# SMART CHARGE

## Charging Electric Vehicles to Support a Low Carbon Grid

Spring 2019

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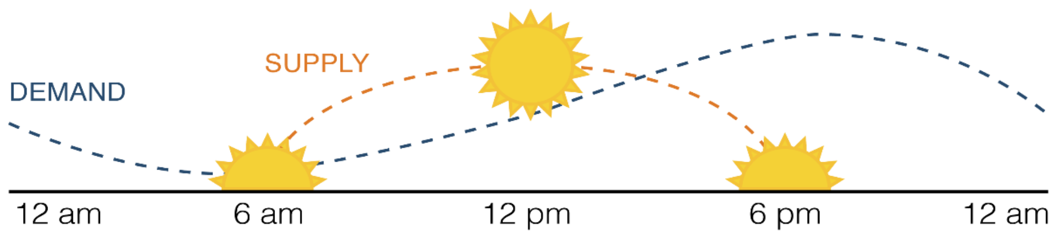
## ELECTRIC VEHICLES & THE GRID

Transportation accounts for 40% of California's greenhouse gas emissions (GHGs). To reduce these emissions, the state is incentivizing **electrification of the transportation sector**. Current state targets aim to increase the number of zero emission vehicles on the road from 570,000 to 5 million by 2030. The climate benefits of electric vehicles (EVs), however, are partly tied to when they charge. If EV charging is left unmanaged, EVs will primarily charge in the evenings, when demand is often met by carbon-intensive fossil fuel resources. Electricity demand during this period is already high, as indicated by the blue line in the figure below. However, if managed effectively, EV charging could be shifted to the middle of the day, when California has an excess of solar energy, as shown by the figure's orange line. Charging in the middle of the day allows EVs to take advantage of California's **surplus solar energy** to maximize their **potential to reduce greenhouse gas and air pollution emissions** and help balance supply and demand on the electrical grid.

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## OUR PROJECT

Southern California Edison (SCE), the largest electric utility in Southern California, is investigating ways to incentivize EV drivers to shift their charging to the middle of the day through their Charge Ready Pilot. To complement this work, our team develops models estimating how price and non-price interventions encourage drivers to shift to charging midday in four long-dwell locations:

Workplaces | Destination Centers | Fleets | Multi-Unit Dwellings

## RESEARCH QUESTIONS

In evaluating the opportunity of **managing charging**, we examine 3 research questions:

1. **What interventions shift charging demand to midday?**
2. **How much demand can be shifted by these interventions?**
3. **What are the greenhouse gas and air pollution implications of shifting charging demand?**

To answer these questions, we create 3 outputs: an economic model that can be accessed and run online, an analysis of how much demand can be provided by charging infrastructure and load shifting in 2030, and an evaluation of SCE's pilot.

## KEY FINDINGS

**I** — **Load reduction is more significant than load shifting**

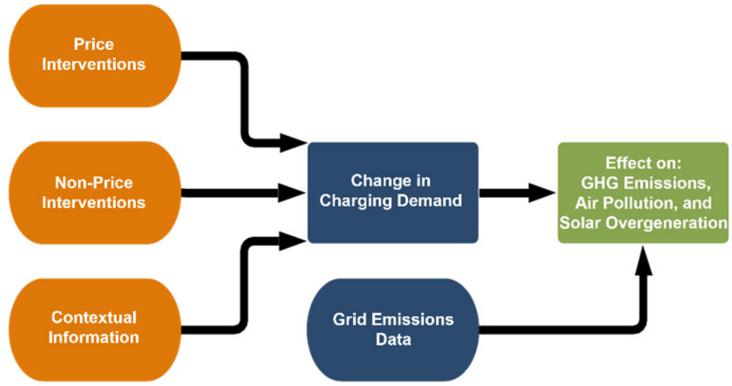
**II** — **Load shifting and reduction reduce daily greenhouse gas and air pollution emissions**

**III** — **Communication is essential to create behavior change**

**IV** — **Load shifting in 4 long-dwell locations will not support all charging demand in 2030**

# MODEL METHODS

Our model considers how **price, communication, and technology** shift EV charging to different periods of the day, and how this impacts human health, the environment, and the electrical grid. Our model combines price and non-price interventions with basic contextual information to determine how demand may change. The diagram to the right summarizes this framework.




Our **price interventions** include discounts, rebates, and completely new price schedules (Time-of-Use [TOU] rates). A discount is typically a price reduction in the middle of the day intended to encourage load increase. A rebate is a payment to a consumer for reducing load when demand is high. Price is factored in using *elasticities*, which represent how electricity demand responds to price increases or decreases at any point in the day. Until elasticities are estimated empirically for our 4 long-dwell locations, elasticities from other charging locations provide a reasonable proxy.

Our 2 **non-price interventions** are throttling and communication. Throttling represents a 50% forced reduction in load, which occurs when the utility physically reduces power to the charger. A communication intervention involves notifying drivers about a price change or the impact of charging on air pollution.

| Intervention | Value | How Applied |
|---|---|---|
| Price | Discount, Rebate, TOU Rate, Time | Elasticities[1] |
| Throttling | Time | 50% Direct Cut |
| Communication | Air Pollution, Price | Percentages[2] |

Using this information, we model the change in EV charging demand over the course of the day under any package of interventions. We then consider the impacts of these changes on climate change, health, and solar energy use, by using projected, conservative hourly fuel mixes and emissions factors for 2018 and 2030.

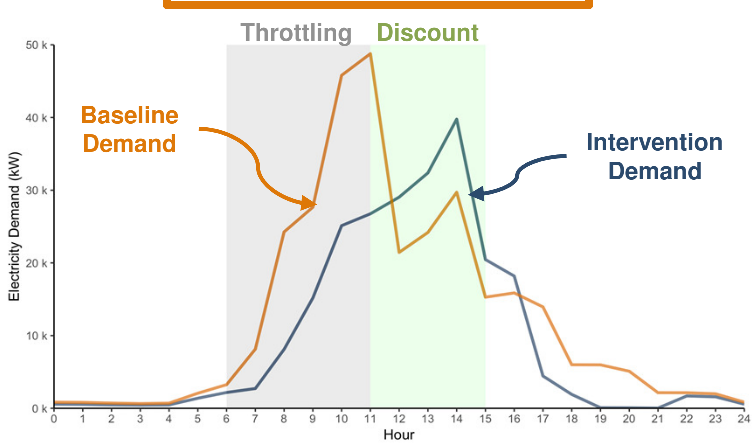
# MODEL RESULTS

Our model allows us to test a wide variety of scenarios. Below is a summary of the most impactful set of interventions for an average day in each location.

## WORKPLACE

31,435 Chargers, TOU 2019

Discount, Throttling, Price & Air Pollution Communication

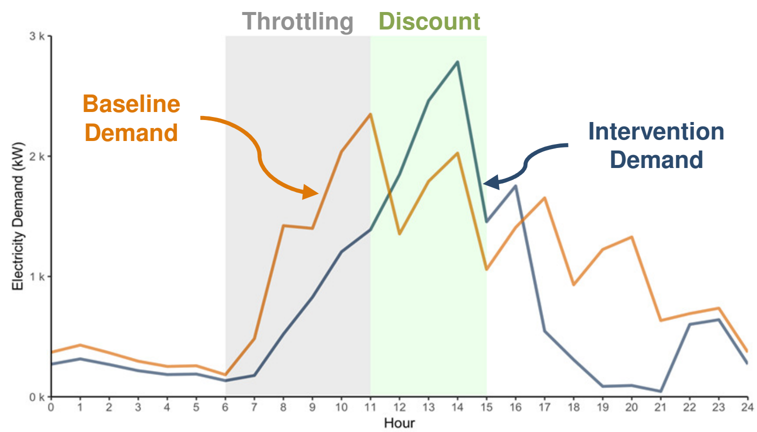



In workplaces, demand is typically high in the morning when people arrive at work and then tapers off as the day progresses and people leave the office. For this reason, we lower price in the middle of the day (discount), and apply throttling in the morning. This intervention successfully reduces load in the morning and causes load to shift slightly into the middle of the day, resulting in the following daily changes:

# DESTINATION CENTER

4,378 Chargers, TOU 2019

Discount, Throttling, Price and Air Pollution Communication




Like workplaces, destination centers, such as malls and city facilities, typically have a high demand in the morning. Thus, we implement a midday discount and morning throttling. As a result, load falls in the morning and increases midday. The following daily changes are seen:

- 34% GHGs

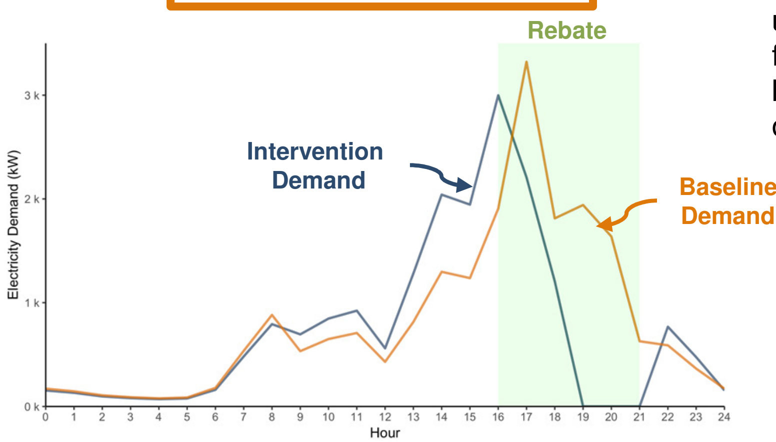
- 37% Air Pollution

- 34% Demand

# FLEET

4,378 Chargers, TOU 2019

Rebate, Price Communication




Since fleets are typically deployed in the middle of the day and charge in the evenings, we consider the impact of paying people to reduce their energy usage in the evenings (rebate). Load falls to zero for part of the evening period and increases slightly late in the afternoon. The following daily changes occur:

-24% GHGs

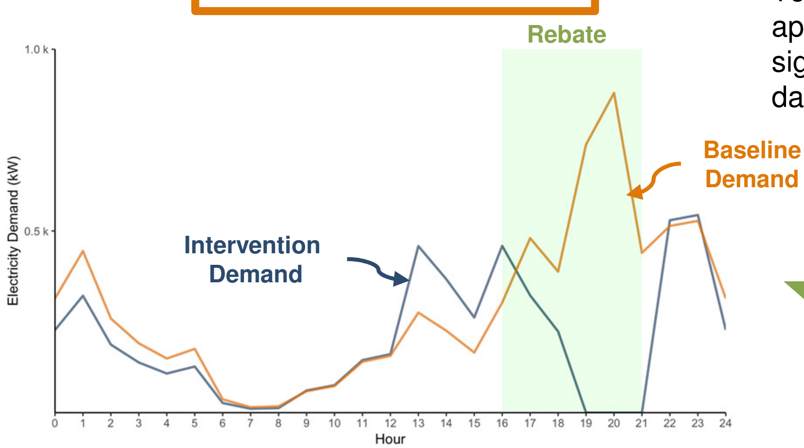
-24% Air Pollution

-11% Demand

# MULTI-UNIT DWELLING

4,378 Chargers, TOU 2019

Rebate, Price Communication




At multi-unit dwellings, demand is typically high in the evenings when EV owners return from work. To shift this load into the middle of the day, we apply a rebate. As with fleets, demand falls significantly in this period. Over the course of the day, the following occurs:

-17% GHGs

-23% Air Pollution

-17% Demand

## HYPOTHETICAL ANALYSIS

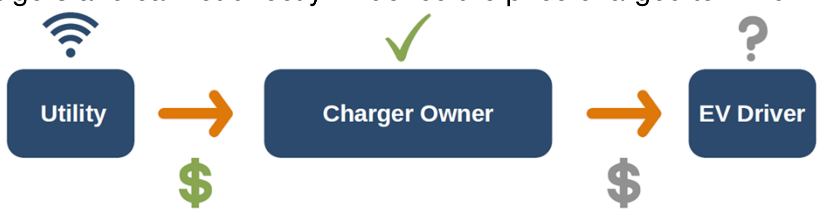
In 2030, if there were 50,000 chargers in SCE's territory – all at our long-dwell locations – and they only worked from 11:00 a.m. to 3:00 p.m., could we meet all daily EV charging demand? We find that this would only meet 13% of all daily demand for EV charging, and the daily emission reductions would be minimal:

**- 4%** Greenhouse Gases | **13%** Daily Demand | **- 6%** Air Pollution

This highlights that the **demand analyzed in our modeled scenarios represents a fraction of the possible demand that could be shifted.** Therefore, we need to expand load shifting to other charger locations to maximize EVs' greenhouse gas and air pollution reduction potential.

## PILOT ANALYSIS

We analyze the impact of 8 real-world events that applied price and throttling interventions and compare them to our modeled scenarios. Our **modeled response is higher than that of EV drivers during these SCE pilot events**, revealing the communication challenge outlined in the figure below: SCE can only communicate to the owners of the chargers and cannot directly influence the price charged to EV drivers.




## RECOMMENDATIONS

***Test Other Strategies:*** Craft location-differentiated strategies and align prices and throttling periods more closely with behavior in each location. Consider alternative strategies, such as subscription charging, graduated pricing, and limited morning throttling.

***Research Driver Behavior:*** Track how and why EV drivers shift their charging from residential to non-residential long-dwell locations. Conduct a robust economic study of how drivers respond to changes in price in non-residential locations and calculate the elasticities. These elasticities may reveal that load shifting is more prevalent than it appears in our modeled results.

***Close the Communication Gap:*** Develop a strategy to help charger owners communicate to EV drivers. Consider requiring or incentivizing charger owners to pass interventions along to drivers.

***Expand the Program:*** Include other locations, such as single-family homes or other public locations, in load shifting programs.

## ACKNOWLEDGMENTS


We would like to extend our thanks to the numerous people who supported this project, including our faculty advisor, Chris Costello, our external advisors, and the entire Charge Ready team at SCE. We are also grateful for the community of staff, faculty, and students at the Bren School and our funders at Yardi Systems.


## REFERENCES


1. Jonathan Cook et al., "Final Evaluation for San Diego Gas & Electric's Plug-in Electric Vehicle TOU Pricing and Technology Study" (Nexant, February 20, 2014); Ahmad Faruqui et al., "Will Smart Prices Induce Smart Charging of Electric Vehicles?," *SSRN Electronic Journal*, 2011.
2. Katrina Jessoe and David Rapson, "Knowledge Is (Less) Power: Experimental Evidence from Residential Energy Use," *American Economic Review* 104, no. 4 (April 2014): 1417–38; Omar I. Asensio and Magali A. Delmas, "Nonprice Incentives and Energy Conservation," *Proceedings of the National Academy of Sciences*, January 7, 2015, 6.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