BEFORE THE NORTH CAROLINA UTILITIES COMMISSION
DOCKET NO. E-2, SUB 1219

In the Matter of:	**)**
Application of Duke Energy Progress,	**)**
LLC for Adjustment of Rates and	**)**
Charges Applicable to Electric Service	**)**
in North Carolina	**)**

DIRECT TESTIMONY OF
JUSTIN R. BARNES
ON BEHALF OF
NORTH CAROLINA SUSTAINABLE ENERGY ASSOCIATION

EXHIBIT JRB-1

JUSTIN R. BARNES

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EDUCATION

Michigan Technological University Houghton, Michigan
Master of Science, Environmental Policy, August 2006
Graduate-level work in Energy Policy.

University of Oklahoma Norman, Oklahoma
Bachelor of Science, Geography, December 2003
Area of concentration in Physical Geography.

RELEVANT EXPERIENCE

Director of Research, July 2015 – present
Senior Analyst & Research Manager, March 2013 – July 2015
EQ Research, LLC and Keyes, Fox & Wiedman, LLP Cary, North Carolina

- Oversee state legislative, regulatory policy, and general rate case tracking service that covers policies such as net metering, interconnection standards, rate design, renewables portfolio standards, state energy planning, state and utility incentives, tax incentives, and permitting. Responsible for service design, formulating improvements based on client needs, and ultimate delivery of reports to clients. Expanded service to cover energy storage.
- Oversee and perform policy research and analysis to fulfill client requests, and for internal and published reports, focused primarily on drivers of distributed energy resource (DER) markets and policies.
- Provide expert witness testimony on topics including cost of service, rate design, distributed energy resource (DER) value, and DER policy including incentive program design, rate design issues, and competitive impacts of utility ownership of DERs.
- Managed the development of a solar power purchase agreement (PPA) toolkit for local governments, a comprehensive legal and policy resource for local governments interested in purchasing solar energy, and the planning and delivery of associated outreach efforts.

Senior Policy Analyst, January 2012 – May 2013;
Policy Analyst, September 2007 – December 2011
North Carolina Solar Center, N.C. State University Raleigh, North Carolina

- Responsible for researching and maintaining information for the Database of State Incentives for Renewables and Efficiency (DSIRE), the most comprehensive public source of renewables and energy efficiency incentives and policy data in the United States.
- Managed state-level regulatory tracking for private wind and solar companies.
- Coordinated the organization's participation in the SunShot Solar Outreach Partnership, a U.S. Department of Energy project to provide outreach and technical assistance for local governments to develop and transform local solar markets.
- Developed and presented educational workshops, reports, administered grant contracts and associated deliverables, provided support for the SunShot Initiative, and worked with diverse group of project partners on this effort.
- Responsible for maintaining the renewable portfolio standard dataset for the National Renewable Energy Laboratory for use in its electricity modeling and forecasting analysis.
- Authored the *DSIRE RPS Data Updates*, a monthly newsletter providing up-to-date data and historic compliance information on state RPS policies.

- Responded to information requests and provided technical assistance to the general public, government officials, media, and the energy industry on a wide range of subjects, including federal tax incentives, state property taxes, net metering, state renewable portfolios standard policies, and renewable energy credits.
- Extensive experience researching, understanding, and disseminating information on complex issues associated with utility regulation, policy best practices, and emerging issues.

SELECTED ARTICLES and PUBLICATIONS

- EQ Research and Synapse Energy Economics for Delaware Riverkeeper Network. *Envisioning Pennsylvania's Energy Future*. 2016.
- Barnes, J., R. Haynes. *The Great Guessing Game: How Much Net Metering Capacity is Left?*. September 2015. Published by EQ Research, LLC.
- Barnes, J., Kapla, K. *Solar Power Purchase Agreements (PPAs): A Toolkit for Local Governments.* July 2015. For the Interstate Renewable Energy Council, Inc. under the U.S. DOE SunShot Solar Outreach Partnership.
- Barnes, J., C. Barnes. *2013 RPS Legislation: Gauging the Impacts*. December 2013. Article in Solar Today.
- Barnes, J., C. Laurent, J. Uppal, C. Barnes, A. Heinemann. *Property Taxes and Solar PV: Policy, Practices, and Issues.* July 2013. For the U.S. DOE SunShot Solar Outreach Partnership.
- Kooles, K, J. Barnes. *Austin, Texas: What is the Value of Solar; Solar in Small Communities: Gaston County, North Carolina*; and *Solar in Small Communities: Columbia, Missouri.* 2013. Case Studies for the U.S. DOE SunShot Solar Outreach Partnership.
- Barnes, J., C. Barnes. *The Report of My Death Was An Exaggeration: Renewables Portfolio Standards Live On.* 2013. For Keyes, Fox & Wiedman.
- Barnes, J. *Why Tradable SRECs are Ruining Distributed Solar.* 2012. Guest Post in Greentech Media Solar.
- Barnes, J., multiple co-authors. *State Solar Incentives and Policy Trends.* Annually for five years, 2008-2012. For the Interstate Renewable Energy Council, Inc.
- Barnes, J. *Solar for Everyone?* 2012. Article in Solar Power World On-line.
- Barnes, J., L. Varnado. *Why Bother? Capturing the Value of Net Metering in Competitive Choice Markets.* 2011. American Solar Energy Society Conference Proceedings.
- Barnes, J. *SREC Markets: The Murky Side of Solar.* 2011. Article in State and Local Energy Report.
- Barnes, J., L. Varnado. *The Intersection of Net Metering and Retail Choice: an overview of policy, practice, and issues*. 2010. For the Interstate Renewable Energy Council, Inc.

TESTIMONY & OTHER REGULATORY ASSISTANCE

North Carolina Utilities Commission. Docket No. E-7 Sub 1214. January 2020. On behalf of the North Carolina Sustainable Energy Association. Duke Energy Carolinas general rate case. Provided analysis of available rate options for electric vehicle charging and recommended the adoption of residential and non-residential EV-specific rate options and appropriate design characteristics for those rate options.

Virginia State Corporation Commission. Docket No. PUR-2019-00060. November 2019. On behalf of Appalachian Voices. Old Dominion Power Company general rate case application. Analysis of the cost basis for the residential customer charge, proposal to change the residential customer charge from a monthly charge to a daily charge, and design of proposed customer green power program and utility owned commercial behind the meter solar proposal. Proposed modified optional rate structure for mid- to large-size non-residential customers with on-site solar and/or low load factors.

Georgia Public Service Commission. Docket No. 42516. October 2019. On behalf of Georgia Interfaith Power and Light, Southface Energy Institute, and Vote Solar. Georgia Power Company general rate case application. Analysis of the cost basis for the residential customer charge, the validity of the utility's minimum-intercept study, and a proposal to change the residential customer charge from a monthly charge to a daily charge.

Hawaii Public Utilities Commission. Docket No. 2018-0368. July 2019. On behalf of the Hawaii PV Coalition. Hawaii Electric Light Company (HELCO) general rate case application. Provided analysis of HELCO's proposed changes to its decoupling rider to make the decoupling charge non-bypassable and the alignment of the proposed modifications with state policy goals and the policy rationale for decoupling.

Virginia State Corporation Commission. Docket No. PUR-2019-00067. July 2019.* On behalf of the Southern Environmental Law Center. Appalachian Power Company residential electric vehicle (EV) rate proposal. Provided review and analysis of the proposal and developed comments discussing principles of time-of-use (TOU) rate design and proposing modifications to the Company's proposal to support greater equity among rural ratepayers and greater rate enrollment. ***This work involved comment preparation rather than testimony.**

New York Public Service Commission. Case No. 19-E-0065. May 2019. On behalf of The Alliance for Solar Choice. Consolidated Edison (ConEd) general rate case application. Provided review and analysis of the competitive impacts and alignment with state policy of ConEd's energy storage, distributed energy resource management system, and earnings adjustment mechanism (EAM) proposals. Proposed model for improving the utilization of customer-sited storage in existing demand response programs and an alternative EAM supportive of utilization of third party-owned battery storage.

South Carolina Public Service Commission. Docket No. 2018-318-E. March 2019. On behalf of Vote Solar. Duke Energy Progress general rate case application. Analysis of the cost basis for the residential customer charge and validity of the utility's minimum system study, AMI-enabled rate design plans, excess deferred income tax rider rate design, and grid modernization rider proposal, including the reasonableness of the program, class distribution of costs and benefits, and cost allocation.

South Carolina Public Service Commission. Docket No. 2018-319-E. February 2019. On behalf of Vote Solar. Duke Energy Carolinas general rate case application. Analysis of the cost basis for the residential customer charge and validity of the utility's minimum system study, AMI-enabled rate design plans, excess deferred income tax rider rate design, and grid modernization rider proposal, including the reasonableness of the program, class distribution of costs and benefits, and cost allocation.

New Orleans City Council. Docket No. UD-18-07. February 2019. On behalf of the Alliance for Affordable Energy. Entergy New Orleans general rate case application. Analysis of the cost basis for the residential customer charge, rate design for AMI, DSM and Grid Modernization Riders, and DSM program performance incentive proposal. Developed recommendations for the residential customer charge, rider rate design, and a revised DSM performance incentive mechanism.

New Hampshire Public Utilities Commission. Docket No. DE 17-189. May 2018. On behalf of Sunrun Inc. Review of Liberty Utilities application for approval of customer-sited battery storage program, analysis of time-of-use rate design, program cost-benefit analysis, cost-effectiveness of utility-owned vs. non-utility owned storage assets. Developed a proposal for an alternative program utilizing non-utility owned assets under an aggregator model with elements for benefits sharing and ratepayer risk reduction.

North Carolina Utilities Commission. Docket No. E-7 Sub 1146. January 2018. On behalf of the North Carolina Sustainable Energy Association. Duke Energy Carolinas general rate case application. Analysis of the cost basis for the residential customer charge and validity of the utility's minimum system study, allocation of coal ash remediation costs, and grid modernization rider proposal, including the reasonableness of the program, class distribution of costs and benefits, and cost allocation.

Ohio Public Utilities Commission. Docket No. 17-1263-EL-SSO. November 2017*. On behalf of the Ohio Environmental Council. ***Testimony prepared but not filed due to settlement in related case.** Duke Energy Ohio proposal to reduce compensation to net metering customers. Provided analysis of capacity value of solar net metering resources in the PJM market and distribution of that value to customers. Also analyzed the cost basis of the utility proposal for recovery of net metering credit costs, focused on PJM settlement protocols and how the value of DG customer exports is distributed among ratepayers, load-serving entities, and distribution utilities based on load settlement practices.

North Carolina Utilities Commission, Docket No. E-2 Sub 1142. October 2017. On behalf of the North Carolina Sustainable Energy Association. Duke Energy Progress general rate case application. Analysis of the cost basis for the residential customer charge and validity of the utility's minimum system study, allocation of coal ash remediation costs, and advanced metering infrastructure deployment plans and cost-benefit analysis.

Public Utility Commission of Texas, Control No. 46831. June 2017. On behalf of the Energy Freedom Coalition of America. El Paso Electric general rate case application, including separate DG customer class. Analysis of separate DG rate class and rate design proposal, cost basis, DG load research study, and analysis of DG costs and benefits, and alignment of demand ratchets with cost causation principles and state policy goals, focused on impacts on customer-sited storage.

Utah Public Service Commission, Docket No. 14-035-114. June 2017. On behalf of Utah Clean Energy. Rocky Mountain Power application for separate distributed generation (DG) rate class. Provided analysis of grandfathering of existing DG customers and best practices for review of DG customer rates and DG value. Developed proposal for addressing revisions to DG customer rates in the future.

Colorado Public Utilities Commission, Proceeding No. 16A-0055E. May 2016. On behalf of the Energy Freedom Coalition of America. Public Service Company of Colorado application for solar energy purchase program. Analysis of program design from the perspective of customer demand and needs, and potential competitive impacts. Proposed alternative program design.

Public Utility Commission of Texas, Control No. 44941. December 2015. On behalf of Sunrun, Inc. El Paso Electric general rate case application, including separate DG customer class. Analysis of separate rate class and rate design proposal, cost basis, DG load research study, and analysis of DG costs and benefits.

Oklahoma Corporation Commission, Cause No. PUD 201500271. November 2015. On behalf of the Alliance for Solar Choice. Analysis of Oklahoma Gas & Electric proposal to place distributed generation customers on separate rates, rate impacts, cost basis of proposal, and alignment with rate design principles.

South Carolina Public Service Commission, Docket No. 2015-54-E. May 2015. On behalf of The Alliance for Solar Choice. South Carolina Electric & Gas application for distributed energy programs. Alignment of proposed programs with distributed energy best practices throughout the U.S., including incentive rate design and community solar program design.

South Carolina Public Service Commission, Docket No. 2015-53-E. April 2015. On behalf of The Alliance for Solar Choice. Duke Energy Carolinas application for distributed energy programs. Alignment of proposed programs with distributed energy best practices throughout the U.S., including incentive rate design and community solar program design.

South Carolina Public Service Commission, Docket No. 2015-55-E. April 2015. On behalf of The Alliance for Solar Choice. Duke Energy Progress application for distributed energy programs. Alignment of proposed programs with distributed energy best practices throughout the U.S., including incentive rate design and community solar program design.

South Carolina Public Service Commission, Docket No. 2014-246-E. December 2014. On behalf of The Alliance for Solar Choice. Generic investigation of distributed energy policy. Distributed energy best practices, including net metering and rate design for distributed energy customers.

AWARDS, HONORS & AFFILIATIONS

- Solar Power World Magazine, Editorial Advisory Board Member (October 2011 – March 2013)
- Michigan Tech Finalist for the Midwest Association of Graduate Schools Distinguished Master's Thesis Awards (2007)
- Sustainable Futures Institute Graduate Scholar Michigan Tech University (2005-2006)

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The State of Electric Vehicle Home Charging Rates

A SUMMARY

PRESENTED TO
Colorado PUC

PREPARED BY
Ahmad Faruqui
Ryan Hledik
John Higham

October 15, 2018

THE Brattle GROUP

Introduction and Methodology

Introduction

- The purpose of this presentation is to summarize residential EV-specific rate offerings in the United States
- The presentation includes the following sections:
  - Drivers and goals of EV-specific rates
  - A survey of current EV-specific rate offerings
  - Review of two pilot studies of EV-TOU effectiveness

Methodology

- The survey draws upon the following sources:
  - OpenEI Utility Rates Database
  - Utility tariff sheets

Drivers and Goals of EV-Specific Rates

Background

EV rate offerings are an opportunity improve the economic efficiency of EV charging behavior

- Consumer electric vehicles use approximately 225-275 kWh per month
- Level 1 charging consumes 1.4 kW of power
- Level 2 charging uses 6.2-7.6 kW of power
- A majority of EV charging occurs at home

Possible Utility Goals

1. Encourage EV adoption by reducing charging costs
2. Provide price signals that encourage optimal EV charging patterns while accurately collecting costs

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

Annual EV Charging Cost per Traveler

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

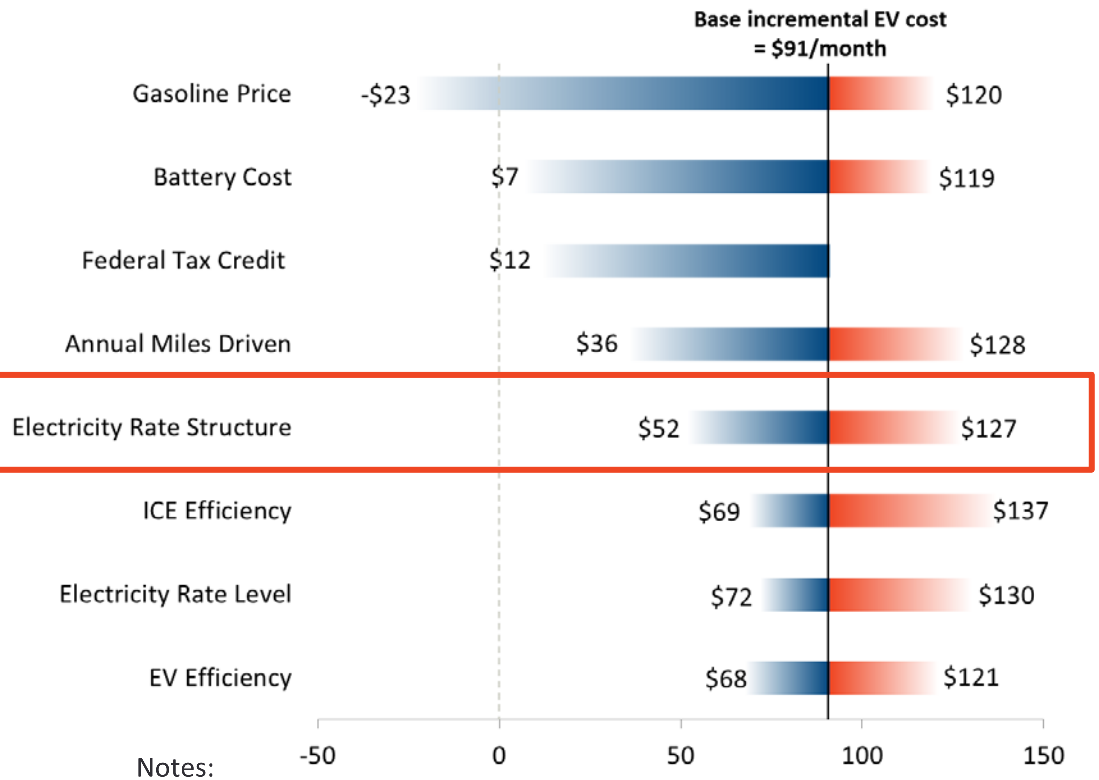
Comparable annual fuel cost of an ICE vehicle at $3/gal, 30 mpg is **$1,460**

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, though this is heavily dependent on charging patterns
- Additionally, there are significant non-economic drivers of vehicle adoption
- Thus, rate design may be a better tool for influencing the behavior of EV owners rather than being a primary consideration in the vehicle purchase decision

Utilities and Types of Rates

21 US 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

Rates – General Trends

- Diverse array of rate offerings
- 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.

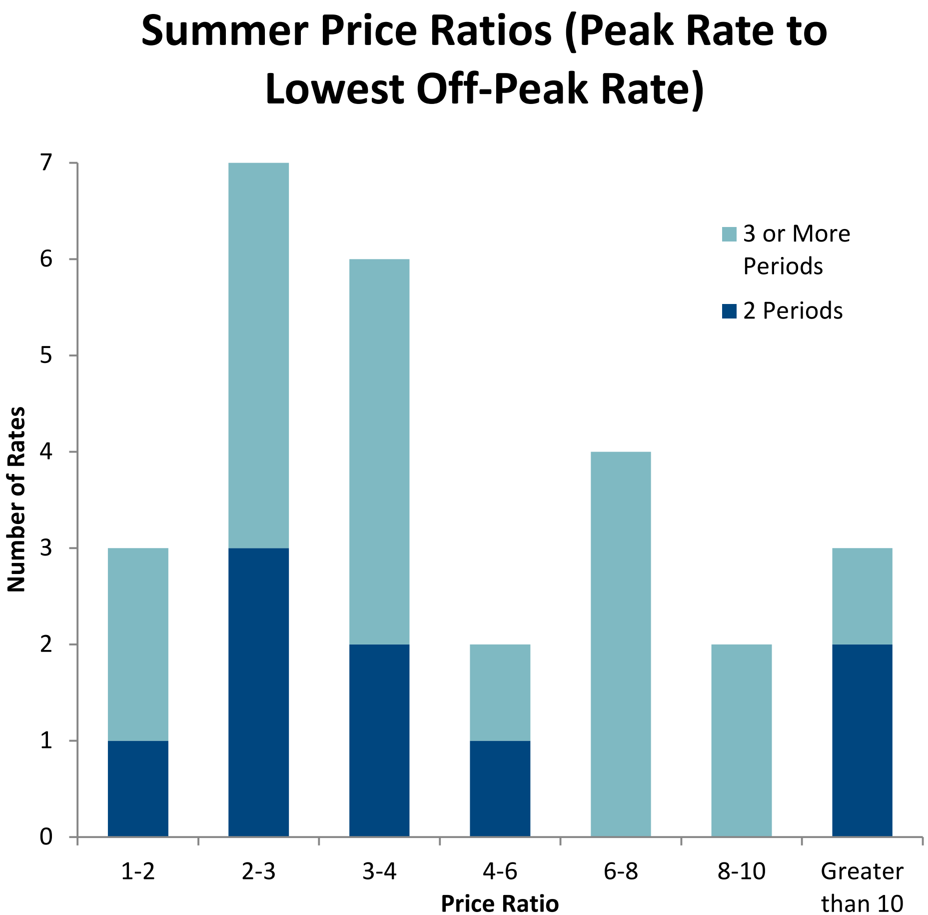
TOU Rates

Of the 27 TOU rates:

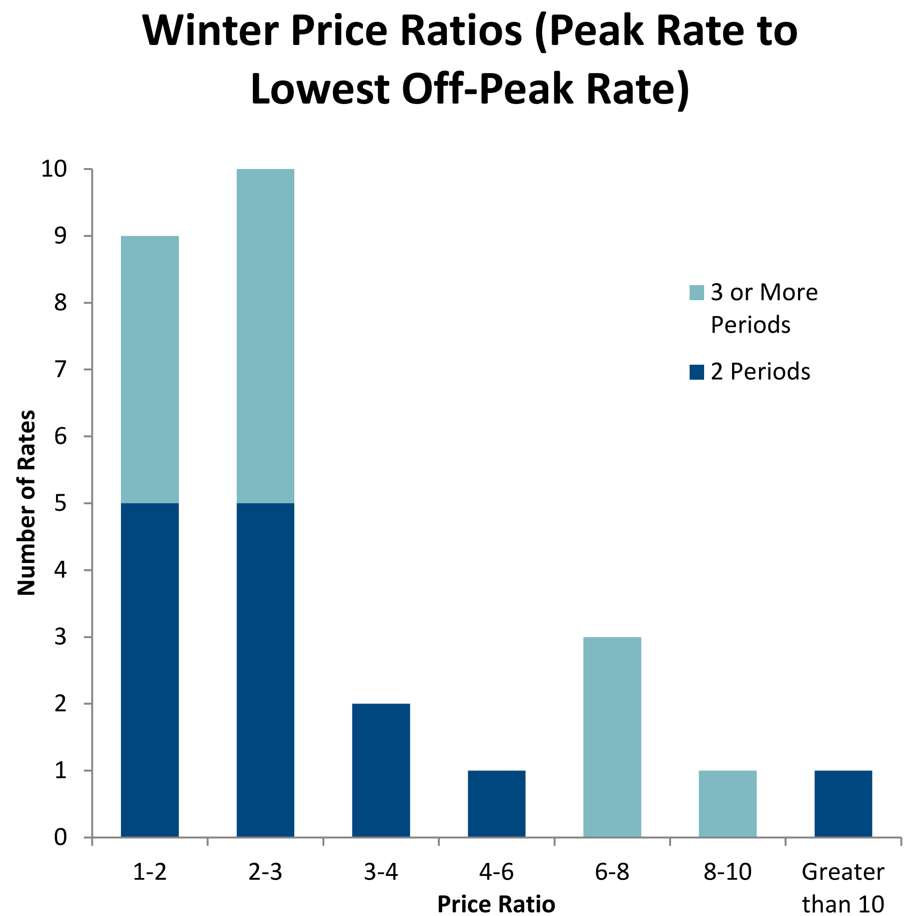
- 9 have 2 pricing periods in both Summer and Winter
- 11 have 3 pricing periods in both Summer and Winter
- 5 have 3 pricing periods in Summer but 2 in Winter
- 2 have 4 pricing periods

Many different arrangements of pricing periods, seasons, price ratios, and fixed costs.

TOU Rates – Price Ratios

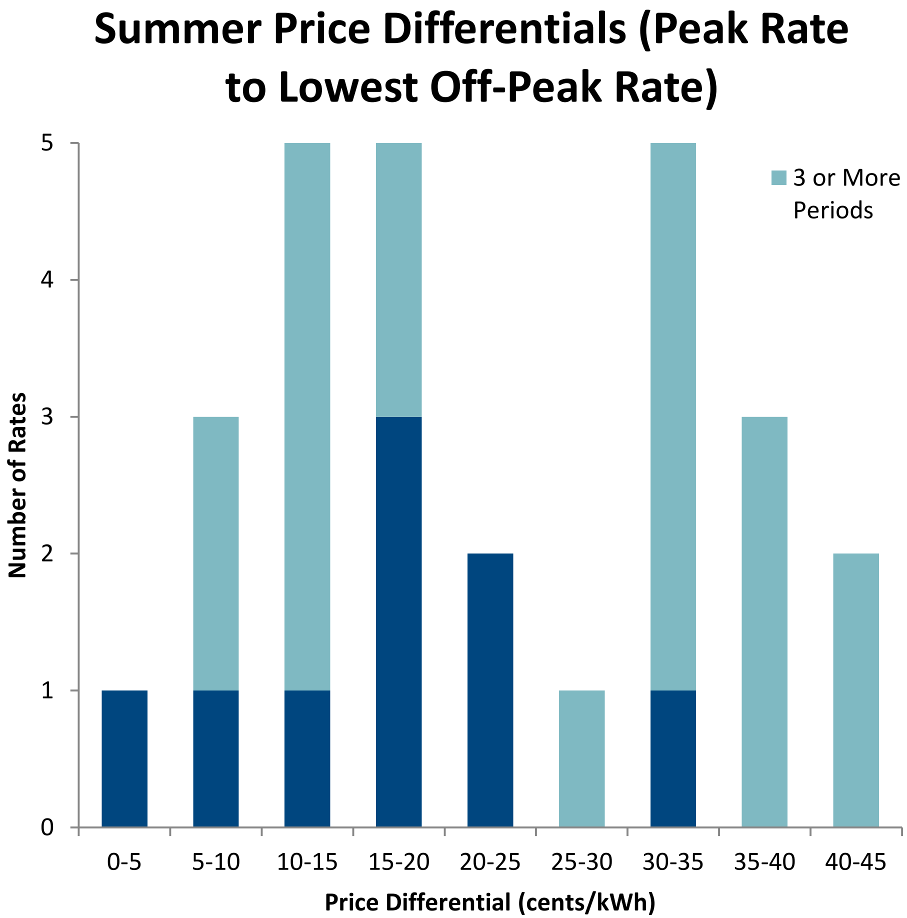


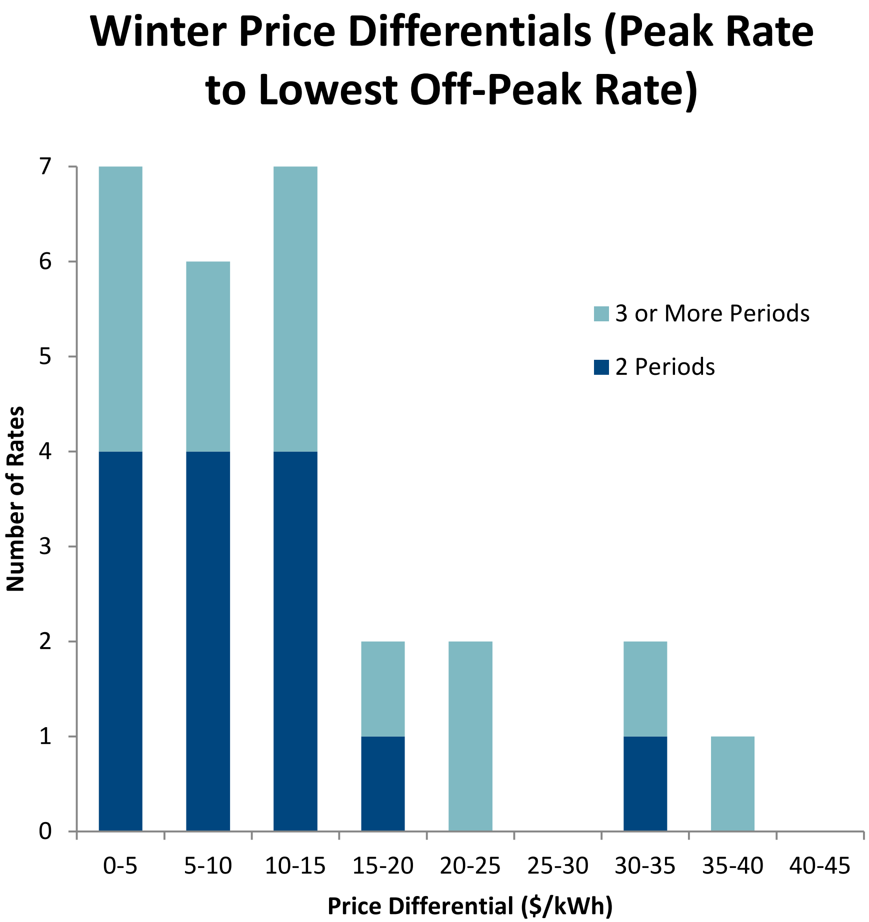
2 Period Median = 3.19
3 or More Period Median = 3.74



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

TOU Rates – Price Differentials



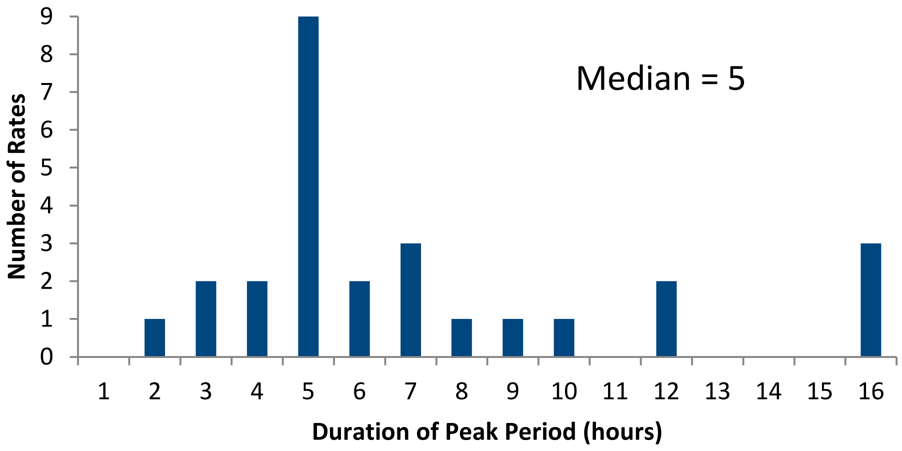


2 Period Median = 17 cents/kWh
3 or More Period Median = 28 cents/kWh

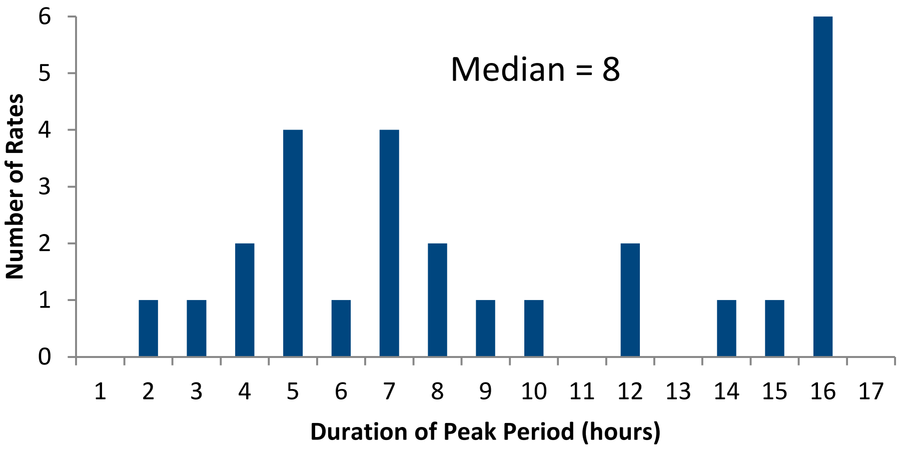
2 Period Median = 9 cents/kWh
3 or More Period Median = 12 cents/kWh

TOU Rates – Duration of Peak Window

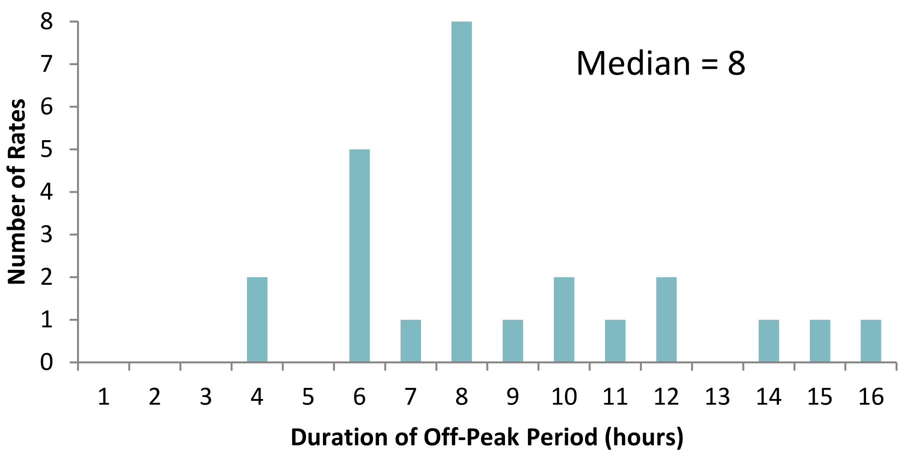
Summer Peak Period Duration



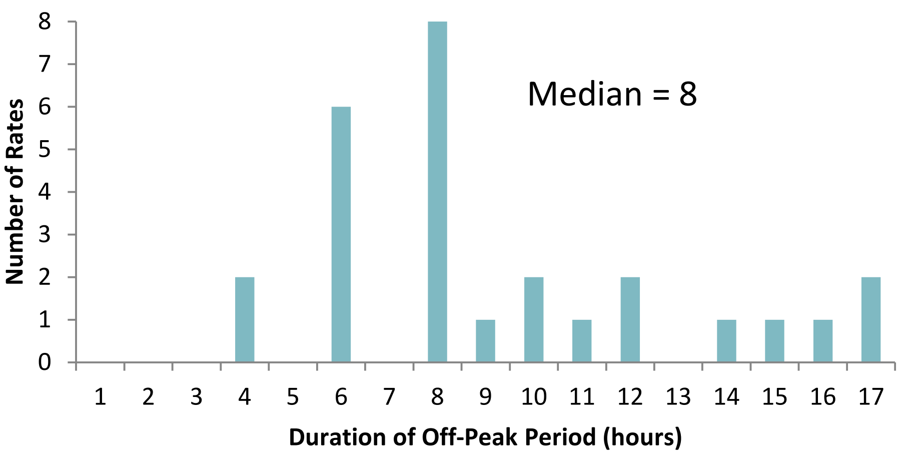
Winter Peak Period Duration



Summer Off-Peak Period Duration



Winter Off-Peak Period Duration



Pilot Studies

San Diego Gas & Electric – EV TOU Pilot Study

- 3 different 3-period rates with varying price ratios (roughly 2, 4, and 6 for peak/super off-peak)
- All rates applied strictly to EV charging, not the entire residence
- 430 participants owning a Nissan LEAF with a charging timer and Level 2 charging
- EV owners were found to be responsive to price signals and shifted a majority of charging to super off-peak hours
- Participants exhibited learning behavior, increasingly shifting consumption as the study progressed

EPRI – Salt River Project EV Driving, Charging and Load Shape Study

- Observational study of 70 EVs of various models subject to different rate plans
- TOU rates found to be highly effective in shifting peak loads
- Energy use and charging load varied widely across different models and charger types

Conclusions

- Electric vehicle owners have significantly different needs, load shapes, and flexibility than other residential customers, supporting the creation of new rate offerings
- EV TOU rates encourage optimal charging patterns, creating a win-win for utilities and EV owners
- Initial findings from two EV charging pilots indicates that charging load is highly responsive to rate design, though further empirical research is needed in this area

References

- Electric Power Research Institute. “Electric Vehicle Driving, Charging, and Load Shape Analysis: A Deep Dive Into Where, When, and How Much Salt River Project (SRP) Electric Vehicle Customers Charge.” 3002013754. July 2018.
- Cook, Jonathan, Candice Churchwell, and Stephen George. “Final Evaluation for San Diego Gas & Electric’s Plug-in Electric Vehicle TOU – Pricing and Technology Study.” Nexant, Inc. Submitted to San Diego Gas & Electric. February 20, 2014.

Appendix: Monthly Cost of EV Ownership Assumptions

General Assumptions:

- 10 year vehicle life
- 24 kWh battery
- 10% registration fee
- 12% charging losses
- $600 charger cost
- 7% annual discount rate

Sensitivity Assumptions:

Component	**Units**	**Low**	**Base**	**High**
Electricity Rate Level	*cents/kWh*	8	**12**	20
Electricity Rate Structure		Off-Peak w/ TOU (10:1)	**Flat**	Post-Commute w/ Demand Charge
EV Efficiency	*miles/kWh*	5.0	**3.0**	2.0
ICE Efficiency	*MPG*	25	**30**	50
Annual Miles Driven	*miles/year*	30,000	**15,000**	5,000
Federal Tax Credit	*$*	7,500	**0**	---
Battery Cost	*$/kWh*	200	**500**	600
Gasoline Price	*$/gal*	$5.00	**$3.00**	$2.00

PRESENTED BY
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Ahmad Faruqui's consulting practice is focused on the efficient use of energy. His areas of expertise include rate design, demand response, energy efficiency, distributed energy resources, advanced metering infrastructure, plug-in electric vehicles, energy storage, inter-fuel substitution, combined heat and power, microgrids, and demand forecasting. He has worked for nearly 150 clients on 5 continents. These include electric and gas utilities, state and federal commissions, independent system operators, government agencies, trade associations, research institutes, and manufacturing companies. Ahmad has testified or appeared before commissions in Alberta (Canada), Arizona, Arkansas, California, Colorado, Connecticut, Delaware, the District of Columbia, FERC, Illinois, Indiana, Kansas, Maryland, Minnesota, Nevada, Ohio, Oklahoma, Ontario (Canada), Pennsylvania, ECRA (Saudi Arabia), and Texas. He has presented to governments in Australia, Egypt, Ireland, the Philippines, Thailand and the United Kingdom and given seminars on all 6 continents. His research been cited in Business Week, The Economist, Forbes, National Geographic, The New York Times, San Francisco Chronicle, San Jose Mercury News, Wall Street Journal and USA Today. He has appeared on Fox Business News, National Public Radio and Voice of America. He is the author, co-author or editor of 4 books and more than 150 articles, papers and reports on energy matters. He has published in peer-reviewed journals such as Energy Economics, Energy Journal, Energy Efficiency, Energy Policy, Journal of Regulatory Economics and Utilities Policy and trade journals such as The Electricity Journal and the Public Utilities Fortnightly. He holds BA and MA degrees from the University of Karachi, an MA in agricultural economics and Ph. D. in economics from The University of California at Davis.

Brattle Projects & Research on Electrification

Ongoing

- Forecasting the impacts of new utility initiatives on EV adoption (EPRI)
- System Dynamics based modeling of EV adoption and impacts on utilities (ComEd)
- Developing a framework for evaluating the cost-effectiveness of ratepayer-funded electrification programs (EPRI)
- Reviewing rate design alternatives for public EV fast charging stations (EEI)
- Developing forward-looking ratemaking strategies, including rate design for EVs (GRE)

Recent

- Assessment of the benefits and costs of residential grid-interactive electric water heating (NRECA/NRDC)
- Assessment of the economy-wide technical potential for electrification (Brattle White Paper)
- Exploration of the implications of ride sharing and vehicle automation for electric utilities (Brattle White Paper, Electricity Journal Article, PUF Article)

Additional Brattle Resources

The Electrified Future is Shared, Jürgen Weiss, Public Utilities Fortnightly, PUF 2.0, Mid-February 2018

The electrification accelerator: Understanding the implications of autonomous vehicles for electric utilities, Jürgen Weiss, Ryan Hledik, Roger Lueken, Tony Lee, Will Gorman, The Electricity Journal 30 (2017) 50–57, December 2017

New Sources of Utility Growth: Electrification Opportunities and Challenges; Retail Energy Practice Briefing Series; The Brattle Group, November 2017

Electrification: Emerging Opportunities for Utility Growth, Jürgen Weiss, Ryan Hledik, Michael Hagerty and Will Gorman, January 2017

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Our Electrification Services

- Market Potential Assessments
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- Multi-criteria Screening of Electrification Options
- Electrification Strategy Development
- Macroeconomic Impact Modeling
- Rate Design for Electric Vehicle (EV) Charging
- EV Adoption Modeling
- Regulatory Strategy and Support
- Pilot Development

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- Competition & Market Manipulation
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- Electricity Market Modeling & Resource Planning
- Electrification & Growth Opportunities
- Energy Litigation
- Energy Storage
- Environmental Policy, Planning and Compliance
- Finance and Ratemaking
- Gas/Electric Coordination
- Market Design
- Natural Gas & Petroleum
- Nuclear
- Renewable & Alternative Energy

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- Analysis of Market Manipulation
- Antitrust/Competition
- Bankruptcy & Restructuring
- Big Data & Document Analytics
- Commercial Damages
- Environmental Litigation & Regulation
- Intellectual Property
- International Arbitration
- International Trade
- Labor & Employment
- Mergers & Acquisitions Litigation
- Product Liability
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- White Collar Investigations & Litigation

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EXHIBIT JRB-3

Smart Electric Power Alliance

Residential Electric Vehicle Rates That Work

ATTRIBUTES THAT INCREASE ENROLLMENT

November 2019

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About E4TheFuture

E4TheFuture is a nonprofit organization advancing clean, efficient energy solutions. Advocating for smart policy with an emphasis on residential solutions is central to E4TheFuture's strategy. "E4" means: promoting clean, efficient Energy; growing a low-carbon Economy; ensuring low income residents can access clean, efficient, affordable energy (Equity); restoring a healthy Environment for people, prosperity and the planet. Dedicated to bringing clean, efficient energy home for every American, E4TheFuture's endowment and primary leadership come from Conservation Services Group whose operating programs were acquired in 2015 by CLEAResult. Visit www.e4thefuture.org.

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Enel X is Enel's global business line dedicated to developing innovative products and digital solutions. Enel X's e-Mobility division is the leading provider of grid-connected electric vehicle charging stations with over 50,000 smart stations across the world. The company's JuiceNet® platform provides smart grid management of EV charging, which is used by thousands of drivers, global automakers, commercial businesses and utilities. In North America, Enel X has ~3,400 business customers, spanning more than 10,400 sites, representing approximately 4.6 GW of demand response capacity and 20+ battery storage projects. For more information please visit www.enelx.com.

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The Brattle Group provides consulting and expert testimony in economics, finance, and regulation to corporations, law firms, and governments around the world. We help energy and utility market participants worldwide anticipate and navigate the challenges and opportunities in changing markets and regulatory environments. Brattle's experts are at the forefront of the latest developments and trends facing the energy industry, and our experience spans the full spectrum of complex, high-stakes matters relating to resource planning and approvals, regulatory policy assessments, rate design, contract litigation, market conduct, performance and enforcement, financial analysis, and mergers & acquisitions. For more information, please visit www.brattle.com.

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Executive Summary

Electric vehicle (EV) market forecasts predict strong growth in adoption, with much of the associated charging load occurring at home. Utilities can influence home charging behaviors through EV time-varying rates that incentivize residential customers to charge off-peak thereby minimizing distribution system impacts and avoiding the need for costly infrastructure upgrades and investments. This report analyzes residential EV time-varying rates based on survey results from customers and utilities and identifies factors that increase rate enrollment. For the purposes of this report, we included **residential time-varying rates that were identified and marketed as rates specifically available to EV drivers**.

To collect insights on residential EV time-varying rates implemented to date, SEPA worked with The Brattle Group to develop and administer a survey for U.S. utilities that had a qualified rate in-place for at least one year. In addition, to collect insights from EV drivers on time-varying rates, SEPA co-developed a survey with Enel X which was distributed nationwide to the company's JuiceNet-enabled charging station customers.

Why Residential EV Time-Varying Rates Are Important

EVs can use between 3.3 to 20 kilowatts (kW) of electricity, which can exceed the total peak demand of a home in some regions. The increase in peak load can also strain the local distribution system, particularly when several EVs are clustered on single transformers. Residential EV charging load is well-suited to respond to price signals. Most light-duty EVs are parked the majority of the day[1] and can be easily programmed through the car and/or the charger to begin charging at a pre-set time. In the future, it will be desirable to have this and more advanced control capabilities across the grid in a more dynamic framework, in order to respond to real-time market and operating conditions.

As illustrated by our utility and customer survey results, time-varying rates are an effective tool for utilities to influence EV customer charging behavior by incentivizing home charging during off-peak periods. While some industry representatives have questioned the need for EV-specific rates—rates designed for and marketed to EV drivers—to capture benefits, we found that customers on an EV time-varying rate were generally 1) more familiar with the rate rules and 2) more likely to charge off-peak compared to their generic time-varying rate counterparts. EV-specific rates also allow utilities to offer rate options that appeal to a wider range of customer types and preferences across their service territories than they could with only a generic time-varying rate. In the near-term, EV-specific time-varying rates—a form of passive managed charging—offer utilities an effective mechanism to shift residential EV charging behavior to off-peak time periods. The following sections highlight key findings from our research.

Factors that Increase Enrollment

According to the research, certain EV time-varying rate attributes lead to higher customer uptake. Utilities that have a marketing budget for these rates see a 3x increase in enrollment. Further, those using more than three marketing channels have a 1.4x increase in customer enrollment (Figure 1). Utility-driven EV time-varying rate initiatives, as opposed to those required or recommended by customers, governance boards, or legislatures, also have a corresponding 2.4x increase in enrollment. Other important factors include free enrollment and realized bill savings for average EV customers.

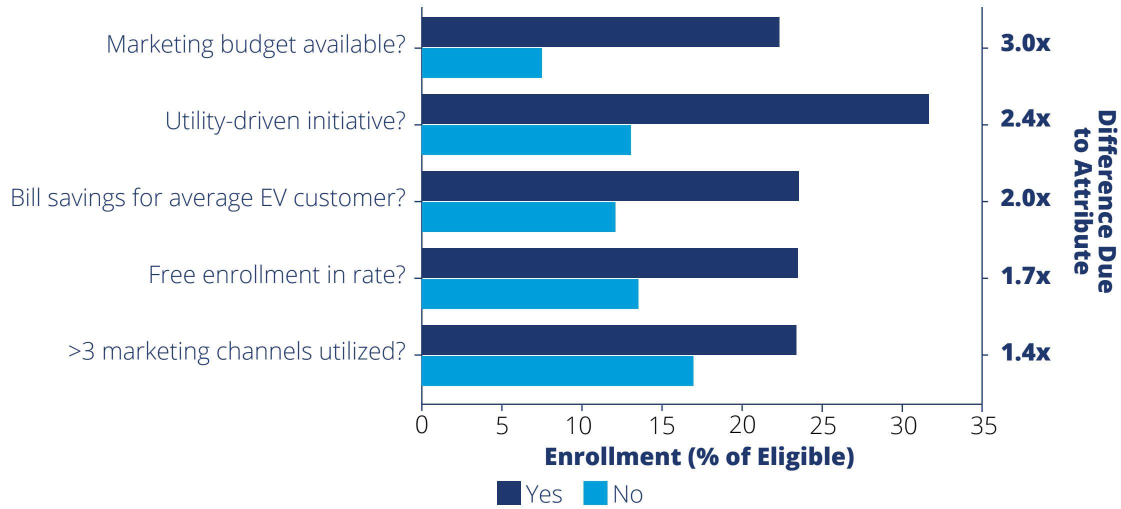
Rate Design and Marketing Are Important

Rate design considerations for time-varying rates, such as bill neutrality, peak/off-peak pricing windows, and peak-to-off peak pricing ratios are also important. An effective rate design conveys price signals that are transparent and actionable, giving customers the necessary information and a strong incentive to shift their charging load from the utility's system peak hours to designated off-peak periods. These factors also directly affect the value proposition for customer enrollment in a time-varying rate. As outlined in this report, the opportunity to reduce their bill is a top motivation for customers. The utility survey results in this report demonstrate that the time-varying rates offered by utilities have successfully shifted charging to off-peak periods, lowering utility bills for the average EV customer.

Further, providing meaningful rate choices, such as offering larger discounts, varied off-peak hours and other significant variations, to customers is more likely to induce higher enrollment and increase off-peak charging behavior. This is reflected in the utility survey results and in the San

1 See Donald Shoup, 2011, The High Cost of Free Parking, which asserts cars are parked up to 95% of the time.

Figure 1: Average Enrollment by EV Time-Varying Rate Attribute



Source: Smart Electric Power Alliance & The Brattle Group, 2019. N=20

Diego Gas & Electric case study summarized in the report. Rate design considerations can include combinations of whole-home and EV-only rates, metering configurations, and off-peak hour definitions that better serve individual customer and grid-wide needs. Dynamic rates, retroactive bill credits via load disaggregation, or subscription rates can also provide more choices and appeal to a broader base of customers compared to straight time-of-use rates, which represent the majority of rates implemented to date.

Marketing directly affects enrollment and need not be expensive. According to the survey, 70% of customers learned about their time-varying rate through low-cost marketing efforts, such as rate information on the utility website. Of survey respondents that didn't enroll in an available rate, it was largely due to their lack of awareness of the rate and the related potential for savings. While customer awareness of EV rates is high, utilities can take measures to improve education and customer understanding of the rates.

Metering Considerations

Metering techniques are important for rate implementation and can determine the difference between a successful program and a program failure. Meter option considerations include the cost of enrollment and equipment, the type of administration, the ease of integration with existing billing systems, the security and reliability of charging signals, and the ability of the program to handle EV technology evolution.

Today, utilities employ at least five metering approaches to implement EV time-varying rates: 1) existing meter, 2) submeter, 3) secondary meter, 4) telemetry in the EV charger, or 5) load disaggregation via data pulled from a meter or other device, such as a meter collar. While the survey didn't identify a correlation between enrollment and a specific metering approach, it is clear from the data that customers want options that minimize enrollment costs. The report provides case studies of innovative rate programs and metering approaches from Indiana Michigan Power (a subsidiary of American Electric Power), San Diego Gas & Electric, Austin Energy, Xcel Energy Minnesota, and Braintree Electric Light Department.

A Bridge to Direct Load Management

As the utility industry builds the capabilities for direct EV charging load control, utilities may be able to leverage the on-board EV batteries for advanced grid benefits. Time-varying rates are an effective first step in developing a strong relationship with EV customers. Creating a positive customer experience with load management is important. Eventually, direct load control can complement time-varying rates and provide more dynamic grid services than can rates alone. Direct load control can also help minimize the challenges posed by the formation of new 'timer peaks' on the distribution system (e.g., if customers begin charging simultaneously when the off-peak window begins, creating a new spike in load).

Beyond EVs, residential demand response and price-responsive controlled usage can also be provided by other equipment, such water heaters, air conditioners, swimming pool pumps, and laundry equipment. As customers become more comfortable with controlled loads through managed EV charging programs, it may also lead to greater acceptance of other utility load-control programs.

Based on our findings, utilities should engage EV customers early to avoid losing customer engagement "momentum." Understanding customer motivation is valuable, and while customers are primarily motivated by savings, a large percentage of customers in our survey are also interested in helping the environment. Describing how load management can lead to increased use of renewable energy and other environmental goals can help utilities increase enrollment and participation in EV time-varying rate programs.

Residential EV time-varying rates can serve as a bridge between passive and active managed charging options by showing customers how, in exchange for providing grid benefits by controlling their charging, they can save money. Utilities should also consider incorporating direct load control with a time-varying rate program. The timing for doing so will depend on EV penetration and the cost-benefit of load management options. Although the need for direct load control may not be immediate, utilities should ensure that equipment installed today is compatible with future pricing and system reliability frameworks by testing options today.

Report Contents

This report provides a comprehensive overview of residential EV time-varying rates and draws conclusions about next steps for residential EV rate design and programs based on the results of a utility survey and a customer survey. The appendices provide a complete list of EV time-varying rates offered by utilities as of September 2019, a list of suggested reading materials, and definitions of time-varying rates. This report was made possible by funding from E4TheFuture and Enel X.

Table 1: Report Roadmap

The Case for Time-Varying Rates	Defines time-varying rate options and describes the benefits and limitations of these rates.
Residential EV Time-Varying Rates Landscape	Describes why utilities are pursuing these rates, how utilities are marketing them, and why customers are interested in residential EV rates.
Consumer Insights	Provides the customer survey results from nearly 3,000 EV drivers who have either 1) enrolled in a time-of-use (TOU) program or 2) had a utility TOU rate option available, but chose not to enroll.
Features of Effective EV Time-Varying Rates	Highlights the utility survey results to identify the features of rates and programs that contribute to the highest customer enrollment.
What To Do About Metering	Highlights utility metering approaches, the pros and cons of each, and outlines case studies of utilities that have developed innovative rate programs through various metering approaches.
Conclusion	Recommendations for utilities as they consider options for EV time-varying rates and describes other research topics to explore, as the industry continues to investigate load management strategies.
Appendices	▪ Appendix A includes a complete list of EV time-varying rates ▪ Appendix B includes suggested reading materials ▪ Appendix C includes expanded definitions of time-varying rates and illustrations

Source: Smart Electric Power Alliance, 2019.

1) Introduction

Electric vehicles (EVs), in certain regions of the U. S., are quickly becoming one of the largest flexible loads on the grid. Depending on vehicle type, a single EV represents from 1.4 kW to 20 kW of instantaneous load[2], or 500 to 4,350 kWh/year of energy consumption.[3] This is similar to the impact of introducing air conditioning systems and electric water heaters decades ago. As of July 2019, customers have purchased over 1.28 million EVs in the United States,[4] consuming an estimated 4.97 terawatt-hours (TWh) per year.[5]

EV adoption is expected to increase as vehicle prices decline and new models become available. Navigant forecasts that EVs in the U.S. will reach over 20 million in 2030 with an energy consumption of 93 TWh.[6] According to forecasting models by the National Renewable Energy Laboratory (NREL), electrified transportation may result in between 58 to 336 TWh of electricity consumption annually by 2030, depending on the speed and type of vehicle deployment.[7] This represents the equivalent average annual energy consumption of 5.6 million to 32.3 million U.S. homes.[8]

Forecasts predict that much of the future charging load will occur at home, as it does today. Utilities can strongly influence residential charging behavior by incentivizing their customers to charge off-peak to minimize distribution system impacts and avoid the need for costly infrastructure upgrades and investments. As described in the 2019 SEPA report, *A Comprehensive Guide to Electric Vehicle Managed Charging*, this is known as managed charging.

There are two forms of managed charging: passive and active.[9] Passive managed charging uses behavioral load control strategies, including rates and incentives, to influence customers. Active managed charging is direct load control enabled through the charger, the vehicle, or some other interface that can remotely control a charging event to respond to real-time grid conditions.[10]

This report presents empirical evidence regarding the effectiveness and benefits of passive managed charging via time-varying rates for residential EV customers. In the near-term, passive managed charging offers utilities an effective strategy for shifting residential EV charging behavior to off-peak time periods that can effectively lead to more sophisticated active managed charging programs, as discussed in Chapter 2.

In order to collect insights on residential EV time-varying rates implemented to date, SEPA collaborated with The Brattle Group ("Brattle") to develop and administer a survey ("utility survey") for all U.S. utilities that had a qualified rate for at least one year. Further, to collect insights from EV drivers on time-varying rates, SEPA co-developed a survey with Enel X (formerly known as eMotorWerks) which was distributed nationwide to the company's JuiceNet-enabled charging station customers ("customer survey"). Additional survey information is provided in the research methodology.

2 Using Level 1 to Level 2 charging stations; Direct Current Fast Charging (DCFC) load would be higher.

3 SEPA, 2019, *A Comprehensive Guide to Electric Vehicle Managed Charging*.

4 Electric Drive Transportation Association, July 2019, https://electricdrive.org/index.php?ht=d/sp/i/20952/pid/20952

5 Assumes 3,858 kWh per EV per year based on data from the U.S. Department of Energy Alternative Fuels Data Center. Assumes all vehicles sold since 2010 are still operating in the U.S.

6 Navigant forecast provided in April 2019 to SEPA staff. See also: EEI/IEI, November 2018, *EV Sales Forecast and the Charging Infrastructure Required through 2030.*

7 National Renewable Energy Laboratory, 2018, *Electrification Futures Study: Scenarios of Electric Technology Adoption and Power Consumption for the United States*, https://www.nrel.gov/docs/fy18osti/71500.pdf.

8 Based on 2017 U.S. Energy Information Administration data that residential U.S. electricity consumers used an average of 10,400 kWh per year. See https://www.eia.gov/tools/faqs/faq.php?id=97&t=3.

9 Note: other terms used for managed charging include smart charging, V1G, intelligent charging, direct load control, or passive load control.

10 Additional information about active managed charging can be found in SEPA's 2019, *A Comprehensive Guide to Electric Vehicle Managed Charging* report.

Research Methodology

SEPA collected primary research data from electric utilities that have developed time-varying rates for EV customers. The majority of the rates currently offered by the sampled utilities are time-of-use (TOU) rates. SEPA contacted 50 utilities, of which 28 responded to the survey with a total of 40 EV specific time-varying rates. Of the 28 utilities, 19 were investor-owned, 4 were municipally owned, 4 were member-owned cooperatives and one was a community choice aggregator.

The SEPA survey team employed best practices to maximize response rates, and performed data verification and validation with survey respondents while collaborating with Brattle to analyze the results.

Brattle's analysis focused on identifying factors that contribute to a "successful" EV TOU rate. For the purposes of this analysis, "success" is defined as a high enrollment rate or significant shifting of load to desirable (i.e., lower-priced off-peak) periods. The load shifting data indicates that the TOU rates shifted the majority of charging to off-peak hours. Estimates of rate enrollment were significantly more varied. Brattle's analysis limited consideration of the survey responses to those that would be useful for analyzing drivers of high enrollment. They eliminated survey responses that appeared to be duplicates, where rates had expired, and where enrollment estimates were not provided. Survey responses were reviewed and assigned to specific categories relevant to the quantitative analysis (e.g., assigning a "yes" or "no" flag based on whether or not a utility indicated that budget was available to market the rate). Average enrollment was calculated for each specific category (e.g., average enrollment among those utilities that had a marketing budget versus those that did not). The averages were calculated as a simple average across utilities, rather than weighting by number of customers which would skew the results to the findings of larger-sized utilities. A statistical technique known as "lasso analysis" was then applied to empirically estimate the relative importance of each factor in driving higher enrollment in the TOU rates.[11] Brattle shared their insights with SEPA for the purposes of developing the report.

Concurrent with the utility survey, Enel X and SEPA developed and distributed a customer survey which generated 2,967 US-based responses from JuiceNet users. This provided data on EV customer familiarity with their rate structure and behavioral energy insights. JuiceNet respondents represented a wider customer sample beyond the utilities included in the SEPA/Brattle survey. Many of Enel X's customers reside in California, where close to half of the nation's EVs are located and where residential TOU rates will be the default rate within investor-owned utility service territories. Nearly 50% of respondents to Enel X's survey (1,422 out of 2,967 respondents) live in California. Further, since the survey only sampled the customers of one EV charging manufacturer, the pool of respondents may reflect customers that were specifically interested in the JuiceNet smart charging features.

2) The Case for Time-Varying Rates

As EV adoption grows, significant load will be added to the grid. If customers charge their EVs during peak demand hours, this increase in demand could create unwelcome effects. One way to minimize peak load impacts is through the use of time-varying rates. This section defines time-varying rate options and describes the benefits and limitations of these rates.

A. What Are Time-Varying Rates?

For much of the day, less than half of the electric grid's capacity is being used. This is because the grid is designed to handle peak demand.[12] As a result, reducing the peak—during which the generation and delivery of electricity is more costly—is advantageous for both the utility and customer, as it minimizes the system costs and therefore

11 Least Absolute Shrinkage and Selection Operator (LASSO) is a technique used to improve the prediction accuracy of regression models by identifying a subset of covariates (i.e., model variables) that generally have the most predictive value.

12 Girouard, Coley., 2015, *Time Varying Rates: An Idea Whose Time Has Come?*, https://blog.aee.net/time-varying-rates-an-idea-whose-time-has-come.

the electricity rate ultimately charged to customers. By pricing electricity higher at times when demand is at its peak, customers are incentivized to shift their use to off-peak times, minimizing their electricity use when it matters most to the grid. Rates with prices that vary throughout different hours of the day or days of the week are known as time-varying rates.

The benefits of time-varying rates to utilities and customers are not limited to aligning rates more closely with the underlying costs associated with generating and delivering electricity. Time-varying rates are also an effective tool for motivating customers to shift their energy usage to off-peak or other desirable time periods to help achieve certain grid outcomes, such as renewable energy integration. For example, time-varying rates can help utilities maintain grid stabilization by signaling lower prices to customers for hours during which there is a significant amount of uncurtailable renewable generation.

While a form of time-varying rates—TOU rates—have been offered by utilities for decades, the recent increase in consumer adoption of distributed energy resources has spurred a new wave of rate offerings, including those specifically designed for EV customers.

Definition of EV Time-Varying Rates

For the purposes of this report, we included residential time-varying rates that were identified and marketed as rates specifically available to EV drivers. Often, these rates have specific off-peak or super off-peak windows designed to accommodate the charging duration needs of EVs and to incentivize charging during designated off-peak periods. The rates are sometimes—though not always—limited to EV drivers. Some of these rates apply to the customer's entire home energy usage, while other rates are specific to the customer's EV charging load. There are instances where an EV TOU rate looks similar in design to a generic TOU rate and is marketed as an EV rate. The authors used the rate title and descriptions developed by the utilities to identify the residential EV rates listed in Appendix A and the utility survey outreach contact list.

A typical on-board EV charger consumes about 3.3 to 9 kilowatts (kW) of demand, which can exceed the total peak demand of a home, depending on the region. Level 2 charging loads for vehicles with larger battery packs can be up to 20 kW.[13] A concern utilities face, as the penetration of EVs continues to increase, is the potential for the clustering of EVs in certain sections of the distribution system. If an EV cluster develops on a particular feeder, it could become overloaded and result in the need for costly repairs and upgrades by the utility. Time-varying rates offer utilities a potential solution by incentivizing customers to shift their EV charging load from peak to off-peak time periods, during which feeders have more available capacity and are less likely to become overloaded.

Residential EV charging load is well-suited to respond to price signals.[14] Most light-duty EVs are parked the majority of the day and overnight[15] and can be easily programmed through the car and/or the charger to begin charging at a pre-set time. Time-varying rates are an effective tool to incentivize customers to shift their charging to off-peak periods, as confirmed by our utility and customer survey findings.

In this report, time-varying rates are placed in one of seven categories: Time-of-Use, Subscription Rates, Off-Peak Credits, Real Time Pricing (RTP), Variable Peak Pricing (VPP), Critical Peak Pricing (CPP), and Critical Peak Rebates (CPR):[16]

- **Time-of-Use Rates** typically have two or more price intervals (e.g., peak, off-peak, super-off-peak) that differ based on levels of demand observed throughout the day. Sometimes, these prices vary by season, but both the prices and the designated price interval hours for each tier remain constant.
- **Subscription Rates** allow customers to pay a fixed monthly fee for electricity and other utility-provided services in exchange for unlimited consumption during specified hours of the day or days of the week.
- **Off-Peak Credits** can take the form of a fixed or variable incentive provided as a rebate or a bill credit in exchange for restricting consumption to designated hours of the day or days of the week.
- **Real Time Pricing (RTP)** are variable, hourly prices determined either by day-ahead market prices or real-time spot market prices.

13 SEPA, 2019, *A Comprehensive Guide to Electric Vehicle Managed Charging*, see Table 1.

14 Multi-Unit Dwelling (MUD) customers may face different considerations than typical residential customers when responding to time-varying price signals. For example, tenants residing in MUDs may share common EV chargers and would likely not have equal access to the chargers during lower-priced off-peak time periods. This could result in potential access and equity issues based on the schedules of each tenant.

15 See Donald Shoup, 2011, *The High Cost of Free Parking*, which asserts cars are parked up to 95% of the time.

16 Definitions adapted from: Environmental Defense Fund, 2015, *A Primer On Time-Variant Electricity Pricing*, https://www.edf.org/sites/default/files/a_primer_on_time-variant_pricing.pdf. Subscription Rates and Off-Peak Credits are not discussed in the EDF primer.

- **Variable Peak Pricing (VPP)** is a hybrid of TOU and RTP, with price intervals (e.g., peak, off-peak) that are constant like a TOU rate but allow for the price charged during the peak tier to differ day to day.
- **Critical Peak Pricing (CPP)** has a higher rate at designated peak demand events (also called "critical events") on a limited number of days during the year to reflect the higher system costs during these hours.
- **Critical Peak Rebate (CPR)**, also called Peak Time Rebate (PTR), is the inverse of CPP. Utilities pay customers a rebate for each kWh of electricity they reduce during peak hours of peak demand events.

The latter four rate structures are known as "dynamic pricing" because the price signals are not static and more closely reflect the real-time market conditions. Some of these rate options can be combined on a single rate schedule. For example, a number of utilities offer customers a rate schedule which pairs a TOU rate with a CPP component.

Further details about time-varying rate options and illustrations are provided in Appendix C.

B. Benefits of Time-Varying Rates

Time-varying rates are successful in altering customers' charging habits. Benefits of shifting charging habits via rates, as defined by the Environmental Defense Fund[17] and others include:

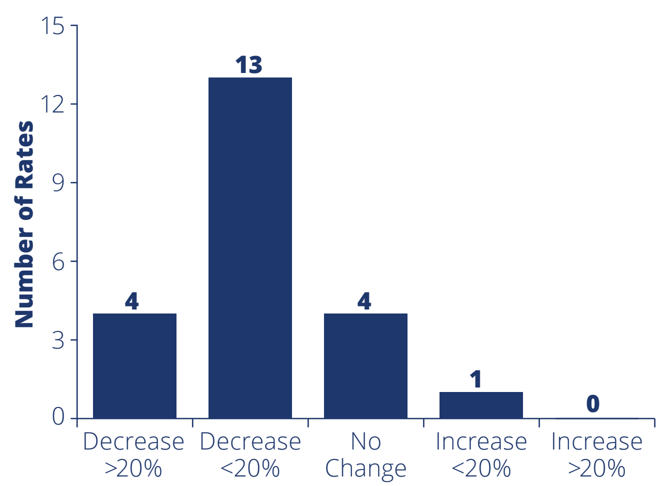
- Reducing energy supply costs by making greater use of lower-cost resources and limiting the use of the highest-cost energy;
- Reducing pollution by shifting demand to times when clean energy sources are generating electricity;
- Providing economic benefits to all utility customers through the grid efficiencies captured using off-peak charging;
- Avoiding or deferring capacity investments in generation, transmission, and distribution;
- Reducing the cost of infrastructure upgrades/replacement/repairs, particularly transformers;
- Responding to customer needs, incentivizing customer EV adoption, and influencing beneficial customer charging behavior; and
- Encouraging sustainable behavior changes, resulting in more reliable, predictable, and pronounced peak load reductions for utilities.

While some industry representatives have questioned the need for EV-specific rates to capture these benefits, our customer survey found those on an EV TOU rate were 1) more likely to charge off-peak a greater percentage of the time compared to their generic TOU rate counterparts and 2) more familiar with the rate rules (see "Customer Insights" chapter).

With the proper rate structure, utilities can use EV specific rates to provide load management, generate cost savings for EV owners, encourage more off-peak charging, and increase customer satisfaction (as indicated by enrollment length). These benefits are verified by responses to the utility survey, including:

- Utilities reported, on average, more than 90% of customers responded to the off-peak price signal.[18]
- The majority of utility respondents saw their average EV customer's charging bill decline (see Figure 2).
- Approximately 40% of utilities surveyed reported persistent changes in charging behavior after the introduction of EV time varying rates.[19]

Figure 2: Change in Customer EV Bill After Enrolling in EV Rate



Source: Smart Electric Power Alliance & The Brattle Group, 2019. N=30
Note: Six respondents indicated that the bill change was 'unknown'.

17 Environmental Defense Fund, 2015, *A Primer On Time-Variant Electricity Pricing*, https://www.edf.org/sites/default/files/a_primer_on_time-variant_pricing.pdf

18 Results from utility survey respondents. N=15

19 Results from utility survey respondents. N=29

- Utilities also saw a high level of retention on their EV rate, with over 95% of participants who were enrolled at the beginning of the year remaining enrolled at the end of the year.[20]

A 2014 San Diego Gas & Electric EV pricing pilot[21] found that EV owners were highly responsive to modest price signals and even more so to higher price ratios. Customers exposed to a price ratio of 1-to-1.2-to-2 (super-off-peak to off-peak to peak hours) shifted 73% of their charging to the super-off-peak period, while customers exposed to a price ratio of 1-to-2.4-to-3.8 (super-off-peak to off-peak to peak hours) shifted 84% of their charging to the super-off-peak period. The degree of load shifting increased consistently over the study horizon as customers became more familiar with the time-varying rate. This evidence of customer price-responsiveness is consistent with the customer survey results as discussed in the "Customer Insights" chapter of this report.

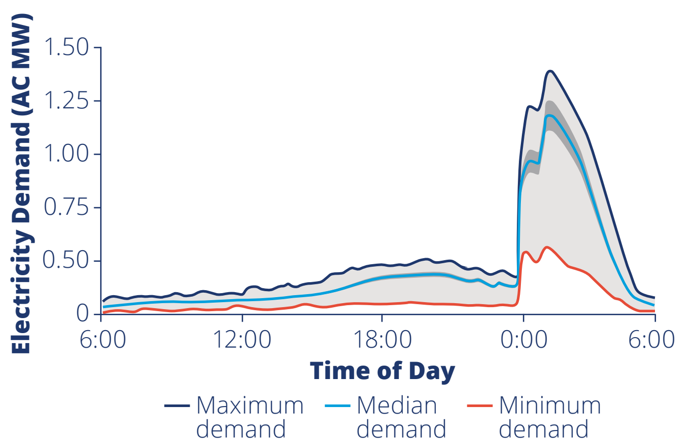
C. Considerations for Time-Varying Rates

While time-varying rates can provide a range of system benefits, they can also present operational challenges, particularly when applied to EV charging. Some concerns exist regarding the potential for households to program their EVs to begin charging exactly at the same off-peak time, leading to a new load "spike" (also known as a "timer peak") during these off-peak hours as illustrated in Figure 3. At the local distribution level, the result could be a new peak that would contribute to capacity constraints, the effect of which could be exacerbated by geographically clustered EVs. This issue was discussed at length in the SEPA report, *A Comprehensive Guide for Electric Vehicle Managed Charging*.[22]

Similarly, FleetCarma found in a 2019 study that static residential TOU rate structures reduce variability but can cause unintentional coincident load.[23] Innovative rate design practices, such multiple pricing intervals that gradually increase the price from the off-peak period over several hours, could help to address this concern. It is, however, an issue that could warrant more active management of charging load as EV adoption increases.

Active managed charging, which enables the utility or another third party to shift charging loads to reduce potential distribution system impacts and better align charging with lowest-cost electricity and renewable generation (e.g., during wind or solar peaks) could provide additional benefits. Beyond EVs, residential demand response and price-responsive controlled usage can also be provided by other equipment, such water heaters, air conditioners, swimming pool pumps, and laundry equipment. Gaining customer comfort with controlled loads, such as enrollment in an EV managed charging program, may contribute to greater acceptance of other programs.

Figure 3: Illustration of San Diego Gas and Electric Weekday "Timer Peak"



Source: MJ Bradley & Associates, 2017[24]
Note: This is a rendition of the original graphic.

As part of a comprehensive EV strategy, utilities should identify the stage gates at which they can introduce active managed charging in addition to passive managed charging programs, such as a time-varying rate. The timing of an active managed charging program will depend on several variables, including the penetration of EVs in a utility service territory (especially among those that can shift loads) and the cost-benefit of load management options. While the exact parameters of this transition are not yet fully defined, from a qualitative perspective, it may resemble Table 2. As an example, utilities in states

20 Results from utility survey respondents. N=16

21 Nexant, February 2014, *Final Evaluation for San Diego Gas & Electric's Plug-in Electric Vehicle TOU Pricing and Technology Study*. https://www.sdge.com/sites/default/files/SDGE%20EV%20%20Pricing%20%26%20Tech%20Study.pdf

22 Smart Electric Power Alliance, May 2019, *A Comprehensive Guide to Electric Vehicle Managed Charging*, www.sepapower.org.

23 FleetCarma, 2019, *EV Profile & Manage EV Charging Load For Demand Response*, https://www.fleetcarma.com/docs/ProfileandManage2019-FleetCarma-web.pdf&sa=D&ust=1565040346133000&usg=AFQjCNGcJrPwvJjBb1wDd4vihfFWAh_m8w

24 MJ Bradley & Associates, April 2017, *Electric Vehicle Cost-Benefit Analysis*, https://mjbradley.com/sites/default/files/CO_PEV_CB_Analysis_FINAL_13apr17.pdf

like Hawaii and California facing rapid growth in EVs, high amounts of distributed solar, and higher electricity costs may achieve greater grid benefits through an active managed charging solution than through a traditional TOU rate.

Residential EV time-varying rates could serve as a bridge between passive and active managed charging options. As customers begin their EV journey, building a high level of trust between the customer and the utility is essential to the success of active managed charging. Customers don't buy EVs to provide grid support; however, if they had a positive load management experience using time-varying rates, they may be more likely to consider an active managed charging program.

American Electric Power (AEP) and its subsidiaries, are planning to leverage their existing utility smart meter networks to enable EV-only TOU rate offerings and implement an active load management program as highlighted in the case study in Chapter 6.

Table 2: Potential Residential EV Load Management Options Based on Utility System Conditions

EV Load Management Option	Penetration of Light-duty Residential EVs	Available Distribution Capacity (including substations/ transformers/ feeders)	Integration of Intermittent Loads (e.g., solar, wind)	Cost of On-Peak Electricity
Passive				
Behavioral Load Control (e.g., text message during system peak)	Low	High	Low	Average
Generic Time-of-Use Rate	Low	High	Medium	Above average
Generic Dynamic Pricing Rate	Low	High	High	High
EV Time-of-Use Rate	Medium	Medium	Medium	Above average
EV Dynamic Pricing Rate	High	Medium	High	High
Active				
Managed Charging (designed to minimize distribution impacts)	High	Low	High	Above average
Managed Charging (designed to minimize on-peak electricity costs)	High	Medium	High	High
Vehicle-to-Grid	High	Low	High	High

Source: Smart Electric Power Alliance, 2019.

3) Residential EV Time-Varying Rates Landscape

Utilities are introducing residential EV time-varying rates with a variety of design features, configurations, and marketing strategies. This section identifies the current rates landscape, why utilities are pursuing them, how utilities are marketing them, and the levels of customer interest in residential EV rates.

A. Current Status

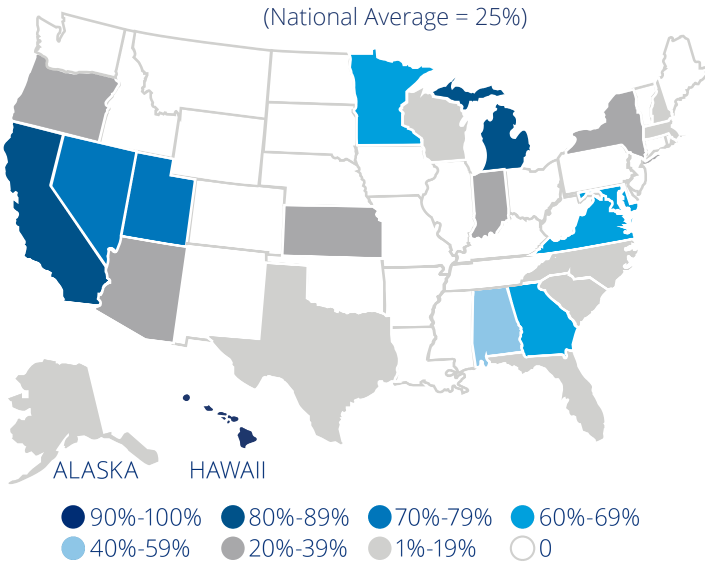
With the expanded adoption of residential advanced metering infrastructure (AMI), many utilities so-equipped are offering at least one residential time-varying rate. As of 2017, approximately 9% of U.S. utilities and energy suppliers offered a residential time-varying rate with over 6.5 million customers enrolled.[25]

As of September 2019, SEPA and Brattle identified 64 active residential EV rates being offered by 50 utilities.

The landscape of residential EV time-varying rate offerings is changing quickly with the majority of these rates introduced in the past few years. Figure 4 illustrates where these residential EV time-varying rates are located and the share of residential customers with access. It also highlights observations about these rates. Table 3 provides specific insights into the EV time-varying rates provided by the utility survey respondents.

Figure 4: Characteristics of Active Residential EV Time-Varying Rates

Percent of Residential Customers in Each State with Access to Time-Varying EV Rates
(National Average = 25%)



28 investor-owned utilities, **12** municipal utilities, and **10** electric cooperatives

18 pilot programs, **46** fully implemented residential rates

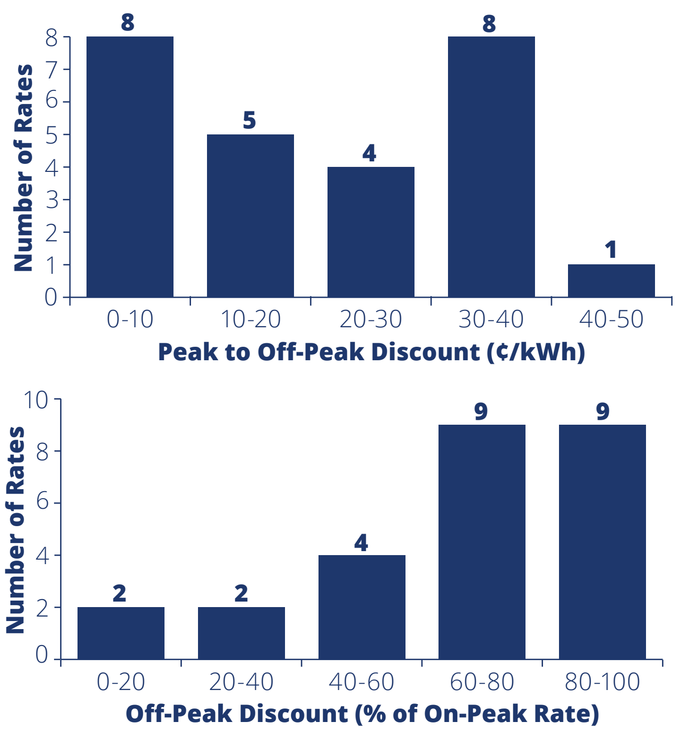
Of the 64 EV rates, **58** were TOU rates, **1** was a subscription rate with an on-peak adder, and **5** were off-peak credit programs.

How the rate applies to the home load:

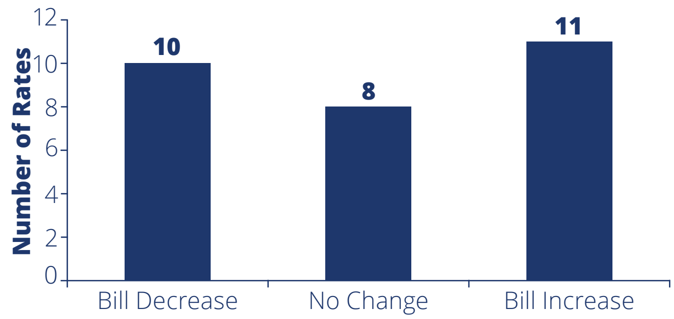
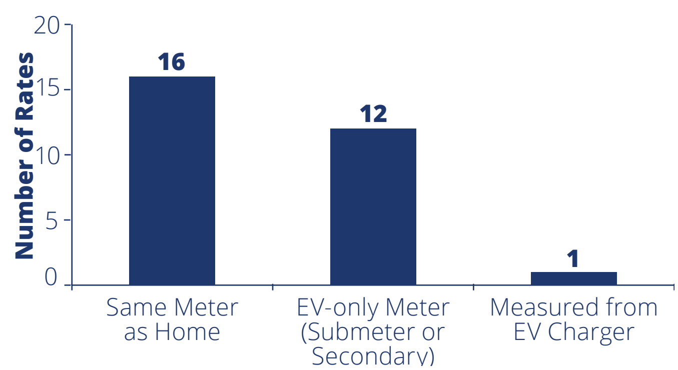
- **35** rates apply to the **total household energy consumption**, including the EV charging load.
- **21** rates **apply strictly to EV charging**. These rates typically require the installation of a second meter or submeter, and two rates are metered from a submeter in the EV charger itself.
- **8** rates allowed customers to **choose between whole home or EV-only options**.

Source: Smart Electric Power Alliance & The Brattle Group, 2019.

25 U.S. Energy Information Administration, Form EIA-861, 2017. https://www.eia.gov/electricity/data/eia861/. A total of 310 EIA electric power industry survey participants had residential time-varying rates with customers enrolled, in a population of 3,421 utilities and nontraditional entities such as energy service providers. Includes 290 entities with residential TOU rates, 14 with real time pricing, eight with variable peak pricing, 25 with critical peak pricing, and 12 with critical peak rebates. Note that Form EIA-861 does not include Subscription Rates and Off-Peak Credits as forms of time-varying rates.

<table>
<tr><th colspan="2">Table 3: Insights from Utility Survey Respondents with EV Time-Varying Rates</th></tr>
<tr><td>Utility Motivations for Offering Rate</td><td>Utilities designed the rates to:
▪ Encourage charging during low or negatively-priced wholesale power hours, such as when renewable generation is being curtailed.
▪ Discourage charging during specific times when the distribution system is constrained.
▪ Encourage EV adoption by lowering the overall total cost of ownership.</td></tr>
<tr><td>Rate Design Features</td><td>The TOU rate offerings in the survey differ significantly across design features such as:
▪ The peak-to-off-peak price ratio. Several pilot programs have begun testing rates with significant differentials between the peak and off-peak period, such as peak-to-off-peak price ratios in excess of 10-to-1.
▪ Number of pricing periods.
▪ The timing of those periods.
▪ Seasonality.</td></tr>
<tr><td>Peak-to-Off-Peak Price Ratios</td><td>The price ratios of the rates varied from 1.2-to-1 to 15.5-to-1, with a median of 3.6-to-1. Similar variation is observed in the absolute price differentials, which range from $0.02 per kWh to $0.44 per kWh, with a median of $0.20 per kWh. Figure 5 illustrates the peak to off-peak discount in cents per kWh as identified by the utility survey.
Figure 5: Peak to Off-Peak Discount by Cents/kWh and Percent of On-Peak Rate


Source: Smart Electric Power Alliance & The Brattle Group, 2019. N=26.</td></tr>
</table>

Table 3: Insights from Utility Survey Respondents with EV Time-Varying Rates (Continued)	
Bill Neutrality Is Not a Standard Feature	Approximately one-third of the time-varying EV rates analyzed in the utility survey would provide an average participant with bill savings compared to the default rate, even in the absence of changes in charging behavior. For the other two-thirds, the customer's bill would remain the same or increase if charging load was not shifted to the off-peak period. Rates offering bill neutrality or savings encourage enrollment, however, as Figure 6 shows, this is not a standard feature. **Figure 6: Expected Bill Impact for EV Customer if Enrolled in EV Rate Without Change to Charging Pattern**  Source: Smart Electric Power Alliance & The Brattle Group, 2019. N=29.
Upfront Customer Costs	Despite potential savings, **some customers are deterred by the initial enrollment fees** for the installation of additional metering equipment (e.g., second meter, submeter, meter collar, EVSE). Some utilities socialize those expenses as part of a broader EV program so the customer enrollment fee is less of an issue for participants.
Cost Savings	Most of the rates are **more advantageous for flexible loads such as EVs** (including customers willing to shift EV charging to off-peak periods) **than the otherwise applicable residential rate**, offering significant savings opportunities through cheaper off-peak rates and reduced or eliminated rate tier(s).
Rate Enrollment rRequirements	In some cases, rate enrollment was required for customers to receive **utility-sponsored EV rebates or utility-financed charging infrastructure**.
Metering Configurations	Metering configurations varied widely with a majority being applied to the whole home (Figure 7). **Figure 7: EV Rate Metering Configuration for Utility Survey Respondents**  Source: Smart Electric Power Alliance & The Brattle Group, 2019. N=29.

Source: Smart Electric Power Alliance, 2019

Innovative Rate Example: Free Energy! Cobb EMC NiteFlex Rate

Cobb Electric Membership Corporation in Georgia created a unique rate to incentivize EV owners to shift their charging to off-peak hours. Using the NiteFlex rate, customers can recharge their EV during super off-peak for free for the first 400 kWh per month.[26] The rate is split into three tiers with peak, off-peak, and super off-peak times:

- The **peak** rate ($0.1350/kWh) is between 1pm - 9pm.
- The **off-peak** rate ($0.07181/kWh) is between 9pm - Midnight and 6am - 1pm.
- The **super off-peak** rate is between Midnight - 6am where the initial 400 kWh are free, and any additional usage is at a rate of $0.045/kWh.

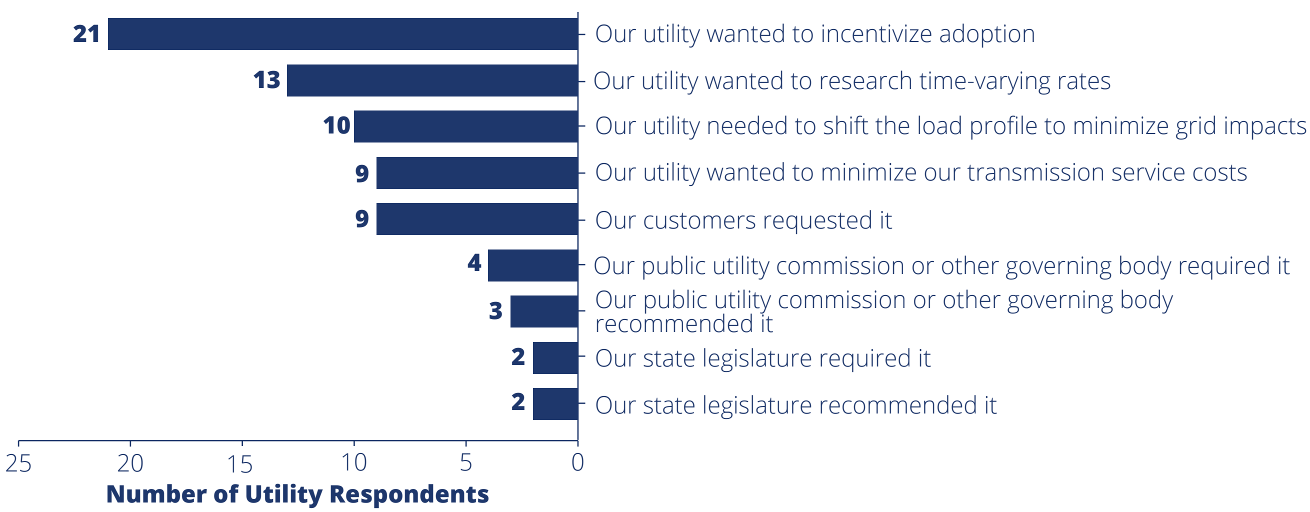
In addition to EVs, this rate also applies to other smart appliances or energy loads that can be shifted to later hours.

B. Why Are Utilities Pursuing EV Time-Varying Rates?

In response to the increased customer adoption of light-duty residential EVs, utilities have been developing and offering their customers EV time-varying rates. As Figure 8 shows, the four most commonly cited reasons were to incentivize (in the context of encouraging and promoting) EV adoption, research time-varying rates, shift the load profile, or minimize transmission costs. Less than half the utilities offering residential EV time-varying rates did so because their customers requested it or because the utility governance board or legislative body required or recommended it. Additional insights about utility motivations and lessons learned are included in the chapter, "Features of Effective EV Time-Varying Rates."

Respondents indicated that customers with Level 2 chargers and battery electric vehicles (BEVs) were more likely to enroll in an EV time-varying rate. Though the reasons weren't captured in the utility survey, higher enrollment for customers with Level 2 chargers and BEVs could be due to the amount of energy required to charge larger batteries leading to potentially higher bill savings. Knowing that enrolled customers are highly motivated by saving money, these larger savings may drive BEV customers to enroll. This may indicate that as more customers purchase BEVs over plug-in hybrid electric vehicles (PHEVs), the pool of potential EV rate customers will grow.

Figure 8: Reasons Utilities Created EV Time-Varying Rate



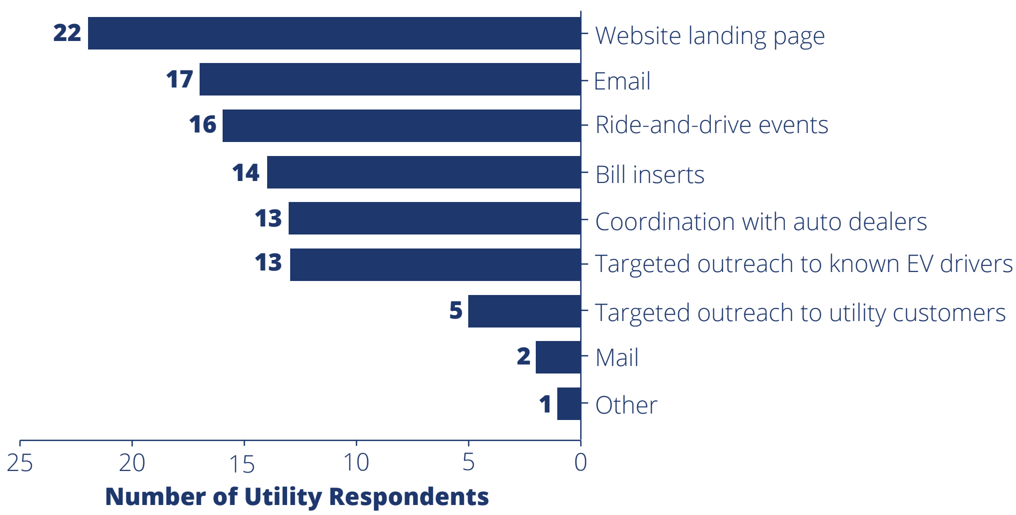
Source: Smart Electric Power Alliance & The Brattle Group, 2019. N=29. Respondents selected all that applied.

26 Cobb EMC, 2019, NiteFlex Rate, https://www.cobbemc.com/content/niteflex.

C. How are Utilities Marketing EV Time-Varying Rates?

A wide range of methods are used to market the EV rates. Utilities typically used more than one method, favoring the easiest and lowest-cost solutions such as a website landing page and emails (Figure 9). Ride-and-drive events are also popular among utilities; however, as discussed in the "Consumer Insights" chapter, ride-and-drive events may be less successful at recruitment.[27] Bill inserts, coordination with auto dealers, and targeted outreach to known EV drivers are also common strategies.

Figure 9: Utility EV Rate Outreach Methods



Source: Smart Electric Power Alliance & The Brattle Group, 2019. N=29. Respondents selected all that applied.

D. Consumer Interest in EV Rates

A recent report, *Rate Design: What Do Consumers Want and Need?*[28], by the Smart Energy Consumer Collaborative (SECC), a nonprofit that has been researching consumers' energy-related needs and wants since 2011, identified interest in EV rates from residential customers. SECC surveyed consumers from two types of rate states:

- **Alternative rate states**[29] offer rates beyond flat rates including TOU, interruptible load, VPP, CPP, RTP, net energy metering, low-income subsidies, and green power plans. These states include California, Wisconsin, Oklahoma, Delaware and the District of Columbia.
- **Traditional rate states** offer flat rates, flat progressive (include pricing tiers that increase in price with volume) rates, and flat regressive (including pricing tiers that decrease in price with volume) rates. These include all remaining states divided between the Northeast, Midwest, South and West.

When customers were asked to rate their interest on a scale of 0-10, with 0 meaning "not at all" and 10 meaning "very interested", respondents gave an average of 6.2 across all states (Table 4).

Interest did not vary significantly from state to state; however, different segments of the population had widely varying levels of interest (Table 5). Green Innovators and Tech-savvy Proteges both indicated an above average level of interest.[30]

27 A possible reason for this difference in data could be that utilities with higher enrollment were more proactive in outreach, and ride-and-drive events were a part of that outreach. The apparent success of ride-and-drive events from the utility's perspective could merely be a sign of the utility's overall more effective methods of outreach.

28 The full versions of SECC's research reports are available exclusively to members of the organization. Learn more about membership at smartenergycc.org.

29 Alternative rate states were defined by SECC and described in the report research methodology.

30 See also: *SECC, Consumer Pulse and Market Segmentation—Wave 7*, 2019. https://smartenergycc.org/consumer-pulse-and-market-segmentation-wave-7-report/.

Table 4: Residential Interest in EV Rate Plans, by State Type			
State Type	**States Include**	**Customer Interest**	**# Responses**
Alternative Rate State	California, Wisconsin, Oklahoma, Delaware and the District of Columbia	6.2 out of 10	N=546
Traditional Rate State	All remaining states that are not alternative rate states	6.0 out of 10	N=592
All States	All states	6.2 out of 10	N=1,138

Source: Smart Energy Consumer Collaborative, 2019.[31]

Table 5: Residential Interest In EV Rate Plans, by Segment			
Segment	**Characteristics**	**Customer Interest**	**# Responses**
Green Innovators	Lead the way in energy conservation. They are primarily middle aged (40%, 35–54) and evenly split gender-wise. They are more likely to have a post-secondary education. The combination of high education and being established in their career corresponds with another segment characteristic — they have the highest incomes. In fact, one-in-five households has a six-figure income.	7.1 out of 10	N=278
Tech- Savvy Proteges	Consumers who have the skill set and interest to save energy but need a push to take action. This segment is more likely to be male and younger. One-third are aged 18–34. Half have a post-secondary education and live with three or more people. Despite having the highest employment rate (67%), they are more likely to be middle-income earners. While they have the highest homeownership rate, they are also the most transient — half have moved cities in the past five years.	6.5 out of 10	N=392
Movable Middle	Straddles most metrics and are neither tuned-out nor highly engaged. Demographically, the Moveable Middle skews older and they're more likely to be retired. They have lower incomes and are less educated than the Green Innovators and Potential Proteges we have discussed. These consumers like to stay put—70 percent have not moved in the past five years, and over half live in an older home.	5.8 out of 10	N=262
Energy Indifferent	The oldest group of consumers overall. One-third are retirees aged 65+ and most have no post-secondary education. They are cost conscious. Many live in energy inefficient older homes, but because they have fewer appliances, their energy bills are relatively low.	4.7 out of 10	N=206

Source: Smart Energy Consumer Collaborative, 2019.[32]

31 SECC, 2019, *Rate Design: What Do Consumers Want and Need?*

32 Ibid.

This SECC research also shows a high level of interest in EV rates among certain segments of the population, which aligns with the customer types most interested and knowledgeable about EVs produced from additional SECC research in 2016 (Table 6). We would anticipate interest in EV rates to increase as more consumers become aware of the technology. However, in the near-term, customer segmentation should be considered as part of any outreach and marketing strategy.

Table 6: Level of EV Interest Defined by Consumer Segment

Segments	Perspectives	Key Demographics	Awareness and Interest in Solar/EV
Green Champions	"Smart energy technologies fit our environmentally aware, high-tech lifestyle."	Youngest, more likely to be college-educated	Relatively highest levels of solar and EV, nearly four times the interest level of Status Quo.
Savings Seekers	"How can smart energy programs help us save money?"	Younger, more likely to be college-educated	Lower level of awareness and interest in all types of solar and EV.
Status Quo	"We're okay; you can leave us alone."	More likely middle age, lower income renters, living in non-single family dwellings, less likely to be educated	Relatively lowest level of awareness and interest in all types of solar and EV.
Technology Cautious	"We want to use energy wisely, but we don't see how technologies can help."	Most likely homeowners who are older in age, less likely to be college-educated	Marginally higher than Savings Seekers on awareness and moderate interest in solar and EV.
Movers & Shakers	"Impress us with smart energy technology and maybe we will start to like the utility more."	More likely middle age, higher income, singe-family homeowners, college-educated	High levels of awareness comparable to Green Champions on average, but moderate interest levels in solar and EV.

Source: Smart Energy Consumer Collaborative, 2016.[33]

4) Consumer Insights

To identify what customers want from time-varying EV rates[34] and why they may have not participated in available utility rate options, the project team developed a customer survey that was sent nationwide to existing Enel X JuiceNet charger customers. This survey gathered nearly 3,000 responses.[35] The vast majority of those sampled said their utility offered a TOU rate (Figure 10). A very low number of EV drivers (10%) were not aware if the utility offered a TOU rate, signifying that the sample was knowledgeable about their utility rate options.

Many of Enel X's customers reside in California, where close to half of the nation's EVs are located and where residential TOU rates are becoming the default rate for residential customers in the Pacific Gas & Electric, Southern California Edison, and San Diego Gas & Electric service territories.[36] Nearly 50% of respondents to Enel X's survey (1,422 out of 2,967 respondents) live in California. This report isolates the California population from the rest of the survey sample to minimize any survey bias. Not surprisingly, 90% of the California survey population reported having an

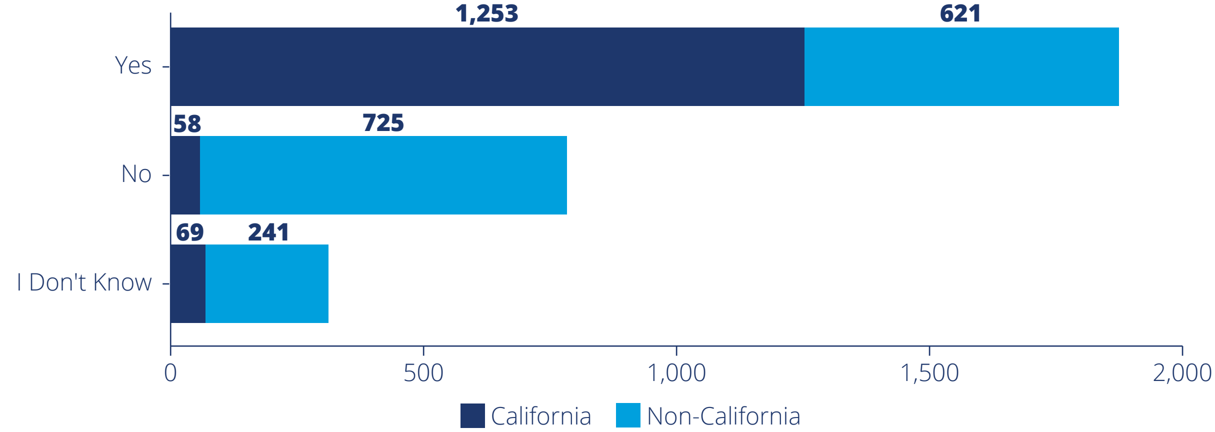
33 SECC, 2016, *Consumer Driven Technologies.*

34 Since the vast majority of time-varying rates currently offered to customers are TOU, we specifically used the term "time-of-use rates" in the survey to minimize customer confusion.

35 Non-U.S. respondents were removed from the sample prior to analysis.

36 Residential customers of these utilities currently have access to an optional TOU rate.

Figure 10: EV Customers with a TOU Rate Option (California and Non-California), by Total



Source: Smart Electric Power Alliance & Enel X, 2019. N=2,967.

available TOU rate. Nearly 40% of the non-California survey population had access to a TOU rate.

Survey Results: Enrolled TOU EV Customers and Non-Enrolled EV Customers

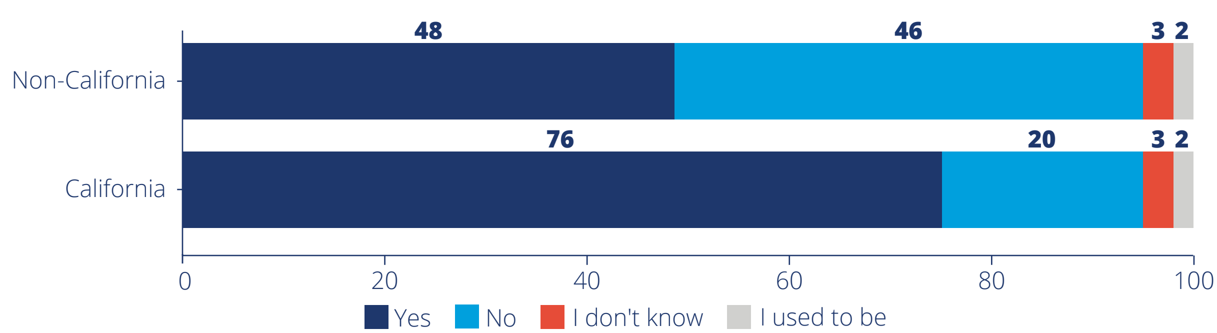
This section analyzes the survey results from two populations of EV driver groups (a total of 1,783 respondents)[37] that had an available utility TOU rate option: 1) enrolled customers and 2) customers that chose not to enroll in a TOU rate, which we term as non-enrolled.

The enrolled customers provided a variety of insights into their motivations, to what type of rate they subscribed (including generic and EV TOU rates), their level of familiarity and participation in the rate, and how they heard about the rate initially. For non-enrolled customers, the survey identified why they didn't participate and what it would take to change their mind.

A. Insights from Enrolled Time-of-Use Rate EV Customers

Among our sample, over 65% of participants in the customer survey said they are currently enrolled in their utility's TOU rate (Figure 11). Among the sample, 75% of California respondents were enrolled and nearly 50% of non-California respondents were enrolled. Of those who are enrolled in a TOU rate, 39% indicated that their TOU rate is EV-specific (Figure 12)—42% for California respondents and 30% for non-California respondents. Only 2% of EV drivers for both populations were enrolled in a

Figure 11: EV Customers Enrolled in a TOU Rate, by Percent



Source: Smart Electric Power Alliance & Enel X, 2019. N=1,880.

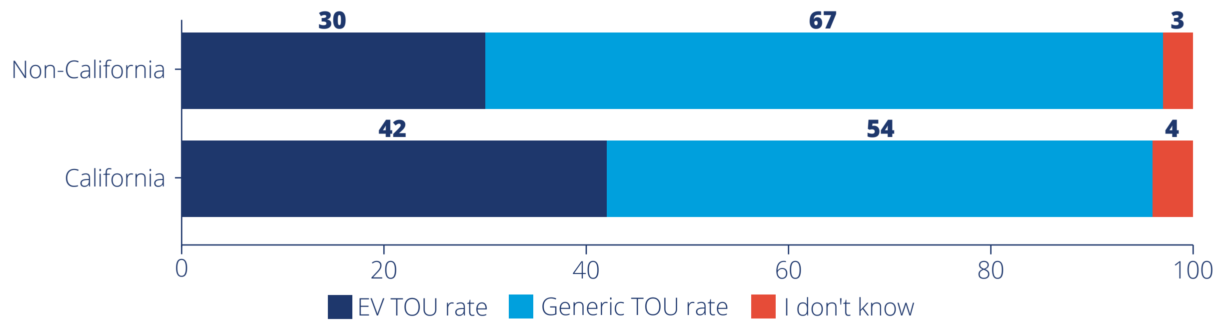
37 This population does not include respondents that did not know if they were enrolled or that were previously (and not currently) enrolled in a TOU rate.

TOU rate, but are no longer. This would suggest that once a customer enrolls, they remain on the rate.

Similar to the results from the utility survey, the Enel X survey respondents reported high levels of behavior shifting, with 87% of consumers charging off-peak 95% to 100% of the time (Figure 13). Respondents on an EV TOU rate were only slightly more likely to charge off-peak compared to their generic TOU counterparts. Perhaps more interesting, 7% more EV rate customers (including CA and non-CA) participated 100% of the time compared to the generic TOU population. This suggests that customers enrolled in a TOU rate understand how to participate and show a willingness to adjust their charging behavior.

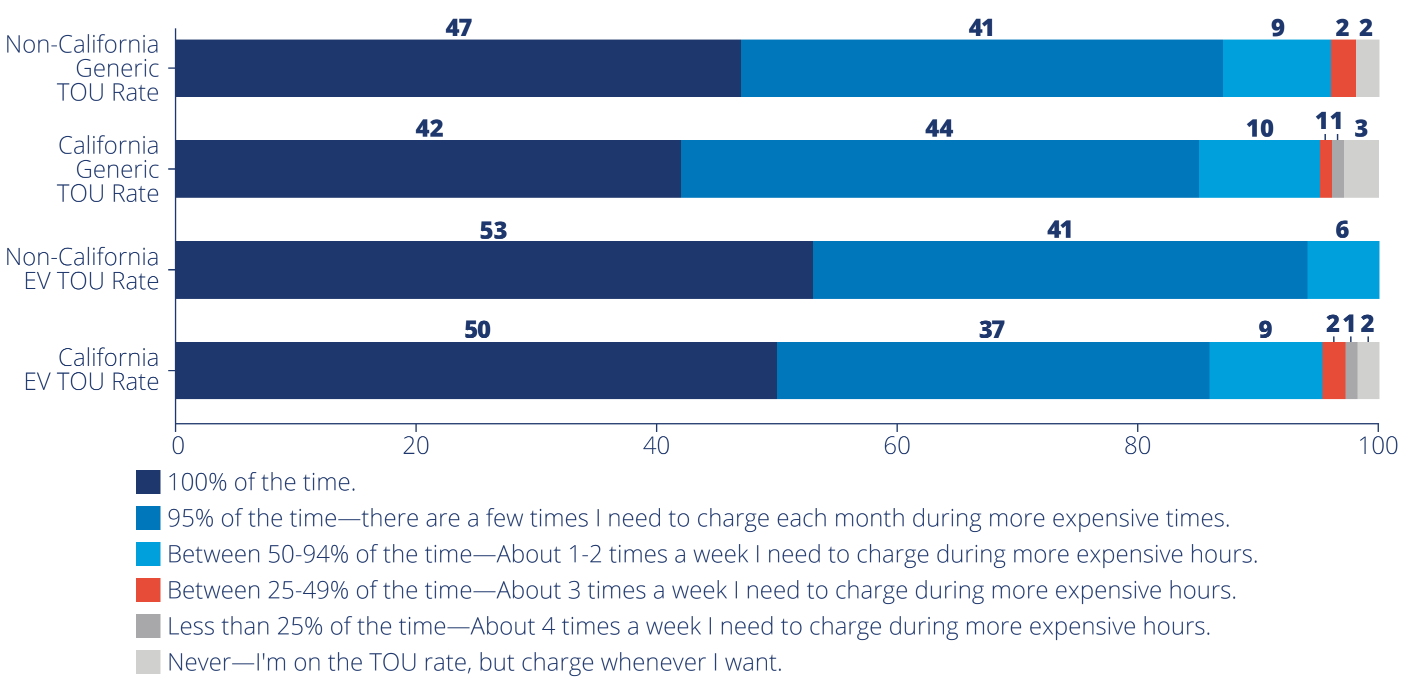
When asked how familiar the EV driver was with the rules around their EV rate, 86% (including CA and non-CA) indicated they were extremely familiar to somewhat familiar. Interestingly, EV drivers on the EV TOU rate were more familiar with their rate rules by nearly 10% (including CA and non-CA) compared to those on a generic TOU rate (Figure 14). While familiarity with these rates was high, these results suggest that utilities could do more to help their customers navigate the rules of the program—particularly with the 'somewhat familiar' group.

Figure 12: EV Customers Enrolled by TOU Type (EV or Generic), by Percent



Source: Smart Electric Power Alliance & Enel X, 2019. N=1,241

Figure 13: Average TOU Enrolled EV Customer Charge Time Done Off-Peak by TOU Type (California and Non-California), by Percent

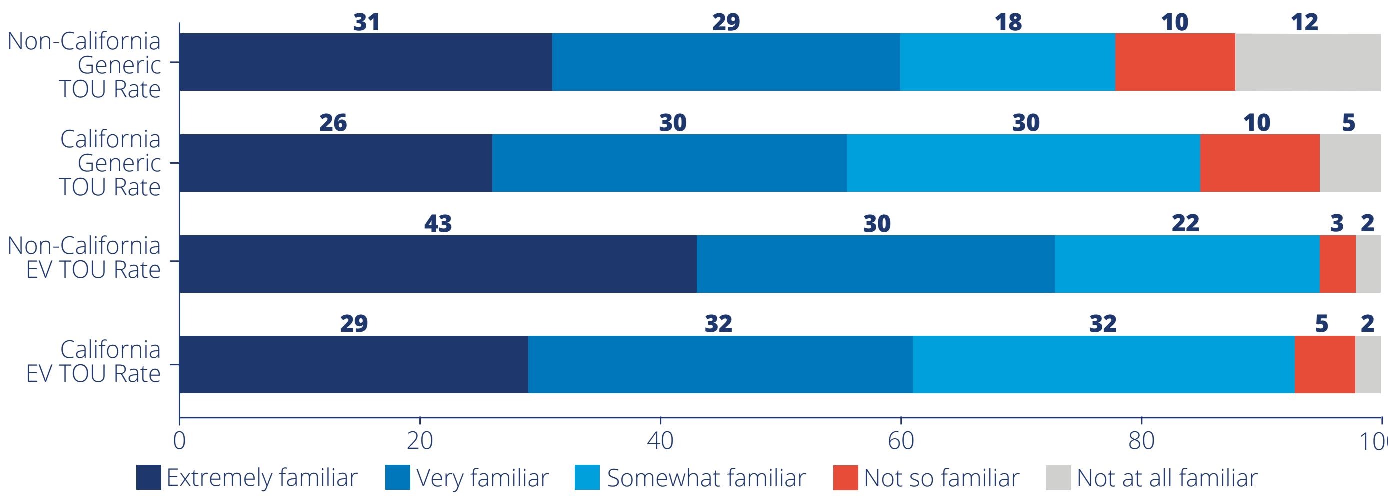


Source: Smart Electric Power Alliance & Enel X, 2019. N=1,167.

When respondents were asked why they enrolled in the TOU rate, 86% (including CA and non-CA) enrolled to save money (nearly 3x more than the next option) and for environmental benefits (Figure 15). Drivers on the EV TOU were 5 percentage points (including CA and non-CA) more motivated by savings than their counterparts on the generic TOU rate. Key for utilities is that while customers are primarily motivated by savings, environmental considerations are also important—by speaking to both of these motivations in program design and marketing campaigns, utilities can appeal to a wider range of customer types and interests.

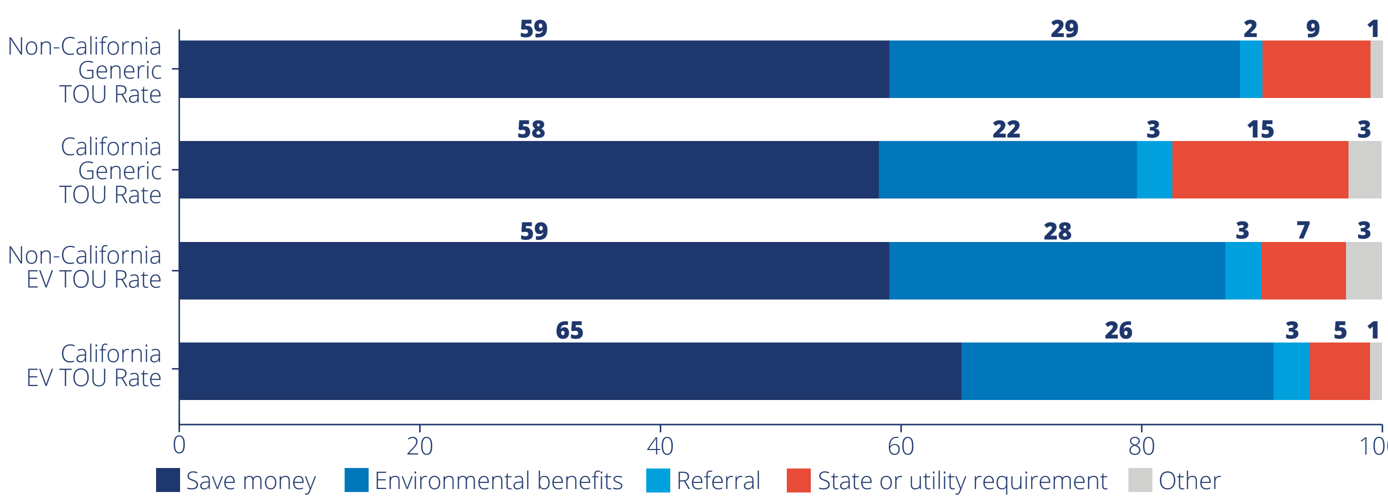
Survey respondents discovered their TOU rate through methods that are inexpensive and easy for utilities to use. Almost 70% discovered the rate through the utility website, bill inserts or flyers, and emails (Figure 16). Only 0.6% (10 out of 1,679) customers discovered their TOU rate through a ride-and-drive event. EV TOU rate participants relied more heavily on information from the utility website and through referrals than their generic TOU counterparts. There was not a significant difference between California and non-California respondents.

Figure 14: Enrolled EV Customer Familiarity with TOU Rate Rules by TOU Type (California and Non-California), by Percent



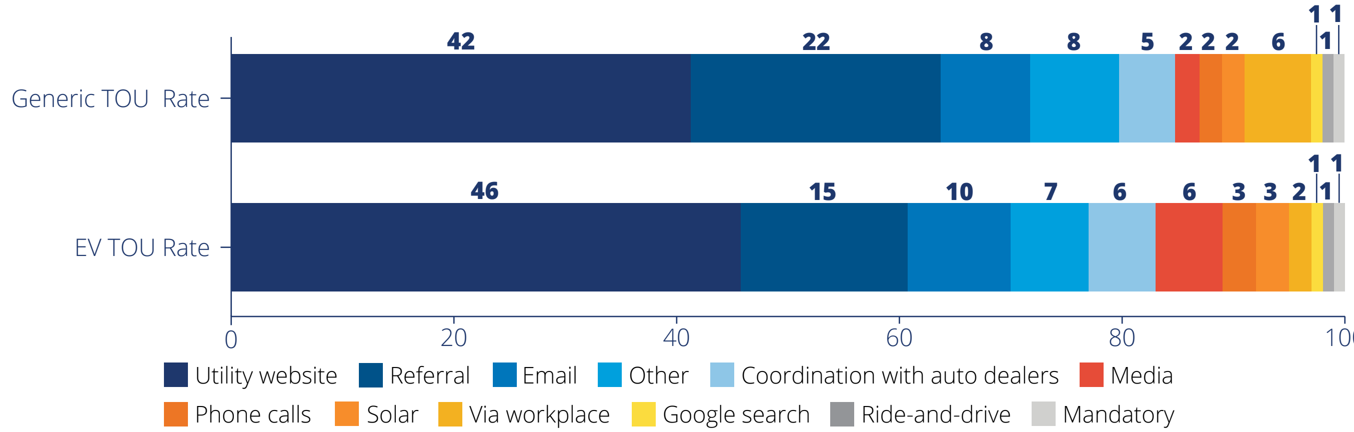
Source: Smart Electric Power Alliance & Enel X, 2019. N=1,107.

Figure 15: Motivation for EV Customer to Enroll by TOU Rate Type (California and Non-California), by Percent



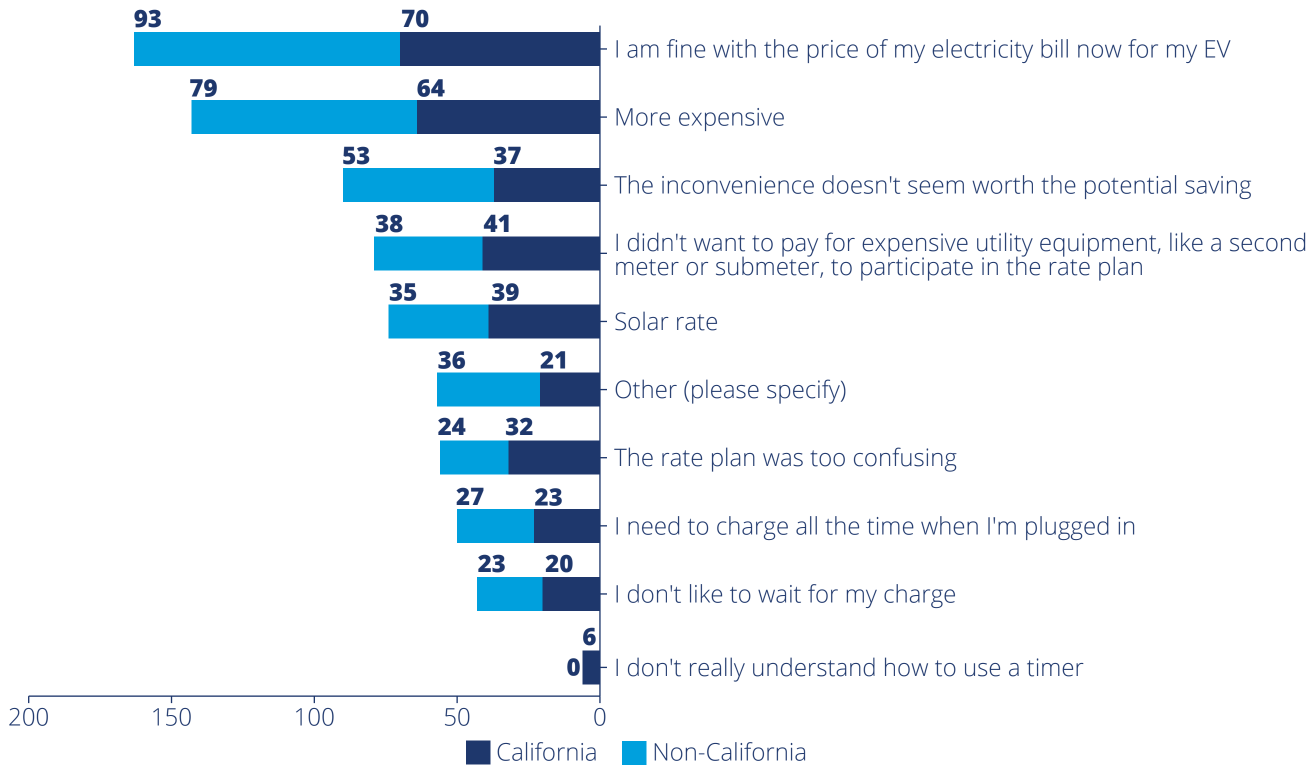
Source: Smart Electric Power Alliance & Enel X, 2019. Respondents selected all that apply. N=1,192. (1,704 options selected)

Figure 16: How Enrolled EV Customers Heard About the TOU Rate by Type, by Percent



Source: Smart Electric Power Alliance & Enel X, 2019. Respondents selected all that apply. N=1,173. (1,611 options selected)

Figure 17: Why EV Customers Did Not Enroll in a TOU Rate, by Total



Source: Smart Electric Power Alliance & Enel X, 2019. N=526. (761 options selected) Respondents selected all that apply.

B. Insights from Non-Enrolled EV Customers

When EV drivers were asked why they didn't enroll in a TOU rate, responses indicated insufficient savings and inconvenience (Figure 17).

Regarding insufficient savings, many did not want to pay for expensive utility equipment, they thought the rate would be more expensive, or they would not save enough money due to their electricity usage behavior. Others indicated that they were satisfied with the current price of their electricity bill. Many also didn't like the inconvenience of waiting for their charge or needed to charge frequently. Responses also indicated confusion about the rate, how to use timers, and conflicts with other existing rates, like solar rates.

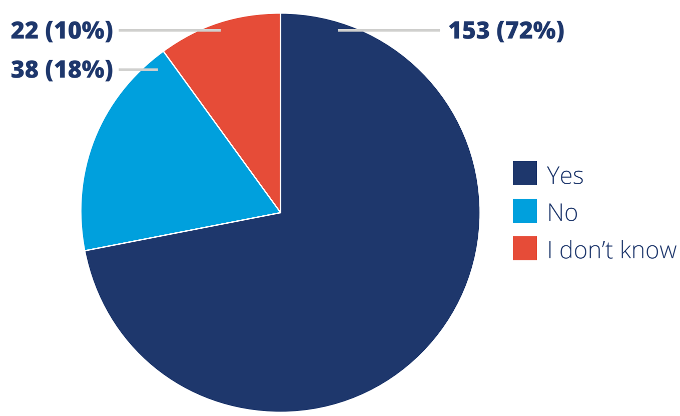
According to the survey, over 72% of non-enrolled customers were willing to charge their EV during off-peak hours (Figure 18).[38] If customers are willing to charge off-peak, but are not sufficiently incentivized by the potential savings, there must be a significant deterrent to enroll. A factor could be the perceived inconvenience of enrollment and compliance with the rate or insufficient financial incentive, as indicated in Figure 19.

Approximately 50% of respondents indicated they would need a savings of $100 or more per year to persuade them to enroll in a TOU rate, though the survey results also indicate that consumer preferences vary and not all customers are equally motivated by savings. Customers seeking more savings through their applicable rate may prefer a time-varying rate with a larger peak to off-peak ratio that offers a higher financial reward for shifting their charging to off-peak periods. Alternatively, as shown by Figure 17, some customers may be deterred by a perceived inconvenience of a time-varying rate with a higher peak to off-peak ratio or a limited off-peak period time window for cheaper charging rates. These findings suggest that it is difficult for utilities to appeal to all different customer types with only one rate design as discussed in the 'What to do about Metering' chapter.

By offering customers multiple rate options with significant variation, utilities may engage broader segments of their customer base and achieve higher enrollment rates.

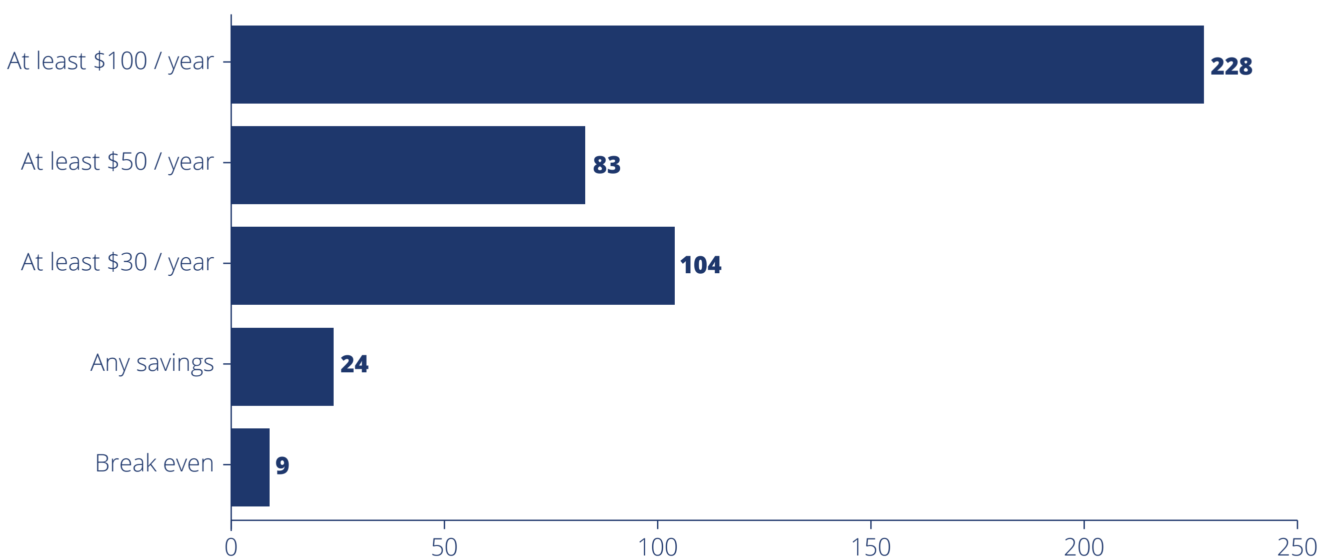
Utilities can employ behavioral programs as an alternative or supplement to a time-varying rate, in order to encourage more customer off-peak charging. Load management may be achieved through a variety of behavioral programs such as email and text alerts or education campaigns. These programs would require nominal utility investment.

Figure 18: Non-Enrolled EV Customers Willing to Charge Off-Peak, by Percent and by Total



Source: Smart Electric Power Alliance & Enel X, 2019. N=213.

Figure 19: Savings Required for EV Customers to Enroll in a TOU Rate, by Total



Source: Smart Electric Power Alliance & Enel X, 2019. N=448.

38 Note: The survey did not ask if customers were aware of the applicable off-peak hours as part of the available TOU rate.

5) Features of Effective EV Time-Varying Rates

This section summarizes the features of EV rates that contribute to the highest levels of customer enrollment. Data on customer enrollment was obtained through the utility survey, with information collected for 20 active, full-scale (excluding pilots) rate offerings. Nearly half (9 of 20 rates) reached enrollment levels of at least 25% (Figure 20). However, variation in enrollment levels is significant, ranging from less than 1% up to 80% of eligible customers (with 80% represented by Braintree Electric Light Department and highlighted in the case study in Chapter 7). Most rates in the utility survey had been offered for between two and five years with an average age of four years.

A. Utility Survey Findings

The survey identified a number of variations in rate design and marketing. Based on analysis by Brattle, some of these characteristics correlate to enrollment. Figure 21 highlights five of the attributes with the strongest relationship to high enrollment levels. In order of most-to-least influential:

1. Rates with an available **marketing budget** have enrollment 3x greater than those without (22% vs. 7%).
2. Rates driven by a **utility initiative** had significantly higher average enrollment than those offered to satisfy legislative or regulatory requirements or customer demands. Utility-driven initiatives had enrollment of over 30% compared to less than 15% for others;
3. **Rates providing bill savings** (in the absence of adjustments to charging behavior) have enrollment levels 2x higher than those with an expected bill increase;
4. Rates with **free enrollment** and no additional metering cost have enrollment 1.7x higher than rates with an additional cost to enroll; and
5. Rates that were promoted using **four or more marketing channels** have enrollment 1.4x those using three or fewer marketing channels.

These findings are intuitive, but many of the existing time-varying EV rate offerings identified in the utility survey did not include these attributes.

The length of time the rate was offered is not a relevant contributor to its achieved enrollment. Average enrollment is similar for rates that have been offered for at least four years (26%) compared to those that have been offered for less than four years (23%) (Figure 22). Offering a rate for a long period of time is not sufficient to attract customer enrollment. Rather, higher enrollment is driven by actively promoting the rate to customers through specific marketing initiatives.

According to the survey, ride-and-drive events and coordination with auto dealers were two marketing tools most significantly related to higher enrollment levels (see Figure 23). The consumer survey would indicate that ride-and-drive events were less helpful in discovering an EV rate, but this may be due to the limited number of utilities that currently offer them limiting the sample population with the opportunity to participate in an event. It's important to note that those utilities offering ride-and-drive events are using other marketing channels as well. As such, it was difficult to determine a cause and effect relationship specifically related to ride-and-drive events.

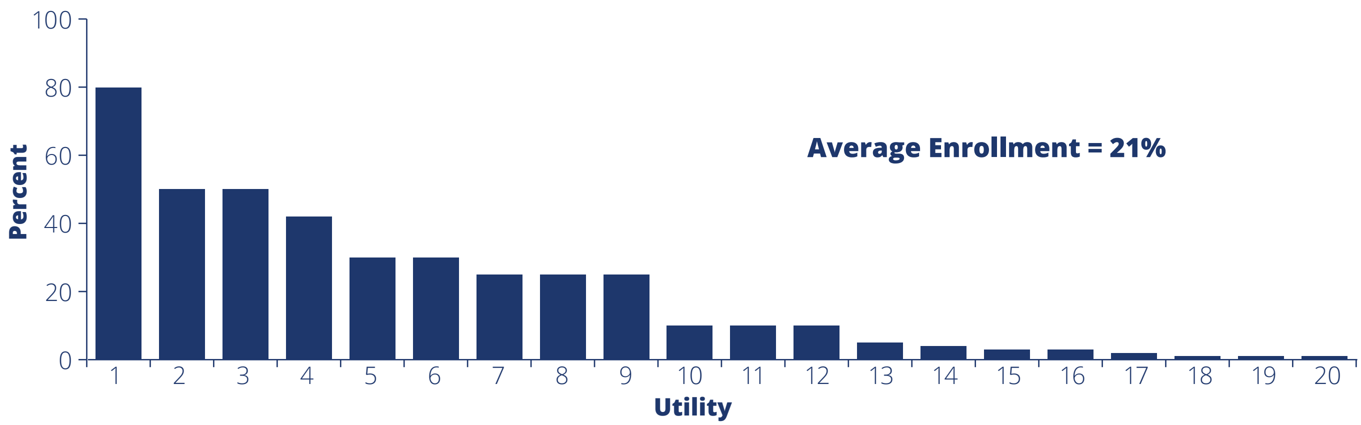
B. Utility Lessons Learned

Utility survey respondents offered lessons learned, primarily regarding customer interest, marketing, rate design considerations, and metering (discussed further in Chapter 7). EV rate design practices are in the formative stages, and the experiences of utilities with EV rates provide unique and useful insights. The following summarizes these perspectives; varied experiences sometimes produce conflicting insights.

Customer Insights and Marketing

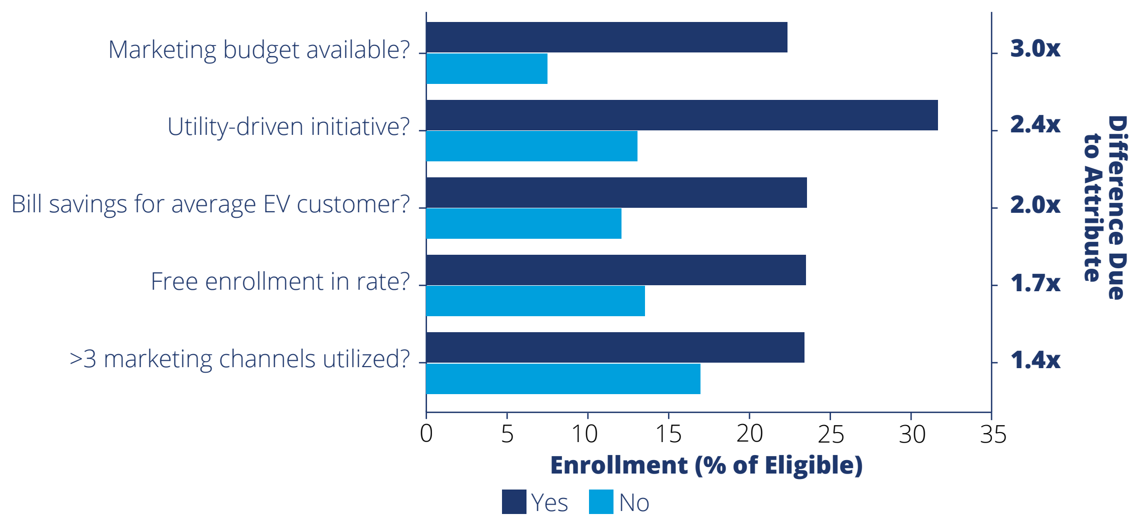
- Customer communication is key. Utilities should not depend on third-parties, such as dealers, to provide utility rate information.

Figure 20: Share of Eligible EV Customers Enrolled in the EV Rate



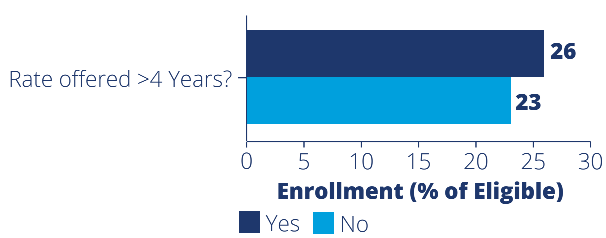
Source: Smart Electric Power Alliance & The Brattle Group, 2019. N=20.

Figure 21: Average Enrollment by Attribute



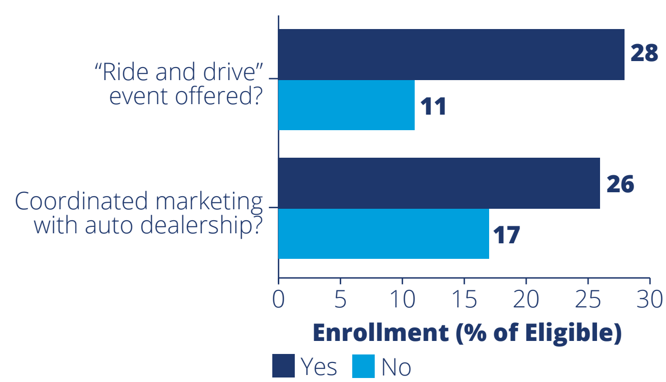
Source: Smart Electric Power Alliance & The Brattle Group, 2019. N=20

Figure 22: Rate Offering Duration Is Not a Factor in Enrollment Success



Source: Smart Electric Power Alliance & The Brattle Group, 2019. N=20.

Figure 23: Rate Marketing Efforts Are Important



Source: Smart Electric Power Alliance & The Brattle Group, 2019. N=20

- Creative recruitment is required, as enrolling customers is very challenging, even with large incentives and attractive rates.
- One western state utility experienced, “consistently high enrollment in their EV rate over the last 4-5 years, with approximately 25% of EV owners enrolled. This occurred with little active marketing, illustrating that customers (at least early adopters) are interested in saving on fuel costs.”
- While some utilities see EV rates as a way to promote EV adoption, one utility suggested that their in-state tax credit was a bigger sales incentive. The rate might encourage those customers to charge at night, but in their state, EV sales were driven mostly by state tax incentives. Further, other rates offered by the utility (e.g., a demand rate) could yield better savings for EV drivers.
- One utility said, “customers are very satisfied with the EV rate and change their charging behavior to maximize their savings. Promote/publicize the EV rate in every way possible and practical to inform the public.”

Rate Design

- One utility indicated a need to closely consider the number of hours for the off-peak rate and the price differential between the off-peak and super off-peak. In their case they had six hours in the super off-peak, but that customers preferred eight.
- One utility stated, “Customers are apprehensive to sign up for a rate that applies to their whole house usage as opposed to just their EV charging behavior.” Other utilities felt the opposite was true, due to customer apprehension about additional metering costs.
- Utilities also recommended building flexibility into the rate to accommodate changing grid conditions, such as a shift in the timing of the net system peak demand due to growing solar PV adoption.
- Though some utilities are concerned about eroding profitability through favorable off-peak pricing, one utility stated, “Even with a fairly high on-/off-peak differentials, enough usage occurs during peak that revenue is not as severely compromised as some expected.”
- As previously noted, the cost to participate is a major factor in enrollment. One utility stated, “Customers are sensitive to up-front costs to participate in the program.”
- Another utility found that a one-size-fits-all approach will not work. They suggest giving customers options that help them save money on their EVSE and metering costs. They also suggested using company-provided electricians to help customers set the charging schedule on their vehicles or in the chargers, which increased the possibility of 96% off-peak charging.
- From one utility’s perspective, they thought a discount during off-peak hours was a better alternative than increasing the price during the peak period.

Metering

- Utilities had varying opinions about the most effective way to meter and bill customers under a time-varying EV rate. One utility felt that submeters were the most effective metering method for EV time-varying rates given the wide variety of charging equipment options available to customers. Another utility felt that a submetered rate was successful at influencing charging behavior, but at a cost to the customer and the utility. They stated, “Managing that cost will be the primary hurdle to deploying submetering. It is still unclear how much more effective a submetered rate would be at influencing behavior when compared to a whole house rate.” A different utility suggested to not mandate a submeter, which for them, resulted in hundreds of extra dollars in cost of installation. They felt that a better alternative was to “require a smart EV charging station that could communicate and send the utility the off-peak usage data to provide an ‘incentive’ check each month or quarter.”
- A utility shared on second service metering options, “a separately metered EV rate is largely unpopular among EV owners. The added cost, time, and effort of adding a separate service is not attractive, and there are not easily apparent savings compared to the whole-house rate, which had similar pricing.”
- Another utility stated that due to the unpopularity of the up-front costs for second service, they were piloting other services/technologies, though “the second service is the more economic option.. [for example] cases with detached garages and a fully loaded existing service panel in the customer’s home.”
- “Whole house EV rates seem successful at influencing behavior, but prevents visibility into specific charging behavior. These rates are relatively straightforward to deploy,” was the opinion of another utility.

Notably, the top three drivers of time-varying EV rate enrollment are all factors the utility can control, including:

1. **Residential EV rates that offer customers the opportunity for savings compared to the standard rate:** EV rates must provide customers with an opportunity for financial savings, in order to be attractive to customers. Rates should be designed such

that the price signals are transparent and actionable, so customers have the information necessary and a sufficient incentive to shift their charging load to designated off-peak periods. Rates that are successful in encouraging off-peak charging behavior lower the utility's cost to serve, resulting in lower prices for customers.

2. **No additional metering charge or customer investment required:** The up-front costs associated with any of the metering options, for example a second meter or a submeter, was identified by several utility survey respondents as a deterrent to enrollment. One option to overcome this barrier is to include the customer's entire home load under the time-varying rate, minimizing the initial investment. However, some customers may not want to subject their entire home load to a time-varying rate.This presents a catch-22 for rate analysts. Creative rate design offerings are needed to overcome this tension. For example, the combination of a whole-house meter that does not differentiate by time, and a smart charger that reports TOU data for the EV consumption, can address this.
3. **The rate is promoted via a dedicated marketing effort:** To maximize enrollment, the rate should be promoted when customers are most engaged. This can be achieved at dealerships and ride-and-drive events when customers are making the EV purchasing decision, by electricians and charging station installers when customers are thinking about charging costs, and by tying enrollment to eligibility for utility-sponsored EV rebates or charging infrastructure purchases. This ensures the consumer is aware of the rate early in the process. **Typically, once the EV is purchased and the charger is installed, customer engagement is reduced and "momentum" towards the EV time-varying rate enrollment is lost.**

6) What To Do About Metering

There are many important rate design program considerations, but one of the most important is the meter. The available metering configurations influence the type of rates than can be offered to customers, the costs of enrollment, the type of administration, the ease of integration with existing billing systems, the security and reliability of charging signals, and the adaptability of the program to handle future EV technology changes. There are five basic ways to meter and bill residential customers for EV time-varying rates. The pros and cons for each are discussed in the section below and presented in Table 7.[39]

1. **Existing Meter:** This is used for a whole house rate, and leverages the existing meter.
2. **Second Meter:** This would be for an EV-only rate and requires a second service and the necessary home wiring, in addition to the customer's existing residential service.
3. **Submeter:** This would be used for an EV-only rate and would be connected to the primary meter, and may not require similar additional home wiring.
4. **EVSE Telemetry:** Utilities could leverage 1) built-in EVSE telemetry routed to the utility through the vendor/network service provider or 2) the EVSE would send data to the utility via AMI backhaul enabled by Power Line Communication (PLC) (e.g., Zigbee, GreenPHY).
5. **Load disaggregation:** Utilities would collect primary meter data and use an analytical tool to disaggregate the load and identify the portion used by the EV. This could also be accomplished with the assistance of a device, such as a meter collar.

Utility approaches to metering varied across the sample set. As new technologies providing improved capabilities emerge, those options will continue to expand. This section highlights utility approaches to metering today, the pros and cons of specific approaches, and case studies highlighting utilities that have developed innovative rate programs via their metering approach.

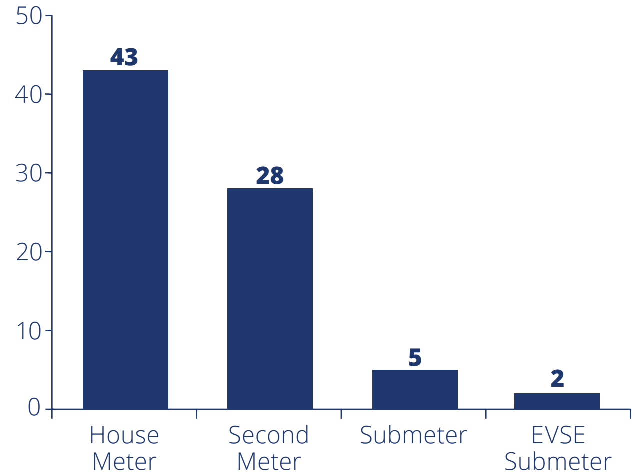
39 In addition to the evaluation of metering options in Table 7 and discussed throughout this section, utilities must also consider the relevant statutory and regulatory requirements applicable in their jurisdiction. Some metering configurations presented in this report may not be covered or allowed by existing statutes and regulations. For example, the Maryland Public Service Commission recently granted a temporary waiver of certain regulations governing the submetering process to the investor-owned utilities in the state for a five-year EV portfolio program. By granting the temporary waiver, the utilities can utilize customer EVSE devices as electric submeters for billing purposes without violating Code of Maryland Regulations. For more information, see Order No. 88997, "In the Matter of the Petition of the Electric Vehicle Work Group for Implementation of a Statewide Electric Vehicle Portfolio", Public Service Commission of Maryland, Case No. 9478, January 14, 2019.

A. Utility Approaches to Metering Vary

Utilities with active EV time-varying rates (see list in Appendix A) have employed a variety of approaches to metering and billing of EV charging load. Of the 64 EV rates, 43 used the primary meter (of which one used load disaggregation), 28 had a second meter, and 7 used a submeter (of which 2 were through the EVSE) as shown in Figure 24. Thirteen of the rates allowed more than one option under the same rate tariff.

It is important to note that the project team was unable to identify a correlation between the metering configuration and enrollment levels. As discussed in Table 7, challenges exist with all metering approaches, but utilities can develop creative solutions that help consumers meet their needs. For example, Braintree Electric—one of the featured case studies in this section—successfully enrolled 80% of EV customers in a whole home rate using load disaggregation to incentivize off-peak charging through a retroactive incentive payment (also known as an off-peak credit). Utilities also overcame metering limitations through effective marketing strategies.

Figure 24: Metering Configuration for EV Rate Population



Source: Smart Electric Power Alliance, 2019. N=64
Note: The authors did not identify AMI vs. non-AMI meters.

Using a whole-house meter avoids the costs of installing a second meter or submeter, however, it requires the entire home to be on the same rate as the EV. This creates customer concerns about bill increases or potential inconvenience related to changing behavior. While there are some tools customers can use to mitigate these concerns, a preferable solution may be to use a secondary meter or submeter to separately bill the EV portion of the consumption. However, it is important to address how to recoup the equipment and installation costs for the secondary meter or submeter through cost recovery.

There are two options for cost recovery:

1. collecting the costs directly from the customer (this could be via a lump-sum fee or monthly charge) or
2. socializing the costs across a broader group of customers.

According to the utility survey, 50% recovered the costs directly from the EV rate customer (in a lump sum fee or a monthly charge) and the other 50% recovered from all customers.[40]

Alternatively, utilities could leverage the primary smart meter through whole-home rates or load data disaggregation techniques to provide a more accurate accounting of EV charging load. One such technique, known as non-intrusive load monitoring (NILM) has been developed to disaggregate load components based on historical data of load signatures. These techniques become considerably more accurate when load data is collected in sub-hourly intervals. An example of this is highlighted in the Braintree Electric Light Department case study.

While there are potential benefits of using the telemetry in the EVSE, including lower submetering costs and customer choice, a major challenge is providing the data from an independent vendor/network service provider to the utility billing system. The integration is often costly and varies from utility to utility. Open standards will assist in lowering these costs but have not yet been implemented. The data needs to be in the proper format, and the business processes to use it have to be aligned, as well (e.g., timing of data delivery, rules for dealing with missing or invalid data, how the data file transaction occurs—i.e., how is it started, how is data receipt confirmed). Additional information about using the EVSE telemetry can be found in the Xcel Minnesota and San Diego Gas & Electric case studies in Section C.

40 Based on utility survey. N=12

Table 7: Pros and Cons of Different Metering Approaches

	Existing Meter	Secondary Meter	Submeter	EVSE Telemetry	AMI Load Disaggregation
Ability to Meter EV Charging Separately	No—Does not separate the EVSE from rest of load	Yes	Yes	Yes—Accuracy for billing purposes depends on EVSE manufacturer	Yes—Accuracy depends on ability to identify unique kW signature of EVSE
Utility Bill Integration	Easiest to integrate	Easiest to integrate	Easier to integrate	Difficult to standardize among multiple vendors and retroactively integrate into billing system; data via AMI backhaul more accurate	Depending on the format of the disaggregated data, may not integrate
Consumer Participation Cost	No additional cost	Depending on tariff, no up-front cost to consumer, or consumer pays for the full cost	Depending on tariff, no up-front cost to consumer, or consumer pays for the full cost	No additional cost if consumer already purchased the equipment; potential additional cost for compatible EVSE	Depending on tariff, some cost for administration, third-party costs, or equipment
Volume of Eligible Customers with AMI	Highest—independent of EVSE type	Highest—independent of EVSE type	Highest—independent of EVSE type	Limited to eligible EVSE vendors	Highest—independent of EVSE type

Source: Smart Electric Power Alliance, 2019.

B. Pairing Rates with Meters: Offering Customers More Choices

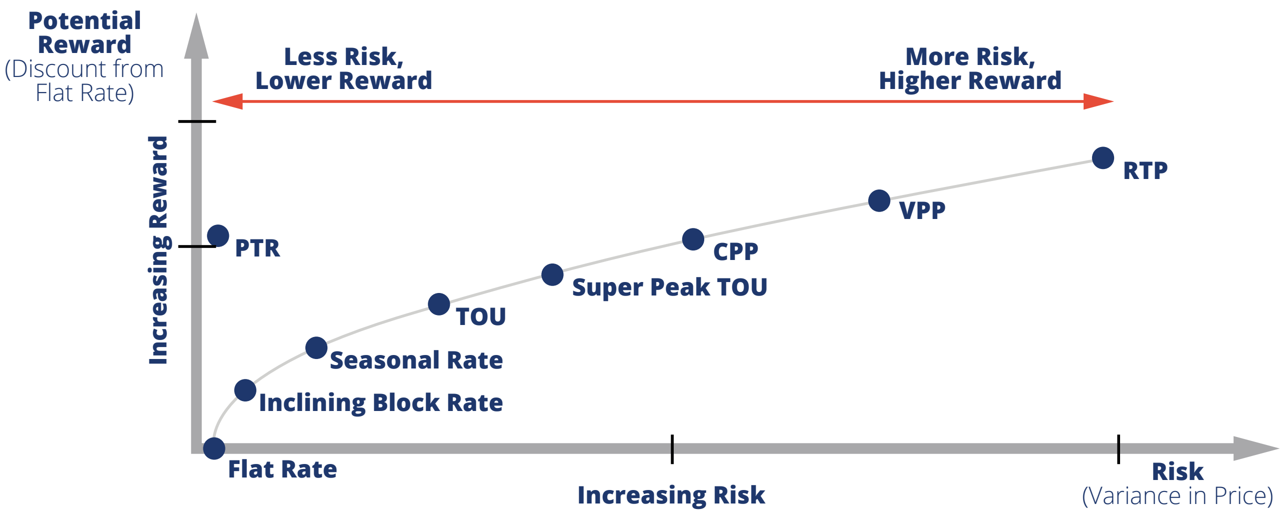
Rather than focusing on identifying a system-wide metering solution, utilities and customers may be better served by a combination of rate and metering configurations. As highlighted above in Table 7, and further explained below in the utility case studies, each type of rate offering and metering configuration offers advantages and disadvantages for utility implementation and customer appeal. For example, a separately-metered EV-Only rate option may allow utilities to design a rate to convey price signals specific to customer EV usage patterns. A benefit of this option is that utilities do not have to consider other household appliances and load in the design of the rate. Likewise, customers will not be required to adjust their non-EV residential energy consumption in order to maximize savings under the rate. This flexibility could allow the utility to design a rate that appeals to EV customers with higher financial risk tolerances by offering a TOU rate with a higher peak-to-off-peak price ratio or a dynamic pricing rate.

When considering time-varying rate options, financial risk-reward trade-offs are associated with each rate that utilities consider, as not all customers will tolerate the same risk (see Figure 25). According to the Regulatory Assistance Project, "rates offering the most reward (in terms of bill savings potential) are also the most risky (in terms of exposing the customer to the volatility of wholesale electricity markets). Which rates customers select will be determined by their risk tolerance."[41]

Alternatively, a whole-house rate may offer utilities a more forward-looking approach to encourage customer off-peak consumption for not just their EV, but other energy-intensive appliances such as electric water heaters. As rate designs continue to evolve and technologies mature, utilities may find that more complex and comprehensive "smart house" rates—providing grid-integrated water

41 Regulatory Assistance Project and The Brattle Group, July 2012, *Time-Varying and Dynamic Rate Design*, https://www.raponline.org/wp-content/uploads/2016/05/rap-faruquihledikpalmer-timevaryingdynamicratedesign-2012-jul-23.pdf.

Figure 25: Conceptual Representation of the Risk-Reward Tradeoff in Time-Varying Rates



Source: The Brattle Group, 2012.[42]

heating, smart thermostats, smart laundry, and smart charging as a package, for example—offer an appealing opportunity for grid benefits and customer savings in addition to technology or appliance-specific rates.

The best metering configuration for a customer is influenced by multiple factors, such as pricing, their rate structure (e..g, TOU or a dynamic rate), applicable enrollment or equipment fees, and the hours designated as peak and off-peak time periods. In addition to a customer's financial risk tolerance, utilities also need to consider important behavioral considerations, such as work schedules and the flexibility to shift electricity consumption to designated off-peak hours for particular appliances or for the entire home. These factors interact, and can represent an array of different EV customer "types" (Figure 26). Examples could include:

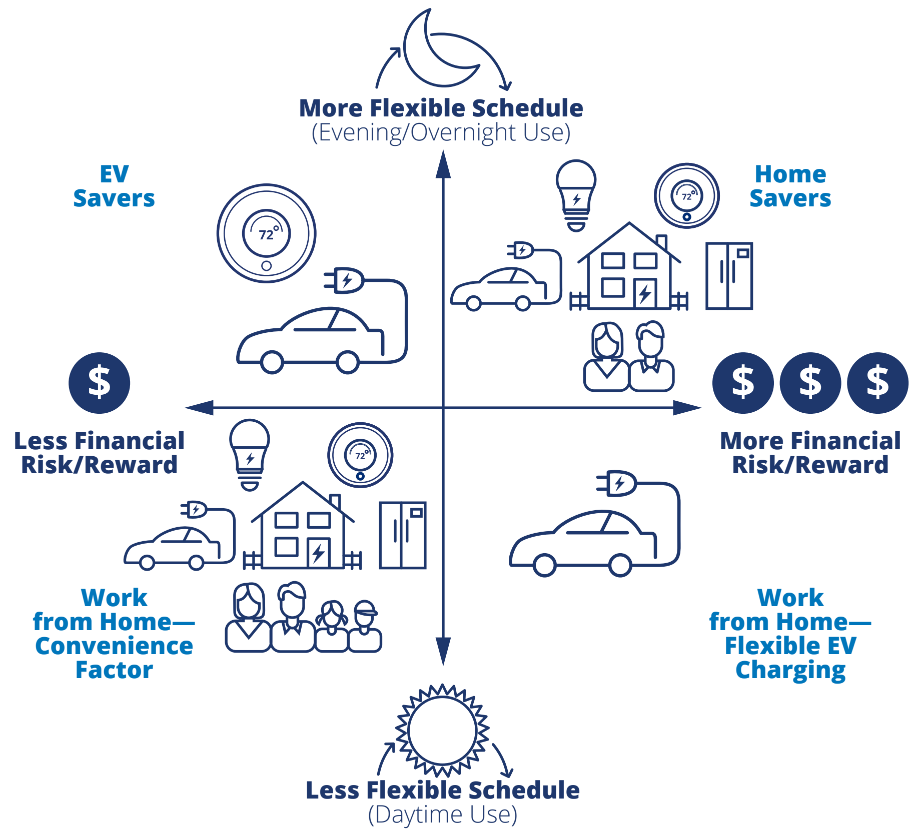
- **"Home Savers"—Outside the house during the day:** Households with more flexibility to shift entire household load to the off-peak hours and a strong interest in savings (Potential Solution: Whole House time-varying rate).
- **"EV Savers"—Outside the house during the day:** Households with flexibility to shift some load to the off-peak hours but less interested in savings, and more concerned with avoiding higher prices for entire household consumption (Potential Solution: Separately-metered time-varying rate for EV Only + other select household appliances).
- **"Work from Home"—Flexible EV charging:** Households with less flexibility to shift entire household load to avoid on-peak usage, but still have a strong interest in savings (Potential Solution: Separately-metered time-varying rate for EV only).
- **"Work from Home"—Convenience factor:** Households with less flexibility to shift entire household load to the off-peak hours and are more concerned with avoiding higher prices for on-peak usage (Potential Solution: Participate in a retroactive bill credit program.

As previously highlighted, a number of utilities offer their customers multiple rate and metering configurations for their home charging. Of the rates surveyed, 13 allow for more than one metering configuration under the same rate schedule. The most common pairing is a Whole House TOU rate (serviced on a single home meter) and a separately-metered EV-only TOU rate.

In addition eliminating barriers to participation, such as up-front costs or fees for customers, utilities can encourage higher enrollment by offering customers different rate and metering configuration options that appeal to a wider group of customer types and preferences across their service territories.

42 Regulatory Assistance Project and The Brattle Group, July 2012, *Time-Varying and Dynamic Rate Design*, https://www.raponline.org/wp-content/uploads/2016/05/rap-faruquihledikpalmer-timevaryingdynamicratedesign-2012-jul-23.pdf.

Figure 26: Illustrative EV Customer "Types"



Source: Smart Electric Power Alliance, 2019.

C. Utility Metering Case Studies

It is worthwhile to explore options to 1) integrate EV charging data into a utility billing system at the lowest cost, 2) increase convenience and satisfaction for the customer, and 3) ensure accuracy, reliability, and security. The following case studies feature innovative utility programs that implement different metering methods, specifically for:

1. Submeter (Indiana Michigan Power)
2. Submeter—EVSE telemetry (San Diego Gas & Electric)
3. Submeter—EVSE telemetry (Xcel Energy Minnesota)
4. Second meter—subscription rate (Austin Energy)
5. AMI load disaggregation (Braintree Electric Light Department)

The case studies discuss these integration opportunities, and highlight rate design and program implementation opportunities. These were among the most innovative programs identified in the survey.

1) Submeter: Indiana Michigan Power Leveraging Smart Meter Networks

Indiana Michigan Power—a subsidiary of American Electric Power (AEP)—found that EV customers want to know two things from their utility company: 1) how much it costs to charge their vehicles, and 2) if the utility offers incentives for charging. According to AEP, many EV owners either receive charging hardware with their vehicle or purchase directly from a retailer, and therefore may not need or want utility program-specific charging hardware.

One of the first decisions customers make after buying an EV is how they charge at home. Some customers are content with level 1 charging, others use the level 2 cordset chargers that come with their car (e.g., Tesla, Nissan, Audi) and install 240 volt service, while some others purchase a more sophisticated networked level 2 charging station. Regardless of the charging hardware chosen, EV owners can easily schedule charging through the car's in-dash screen, automaker apps, third-party apps, and even through digital voice assistants.

Given this ease of scheduling charging, customers will typically schedule their charging on nights and weekends if given a price signal. AEP has found TOU pricing to be very effective for shifting EV load to off-peak times.

AEP has identified a problem with offering only whole-house TOU rates in that they often require other customer behavioral changes related to heating and cooling that can hinder customer adoption. Instead, allowing customers to meter only their EV charging with an EV-only TOU rate can remove the customer apprehension around whole-house TOU rates.

AEP evaluated options for metering EV-only TOU rates:

- Via networked charging stations
- Through a separate utility service connection
- Using an EV-specific AMI submeter

AEP evaluated each option, considering cost, accuracy, security, communication reliability, billing integration, and other factors.

For the option of metering through network charging stations, they found challenges with:

- The reliability and security of customer Wi-Fi when communicating with the chargers.
- The difficulty of integrating charger network data with their existing utility CIS/billing system, which can be expensive to modify. Receiving usage files from a variety of network operators would require manual billing. This can result in mismatched time stamps, missing data due to loss of Wi-Fi connection, and significant opportunity for errors.
- The potential expense of accessing managed charging networks, including unpredictable network fees with uncertain future increases.
- Requiring customers to buy a utility-specified charger and utilize the associated network as a condition of program participation, which the customer may not need or want.
- The ability to adapt to future changes as the EV market evolves. OEMs are increasingly including level 2 cordset chargers as standard equipment with their vehicles, so the utility programs need to accommodate this change.

When considering establishing a separate utility service, AEP found that other utility programs incurred high administrative and equipment costs. The additional service increased costs for customers by requiring additional electrical hardware, incurring a second 'customer account charge', and duplicating other costs. They concluded this wasn't a cost-effective option for their customers.

When evaluating the use of an EV-specific AMI submeter, AEP found many benefits:

- The meter meets the regulatory accuracy requirements for billing tariffs.
- The security of the meter hardware and the interface with AEP's systems is inherent.
- Use of the existing AMI RF communications network is reliable.
- Integration with CIS and billing systems doesn't require significant IT investment or expensive manual billing.
- The purchase price of the meters is reasonable under existing utility-scale purchase volumes.
- The solution avoided exposure to unknowable future charger network access fees.
- AEP could potentially leverage the basic on/off control functionality of the AMI submeters for active-managed charging in the future, if that is needed.

For the customer, this solution avoids the need to completely adjust their behavior to accommodate a whole-house TOU-rate, or to purchase a utility-specified charger. It also allows customers to choose how they wish to control their vehicle charging. AEP found this approach to be the simplest, most convenient, adaptable, and lowest cost option.

2) Submeter—EVSE Telemetry: San Diego Gas & Electric (SDG&E) Power Your Drive

SDG&E developed the Power Your Drive pilot program aimed at workplace and multi-unit dwelling property owners to encourage increased EV adoption, especially in communities of concern. Once the chargers are deployed, EV drivers at the sites can sign up and gain access to over 3,000 charging stations at over 250 locations. The program has a special pricing plan that offers lower prices during grid-friendly times such as times of high renewable penetration or low grid congestion. Customers can set a maximum price to charge their EV. When the hourly price exceeds the maximum price, charging stops.

In the development of this rate, SDG&E tackled challenges of both diversity between circuit and system peaks, as well as diversity of peaks and load shapes across different circuits, while ensuring all customers are treated equitably. Because the program targeted specific locations, locational pricing was a concern for regulators. If a utility charged solely based on load, it could create inequity from one location to another. To address this, SDG&E used a critical peak price (CPP) concept and incorporated circuit level pricing. By applying the same price to every circuit, they resolved the issue of equitable pricing for customers across locations.

Each location has the exact same pricing structure, but at different times.

When examining time-varying rate options, Cyndee Fang, manager of energy research and analysis at SDG&E, recommends utilities ensure that the options they provide customers are purposeful, which may mean a limited number of choices but making the choices meaningful for the customer. Too many rate offerings can be confusing and too few fail to address specific customer needs. A static time-of-use rate is best for customers who are able to shift usage out of defined high cost hours, whereas dynamic rates help customers who are more responsive to tap into additional savings.

Hannon Rasool, the clean transportation business development manager at SDG&E, stated that, "submetered[43] EV-only rates allow for more complexity in the rate design as they require fewer human behavioral adjustments around the home." Given the potential size and flexibility of EV loads, an EV-only rate provides the opportunity to create a rate that is flexible and forward looking. "If you can get the design out there, people are able to get the technology to match the rate design," said Fang.

Rasool added that utilities planning to develop an EV-only time-varying rate should be focused on incorporating the EV load to the grid in a manner that doesn't increase costs. "Proper rate design can help save money and achieve the environmental benefits we all want to see. Utilities planning an EV program should look into how they can incorporate the additional load into the grid and that is where actionable rate signals really matter," said Rasool.

A significant opportunity provided by SDG&E's rate is that despite its complexity, it is a more dynamic rate offering and opens up more low-cost hours for flexible loads such as EV charging. This makes it meaningful for customers, and gives them choices. "Utilities have to be mindful about options put out there and ensure they bring value for customers," said Fang.

3) Submeter—EVSE Telemetry: Xcel Energy Minnesota Residential EV Service Pilot

Xcel Energy Minnesota launched a Residential EV Service Pilot in 2018 offering an EV TOU rate that leveraged networked Level 2 charging equipment to lower the initial cost to enroll.[44] The pilot was designed to test the potential for cost savings and improved customer experiences through a combination of new equipment deployment and off-peak rate design. By leveraging the telemetry capabilities of the EVSE, utilities could use charger equipment to provide billing-quality data. The program avoided the need for customers to pay for the installation and cost of a second meter. In addition, the pilot improved the customer experience while maintaining a safe and reliable electricity service.

The pilot was capped at 100 participants with average savings of the cost of EVSE and metering installation of $2,196 per customer compared to the costs associated with equipment and installation for the separately metered option.[45] Actual savings were dependent on the availability of an existing 240 volt dedicated circuit needed for the Level 2 charger as well as proximity to the garage, panel location, and circuit pathway.

Xcel Energy offered customers chargers from two EVSE manufacturers, ChargePoint and Enel X. Xcel Energy found that while the data provided by the charging equipment was sufficiently accurate, formatting the data so it could be received by the company and successfully uploaded to the billing system required significant collaboration with the vendors. Moving forward, Xcel Energy plans to explore ways in which it can improve integration and operations between its systems and charging equipment options.

The pilot resulted in a 96% of the charging load was off-peak. Based on an assumption of 350 kWh of usage per month and the current level of off-peak charging, enrolled customers would save $9.76 per month or $117.12 per year on the TOU rate.

The pilot provided a positive turn-key customer experience for electric vehicle charging in the home, with customer satisfaction scoring 87% for enrollment and 95% for charging equipment installation. From the 63 survey responses, Xcel Energy also identified areas for improvement, including explaining rate pricing, communicating with customers, and providing information about the charger options. While customers understood and recognized the pricing signal (in that charging their EV during off-peak hours is cheaper and provides benefits), they were confused about the pricing, components of the rate and on-bill presentation, as well as the expected

43 In PYD, SDG&E used data collected from submeters in the EV chargers for billing after qualifying the submeters through a rigorous testing process. Two chargers were accepted, from Siemens and ChargePoint, meeting the testing criteria of +/- 1.0%.

44 Note: This pilot was intended for customers who wanted a new EVSE at their home. Xcel has other rate options, such as a whole home TOU, for customers that prefer level one charging, a non-networked charger, or other options. Additional information about the program is available in the *Residential Electric Vehicle Charging Tariff Docket* No. E002/ M-15-111 and E002/ M-17-817, 2019.

45 The savings are measured by asking electricians to provide the customer with (at least) two estimates for wiring their home—one being a separate service/meter, one being a dedicated circuit behind the customers main panel/existing meter. Xcel identified the difference between these estimates as the savings vs the existing separately metered rate.

fuel savings and payback period for their investment. Xcel Energy plans to leverage digital tools and more comprehensive energy consumption data to provide customers with better insights into the benefits.

Seventy-three percent of participants in the EV Service Pilot preferred to pay for the charging equipment and installation through a bundled monthly charge, instead of the prepayment option, indicating that customers prefer to reduce upfront costs and simplify participation. Xcel Energy plans to adjust the tariff as needed and experiment with subscription models.

4) Second Meters: Austin Energy EV360 Subscription-based Rate

In 2015, Austin Energy developed three new pilot rates with the goal of offering customers more rate options. Along with an EV-only subscription rate, a prepayment rate and a whole-home Time-of-Use rate were piloted. The subscription, titled EV360, offers customers with a capacity demand of less than 10 kW the ability to use unlimited off-peak (7pm-2pm weekdays, anytime during weekends) kWh's for EV charging for a fixed monthly fee of $30.[46] Customers with demand over 10 kW have a fixed monthly fee of $50. Customers are able to charge on-peak, but will incur a bill adder of $0.14/kWh during the winter and $0.40/kWh during the summer.

The subscription coupled TOU-like hours with a fixed charge to give EV customers a predictable bill. To date, the rate has resulted in 99% of participants using off-peak electricity. However, Austin Energy has yet to determine how much it has changed charging behavior beyond initial survey data.

Lindsey McDougall, the Program Manager for the EV360 program, published a report in September 2019 which highlighted key takeaways and lessons learned from the pilot program.[47] A key element of the pilot's success was educating customers. Participation required a large investment by the customer, as they had to install both a conduit and meter socket for the meter, obtain a permit, and hire an electrician. This meant the pilot was limited in reach, with those interested in participating being well-educated and eager to participate. Pilot participation required significant guidance from the utility. Austin Energy worked closely with EVSE installers to inform them about the program and created an "Installers tab" on their website.

As EV360 was a small pilot with 100 participants, management and administration of the program was performed by one person—Lindsey McDougall. While manageable for a small pilot, if Austin Energy decides to offer the rate to all customers, additional staff would be required, as well as training the call center to handle customer inquiries.

Reflecting on the pilot, McDougall noted that subscription rates will be important to EV drivers and utilities. "EV drivers charge off-peak for green initiatives and cost savings and utilities will be expected to have the same values. Consequently, there will be huge demand for utilities to not penalize customers for having an EV, but instead having rate structures that encourage conservation where possible."

In addition to EV-only rates, McDougall also noted that subscription structures could apply to other scenarios, for example the whole home. "Especially with distributed energy service providers, utilities will see a more dynamic relationship between energy resources and consumption. There will become a two-way channel between the utility and the customer."

5) AMI Load Disaggregation: Braintree Electric Light Department (BELD), Bring Your Own Charger®

Advanced metering infrastructure (AMI) is an integrated system of smart meters, communications networks, and data management systems that enables two-way communication between utilities and customers. Typically gathering energy consumption data in 15-minute intervals, AMI meters can generate vast amounts of data, with the exact data varying based on utility and system.

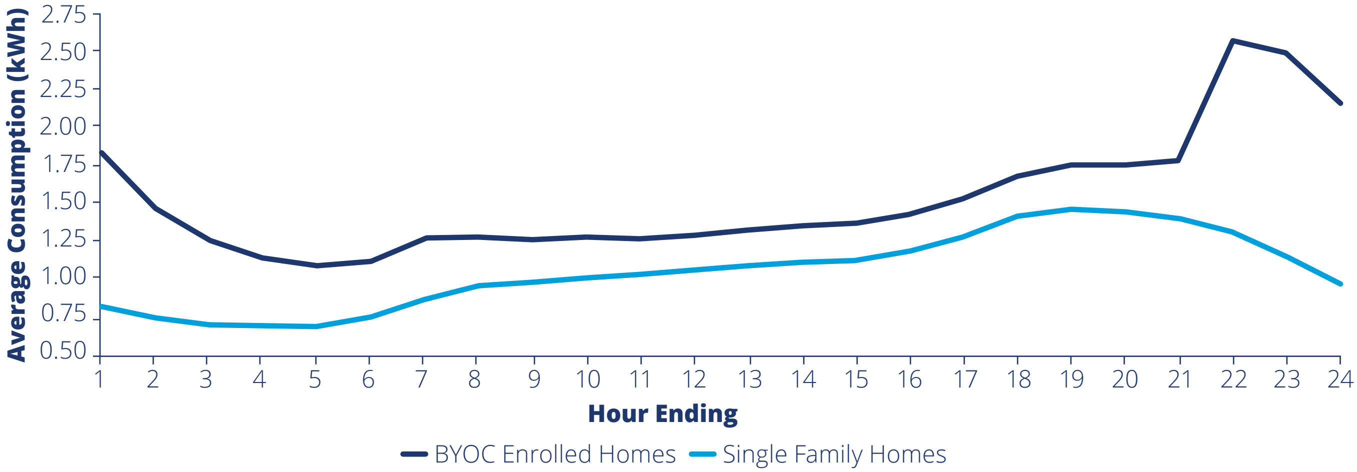
BELD launched Sagewell's Bring Your Own Charger® (BYOC) electric vehicle load management program in 2017, and has approximately 80% of known EVs in their service area under load management. The BYOC program does not require any load control hardware because it utilizes AMI meter data to verify off-peak charging compliance.

BELD began residential EV load management three years ago, initially focusing on load control through EV smart chargers. However, they quickly identified difficulties in getting a significant volume of smart chargers installed and high program costs as key obstacles and transitioned to Sagewell's non-hardware-based BYOC solution to

46 Additional details about the rate design are on page 7: Austin Energy, EV360 Whitepaper, *Austin Energy's Residential "Off Peak" Electric Vehicle Charging Subscription Pilot: Approach, Findings, and Utility Toolkit*, https://austinenergy.com/wcm/connect/b216f45c-0dea-4184-9e3a-6f5178dd5112/ResourcePlanningStudies-EV-Whitepaper.pdf?MOD=AJPERES&CVID=mQosOPJ.

47 See Austin Energy, EV360 Whitepaper, *Austin Energy's Residential "Off Peak" Electric Vehicle Charging Subscription Pilot: Approach, Findings, and Utility Toolkit*, https://austinenergy.com/wcm/connect/b216f45c-0dea-4184-9e3a-6f5178dd5112/ResourcePlanningStudies-EV-Whitepaper.pdf?MOD=AJPERES&CVID=mQosOPJ.

Figure 27: Identifying the Load Profile from Average Enrolled EV Home Compared to Average Single Family Home in Braintree



Source: Sagewell Bring Your Own Charger (BYOC), 2019.

monitor EV charging using whole-home smart meter load disaggregation (Figure 27). Through the program, BELD has tracked customer charging of over 12,000 EV charging days and verified over 95% off-peak charging compliance.

EV owners who agree to program their vehicles to charge during off-peak hours are given a bill credit as an incentive. If on-peak charging is identified from the AMI meter data, customers were reminded they could lose the incentive for the month. This daily tracking and accountability drove significantly higher rates of successful off-peak charging than do TOU rates, which achieve 70% to 80% of EV charging during off-peak hours, based on Sagewell's AMI meter tracking data.

BELD found that eliminating load-control hardware caused a higher percentage of EV owners in its service territory to enroll in the program. The average customer enrollment time is only 7 minutes via smartphone. Sagewell provides support and program oversight to help customers as they begin enrollment. BELD also found that enrolling customers early in their EV ownership led to maximum enrollment as enrollment rates decreased the longer a customer owned an EV. BELD has used Sagewell's EVFinder algorithm daily to find new EVs in utility smart meter data and to direct EV program marketing messages that included BYOC information to those customers who recently acquired an EV.

BELD's analysis of smart meter data also highlighted that utilities should carefully analyze their TOU rates because many may be discounting their regular residential rates too much and giving up more in margins than the peak load reduction justifies. The BYOC program produced significantly higher program participation and larger peak load reduction at a lower cost than TOU rates. Sagewell encourages utilities to carefully analyze their EV load management options and to use their AMI data to find the peak load reduction potential for customers rather than using modeled results or data from other utilities. For example, differences in weather, miles driven and utility coincident peak times between different regions make it challenging to compare results between different EV load management programs and highlights the importance of using local AMI meter data for the analysis.

7) Conclusion

Time-varying rates are a valuable tool for utilities to manage system costs by influencing residential EV charging behavior. Specifically, the quantitative analysis described in this study shows that EV time-varying rates effectively incentivize off-peak charging, and that customers are interested in using them. Enticing the maximum number of EV customers to enroll in these rates is essential to ensuring that EV charging load is managed effectively. Designing rates that encourage off-peak charging, save customers money, require limited up-front fees, and that are easily available to EV customers leads to the highest customer enrollments.

This section includes recommendations for utilities as they consider options for EV time-varying rates, and provides next steps for other research topics, as we continue to refine our knowledge about load management strategies.

A. Recommendations

Utilities can take advantage of early opportunities to improve EV-grid integration through time-varying rates. Recommendations compiled from the survey results and utility interviews include:

1. Minimize the up-front costs for customer enrollment wherever possible. Utility costs may include metering equipment (and in some cases EVSE), installation, and in-house utility overhead such as IT setup, marketing, etc. Determining which costs the customer bears, the manner in which they are collected (e.g., bundled monthly charge versus a prepayment option), as well as the recovery mechanisms for costs not recovered directly from participants are critical considerations for utilities and regulators.
2. Make the price differential between 'on-peak' and 'off-peak' significantly large to incentivize participation, but not so large that it deters customers from enrolling. Offering multiple rate options with different designs allows utilities to appeal to and engage more customer types and preferences.
3. Where possible, incorporate an "opt out" rather than passive "opt in" elective—especially for programs containing a rebate or incentive for a charger or vehicle purchase.
4. Make the time-varying rate options for consumers meaningful, with substantive differences in the rate structures rather than offering customers several rates that have only slight variations. Provide tools and information to help customers make a rate choice that works best for them.
5. Consider innovative approaches to rates and incentives, such as dynamic rates, off-peak credits, subscription rates, and load disaggregation with retroactive incentives.
6. Ensure adequate marketing funding to promote the rate to customers. Use multiple marketing channels to amplify the message. Target rate marketing among known or likely EV drivers.
7. Build a long-term strategy to transition from passive managed charging to active managed charging, considering the time it may take to introduce and get regulatory approval for new rates and programs.
8. Work with EVSE providers to deliver unified open standards that could lower the cost of integrating networked EV charger telemetry.

B. Future Research

While this report provides valuable new insight into EV time-varying rates, a number of questions remain. These include elements of rate design, evaluation, measurement, and verification (EM&V) of rate effectiveness, lower-cost alternatives to collecting charging data, how to measure the key performance indicators (KPI) of marketing efforts, the appropriateness of ratebasing program costs, and more, as outlined below.

Active Load Management

- What is the time horizon for active load management offered by utilities and private vendors? What is the value of active load management and what are the use cases?

Rate Design

- Which customer segments prefer a separately metered EV-only rate to a whole-home rate? What portion of the customer base—enough to justify utilities offering customers both options?
- How can utilities design rates to promote efficient utilization of lower-cost and clean generation resources?
- Will customers shift load to the off-peak period if it occurs in the middle of the day (e.g., when there is excess solar PV output)?
- Do customers respond differently to peak/off-peak pricing than to rate discounts, monthly incentives, or bonuses for charging at night?

- Nearly all of the EV Time-Varying Rates reviewed in this report are TOU programs. Should utilities explore other time-varying rate options for EV charging and would some residential EV customers be better off under one of these alternatives versus a TOU rate?
- Should time-varying rates be required for participants in ratepayer-funded EV home charging programs to ensure that all customers benefit from large-scale shifts in EV charging load to off-peak periods?

Rate Performance

- Is time-varying EV pricing effective at encouraging EV adoption, or is it primarily for encouraging off-peak charging once the EV has been purchased?
- How will these rates impact charging behavior—especially among later adopters of EV technology?
- How will utilities evaluate, measure, and verify the effectiveness of EV rates—particularly utilities transitioning from a pilot to a rate of general application?
- How do you measure the KPI of marketing expenditures to increase the number of consumers on a rate and/or who purchase an EV as a result of the rate?

Cost Recovery

- Should secondary or submetering costs be recovered from participants (which could be a significant deterrent to participating) or will the rate lead to off-peak charging and benefit all customers, thereby justifying recovery of the meter cost from a broader group of customers? Should costs be recovered differently for "early adopters" versus "late adopters" of EV technology? How should the costs associated with EV rate and program marketing, IT set up costs, and other overhead be recovered?

Technology Considerations

- Will additional incentives encourage higher enrollment and more off-peak charging?
- Can customers enrolled in one demand management program, such as EV charging, be motivated to join other programs, such as smart thermostats or grid-integrated water heating?
- How can new tools help increase enrollment, such as showing customers their average charging patterns in monthly bills, compared to a different charging pattern or a different rate?

Appendix A: List of Available Residential EV Time-Varying Rates

The list of available residential EV time-varying rates was compiled using research from SEPA The Brattle Group, OpenEI, and other online resources. This list was updated through September 2019 and includes 64 rates from 50 utilities that were open for enrollment at the time they were collected. This list does not include expired or grandfathered rates.

Table 8: Available Residential EV Time-Varying Rates, September 2019

	Utility Name	Rate Name	Rate Type
1	Alabama Power Company	PEV Rate Rider	Time-of-Use
2	Alaska Electric Light and Power Co.	Off-Peak Electric Vehicle Charging	Time-of-Use
3	ALLETE (Minnesota Power)	EV TOU Rate	Time-of-Use
4	Anaheim Public Utilities	Developmental Schedule D-EV Rate (Developmental Domestic Electric Vehicles)	Time-of-Use
5	Austin Energy	EV360	Subscription
6	Baltimore Gas and Electric	Schedule EV	Time-of-Use
7	Belmont Light	Bring Your Own Charger	Off-Peak Credit
8	Berkeley Electric Coop Inc.	Off-Peak EV Rate	Time-of-Use
9	Braintree Electric Light Department	Bring Your Own Charger Program	Off-Peak Credit
10	City of Burbank Water and Power	Optional Time-of-Use Rates for Electric Vehicle Owners	Time-of-Use
11	Coastal EMC	TOU-PEV-1	Time-of-Use
12	CobbEMC	NiteFlex	Time-of-Use
13	Concord Municipal Light Plant	Rate R-1	Time-of-Use
14	Concord Municipal Light Plant	EV Miles Program	Off-Peak Credit
15	Consolidated Edison Company	Special Provision E of SC1 Rate III	Time-of-Use
16	Consolidated Edison Company	Special Provision F of SC1 Rate III	Time-of-Use
17	Consumers Energy Co.	REV-1	Time-of-Use
18	Consumers Energy Co.	REV-2	Time-of-Use
19	Dakota Electric Cooperative	Schedule EV-1 Pilot—Residential Electric Vehicle Service	Time-of-Use

Table 8: Available Residential EV Time-Varying Rates, September 2019			
	Utility Name	**Rate Name**	**Rate Type**
20	Delmarva Power & Light	R-PIV	Time-of-Use
21	DTE	D1.9 EV Time-of-Use	Time-of-Use
22	Evergy	Residential Electric Vehicle Rate	Time-of-Use
23	Georgia Power Company	Schedule TOU-PEV-6—Plug-in Electric Vehicle	Time-of-Use
24	Gulf Power Co.	Rate Schedule RSVP Residential Service Variable Pricing	Time-of-Use
25	Hawaii Electric Light Company	Schedule TOU-RI	Time-of-Use
26	Hawaiian Electric Company	Schedule TOU-RI	Time-of-Use
27	Indiana Michigan Power Company	Tariff RS-PEV	Time-of-Use
28	Indianapolis Power & Light Company	IPL Response: Rate EVX	Time-of-Use
29	Jackson EMC	Residential Plug-in Electric Vehicle Rate (APEV-19)	Time-of-Use
30	Los Angeles Department of Water and Power	EV TOU	Time-of-Use
31	Madison Gas & Electric	Shift & Save	Time-of-Use
32	Maui Electric Company	TOU EV	Time-of-Use
33	New Hampshire Electric Cooperative	EV Time-of-Use Rate	Time-of-Use
34	Norwood Light Department	Bring Your Own Charger Program	Off-Peak Credit
35	NV Energy	OD-REVRR-TOU	Time-of-Use
36	NV Energy	ODM-1-TOU REVRR	Time-of-Use
37	NV Energy	ORS-TOU REVRR	Time-of-Use
38	NV Energy	ORM-TOU RMEVRR	Time-of-Use
39	Orange and Rockland Utilities	O&R SC19	Time-of-Use
40	Otter Tail Power Company	Off-Peak EV	Time-of-Use
41	Pacific Gas & Electric	EV-2A; Electric Schedule EV—Rate A	Time-of-Use
42	Pacific Gas & Electric	EV-B; Electric Schedule EV—Rate B	Time-of-Use
43	Pacific Power (PacifiCorp)	Schedule 5—Separately Metered Electric Vehicle Service For Residential Consumer	Time-of-Use
44	Pepco Holdings, Inc.	Whole House EV TOU	Time-of-Use

Table 8: Available Residential EV Time-Varying Rates, September 2019			
	Utility Name	**Rate Name**	**Rate Type**
45	Piedmont Electric Membership Corporation	Schedule R/SGS-TOD-E-PEV	Time-of-Use
46	Rocky Mountain Power (PacifiCorp)	Schedule 2E—Residential Service—Electric Vehicle Time-of-Use Option—Temporary—Rate Option 1	Time-of-Use
47	Rocky Mountain Power (PacifiCorp)	Schedule 2E—Residential Service—Electric Vehicle Time-of-Use Option—Temporary—Rate Option 2	Time-of-Use
48	Sacramento Municipal Utility District	Schedule R-TOD, rate category RT01	Time-of-Use
49	Salt River Project	E-29 Residential Electric Vehicle Price Plan	Time-of-Use
50	San Diego Gas & Electric	EV TOU 2	Time-of-Use
51	San Diego Gas & Electric	EV TOU 5	Time-of-Use
52	San Diego Gas & Electric	EV TOU	Time-of-Use
53	San Francisco Public Utilities Commission	Schedule REV-1	Time-of-Use
54	Sawnee EMC	Schedule PEV-7	Time-of-Use
55	Southern California Edison Co.	TOU-D-PRIME	Time-of-Use
56	Virginia Electric & Power Co.	Schedule EV	Time-of-Use
57	Virginia Electric & Power Co.	Schedule 1EV	Time-of-Use
58	Wake Electric Membership Corporation	EV Rate	Time-of-Use
59	Wake Electric Membership Corporation	EV TOU	Time-of-Use
60	Wellesley Municipal Light Plant	Bring Your Own Charger Program	Off-Peak Credit
61	Wright-Hennepin Cooperative Electric Association	EV TOU Rate	Time-of-Use
62	Xcel Energy MN	Residential Electric Vehicle Pilot Service Rate Code A80	Time-of-Use
63	Xcel Energy MN	Residential Electric Vehicle Pilot Service Rate Code A81	Time-of-Use
64	Xcel Energy MN	Residential Electric Vehicle Service Rate Code A08	Time-of-Use

Source: Smart Electric Power Alliance, 2019. Updated through September 30, 2019.

Appendix B: Recommended Reading

- Baltimore Gas & Electric, 2018, *BGE Electric Vehicle Off Peak Charging Pilot*, Docket 9261: In The Matter of the Investigation Into the Regulatory Treatment of Providers of Electric Vehicle Charging Stations and Related Services.
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  - https://sepapower.org/resource/a-comprehensive-guide-to-electric-vehicle-managed-charging/
- Xcel Energy. 2019. *Residential Electric Vehicle Charging Tariff* Docket No. E002/ M-15-111 and E002/ M-17-817.
  - https://drive.google.com/file/d/1hpIClxrFYwLxulg1tXW2jAPhxbMnloMQ/view

Appendix C: Time-Varying Rate Definitions

For the purposes of this report, time-varying rates are grouped into seven categories: Time-of-Use (TOU), Subscription Rates, Off-Peak Credits, Real Time Pricing (RTP), Variable Peak Pricing (VPP), Critical Peak Pricing (CPP), and Critical Peak Rebates (CPR).[48]

These rates are illustrated in Figure 28.[49]

- **Time-of-Use (TOU)** rates typically have two or more price intervals (e.g., peak, off-peak, super-off-peak) that differ based on levels of demand observed throughout the day. Sometimes these prices vary by season, but generally speaking both the prices and the designated price interval hours for each tier remain constant from day to day.
- **Subscription Rates** allow customers to pay a fixed monthly fee for electricity and other utility-provided services in exchange for unlimited charging during certain hours of the day or days of the week. Customers would subscribe to a plan which meets their specific needs, varying from "economy" packages which give the utility some ability to control their load at restricted and pre-published times to help meet grid needs, to high-priced packages with long-term subscriptions and access to new technologies without upfront costs.
- **Off-Peak Credits** can take the form of a fixed or variable incentive provided as a rebate or a bill credit in exchange for restricting consumption to designated hours of the day or days of the week.

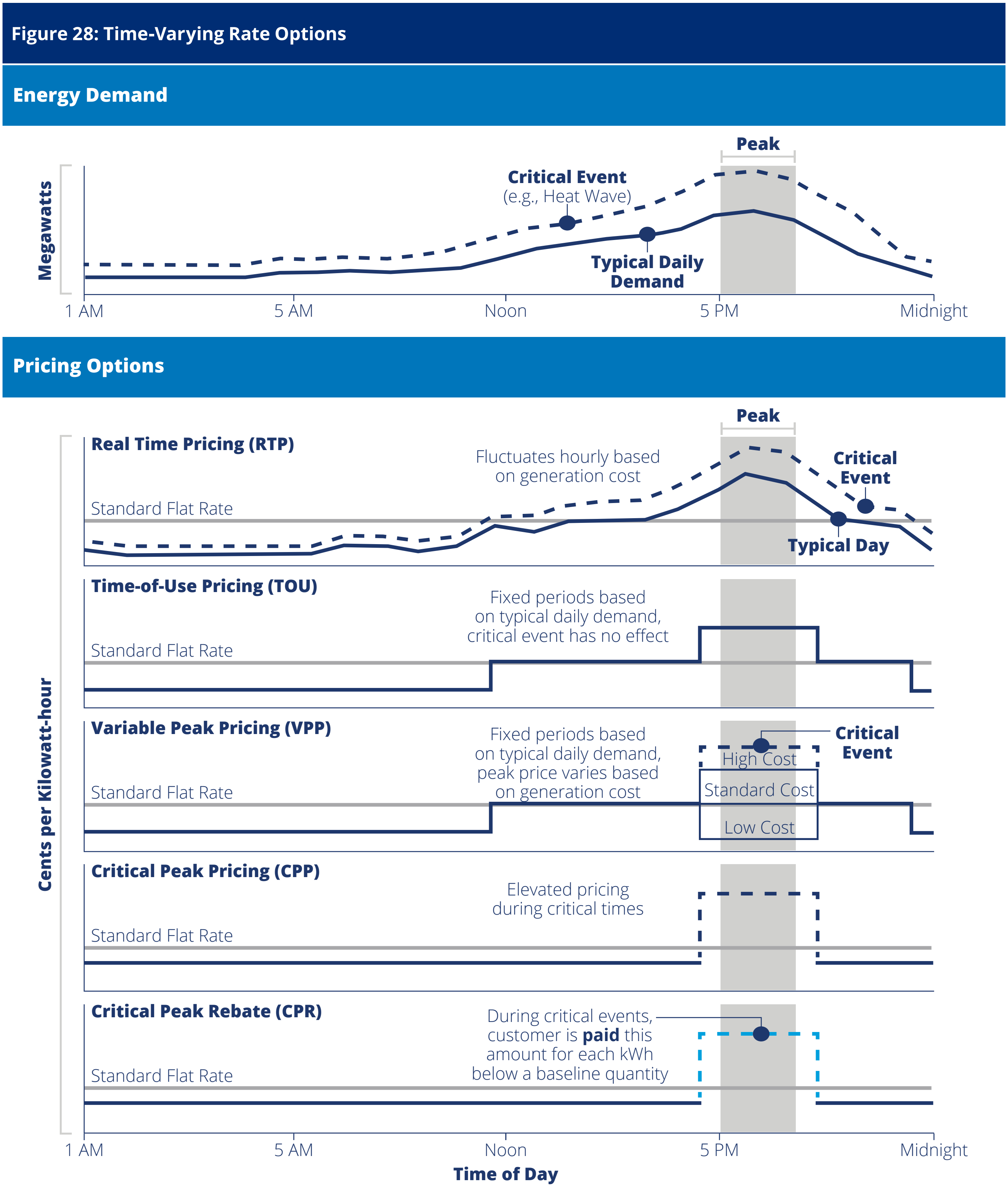
Dynamic Rates (time periods and prices vary based on system conditions and power cost):

- **Real Time Pricing (RTP)** is the most complex time-varying rate. Variable, hourly prices are determined either by day-ahead market prices in order to allow the customer to be notified with time to alter consumption decisions, or real-time spot market prices.
- **Variable Peak Pricing (VPP)** is a hybrid of TOU and RTP, with price intervals (e.g., peak, off-peak) that are constant like a TOU rate but allow for the price charged during the peak tier to differ day to day. The peak price charged varies from day to day either based on market prices or a set of predetermined levels, to reflect system conditions and costs.
- **Critical Peak Pricing (CPP)** has a higher rate at designated peak demand events (also called "critical events") on a limited number of days during the year to reflect the higher system costs during these hours. The customer can avoid paying high prices by reducing electricity use during these periods of high demand (which may only occur up to a predetermined number of times per year) and benefit from a lower price for non-event hours relative to the flat rate.This pricing provides a strong incentive for customers to reduce consumption during peak hours of critical event days, but provides no incentive to reduce use on non-event days or hours.
- **Critical Peak Rebate (CPR)**, also called Peak Time Rebate (PTR), is the inverse of CPP. Utilities pay customers a rebate for each kWh of electricity they reduce during peak hours of peak demand events. Similar to CPP, this pricing incentivizes a reduction in use during even days, but does not provide an incentive for customers to reduce use on non-event days or hours.

48 Definitions adapted from: Environmental Defense Fund, 2015, *A Primer On Time-Variant Electricity Pricing*, https://www.edf.org/sites/default/files/a_primer_on_time-variant_pricing.pdf . Subscription Rates and Off-Peak Credits are not discussed in the EDF primer.

49 Ibid.

Figure 28: Time-Varying Rate Options



Source: Environmental Defense Fund, 2015 with edits by the Smart Electric Power Alliance.[50]

50 Environmental Defense Fund, 2015, *A Primer On Time-Variant Electricity Pricing*, https://www.edf.org/sites/default/files/a_primer_on_time-variant_pricing.pdf

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