

# Impacts of Managed Charging and Other Innovative Rates for Electric Vehicle Charging on EV Customer Load and Utility System Grid

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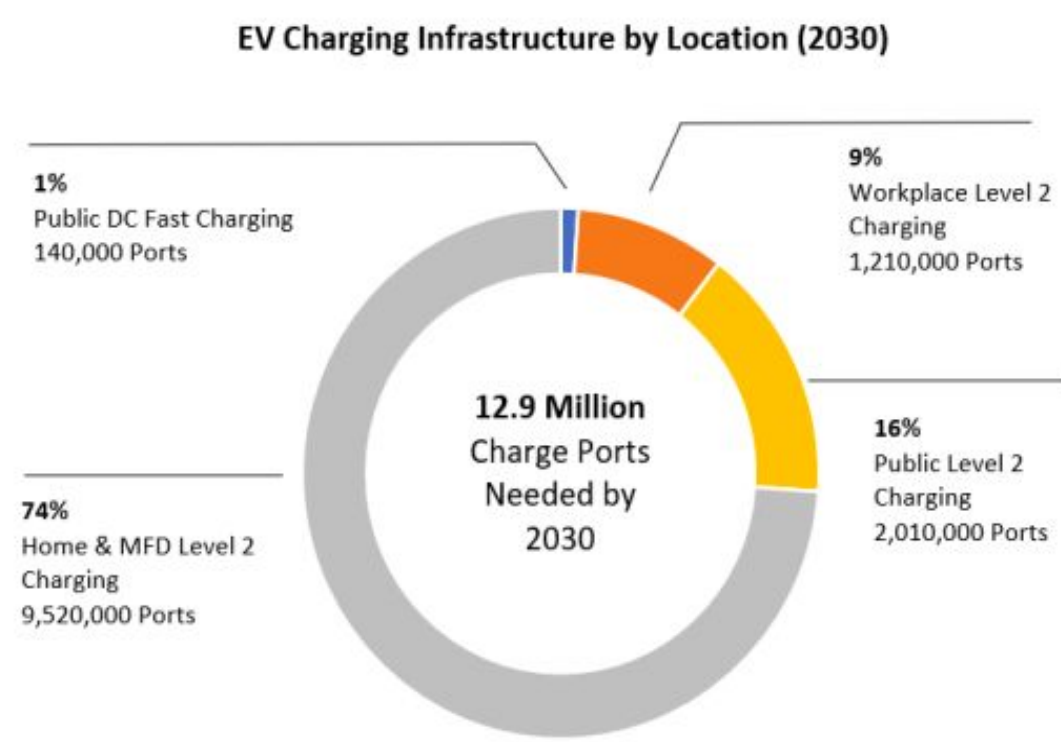
## Project Overview

- Project Scope:**
- The effects of innovative rates on EV charging behavior & utility grid dynamics
- Phase 1: Literature Review (COMPLETE, now revising for policy- and decision-makers)**
- Reviewed industry and academic studies of EV innovative rates.
  - Investigated managed charging's impact on customer & utility load, especially at the local distribution level.
- Phase 2: Development of Analytical Model and Proof-of-Concept (Today's presentation)**
- Customer effects:** Difference in Differences (DiD) method
  - Grid Impacts:** Time Series Power Flow and Monte-Carlo Analysis with Stochastic Inputs for North Carolina
- Phase 3: Case Study**
- Utilize Duke Energy data on EV pricing pilots
    - Impact of Time-of-Use (NC) & Off-Peak Credit rates (FL, SC, IN) on customer load & utility system
    - Current and forecasted

## Innovative Rate Study

### Optimizing Residential Electric Vehicle Charging *The Empirical Gap in Residential EV Charging Literature*

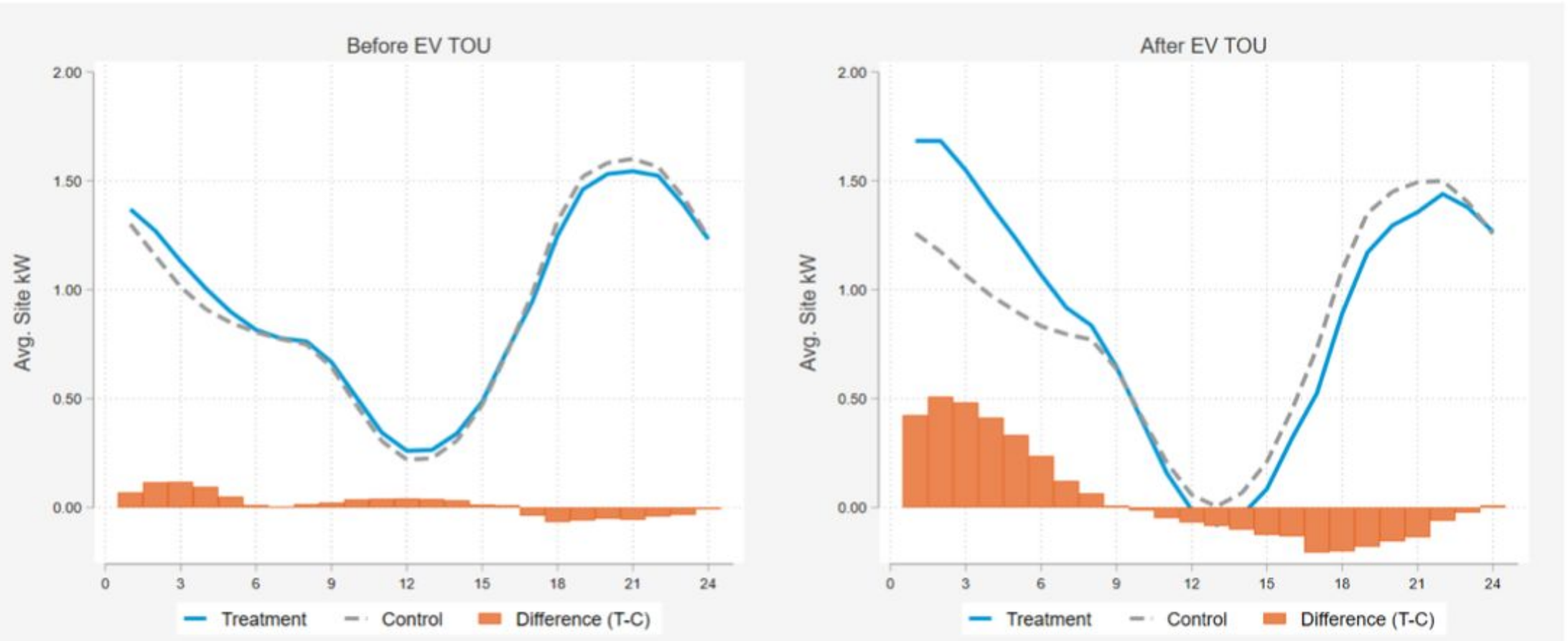
- Charging Patterns:**
- ~75% of EV Charging will occur at home
- Research Gap:**
- Few Empirical Studies on Residential EV Charging
  - Simulation Data vs Real-World Behavior
- Challenges:**
- Potential amplification of peak loads, leading to power losses, reduced power quality, and the risk of exceeding the grid's capacity (Muratori, 2018).
- Critical Efforts:**
- Understand Psychological Drivers
  - Interventions, Incentives & Educational Campaigns
  - Develop Strategies for Sustainable EV Charging



Satterfield, C., & Scheffer, K. (2022, June). Electric Vehicle Forecast & Infrastructure Report. Prepared for Edison Electric Institute.

### Bridging the Divide: Innovations in EV Charging Research *A Difference-in-Differences (DiD) Approach to Evaluate Causal Impact*

Figure 10: Hourly Load Patterns Before and After EVTOU Rates (May-October)



\*The dependent variable is difference between differences after the EV TOU rate and before the EV TOU rate

**Reference:** Bode, J. et al. Load Impact Evaluation of San Diego Gas and Electric's Electric Vehicles Time-of-Use (TOU) Rates: Final Report CAMAC ID: SDG0337, Demand Side Analytics, LLC, April 1, 2022

## Innovative Rate Study

### Empirical Grid Impact of In-Home EV Charging Differs From Predictions (Qiu et al., 2022)

**Model:**

$$kW_{h_{ih}} = \alpha_i + \sum_{i=1}^M \beta_i EV\_Charging_{ih} * I_H + \gamma p_{ih} + f(HDD_{ih})\theta + f(CDD_{ih})\eta + Dayofsample + Hourofday + \varepsilon_{ih}$$

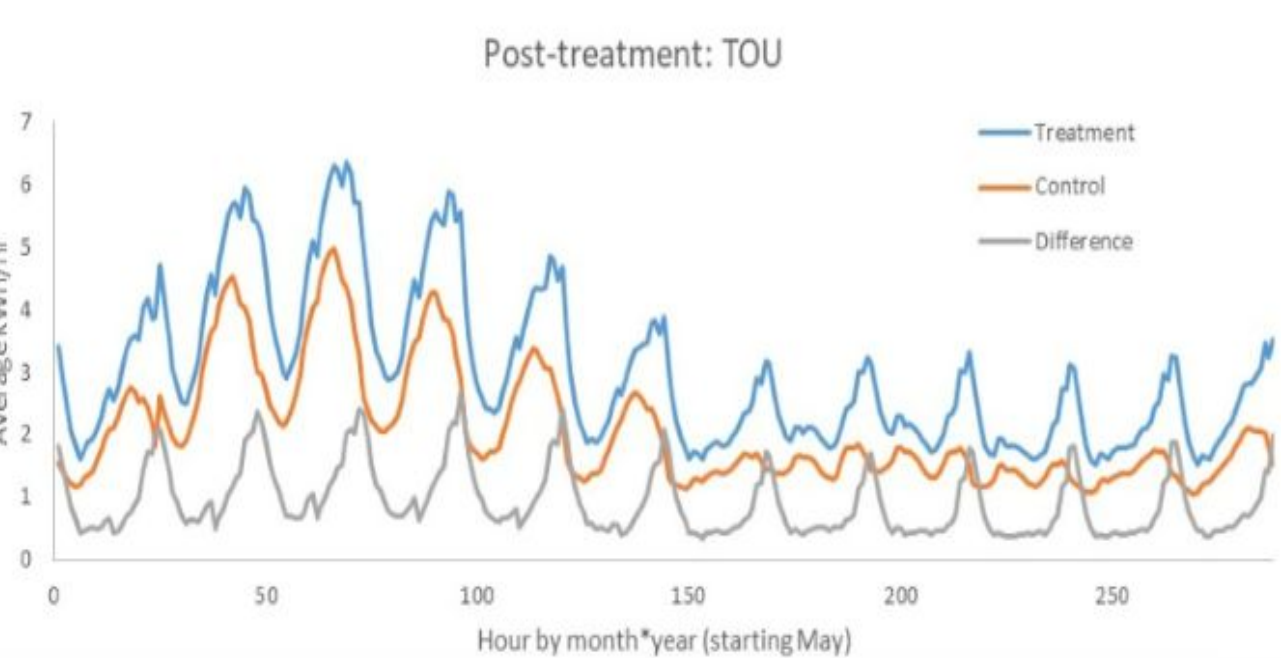


Fig. 1. Average hourly load profiles of the treatment and control groups one year before and after the adoption of EV charging.

**Results:**

- Unmanaged home charging increases system load during peak hours.
- TOU pricing successfully incentivizes charging during off-peak hours.
- Rebound effects are observed for EV customers on increasing block rate.
  - EV owners use less energy midday as they increase their driving due to the lower cost of operating EVs.

**Central Position:**

- In-home EV charging differs from predictions made by simulation models.

**Data & Methods:**

- 1600 homes in Phoenix, AZ served by Salt River Project from 2014 to 2019.
- DiD approach to analyze causal impact of residential charging programs.

## Phase II: Pecan Street Proof-of-Concept

**Dataset:**

- 2018 load profiles of 25 households in Austin, TX.

**Methodological Significance:**

- Utilizes Florida Off-Peak Credit program to determine peak times.
- Placebo Difference-in-Differences (DiD) regression analysis
- Isolated confounding factors and assessed robustness.

**Insights:**

- A baseline for model operation
- Revealed typical unmanaged charging behavior.