**The Future of Electric Vehicle Adoption: A Theoretical Approach**

Derya Eryilmaz, Ph.D., Associate Principal at Charles River Associates. 617-425-3080, deryilmaz@crai.com

Bixuan Sun, Ph.D. Postodctoral Researcher, Humphrey School of Public Affairs, University of Minneosta, sunxx731@umn.edu

## Overview

Grid modernization has been one of the major goals of United States energy policy to have resilient, reliable, secure and sustainable energy systems. Transition into a more modern, sustainable and carbon-free grid has been accelerated through the uptake of advanced energy technologies including customer-owned distributed generation resources. Customer-owned distributed generation technologies enable customers to generate electricity from cleaner resources. Meanwhile, the fast adoption of electric vehicles in the past few years significantly increases the demand for electricity and presents great potential for reducing the dependence on fossil fuels in the transportation sector.

In this study, we develop an optimization model to understand the optimal customer adoption behavior for distributed solar generation and electric vehicles under various market and technology scenarios. Specifically, we model residential consumers’ decision to purchase electric vehicle rather than a conventional vehicle (i.e., fossil fuel vehicle) and/or to install distributed solar systems. Our model assumes heterogeneous consumers with different driving preferences and patterns throughout the day, and considers on-peak and on-off peak charging prices as well as different net metering rate structures.

Existing literature on structural modeling of consumers’ hybrid decision to purchase electric vehicles and distributed solar is limited. We develop a theoretical modeling framework that provides consumers’ economic decisions to invest in electric vehicles and distributed solar under various market conditions. The primary outcome of our model is the electric vehicle adoption rates for residential customers with different driving and charging patterns. We contribute to the existing literature by providing an understanding of the economics of the interaction between electric vehicles purchase and the joint decision to install distributed rooftop solar for customers with different rate structures. Specifically, our simulations consider the impact of varying electric rates and varying demand charges for net metering rates for customers with varying driving habits.

## Method

We model heteregenous consumers hourly driving behavior and their decision to purchase an electric vehicle versus a conventional vehicle. An electric vehicle consumer maximizes their utility as a function of daily driving distance given electricity charging prices and their driving preference. Further, our model incorporates customers’ hybrid decision of purchasing both an electric vehicle and a residential solar system. Distributed solar is used to generate electricity onsite and the excess energy is sold back to the grid at net metering rate. Customer bears the initial investment cost of both the electric vehicle and the solar system while benefiting from existing policy incentives for these technologies and subsequent revenues from solar generation.

We analytically solve the model for the market electric vehicle adoption rate. We run several scenarios to understand how the electric vehicle and distributed solar adoption rates change given different market and policy conditions. Parameters on vehicle costs, the efficiency of electric vehicles and solar panels are calibrated to match the dominant products in the market.

## Preliminary Results

Our preliminary simulation results show that it is optimal for a consumer to adopt electric vehicle when the total miles driven is low and medium. A consumer that drives either too little or too much in a day, then it is optimal to purchase a conventional vehicle. Further, utilities often offer time-of-use charging rates for customers with electric vehicles, of which the on-peak charging is relatively more expensive than off-peak charging hours. We find that charging times and the price difference between on-peak and off-peak charging rate affect the decision to have an electric vehicle, suggesting the charging rate structure can have significant impact on utilities’ load management. Given different market conditions, we also derive the optimal net metering rate structure, as well as rebate incentivee for electric vehicle and solar system purchase.

## Conclusions

This paper provides a theoretical optimization model for customer decision for adopting of electric vehicles and residential distributed solar. Scenario analyses conducted in this study have important policy design implications for the adoption of these new technologies, as well as load management for the utilities.