INNOVATIVE RATE DESIGN AND SMART CHARGING OF EV'S

PRESENTED BY

Ahmad Faruqui, Ph.D.

Principal

PRESENTED TO

Qevcon 2021

Qatar

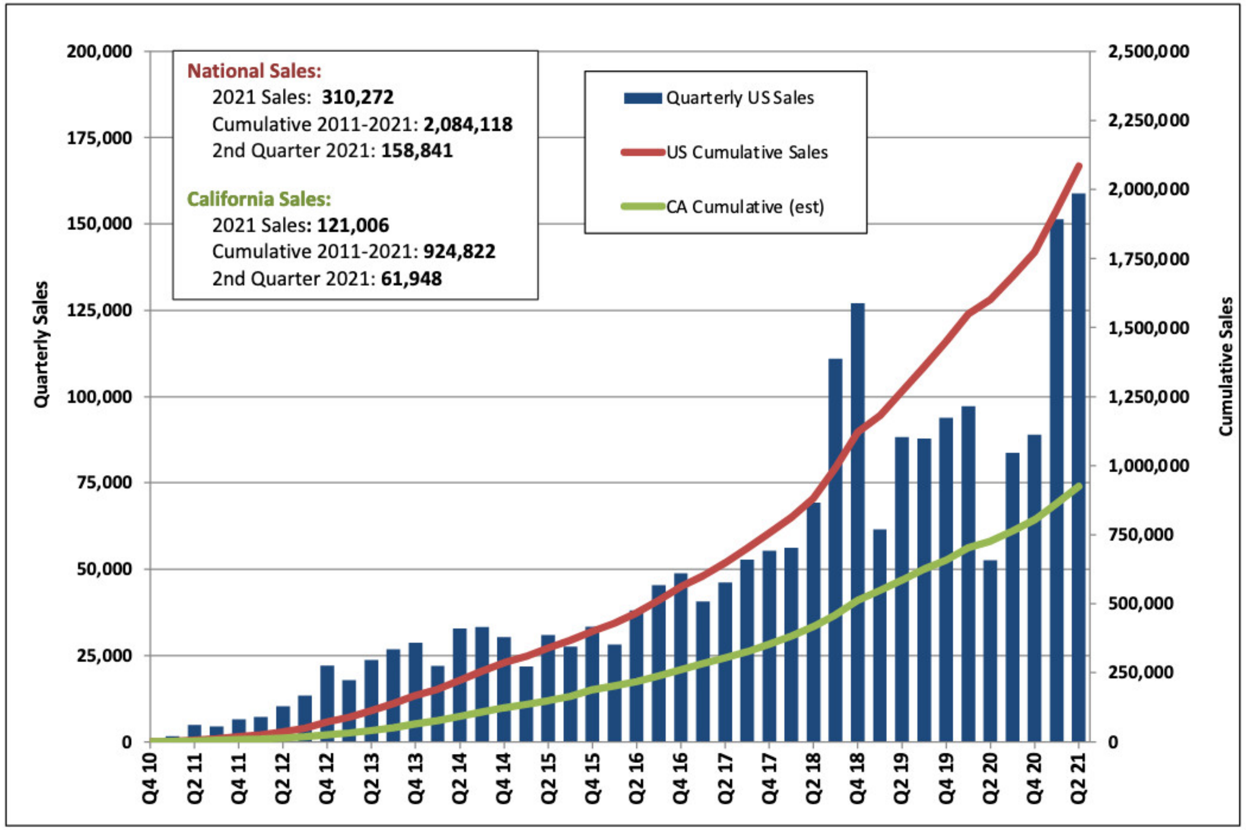
NOVEMBER 17, 2021

Brattle

EV sales have been rising over time, with California dominating the national scene

VELOZ

Electric Vehicle Sales in California and the U.S.

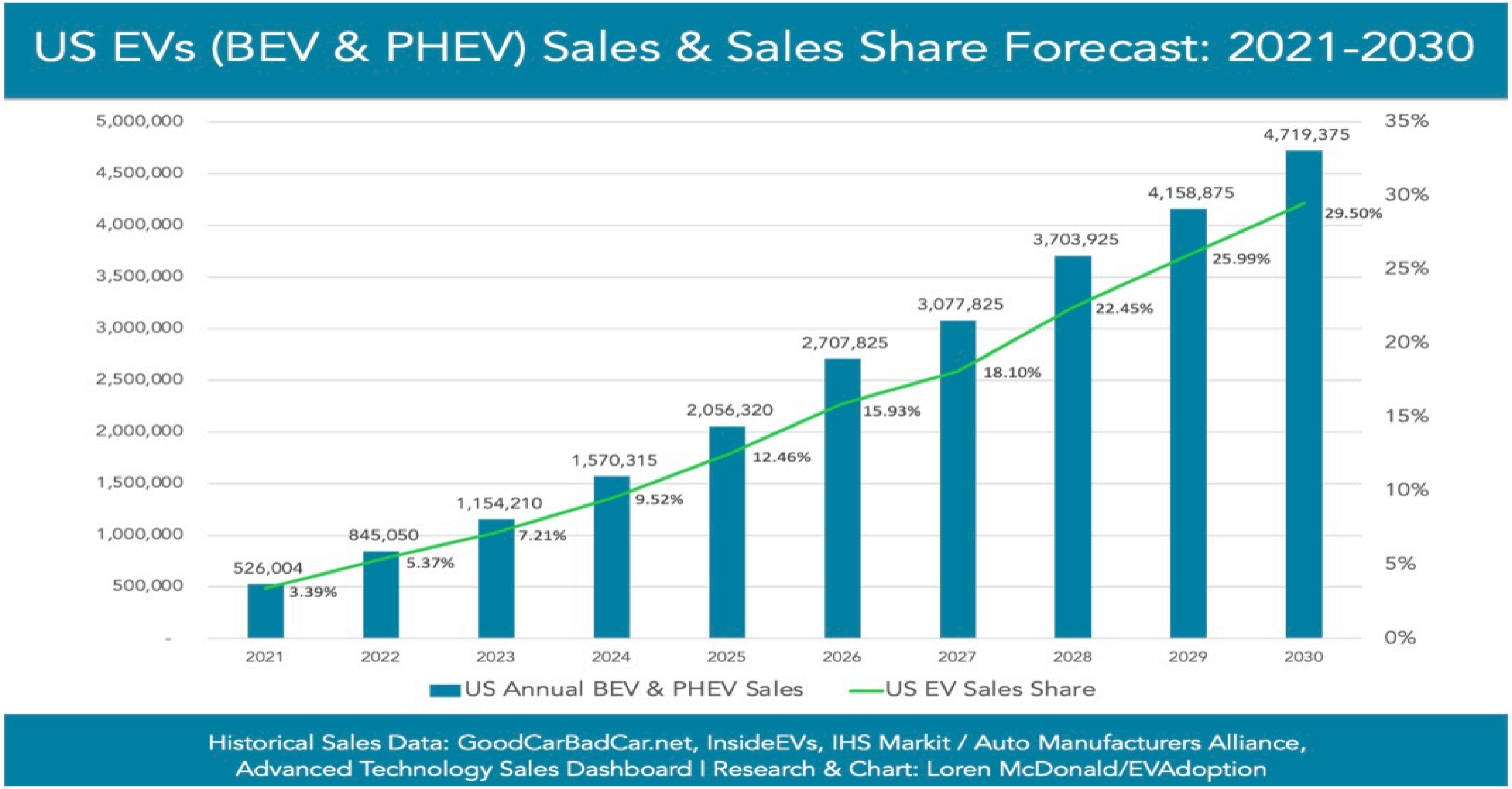


Note: CA sales are 39% of national sales.
Data Source: California Energy Commission (2021).
Retrieved August 3, 2021 from http://www.energy.ca.gov/zevstats

Q2 2021 Data Update.

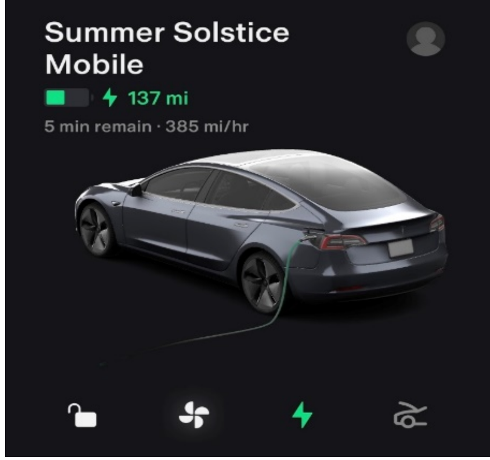
The distribution of EV's in California varies by model and geography

The share of EV sales in the US may rise tenfold by 2030 and reach 30%



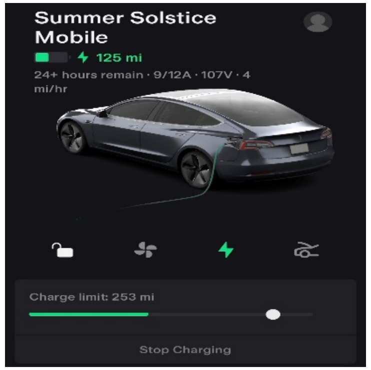
Source: https://evadoption.com/ev-sales/ev-sales-forecasts/

Studies indicate that most EV charging occurs at home

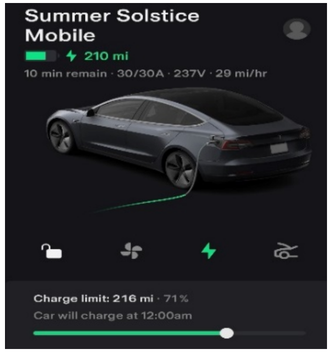


EVs use approximately 225-275 kWh of electricity per month

Level 1 charging draws ~1.5 kW of power and takes forever



Level 2 charging draws ~7 kW of power and takes much less time



The impact of rate design on EV attractiveness depends on (desired/actual) charging patterns

Charging Profiles \ Rate Designs	Flat rate	TOU (3:1 ratio)	TOU (10:1 ratio)	Inclining block rate	Unconstrained demand charge	Peak period demand charge
Off Peak L1	$744	$510	$289	$971	$562	$550
On Peak L1	$744	$1,059	$1,356	$971	$639	$676
Post-Commute L2	$744	$886	$1,021	$971	$976	$1,155
Off Peak L2	$744	$510	$289	$971	$882	$550
On Peak L3	$744	$1,290	$1,807	$971	$1,335	$1,656
Autonomous Fleet	$744	$824	$899	$971	$808	$904

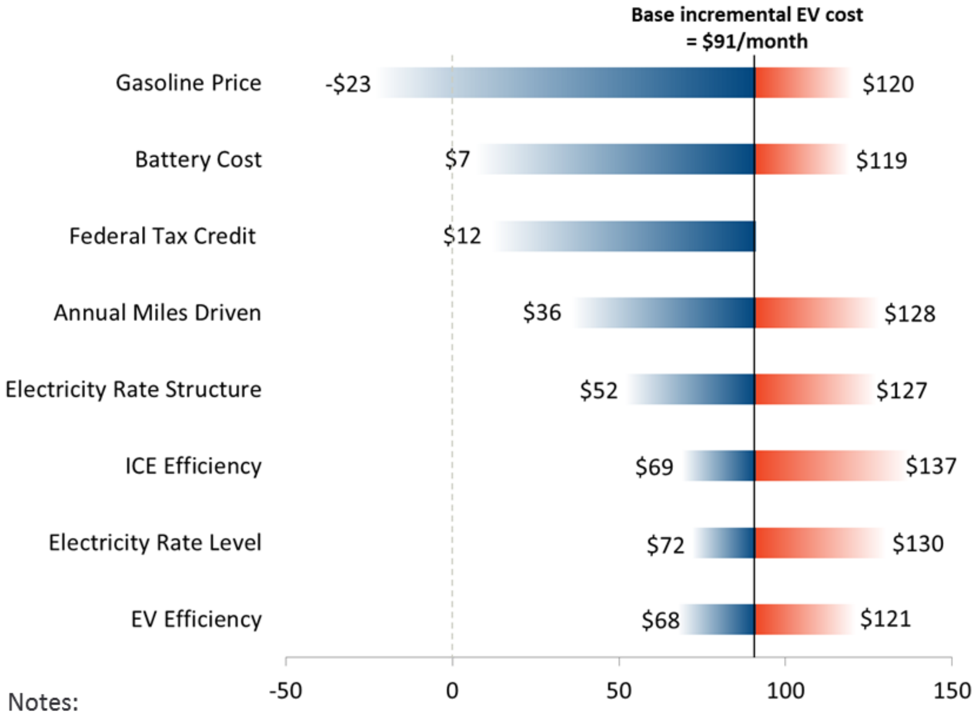
Comparable annual fuel cost of an ICE vehicle at $3/gal, 30 mpg is **$1,460**

Notes:
Rates and charging profiles are purely illustrative
Typical annual residential electricity bill is $1,140
Assumes constant vehicle miles traveled across all charging profiles
Each rate is applicable to whole home load, but figures shown are only incremental EV charging costs
Rates are revenue neutral for a class average residential customer

- TOU and demand charges incentivize off-peak charging but also introduce an element of financial risk for the EV owner
- It will be important to understand the extent to which customers are able and willing to respond to these price signals
- Technology that automates charging control will likely play a key role
- Fleets with higher utilization likely favor frequent, fast charging and potentially have less flexibility to respond to price signals

Rate design appears more likely to influence charging patterns than to impact EV adoption

Incremental Monthly Cost of EV Ownership Relative to ICE Vehicle (Illustrative)

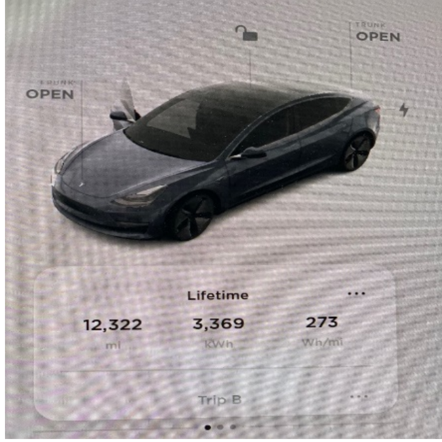


Notes:
Results are illustrative.
The "Base incremental EV costs" is a levelized value over the life of the vehicle (10 years, 150,000 miles) reflecting the higher costs of the battery and lower fuel costs. Range shown is based on "high" and "low" assumptions for each key cost driver. See appendix for assumptions behind sensitivity analysis.

Comments

- Rate design appears to impact total EV ownership costs modestly relative to other cost drivers
- There are significant non-economic drivers of vehicle adoption
- Tate design may be a better tool for influencing the charging behavior of EV owners rather influencing their decision to buy an EV

We surveyed utilities to identify the innovative rates they were offering to EV drivers



21 Utilities are currently offering EV - specific rates

- 12 investor Owned Utilities
- 6 Municipal Utilities
- 3 Cooperatives

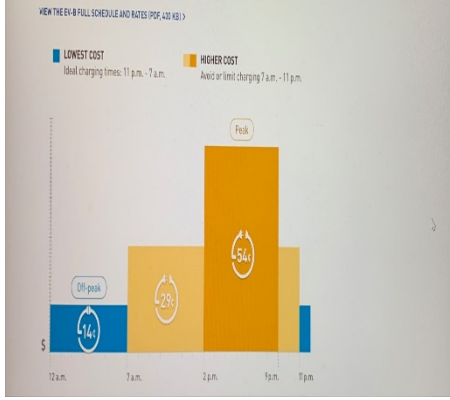
31 unique EV rate designs

- 27 TOU rates (1 of which has inclining blocks)
- 2 Inclining Block rates
- 1 Flat rate
- 1 Flat rate with flat demand charge

Differences in rate applicability

- 18 rates apply to entire residence
- 8 rates apply strictly to EV charging, metered separately (the costs of separate metering are generally incurred by the customer)
- 5 rates can be applied to entire residence or strictly EV charging

A diverse array of innovative rates is being offered by utilities



Most utilities’ EV specific rates are more advantageous than comparable non-EV offerings. Designed to encourage enrollment and off-peak charging by offering:

- Cheaper off-peak rates
- Reduced or eliminated tiers of Inclining block rate

A few rates are less advantageous than comparable non-EV rates (longer or more expensive peak periods). These rates are generally required in order to receive utility-sponsored EV rebates or utility-financed charging infrastructure.

Several pilot programs are testing ultra-high price ratios (>10).

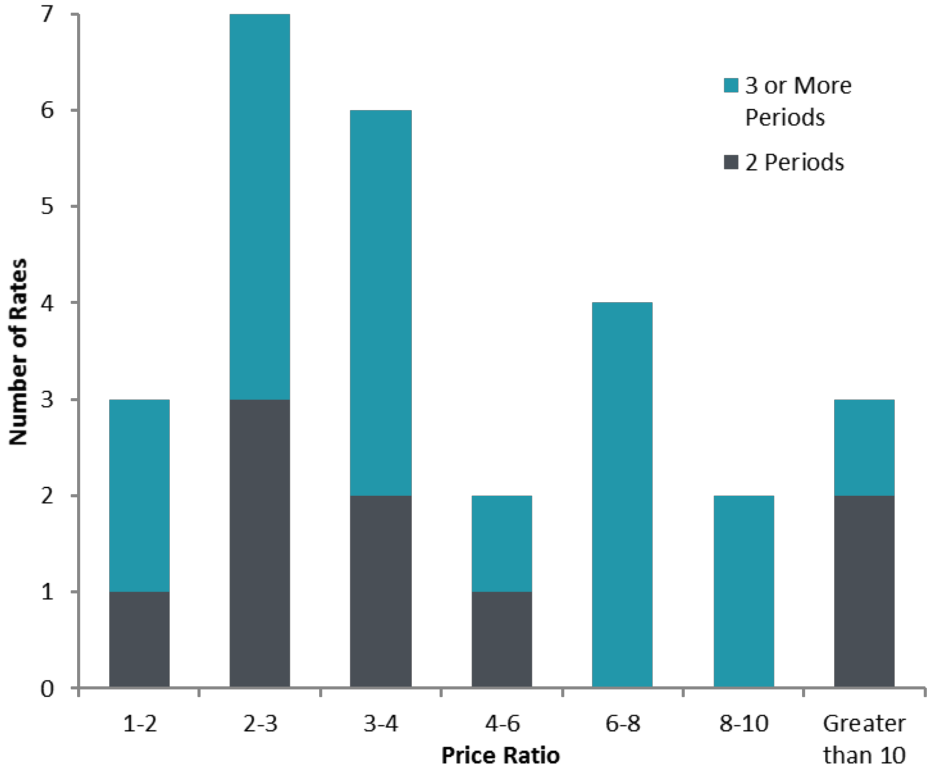
Several rates are either identical to other non-EV residential rates or are the only TOU rates offered.

The 27 TOU Rates differ in the number of seasons, pricing periods, off-peak discounts, and fixed costs

Nine have 2 pricing periods in both Summer and Winter
Eleven have 3 pricing periods in both Summer and Winter
Five have 3 pricing periods in Summer but 2 in Winter
Two have 4 pricing periods

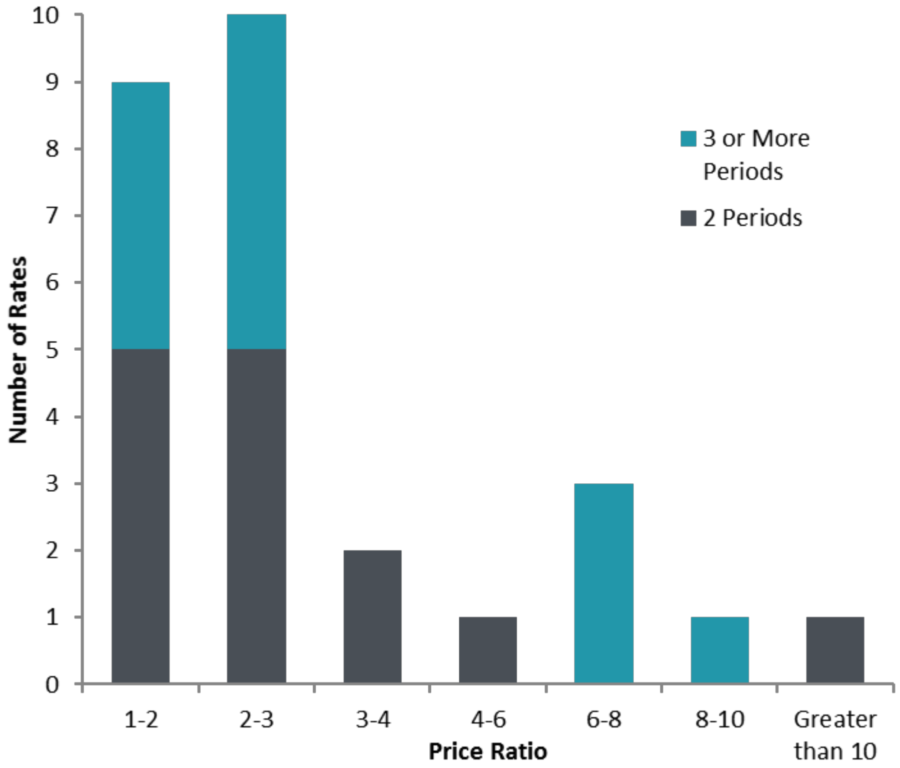
TOU rates vary across utilities in the discount being offered during the off-peak period

Summer Price Ratios (Peak Rate to Lowest Off-Peak Rate)



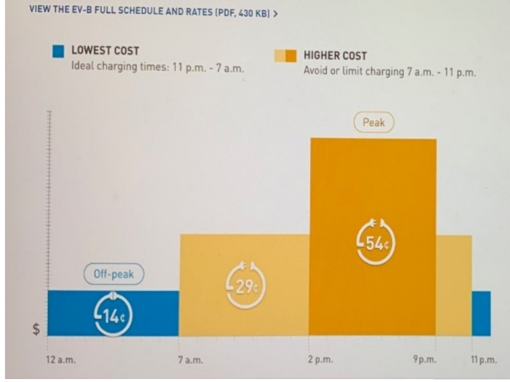
2 Period Median = 3.19
3 or More Period Median = 3.74

Winter Price Ratios (Peak Rate to Lowest Off-Peak Rate)

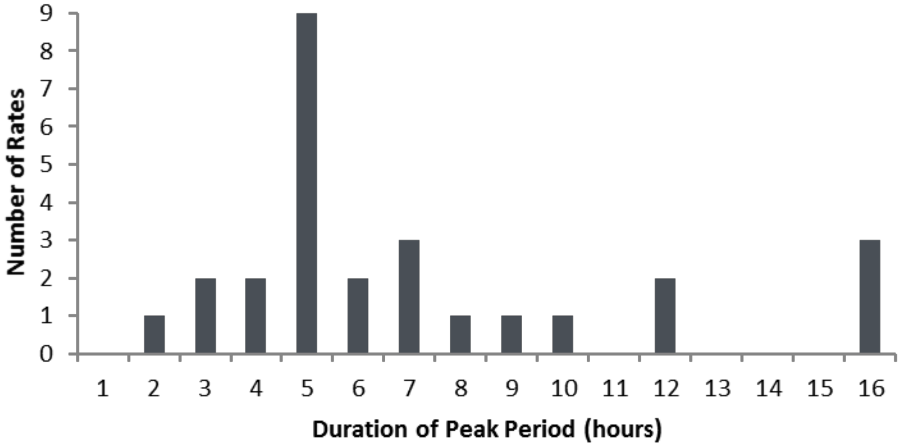


2 Period Median = 2.36
3 or More Period Median = 2.54

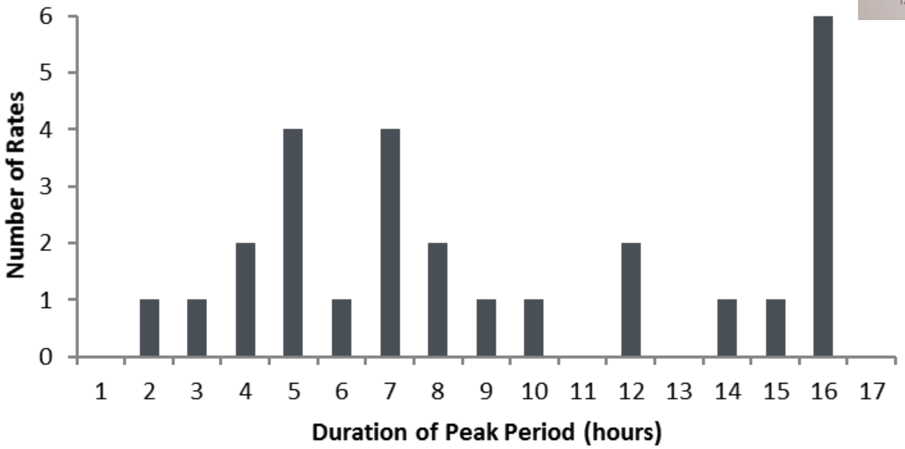
TOU rates also vary across utilities in the duration of the peak period



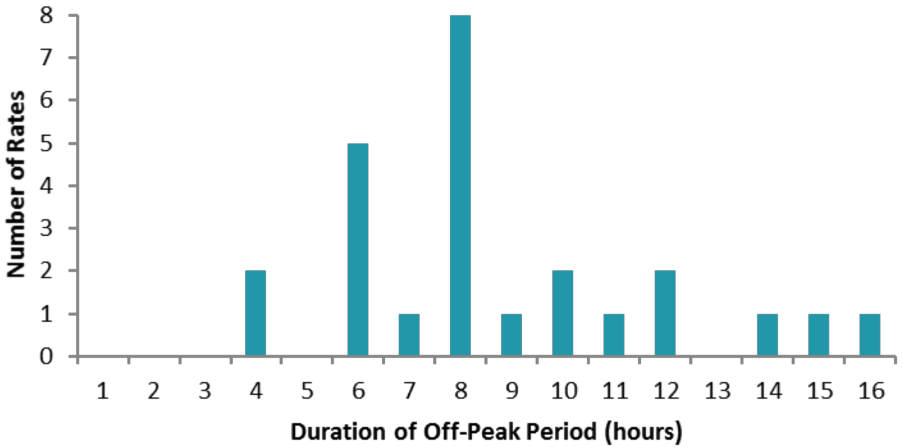
Summer Peak Period Duration



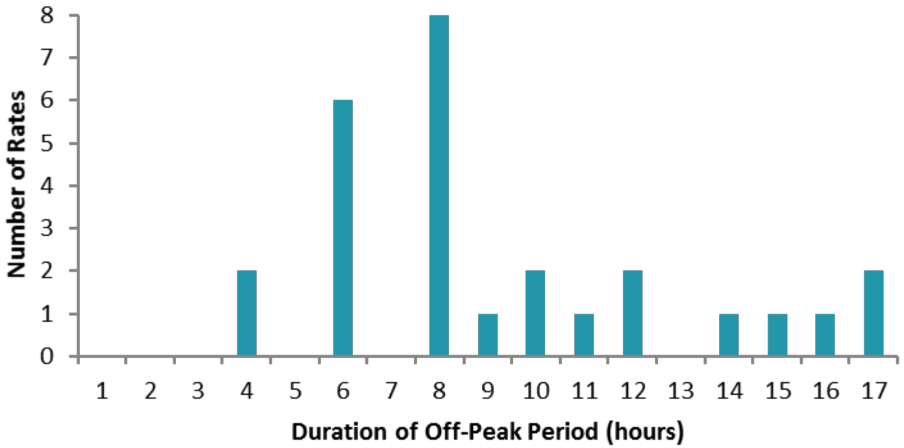
Winter Peak Period Duration



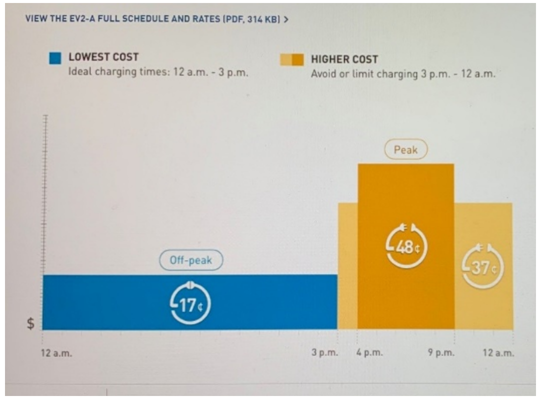
Summer Off-Peak Period Duration

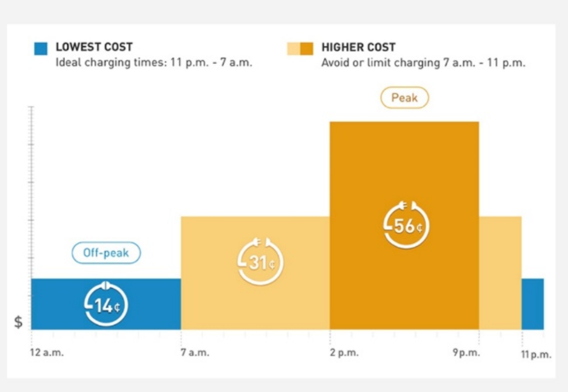


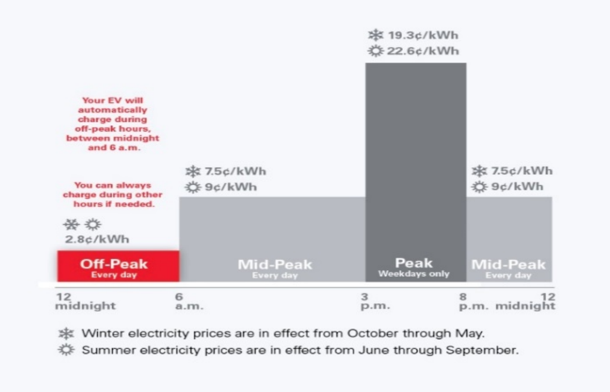
Winter Off-Peak Period Duration

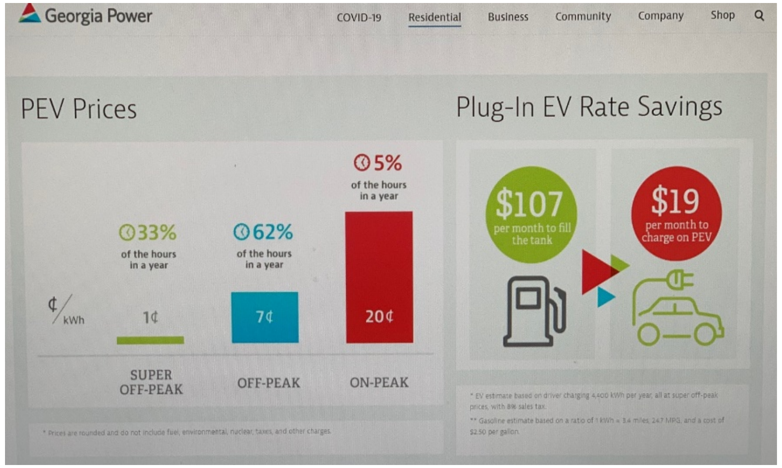


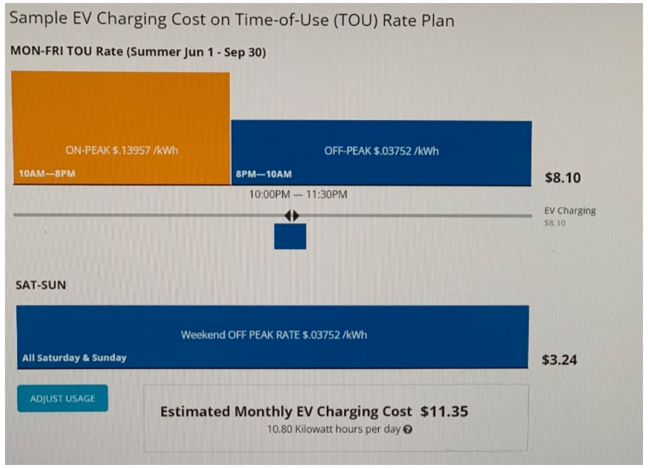
Utilities, such as PG&E (CA), Xcel Energy (MN), Georgia Power and BGE (MD), are offering a variety of TOU rates to EV drivers











SMUD (California) is pushing hard on EV adoption and smart charging

Instant rebate of $1,500 at select dealers

1.5 cent/kWh discount on charging between midnight and 6 AM, every day (vehicle must be registered with DMV using same address as on SMUD account)

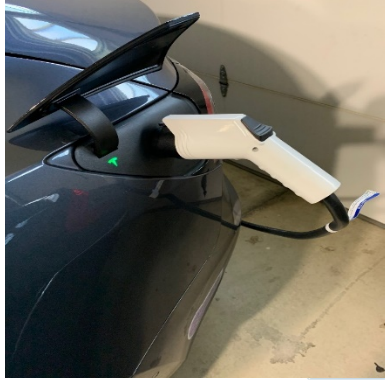
Over 600 public charging stations

TOU/TOD rates provide incentives – approximately 70% of EV customers charging during the off-peak window

Concern: what if everyone starts charging at once?

- A/C starting at full blast = 5 kW
- Typical level 2 home charger = 7 kW

Austin Energy in Texas offers a subscription plan



Includes Plug-in Everywhere™ stations and unlimited off-peak home charging

Off-peak: 7 pm – 2 pm weekdays and anytime on weekends

$30/month for charging demand less than 10 kW

$50/month for charging demand 10 kW+

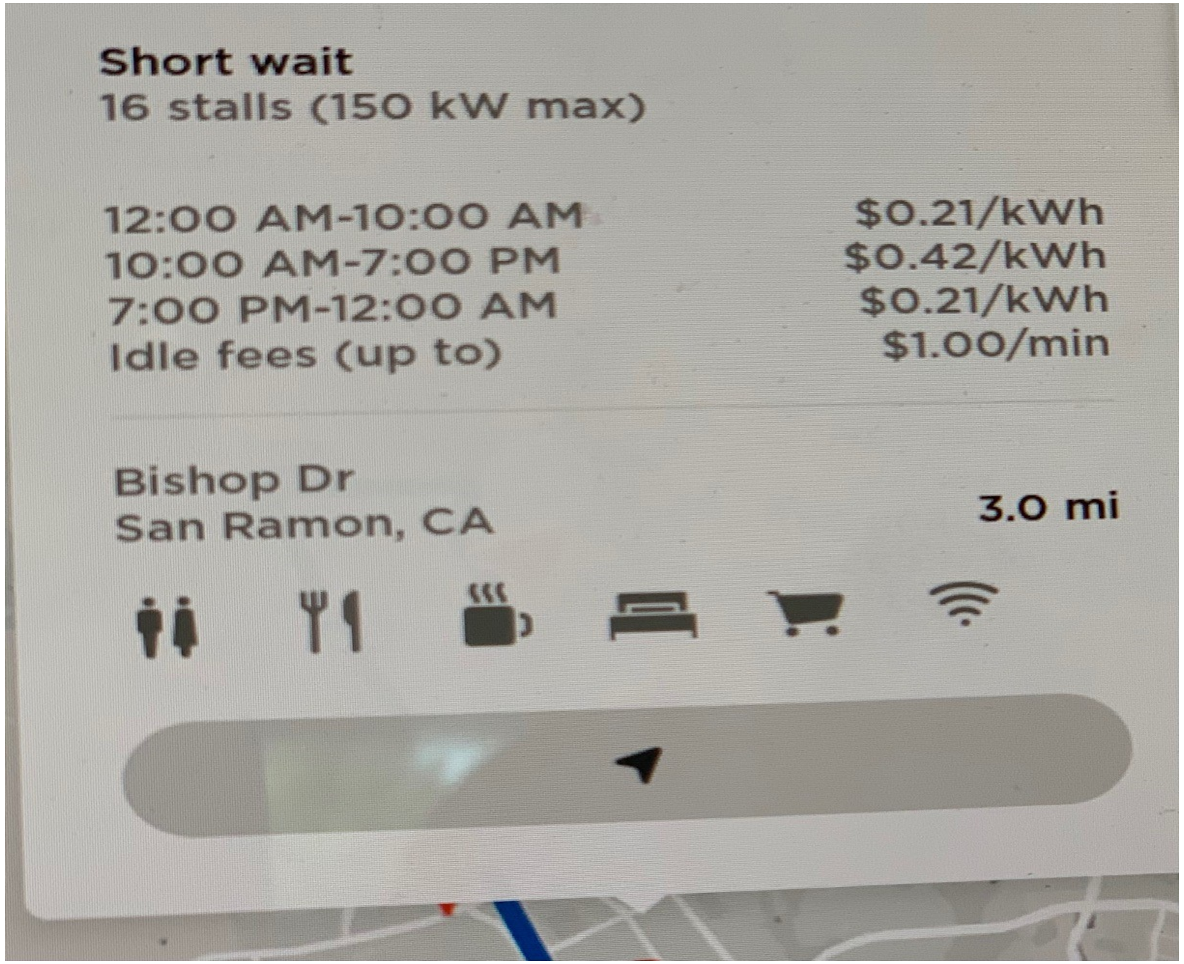
Charging during on-peak times results in seasonally based on-peak adder

Must use submeter and Level 2 charger

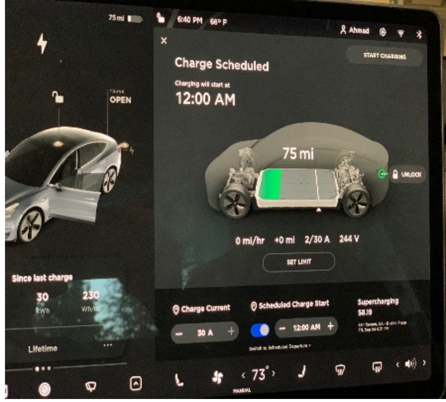
Pilot with capped participation at 100 customers

Renewable energy credits used for home charging

Public charging of EV's is much faster than home charging: Tesla, the dominant brand, is charging TOU rates at its Superchargers



Conclusions



EV drivers have significantly different needs, load shapes, and flexibility than other residential customers, requiring the offering of innovative rate designs

EV TOU rates encourage optimal charging patterns, creating a win-win for utilities and customers that drive EV’s

Empirical research in the US suggests that EV charging load is highly responsive to rate design

Smart meters are a pre-requisite for offering modern rate designs

Public chargers should also offer innovative rate designs and electricity prices should be displayed on the charging station, just like gasoline prices are displayed at gas stations

APPENDIX

A POCKET HISTORY OF RATE DESIGN

A Pocket History of Rate Design

Year	Author	Contribution
1882	Thomas Edison	• Electric light was priced to match the competitive price from gas light and not based on the cost of generating electricity
1892	John Hopkinson	• Suggested a two-part tariff with the first part based on usage and the second part based on connected kW demand
1894	Arthur Wright	• Modified Hopkinson’s proposal so that the second part would be based on actual maximum demand
1897	Williams S. Barstow	• Proposed time-of-day pricing at the 1898 meeting of the AEIC, where his ideas were rejected in favor of the Wright system
1946	Ronald Coase	• Proposed a two-part tariff, where the first part was designed to recover fixed costs and the second part was designed to recover fuel and other costs that vary with the amount of kWh sold
1951	Hendrik S. Houthakker	• Argued that implementing a two-period TOU rate is better than a maximum demand tariff because the latter ignores the demand that is coincident with system peak
1961	James C. Bonbright	• Published “Principles of Public Utility Rates” which would become a canon in the decades to come

A Pocket History of Rate Design (Concluded)

Year	Author	Contribution
1971	William Vickrey	• Proffered the concept of real-time-pricing (RTP) in *Responsive Pricing of Public Utility Services*
1976	California Legislature	• Added a baseline law to the Public Utilities Code in the *Warren-Miller Energy Lifeline Act*, creating a two-tiered inclining rate
1978	U.S. Congress	• Passed the *Public Utility Regulatory Act (PURPA)*, which called on all states to assess the cost-effectiveness of TOU rates
1981	Fred Schweppe	• Described a technology-enabled RTP future in *Homeostatic Control*
2001	California Legislature	• Introduced *AB 1X*, which created the five-tier inclining block rate where the heights of the tiers bore no relationship to costs. By freezing the first two tiers, it ensured that the upper tiers would spiral out of control
2001	California PUC	• Began rapid deployment of California Alternative Rates for Energy (CARE) to assist low-income customers during the energy crisis
2005	U.S. Congress	• Passed the *Energy Policy Act of 2005*, which requires all electric utilities to offer net metering upon request

Presenter Information

AHMAD FARUQUI, PH.D.

Principal | San Francisco, CA

Ahmad.Faruqui@brattle.com

+1.925.408.0149

Ahmad Faruqui's is a globally recognized expert on the efficient use of energy, including rate design for plug-in electric vehicles. He has worked for 150 clients on 5 continents, including electric and gas utilities, regulators, transmission operators, governments, trade associations, research institutes, and manufacturing companies. Ahmad has testified or appeared before commissions nearly 70 times. He has consulted on rate design, demand-side management and demand forecasting issues in The Kingdom of Saudi Arabia from 1994 to 2015. He has given seminars in Australia, Bahrain, Brazil, Canada, Chile, Egypt, France, Germany, Ireland, Malaysia, New Zealand, Philippines, Thailand and the UK. His research been cited in Business Week, The Economist, Forbes, Los Angeles Times, National Geographic, The New York Times, San Francisco Chronicle, San Jose Mercury News, Wall Street Journal, Washington Post, and USA Today. He has appeared on Fox Business News, National Public Radio and Voice of America and lectured at Carnegie Mellon University, Harvard University, Northwestern University, San Jose State, Stanford University, University of California at Berkeley, University of California at Davis, University of Karachi, University of Idaho, and University of San Francisco. He has published 4 books and 150 articles on electricity matters and is on the editorial board of The Electricity Journal. He holds BA and MA degrees from the University of Karachi and an MA in agricultural economics and a Ph. D. in economics from The University of California at Davis.