
- Will present key results where relevant to our model – see paper for more details!

# Real-time data reporting is limited.

Real-time data reporting on August 18, 2024:

| | I-5 | I-10 | I-75 | I-80 | I-90 | I-95 | Total |
|---|---|---|---|---|---|---|---|
| Total Stations | 350 | 187 | 150 | 214 | 189 | 336 | 1,426 |
| **% w/RT Data** | **45.4%** | **31.6%** | **33.5%** | **30.0%** | **23.3%** | **28.6%** | **33.2%** |
| Non-Tesla Stations | 248 | 116 | 91 | 133 | 111 | 188 | 887 |
| **% w/RT Data** | **64.1%** | **50.9%** | **49.5%** | **53.4%** | **39.6%** | **51.1%** | **53.4%** |
| Non-Tesla/EA | 197 | 82 | 70 | 89 | 81 | 150 | 669 |
| **% w/RT Data** | **80.7%** | **72.0%** | **64.3%** | **79.8%** | **54.3%** | **64.0%** | **70.9%** |

# Excluding Tesla and EA improves real-time data reporting, **at the cost of 53% of stations.**

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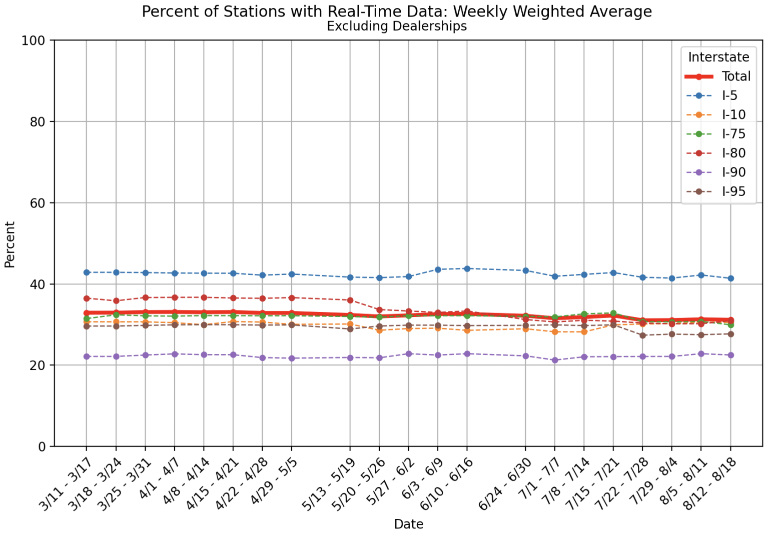
# Real-time data reporting varies substantially.

# Reporting of real-time data is stagnant.

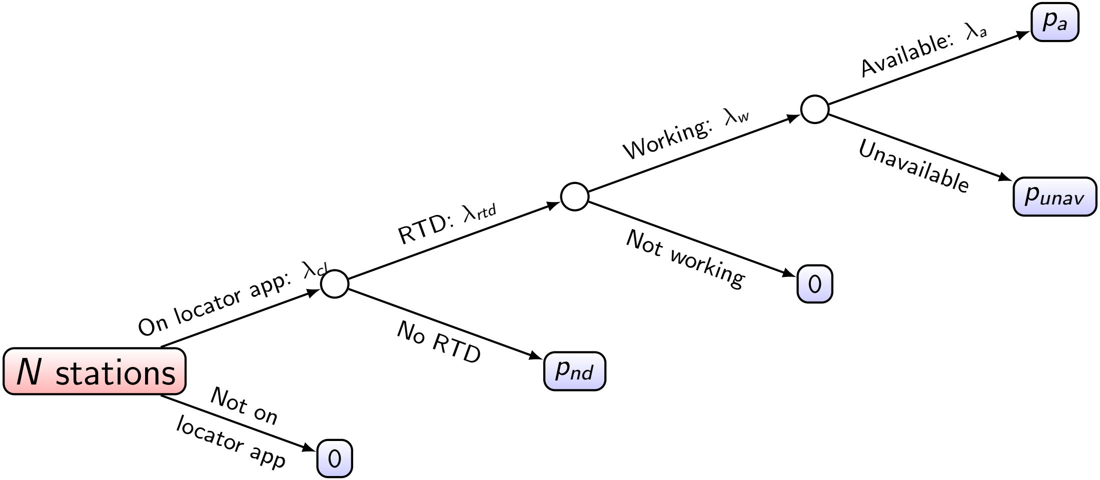


# Model: EV Demand

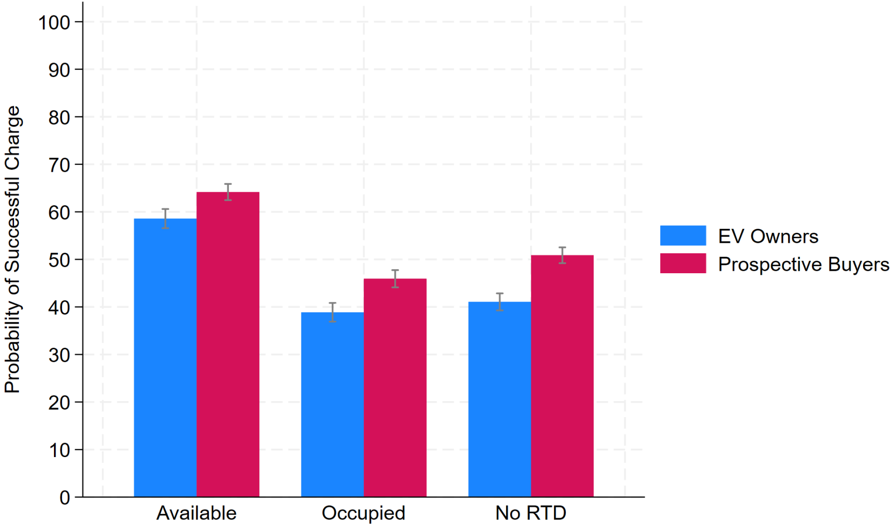
Adapt model from Cole et al (2023), modifying utility function so that number of DC fast chargers is a random variable

- Consumers choose to purchase an EV or ICE within a vehicle class (cars or light trucks) to maximize expected utility
- Utility from an ICE:
$$U_{ijt,ICE} = P_{ICE,t}^{\beta_P} e^{\psi_{ICE,t}} e^{\varepsilon_{ICE,ijt}}$$
- Utility from an EV:
$$U_{ijt} = E[P_{EV,t}^{\beta_p} (\mu_t N_{t,l3})^{\beta_{l3}} (N_{t,l2}/Q_{t-1})^{\beta_{l2}} e^{\psi_{jt,EV}} e^{\varepsilon_{ijt,EV}}]$$
where $\mu_t$ is a Bernoulli random variable representing perceived charger reliability

# Parameterizing $\mu_t$: probability of successful charge across charger types



# Parameterizing $p_a$, $p_{unav}$, and $p_{nd}$ from survey data



# Model: Charging Station Supply

Representative charging firm: profit is expected profit across chargers with and without real-time data

Key assumptions:

- Out-of-service stations and stations not appearing on a charging locator deliver no profit
- Stations without real-time data work with the same probability as stations with real-time data
- Profits from working stations with real-time data are the same as profits from working stations without real-time data

Yields profit function:

$$\pi_t = \lambda_{cl}\lambda_w(exp(\kappa)/(N_t))^{\frac{1}{\gamma}} Q_t$$

# Model: Charging Station Supply

Representative charging firm builds stations until they are indifferent between building today or in the next period:

$$\pi_{t,l3}(N_t, Q_t) = C_t - \frac{1}{1+r} C_{t+1}$$

Yielding our charging station supply function:

$$ln(N_t) = \kappa + \gamma ln(\lambda_{cl}\lambda_w) + \gamma ln(Q_t) - \gamma ln(\tilde{C}_t)$$

# Simulations

4 key simulation scenarios:

- **Baseline**: EV penetration under current policy (IRA & IIJA) with no change in real-time data availability; calibrated to 48% of 2030 new car sales
- **Scenario 1**: Real-time data reporting ($\lambda_{rtd}$) increases to 100% by 2029
- **Scenario 2**: Scenario 1 + uptime for DCFCs ($\lambda_w$) increases to reach 95% in 2029
- **Scenario 3**: Scenario 2 + driver confidence in real-time data ($p_{rtd}$) increases to 100% in 2029

Run Monte Carlo simulations of each scenario, drawing parameters from distributions of scraped PlugShare data and survey data

# Impact of RTD scenarios on EV share of new vehicle sales

| | Baseline | All stations provide RTD | | and 95% uptime | | and full driver confidence in RTD | |
|---|---|---|---|---|---|---|---|
| | | | ppts over baseline | | ppts over baseline | | ppts over baseline |
| 2025 | 11.4% | 11.5% | 0.10 | 11.5% | 0.15 | 11.8% | 0.46 |
| 2026 | 21.0% | 21.3% | 0.32 | 21.2% | 0.20 | 22.3% | 1.37 |
| 2027 | 29.2% | 29.7% | 0.55 | 29.8% | 0.64 | 32.1% | 2.96 |
| 2028 | 36.6% | 37.3% | 0.76 | 37.8% | 1.18 | 41.3% | 4.76 |
| 2029 | 43.0% | 44.0% | 0.94 | 44.7% | 1.67 | 49.4% | 6.36 |
| 2030 | 48.0% | 48.9% | 0.94 | 49.7% | 1.73 | 54.4% | 6.36 |

# Impact of RTD scenarios on EV fleet size

| | Baseline | All stations provide RTD | | and 95% uptime | | and full driver confidence in RTD | |
|---|---|---|---|---|---|---|---|
| | | | % over baseline | | % over baseline | | % over baseline |
| 2025 | 4.61 | 4.63 | 0.39% | 4.63 | 0.54% | 4.69 | 1.71% |
| 2026 | 7.77 | 7.84 | 0.91% | 7.83 | 0.74% | 8.08 | 3.93% |
| 2027 | 12.05 | 12.21 | 1.30% | 12.21 | 1.34% | 12.84 | 6.49% |
| 2028 | 17.22 | 17.49 | 1.58% | 17.57 | 2.02% | 18.75 | 8.85% |
| 2029 | 23.04 | 23.45 | 1.78% | 23.64 | 2.61% | 25.51 | 10.73% |
| 2030 | 29.20 | 29.73 | 1.83% | 30.04 | 2.89% | 32.53 | 11.43% |

# Impact of RTD scenarios on carbon emissions from LDVs

| | All stations provide RTD | and 95% uptime | and full driver confidence in RTD |
|---|---|---|---|
| 2025 | -0.1 | -0.2 | -0.6 |
| 2026 | -0.3 | -0.2 | -1.5 |
| 2027 | -0.7 | -0.8 | -3.9 |
| 2028 | -1.2 | -1.7 | -7.5 |
| 2029 | -1.7 | -2.7 | -11.4 |
| 2030 | -2.4 | -4.0 | -16.0 |

Note: assumptions on power sector emissions from Stock & Stuart (2021)

# Conclusion

- Real-time data reporting is poor, doing little to alleviate bad charging experiences.
- Survey respondents do not fully trust real-time data, but it provides a marked improvement over stations without real-time data.
- Real-time data reporting *alone* has little effect on EV adoption, but can have a significant impact when accompanied by increased driver trust in data:
  - 11.4% increase in the size of the light-duty EV fleet in 2030
  - 6.4 percentage point increase in EV sales share in 2030 from 48.0% to 54.4%
- Can lead to considerable reductions in carbon emissions from LDVs
  - Accomplishes additional 20% of IRA/IIJA reductions from LDVs (as predicted in Cole et al 2023) at virtually no fiscal cost – vs. $451 billion

**Thank you!**

ccole@g.harvard.edu