NARUC
National Association of Regulatory Utility Commissioners

Electric Vehicles: Key Trends, Issues, and Considerations for State Regulators

Charles Harper, Gregory McAndrews, & Danielle Sass Byrnett

October 2019

Acknowledgments and Disclaimers

This report was prepared as an account of work sponsored by the U.S. Department of Energy under Award Number DE-OE0000818. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

This report was authored by Charles Harper, Gregory McAndrews, and Danielle Sass Byrnett of NARUC.

Throughout the preparation process, NARUC staff and members provided the authors with editorial comments and suggestions. However, the views and opinions expressed herein are strictly those of the authors and may not necessarily agree with positions of NARUC or those of the U.S. Department of Energy.

The authors are grateful to the many individuals and organizations that provided their expertise and peer review during the preparation of this report. Specifically, we wish to thank the following individuals:

- **Thomas Ashley**, Greenlots
- **Jamie Barber**, Georgia Public Service Commission
- **Amanda Best**, Maryland Public Service Commission
- **Joey Chen**, Maryland Public Service Commission
- **Deana Dennis**, Electric Power Research Institute
- **Sue Gander**, National Governors Association
- **Matthew Goetz**, Georgetown Climate Center
- **Phil Jones**, Alliance for Transportation Electrification
- **Erick Karlen**, Greenlots
- **Jonathan Levy**, EVGo
- **Colin Murchie**, EVGo
- **Erika Myers**, Smart Electric Power Alliance
- **Patricio Portillo**, National Governors Association
- **Sara Rafalson**, EVGo
- **Matthew Rogotzke**, National Governors Association
- **Kellen Schefter**, Edison Electric Institute
- **Hon. Jason Stanek**, Maryland Public Service Commission

Please direct questions regarding this report to Charles Harper, NARUC Center for Partnerships & Innovation at charper@naruc.org or (202) 821-1693.

Contents

List of Boxes and Figures

1. Introduction

Over the past few years, states across the country have seen increased consumer adoption of electric vehicles (i.e., vehicles with an electric motor, or EVs), thereby increasing electricity demand from the transportation sector. This change is quickly becoming a trend, which provides utilities with an opportunity to increase electricity sales while providing customers with the possibility of lowering emissions and overall vehicle ownership costs compared to traditional internal combustion engine (ICE) vehicles.[1] Electric utilities are at different stages of exploring their role in both building EV charging infrastructure and managing grid impacts, including through rate design and managed charging. As a result, many Public Utility Commissions (PUCs), the state agencies tasked with regulating utilities, are being asked to make decisions in this unfamiliar industry, sometimes without direct legislative guidance. This issue brief provides data about the trends in EV adoption, a synopsis of the types of decisions Commissions are facing, and examples of recent State regulatory approaches to EV questions.

Electric Vehicle Sales Continue to Rise

Through July 2019, nearly 1.3 million plug-in electric vehicles (PEVs) have been purchased in the United States.[2] U.S. sales of EVs grew by 81 percent from 2017 to 2018, with 361,307 vehicles sold in 2018 alone, capping off 12 months of consecutive year-on-year monthly sales growth as of December 2018.[3] Of the 361,307 PEVs sold in 2018, 235,000 were battery-electric vehicles (BEVs), an increase of 128 percent year-on-year. PHEV sales

Types of Electric Passenger Vehicles

There are many varieties of EVs, with the main differences stemming from how they are charged and whether they also have a gas-powered ICE (Table 1).

- **Conventional Hybrids:** The most popular EVs historically, conventional hybrids have both a gasoline engine and an electric motor, but the electric battery cannot be charged by plugging a cable into an outlet. Instead, batteries in conventional hybrids are charged using regenerative braking, which captures the kinetic energy that is generated during braking and converts it into electricity. Since conventional hybrids cannot plug into the electric grid, they are not the focus of this paper.
- **Plug-in Electric Vehicles (PEVs):** PEVs are any vehicle with an electric battery that can be recharged from an external electricity source. Two types of PEVs are Plug-in Hybrid Electric Vehicles (PHEVs) and Battery Electric Vehicles (BEVs).
    - Plug-in hybrid electric vehicles (PHEVs)s are very similar to conventional hybrids, but the electric battery can be charged by plugging it into an outlet or charging station. These cars can run solely on electricity until the battery is depleted, with ranges from 12 to 53 miles before the gas motor kicks in.[4]
    - BEVs are solely powered by their electric motor and therefore have zero tailpipe emissions. Ranges greatly vary from 58 miles for a small all-electric Smart car to 315 miles for the Tesla Model S. BEVs are sometimes referred to as zero emission vehicles (ZEVs), but the term ZEV can also include other alternative fuel vehicles that produce zero emissions at the source, including hydrogen fuel cell vehicles.[5]

---

1 Douris, Constance. "The Bottom Line on Electric Cars: They're Cheaper to Own." *Forbes*. October 24, 2017. Accessed January 23, 2019. https://www.forbes.com/sites/constancedouris/2017/10/24/the-bottom-line-on-electric-cars-theyre-cheaper-to-own/#1a84e41e10b6

2 EDTA, "Electric Drive Sales Dashboard." https://electricdrive.org/index.php?ht=d/sp/i/20952/pid/20952

3 "December 2018 U.S. Plug-In EV Sales Report Card." *Inside EVs*. January 06, 2019. Accessed January 23, 2019. https://insideevs.com/december-2018-u-s-plug-in-ev-sales-report-card/

4 Loveday, Eric. "Top 6 Plug-In Hybrids Ranked by Electric Range." InsideEVs.com. Accessed July 03, 2018. https://insideevs.com/top-6-electric-range-phev/

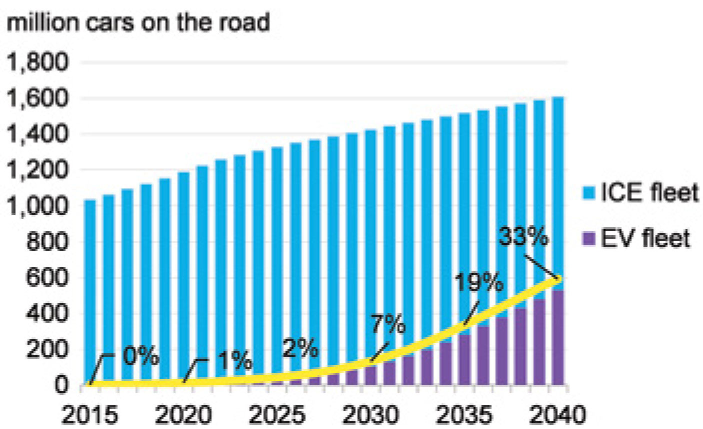
5 "2018 U.S. Models - BEV Range Comparison Infographic." InsideEVs.com. Accessed April 27, 2018. https://insideevs.com/2018-u-s-models-bev-range-comparison-infographic/

Table 1: Different types of electric vehicles and their respective ranges				
Name	Engine/Motor	Power Source	Miles Per Gallon (or electric equivalent)	Electric Range (2018)
Conventional Hybrids	Gasoline engine and electric motor	Gasoline with regenerative braking to power electric motor	40-60 MPG[6]	N/A
PHEVs	Gasoline engine and electric motor	Gasoline and electricity from charging	83-133 MPGe[7]	12-53 miles before gasoline motor activates[8]
BEVs	Electric motor	Electricity from charging	100-140 MPGe[9]	58-315 miles[10]

rose 32 percent year-on-year.[11] In states where EVs experienced larger early adoption or a high number of EV leases, used EV markets have provided opportunities for consumers to purchase EVs at even lower prices than previously thought possible. Two manufacturers of EVs (Tesla and GM) have sold more than 200,000 vehicles each, leading buyers of their vehicles to no longer qualify for the full federal tax credit of $7,500. The National Renewable Energy Laboratory projects that at current growth rates, there will be 15 million EVs on U.S. roads in 2030, while Bloomberg New Energy Finance estimates that by 2040, well over half of all new light-duty vehicles purchased globally will be EVs (Figure 1).[12] Many states also have their own goals for ZEV and BEV adoption.

Three main factors are driving increased EV sales: (1) vehicle costs have been consistently declining, (2) vehicle range is improving (which counterposes "range anxiety" or the worry of an EV driver that the battery will run out of power before the destination or a suitable charging point is reached[13]), and (3) customers have an ever-increasing choice of vehicle types.

Figure 1: Global light-duty vehicle sale projections[14]



Source: *Bloomberg New Energy Finance*

6 Gorzelany, Jim. "10 Most Fuel-Efficient Hybrid Cars Of 2018." Motor1.com. February 16, 2018. Accessed January 23, 2019. https://www.motor1.com/features/229073/most-fuel-efficient-hybrids/.

7 Loveday. "Top 6 Plug-In Hybrids Ranked by Electric Range."

8 Ibid.

9 "2018 U.S. Models - BEV Range Comparison Infographic."

10 Ibid.

11 Bloomberg NEF. *2019 Sustainable Energy in America Factbook.* "Deployment: U.S. Gasoline Consumption and Fuel Economy," 121. https://www.bcse.org/wp-content/uploads/2019-Sustainable-Energy-in-America-Factbook.pdf

12 Bloomberg NEF. "Electric Vehicles to Accelerate to 54% of New Car Sales by 2040." June 05, 2018. Accessed January 23, 2019. https://about.bnef.com/blog/electric-vehicles-accelerate-54-new-car-sales-2040

13 "Range Anxiety | Definition of Range Anxiety in US English by Oxford Dictionaries." *Oxford Dictionaries | English*. Accessed January 23, 2019. https://en.oxforddictionaries.com/definition/us/range_anxiety

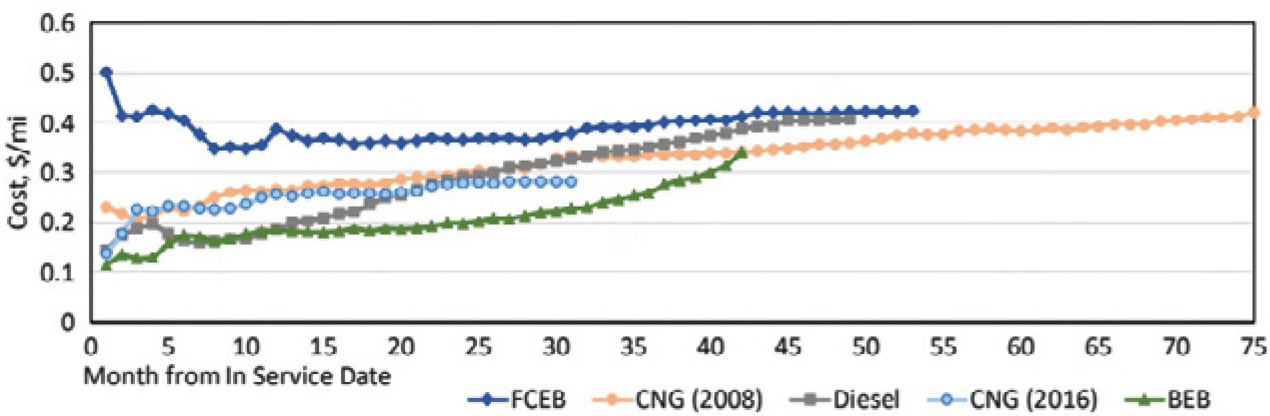
14 Bloomberg NEF. "Electric Vehicles to Accelerate to 54% of New Car Sales by 2040." June 05, 2018. Accessed January 23, 2019. https://about.bnef.com/blog/electric-vehicles-accelerate-54-new-car-sales-2040

The first cause is that EVs are decreasing in price. As economies of scale grow and battery prices decrease, EV sticker prices will decrease as well. From 2016 to 2017, the average price of an EV fell 11 percent.[15] The cost of a lithium-ion battery (the most expensive part of an EV) has fallen from $1,160/kWh in 2010 to $176/kWh in 2018.[16] With federal, state, and utility rebates available and the potential for cost savings due to lower fuel and maintenance expenses compared to ICE vehicles, EVs are becoming more economically attractive to consumers.

It is cheaper to fuel a vehicle with electricity than gasoline in all 50 states, due primarily to the higher efficiency of electric motors and the low cost of electricity.[17] According to the U.S. Department of Energy, gasoline prices would need to decrease to $1.17 per gallon to reach fuel cost parity with electric charging.[18] EV maintenance costs are also lower. A Department of Energy study found that battery electric buses had the lowest maintenance costs of all varieties studied, which included buses powered by diesel, natural gas, and fuel cells (Figure 2).[19] EVs do not require oil changes, have minimal scheduled maintenance, and possess significantly fewer parts that break and require replacement, such as a transmission or spark plugs, which can reduce maintenance costs; EV brakes also typically see less wear due to the benefits of regenerative braking.[20] For passenger EVs, average lifetime maintenance expenses are about $2,510 for a Toyota Prius hybrid and $1,183 for a Nissan LEAF BEV, compared to $5,317 for an average ICE passenger vehicle, according to an Electric Power Research Institute (EPRI) study.[21]

Figure 2: Bus maintenance costs across fuel types

Showing battery electric buses (BEB) with the lowest maintenance costs when compared to fuel cell electric buses (FCEB), compressed natural gas (CNG), and diesel.[22]



Source: U.S. Department of Energy

15 Douris. "The Bottom Line on Electric Cars."

16 A U.S. Department of Energy database of federal, state, and utility incentives and rebates for EVs can be found here: https://www.energy.gov/eere/electricvehicles/electric-vehicles-tax-credits-and-other-incentives

17 McMahon, Jeff. "Electric Vehicles Cost Less Than Half as Much to Drive. *Forbes*. January 14, 2018. https://www.forbes.com/sites/jeffmcmahon/2018/01/14/electric-vehicles-cost-less-than-half-as-much-to-drive/#61e6ef7f3f97

18 U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy. "Saving on Fuel and Vehicle Costs." Accessed June 11, 2019. https://www.energy.gov/eere/electricvehicles/saving-fuel-and-vehicle-costs

19 U.S. Department of Energy, Hydrogen & Fuel Cells Program. "2019 Annual Merit Review Proceedings." https://www.hydrogen.energy.gov/annual_review19_acceleration.html#acceleration

20 U.S. Department of Energy. Alternative Fuels Data Center. "Maintenance and Safety of Hybrid and Plug-In Electronic Vehicles." https://afdc.energy.gov/vehicles/electric_maintenance.html

21 EPRI. "Total Cost of Ownership Model for Current Plug-in Electric Vehicles." June 2013. B1. http://ehcar.net/library/rapport/rapport079.pdf

22 U.S. Department of Energy, Hydrogen & Fuel Cells Program. "2019 Annual Merit Review Proceedings." https://www.hydrogen.energy.gov/annual_review19_acceleration.html#acceleration

Advances in lithium-ion battery technology have enabled EVs to go farther on a single charge, assuaging some consumers' range anxiety concerns. For EVs available in the United States, median all-electric vehicle range grew from 80 miles in model year 2011 to 119 miles in projected model upgrades in 2019 (Figure 3).[23]

This change represents an average increase of 137 percent during that period and an average annual range increase of 17.2 percent through 2019. Average range is estimated to increase for the majority of BEVs by 25 to 40 miles with every battery upgrade (which often occur every two or three years). Projections by the website EVAdoption.com have forecasted an average range of 275 miles by 2022. Forecasts for most luxury BEVs indicate an average range of 350–400 miles by 2024 and 275–300 miles for non-luxury vehicles. If next-era solid-state batteries reach the market, it is possible that some higher end BEV models could surpass 500 miles of range on average by 2025.[24]

Figure 3: Increase in battery ranges for some EVs over model years 2011–2019[25]

BEV Model	2011	2012	2013	2014	2015	2016	2017	2018	2019	Increase in Miles	% Increase	Avg Annual Range Increase: Thru 2019
Kia Soul EV					93	93	93	111	186	93	100%	33.3%
Ford Focus Electric	76	76	76	76	76	76	115	115	115	39	51%	8.6%
Nissan LEAF	84	84	84	84	84	107	151	151	225	141	168%	21.0%
BMW i3				81	81	81	115	115	153	72	89%	17.8%
Tesla Model S		265	265	265	294	294	335	335	335	70	26%	5.3%
Volkswagen eGolf					83	83	125	125	125	42	51%	25.3%
Average	80	142	142	127	119	122	156	159	190	110	137%	17.2%

Chart: Loren McDonald / EVAdoption.com

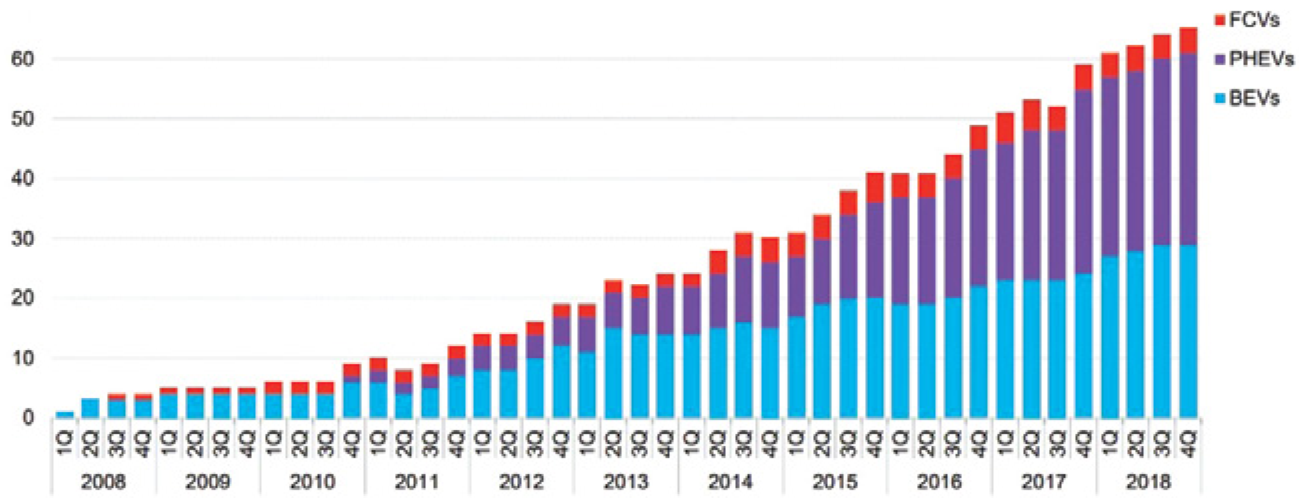
More companies are offering EVs for consumers to purchase, increasing the choices available (Figure 4). In addition to exclusively electric companies like Tesla or other popular models like the Chevrolet Bolt or Nissan LEAF, more companies are now offering BEV and PHEV versions of existing models from compact cars to SUVs (with pickup trucks coming soon from several manufacturers).

23 McDonald, Loren. "US Electric Car Range Will Average 275 Miles By 2022, 400 Miles By 2028 - New Research (Part 1)." CleanTechnica. October 28, 2018. Accessed January 23, 2019. https://cleantechnica.com/2018/10/27/us-electric-car-range-will-average-275-miles-by-2022-400-miles-by-2028-new-research-part-1/

24 Ibid.

25 Ibid.

Figure 4: Increase in number of EV models (including fuel cell vehicles, or FCVs)[26]



Source: BNEF

Charging Infrastructure Expanding but Still Often Insufficient

Public charging station installations have been steadily rising across the country: Only 430 charging ports existed in 2008, growing to 19,460 in 2013 and more than 68,000 as of September 2019 (of which about 18 percent are DC fast chargers).[27, 28] Although the number of chargers has grown rapidly—helping to remedy range anxiety for prospective EV drivers—a gap between predicted EV adoption and planned charging stations still exists. The size of the gap is not certain, as projections for EV adoption and charging station buildout vary. One study by the International Council on Clean Transportation estimates that only one-fourth of the public and workplace charging infrastructure that will be needed by 2025 has been built as of 2017, with some areas less prepared than others (Figure 5).[29] The study does not examine rural areas, which states such as Colorado have identified as a potential gap in coverage.[30]

26 Bloomberg NEF. *2019 Sustainable Energy in America Factbook*, 122. https://www.bcse.org/wp-content/uploads/2019-Sustainable-Energy-in-America-Factbook.pdf - page=122/

27 McCarthy, Niall. "The Evolution of U.S. Electric Vehicle Charging Points [Infographic]." *Forbes*. April 09, 2018. https://www.forbes.com/sites/niallmccarthy/2018/04/09/the-evolution-of-u-s-electric-vehicle-charging-points-infographic/#7d77449c4164

28 U.S. Department of Energy. Alternative Fuels Data Center. "Electric Vehicle Charging Station Locations." https://afdc.energy.gov/fuels/electricity_locations.html#/analyze?fuel=ELEC&country=US&ev_levels=all

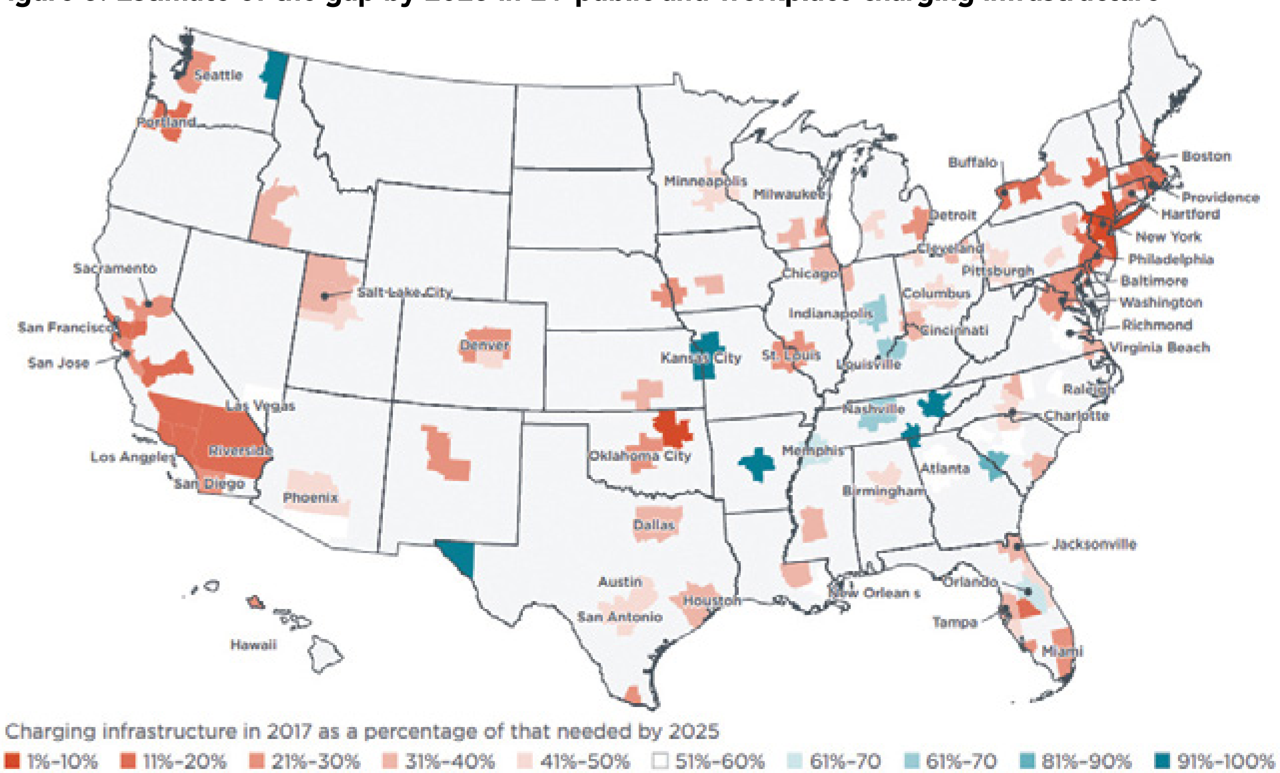
29 Nicholas, Michael, Dale Hall, and Nic Lutsey. "Quantifying the Electric Vehicle Charging Infrastructure Gap across U.S. Markets," ii. https://theicct.org/sites/default/files/publications/US_charging_Gap_20190124.pdf

30 Walton, Robert. "Colorado Passes Bill to Avoid Urban-Rural Divide on EV Chargers." *UtilityDive*. April 12, 2019. https://www.utilitydive.com/news/colorado-passes-bill-to-avoid-urban-rural-divide-on-ev-chargers/552561/

Types of Charging Infrastructure

- **Level 1** refers to charging an EV using an ordinary household outlet at 120V. This is the slowest manner to charge, due to the relatively low voltage involved, requiring 18 to 22 hours on average to completely charge a BEV.[31]
- **Level 2** charging is faster than Level 1, as it supplies electricity at 240V instead of the household 120V. Charging stations using this standard vary in speed, with an average Level 2 charger providing about 25 miles of range per hour (for a 7 kW charger, although the precise charging rate and range provided depend on the charger and vehicle).[32] Many automakers have encouraged customers to install Level 2 charging stations in their own homes, although they average about $2,000 to purchase and install. However, numerous local and state tax credits exist, along with an increasing number of rebate programs, to offset this cost.
- **DC Fast Charging.** The fastest charging method available on the market at the time of this report, these systems are more often found in public spaces, as they are much more expensive to install (up to $100,000 or $200,000) and require significantly higher voltage, with charging capacity ranging from 50kW to 350kW or more. A 50kW charger, for example, can charge a Nissan Leaf to 80 percent in approximately 30 minutes.[33]

Figure 5: Estimate of the gap by 2025 in EV public and workplace charging infrastructure[34]



Source: ICCT

31 U.S. Department of Energy. Alternative Fuels Data Center. "Developing Infrastructure to Charge Plug-In Electric Vehicles." https://www.afdc.energy.gov/fuels/electricity_infrastructure.html

32 Doyle, Kevin. "Level Up Your EV Charging Knowledge." *Chargepoint*. March 23, 2017. https://www.chargepoint.com/blog/level-your-ev-charging-knowledge/

33 McDonald, Zach. "A Simple Guide to DC Fast Charging." *FleetCarma*. February 28, 2018. https://www.fleetcarma.com/dc-fast-charging-guide/

34 Nicholas, Hall, and Lutsey. "Quantifying the Electric Vehicle Charging Infrastructure Gap across U.S. Markets," *The International Council on Clean Transportation*. January 2019 https://theicct.org/sites/default/files/publications/US_charging_Gap_20190124.pdf

Electric Vehicles Expanding Beyond Small and Light Duty

Both the size and the scope of the EV market has changed dramatically over the past 5 to 10 years, as automakers in the United States have expanded their EV models beyond smaller light-duty vehicles (e.g., Nissan LEAF and Chevrolet Bolt).

Some manufacturers have announced that they are moving toward all-electric product offerings. Others are planning to offer electrified versions of every existing model in their lineup, including Toyota, which plans to offer EV versions of all Toyota and Lexus vehicles by 2025.[35] GM has announced plans to eventually go all-electric, with 20 new electric models across their brands scheduled for release by 2023.[36] Volvo has made similar commitments, aiming for 50 percent of its sales to be fully electric by 2025.[37] Volkswagen has committed $50 billion toward the development of EVs, including investing $800 million to build a new BEV at its plant in Chattanooga, TN.

Larger Passenger Vehicles

The auto industry has declared its intent to tap into demand for greater customer choice through offering EV (not just hybrid, but also BEV and PHEV) counterparts wherever possible on their model lines. Audi, BMW, Hyundai, Jaguar, Ford, Tesla, VW, and Rivian all have electric sport utility vehicles (SUVs) either on the market or coming to market in 2018–2019, and GM has a BEV minivan planned.[38] More than half of new EVs planned to be released into the U.S. market in 2019 and 2020 are SUVs and crossovers.[39] In addition to the range of automakers already in the American market, several Chinese automakers are trying to enter the U.S. market with their own larger passenger EVs, including pickup trucks.[40]

Transit Buses

Other manufacturers, like Daimler, Tesla, Toyota, Volvo, and Proterra, are expanding their EV model lines to include heavy-duty and public transit vehicles, with more than 1,000 already on the road and orders for thousands more.[41, 42] There are two main types of electric buses: long-range and quick-charge. Long-range buses travel a minimum of 125 miles on a single charge, powered by batteries with a capacity of at least 300 kWh, charging twice a day at intervals of three to four and a half hours.

An average quick-charge bus carries a 150 kWh battery that relies on on-route fast charging (up to 1 MW or more). These buses can operate for up to four hours or 50 miles on a single charge, requiring six minutes of charge time for every hour of service.

Ten percent of transit buses sold in the United States during 2017 were electric.[43] California was the first state to pass laws requiring all-electric buses, barring transit agencies from purchasing new gas-powered

---

35 Kane, Mark. "Toyota To Electrify Every Model By 2025: Video." *Inside EVs*. January 08, 2019. Accessed January 23, 2019. https://insideevs.com/toyota-electrify-every-model-2025-video/

36 Holley, Peter. "Death of Gas and Diesel Begins as GM Announces Plans for 'all-electric Future.'" *The Washington Post*. October 02, 2017. Accessed January 23, 2019. https://www.washingtonpost.com/news/innovations/wp/2017/10/02/death-of-diesel-begins-as-gm-announces-plans-for-all-electric-future/?noredirect=on&utm_term=.55a50bd7fcad

37 Lambert, Fred. "Volvo Clarifies Electrification Plan, Aims for 50% of Sales to Be 'Fully Electric' by 2025." *Electrek*. April 25, 2018. Accessed January 23, 2019. https://electrek.co/2018/04/25/volvo-electrification-plan-fully-electric/

38 Evarts, Eric C. "2019 Is the Year of the Electric SUV." *Green Car Reports*. July 3, 2018. Accessed November 06, 2018. https://www.greencarreports.com/news/1117536_2019-is-the-year-of-the-electric-suv

39 Tannert, Chuck. "Will SUVs Breathe New Life into the Electric Car Market?" *Forbes*. November 27, 2018. Accessed January 23, 2019. https://www.forbes.com/sites/chucktannert/2018/11/27/will-the-suv-breathe-new-life-into-the-electric-car-market-dont-count-on-it/#1c2fb19517f9

40 Evarts. "2019 Is the Year of the Electric SUV."

41 Bernd Heid, Russell Hensley, Stefan Knupfer, and Andreas Tschiesner. "What's Sparking Electric-Vehicle Adoption in the Truck Industry?" McKinsey & Company. September 2017. https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/whats-sparking-electric-vehicle-adoption-in-the-truck-industry

42 EV Hub. Electronic Trucks and Buses Overview. "Resource Description," July 5, 2019. https://www.atlasevhub.com/resource/electric-trucks-and-buses-overview/

43 "Advanced Energy Year in Review 2018: Breakthroughs, Setbacks, and Holding Patterns." *Advanced Energy Economy Webinar*. December 18, 2018. https://info.aee.net/2018-year-in-review-breakthroughs-setbacks-and-holding-patterns

buses by 2029 and requiring zero-emission buses by 2040.[44] The rule would replace an estimated 14,000 gas-powered buses, while California has around 130 electric buses currently, leaving a long lead time for transit agencies to phase out existing buses in their fleets.

Non-Road Vehicles

Finally, industries such as construction have started to look at electric options for their heavy-duty vehicles. Battery-powered forklifts have existed for decades, currently representing 60 percent of the market.[45] With lower fuel and operating costs, they have been long preferred in indoor warehouses for their lack of emissions.[46] Volvo has developed a concept for an all-electric excavator that carries two 382 kWh lithium batteries, enough for eight hours of digging, and relies on electromechanical linear actuators instead of typical hydraulics.[47] Other facilities, such as ports and airports, are also looking at incorporating EVs.[48]

Commissions Have a Key Role to Play

Consumers have individual-level motivations behind why they purchase EVs, while utilities might see a sales and growth opportunity and a chance to be responsive to their customers. In some states, governors or legislatures have identified additional public policy interests in expanding EV adoption. These may include improved air quality through reductions of tailpipe emissions, enhanced asset utilization through well-timed electricity demand (e.g., absorbing renewable energy, EV load shifting, increasing demand during overnight hours), reduced greenhouse gas emissions, additional economic development, and other factors.

Regardless of motivation, and whether any state policy promotes EV adoption, Commissions are increasingly being asked to balance the interests of various stakeholders and weigh in on utility- and grid-related issues regarding EVs. Following a fundamental regulatory scope question about purview over chargers (see box), PUCs face two primary questions:

1. **Charging station ownership:** Whether regulated utilities should be permitted to own charging stations or provide make-ready investments in front of and behind the meter and earn a rate of return on this investment.
2. **Rate design:** Whether there should be a role for load management via EV rate design or demand response programs. By influencing charging times and lowering overall load factors from EVs, rate design and demand response can manage the grid impacts—positive or negative—that EVs may have on overall system load.

Commissions across the country have been making determinations on each of these issues, depending on their statutory authority and other factors. In all cases, the PUC decisions will have a critical role in influencing the states' timing and approach to EV expansion.

44 Plautz, Jason. "California to Require All-electric Buses by 2040." Smart Cities Dive. December 17, 2018. Accessed January 23, 2019. https://www.smartcitiesdive.com/news/california-to-require-all-electric-buses-by-2040/544462/

45 "The Advantages of an Electric Forklift." Blog. NMC Hexbolt | NMC Inc. Accessed January 23, 2019. http://www.nmc-corp.com/lift-truck/advantages-of-an-electric-forklift/

46 Ibid.

47 Mraz, Stephen. "Are Off-Highway Equipment and Heavy-Duty Trucks Going All-Electric Soon?" Machine Design. May 09, 2018. Accessed January 23, 2019. https://www.machinedesign.com/mechanical/are-highway-equipment-and-heavy-duty-trucks-going-all-electric-soon

48 See, e.g., Port of Long Beach. "Zero Emissions." http://www.polb.com/environment/air/zeroemissions.asp

Commission Jurisdiction over EV Charging Infrastructure

A preliminary question that most PUCs consider early in their exploration of EVs is whether the Commission has jurisdiction over charging infrastructure.[49] Specifically, whether EV charging stations, by reselling electricity through the charger, should fall under the definition of a public utility. This decision might impact whether third-party charging companies (sometimes called network service providers or EVSPs) can operate without implicating utility regulation.

The argument usually presented is that if utilities are not seeking rate recovery or a return on their investment on charging infrastructure, operating a charging station does not constitute a public utility and is exempt from "sale for resale" regulations. Often this ruling is based on state law and is decided in order to provide regulatory certainty to the EV charging industry that they will not be subject to Commission regulation as a public utility. At least 24 states (plus DC) have ruled on the issue, with all deciding that charging stations should not be regulated in the same manner as a utility.[50]

Some Commissions have ruled that charging stations are not public utilities, or that the Commissions lack jurisdiction from their respective state legislatures on this issue. In June 2018, the Alabama Public Service Commission (PSC) ruled that charging station owners and operators will not be considered public utilities subject to regulation. The Commission came to this ruling because they felt they were not given the legislative mandate from the state to regulate such matters.[51]

The Maryland PSC, however, reached a different conclusion in its EV order, relying on its broad statutory authority to regulate the activities of utility companies, including infrastructure investments to develop and maintain the utility's distribution system. In permitting utilities to own and operate public charging infrastructure, the Commission recognized that utilities provide the electricity supply to the public charging stations via their distribution system, and the retail sale of electrons at the charging station is analogous to electricity sales behind a meter.[52] The Commission explained that Maryland's exceptions for owners of EV charging equipment from the definitions of "electricity supplier" and "public service company" aim to accommodate market participant entry and do not preclude electric companies from owning and operating EV charging equipment.[53]

The ruling that EV chargers are not public utilities does not remove EV questions from Commissions' purview. Utilities could still bring forward proposals for charging station or make-ready investments or incentives, and integrating EV charging load through thoughtful ratemaking, managed charging, and distribution system planning would remain important.

The National Association of Regulatory Utility Commissioners' (NARUC's) members have adopted two resolutions urging state and federal policymakers to give due consideration to the potential value of developing and deploying alternative fuel vehicles, including EVs, and to work together to address issues that impede development and deployment. The first, "Resolution on Alternative Fuel Vehicle Development and Deployment,"

49 Docket No. 32694. "Generic Proceeding to Determine the Commission's Jurisdiction Over Electric Vehicle Charging Stations, Request for Comments." Letter to the State of Alabama Public Service Commission. Greenlots, 3–4. December 15, 2017. http://www.psc.state.al.us/Greenlots%20Comments%20to%20AL%20PSC%2012.15.17.pdf

50 Opalka, Bill. "Vermont Says Charging Stations Shouldn't Face Same Rules as Utilities." *Electric Vehicles*. January 25, 2019. https://energynews.us/2019/01/25/northeast/vermont-says-charging-stations-shouldnt-face-same-rules-as-utilities/; Commonwealth of Kentucky. Case No. 2018-00372. "Electronic Investigation of Commission Jurisdiction over Electric Vehicle Charging Stations." https://psc.ky.gov/order_vault/Orders_2019/201800372_06142019.pdf

51 Docket No. 32694. Greenlots.

52 Order No. 88997 - Case No. 9478 - EV Portfolio Order. https://www.psc.state.md.us/search-results/?keyword=9478&x.x=16&x.y=13&search=all&search=case

53 Ibid, 35.

was adopted in 2011 and expanded in 2012 to include several statements supporting further EV infrastructure development.[54] The resolution states that:

- "…alternative vehicles powered by electricity or natural gas from domestic sources can help our country reduce its dependence on oil from unstable foreign sources."
- "State and federal laws and policies can help facilitate the widespread adoption of alternative fuel vehicles"
- "…issues concerning affordability, deployment, infrastructure, and technology need to be addressed."
- "NARUC urges State and federal policymakers to give due consideration to the potential value of developing and deploying alternative fuel vehicles and to work together to address issues that impede development and deployment."

In 2018, a "Resolution Supporting Infrastructure Modernization Programs" also spoke to innovations for EVs, particularly concerning modernization of electric system infrastructure and alternative rate-recovery mechanisms.[55] It states that:

- "Whereas innovations in technology in areas including, but not limited to, electric vehicles…are occurring at a rapid pace;"
- "[NARUC's Board of Directors] encourages regulators and industry to consider sensible programs aimed at accelerating investments in electric system infrastructure to help modernize and protect the nation's electric system;"
- "...alternative rate-recovery mechanisms may help eliminate near-term financial barriers of traditional ratemaking policies such as 'regulatory lag' and promote access to lower-cost capital."

Volkswagen Settlement and Electrify America: Investing in Charging Infrastructure

In late 2016, Volkswagen settled a lawsuit brought by the U.S. Environmental Protection Agency and Federal Trade Commission alleging that the automaker had installed devices on 580,000 "clean diesel" vehicles from model years 2009–2015 that would turn on emission controls only when the vehicle was being tested. While the vehicles had better "real-world" mileage and driving performance when the emissions controls were turned off, the diesel vehicles emitted 9 to 38 times the federal NOx limits, roughly the equivalent of a tractor-trailer truck.[56]

Of the $14.7 billion payout from Volkswagen, $2 billion was mandated to go into ZEV infrastructure and programs. This payout included "Appendix C" funding for VW-owned charging infrastructure company Electrify America. Charging stations run by Electrify America include widely accepted plugs, not just those for Volkswagen EVs. The company has four phases of spending and development, requiring all settlement funding to be spent by Q4 2026.[57] As of February 2019, it has 105 sites with 465 chargers open to the public and planned to install 484 charging station sites with more than 2,000 fast chargers by July 2019.[58] By the end of the second cycle (Q4 2021), Electrify America will create a network covering 18 major metropolitan areas and 47 states, including two cross-country routes along major highways.[59]

continued

54 NARUC. "Resolution on Alternative Fuel Vehicle Development and Deployment." July 20, 2011. https://pubs.naruc.org/pub.cfm?id=539841D1-2354-D714-51B7-E8BBCD1055C8

55 NARUC. "CI-1/EL-2 Resolution Supporting Infrastructure Modernization Program." July 18, 2018. https://pubs.naruc.org/pub/09F5359D-C9ED-BCB3-EDF9-56B03A81F6D2

56 National Association of State Energy Officials (NASEO). "Volkswagen Settlement Beneficiary Mitigation Plan Toolkit," 4. https://www.naseo.org/Data/Sites/1/03-27-17_naseo-vw-beneficiary-mitigation-plan-toolkit-final.pdf

57 NASEO. "Volkswagen Settlement – Environmental Mitigation Trust Training Update." March 21, 2017, 2. http://naseo.org/Data/Sites/1/vw_emt_timeline_032117.pdf

58 Moloughney, Tom. "Electrify America Progress Report: Over 100 Charging Sites Open." *Insideevs.com.*, https://insideevs.com/electrify-america-progress-charging-stations/

59 Ibid.

Another $2.9 billion in "Appendix D" funding was put into an Environmental Mitigation Trust that was distributed to all 50 states, the District of Columbia, Puerto Rico, and tribal groups with allocation of funding dependent on the number of impacted vehicles in those jurisdictions.[60] States may use up to 15 percent of their allocation to fund EV charging station equipment for public places, workplaces, or multi-unit dwellings through competitive grant applications or rebate programs.[61] It is up to each state (often the state EPA or air quality office) to determine how to allocate these funds, with much of the funding already allocated. The National Association of State Energy Officials (NASEO) has set up a website to assist state agencies in developing and tracking plans for settlement funding.[62] Atlas EV Hub also tracks settlement spending on its website.[63] As of July 2019, states had issued preliminary plans for $2.7 billion of the $2.9 billion in total funds. More than $300 million of that funding is going toward ZEV supply equipment such as EV charging infrastructure.[64] PUCs can play a vital role in overseeing utility engagement with planning efforts and coordinating with other state agencies to make sure that EV infrastructure projects are complementary to other efforts.

Commission Approaches to Investigations on EVs

For the most part, Commissions have investigated issues surrounding EVs in formal judicial proceedings involving utility companies bringing forward plans for investment into the charging station space.

Some states have implemented nonjudicial approaches in preparing for EV grid impacts and other related issues, holding stakeholder engagement sessions and technical conferences to bring together representatives from the utility sector, auto companies, charging software and equipment suppliers, transportation planners, vendors, technical experts, and interveners to meet with Commission staff. Nonjudicial proceedings and information gathering are typically intended to inform the PUC prior to opening a potentially contested docket. Three examples include:

- The Minnesota PUC opened an EV Policy Docket in December 2017, which included a technical workshop and notice and comment period throughout 2018. The purpose of the inquiry was to explore the impacts of EVs on the grid, utilities, and customers to see how utilities and regulation can impact EV adoption and to examine possible EV tariff options.[65] Xcel Energy in Minnesota also held a series of five stakeholder meetings in 2018.[66] Stakeholders emphasized the need for both the Commission and Xcel to take into account issues of equity, high charging costs, and economic impacts from pilots and programs on all ratepayers.[67] Two barriers to EV adoption that were identified include lack of vehicle chargers and low public awareness. In response to both processes, the PUC voted unanimously to require all utilities in Minnesota to file detailed plans by June 2019 showing how each utility will raise public awareness of EV benefits and charging

60 NASEO. "Volkswagen Settlement – Overview and Opportunities for State Energy Officials." July 21, 2016, 8. https://www.naseo.org/Data/Sites/1/documents/committees/transportation/volkswagen/Volkswagen-NASEO-Webinar.pdf

61 Ibid, 19.

62 NASEO. Volkswagen Settlement. https://www.naseo.org/volkswagen-settlement

63 EV Hub. VW Settlement. https://www.atlasevhub.com/materials/vw-environmental-mitigation-fund-tracking/

64 Jones, Philip, and Nick Nigro. "Utilities Have a Vital Role in Advancing Electronic Vehicle Infrastructure through the VW Settlement." *NRRI Insights*. September 2019, 3. https://pubs.naruc.org/pub/ADFADCB5-B5C7-92F8-E93F-927F3B045E39

65 Docket No. E-999/CI-17-879. "In the Matter of a Commission Inquiry into Electric Vehicle Charging and Infrastructure." Minnesota Public Utilities Commission. February 1, 2019, 1–2. https://www.edockets.state.mn.us/EFiling/edockets/searchDocuments.do?method=showPoup&documentId={10BBAA68-0000-C413-9799-DF3ED0978E75}&documentTitle=20192-149933-01

66 Great Plains Institute. Minnesota Public Utilities Commission. "Summary of Stakeholder Meetings…." July 31, 2019. https://www.edockets.state.mn.us/EFiling/edockets/searchDocuments.do?method=showPoup&documentId={90A1A968-0000-CA1B-AF47-24D6EC828FED}&documentTitle=20191-149887-01&userType=public

67 Docket No. E002/M-18-643. Great Plains Institute. "Stakeholder Process Clarification…." February 15, 2009. https://www.edockets.state.mn.us/EFiling/edockets/searchDocuments.do?method=showPoup&documentId={000EF368-0000-CF1A-9394-EBCD70494266}&documentTitle=20192-150340-01&userType=public

options and how it will encourage the growth of charging infrastructure and the electrification of large public and private vehicle fleets.[68]

- The Michigan PSC hosted two technical conferences in 2017 and 2018 with industry leaders and EV manufacturers. The Commission's objective from these conferences was to formulate a work plan that could provide guidance for Michigan's EV charging networks and clarify the impact on ratepayers of utility investments in charging stations. After these sessions and a comment period, the Commission reached a formal conclusion that utilities should request EV pilots in upcoming rate cases with four main focuses: education, infrastructure deployment, grid impacts, and rate design.[69] Furthermore, it requested that future programs be economically sound and sustainable.
- The Maryland PSC opened a proceeding in January 2018 to begin implementing its statewide EV portfolio as part of Public Conference 44 (PC44), a Commission proceeding encouraging broad stakeholder participation on grid modernization. The Commission received four proposals from investor-owned utilities, which were then followed by a public comment period. In May and September 2018, the Commission held legislative-style hearings with stakeholders before issuing a concluding order in January 2019. The order authorized more than 5,000 chargers, both utility-owned and nonutility-owned; authorized a managed charging technology demonstration; and instituted a semi-annual reporting requirement so that the Commission could apply lessons learned from this process to future phases of development.[70] A fifth proposal was filed by the largest cooperative in the state on May 14, 2019, and subsequently approved on July 31, 2019, further expanding the total public chargers to be installed under the pilot.

It is also helpful for PUCs to coordinate with other areas of state government with a role in EV policy, including governors' offices, state energy offices, departments of transportation and environment, and the state legislature.

---

68 Kraker, Dan. "Minnesota regulators press utilities to prepare for more electric vehicles in Minnesota." *MPRnews*. December 13, 2018. https://www.mprnews.org/story/2018/12/13/puc-electric-vehicles-pushes-utilities

69 NARUC. "State Commission Staff Surge Call: Electric Vehicles." June 25, 2018. https://www.naruc.org/default/assets/File/EV%20surge%20summary%20070618-final.pdf

70 NARUC. Winter Policy Summit. "Maryland PSC Presentation: Implementing an Electric Vehicle Charging Infrastructure in Maryland." February 10–13, 2019. https://pubs.naruc.org/pub/07E1A01F-9771-C47F-DDE9-0117AD703ED7

2. Key Questions and Decisions Facing Public Utility Commissions

Because EVs require electricity to charge, they necessarily interact with the electric system and utility infrastructure within each Commission's purview. Two primary questions have been frequently raised to PUCs:

1. Who may own EV charging infrastructure?
2. What rate designs and other load management strategies are appropriate to mitigate EVs' potential negative grid impacts and maximize potential grid benefits?

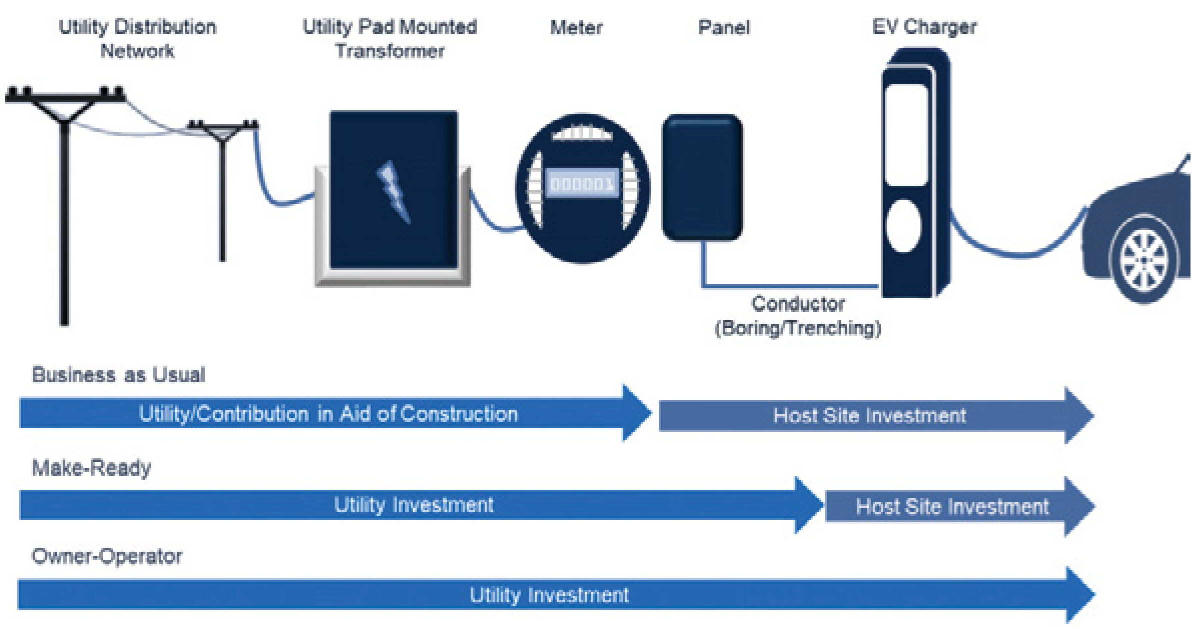
Commissions are being asked to make decisions relating to each of these issues as every state stands at a different phase in developing its EV infrastructure and planning. The following discussions provide a synopsis of the different approaches state PUCs have been taking to date in each topic area and why. Each discussion also includes examples of recent PUC decisions.

2.1. Charging Infrastructure Ownership

According to a 2018 report by the Edison Electric Institute (EEI), the United States will require 9.6 million EV charging ports by 2030 in order to meet projected demand;[71] at the same time, consumers are more likely to purchase EVs when they know they will be able to charge as needed. In many places across the country, policymakers, EV manufacturers, utilities, some private sector charging companies, and some advocacy groups want utilities to install and/or own EV charging stations. On the other hand, other private sector charging companies, consumer advocates, and others, while they are often supportive of utility investments in make-ready infrastructure and rebate programs, typically do not think that utilities should have a large role in installing and owning charging infrastructure, especially when needs may be met by the competitive market.

Figure 6: Different models of utility ownership and investment in EV charging infrastructure[71]

Sometimes known as EV supply equipment (EVSE)



Source: MJ Bradley & Associates and Georgetown Climate Center

71 Edison Electric Institute (EEI)/IEI. EV Sales Forecast and the Charging Infrastructure Required through 2030. November 2018.

72 Allen, Paul, Grace Van Horn, Matthew Goetz, James Bradbury, and Kathryn Zyla. Utility Investment in Electronic Vehicle Charging Infrastructure: Key Regulatory Considerations. M.J. Bradley & Associates and Georgetown Climate Center. November 2017. https://www.georgetownclimate.org/files/report/GCC-MJBA_Utility-Investment-in-EV-Charging-Infrastructure.pdf

Balancing the needs of all stakeholders and ratepayers to determine a utility's role in charging infrastructure ownership has been a challenging question for many PUCs to answer. The four major considerations driving debates around ownership models are:

1. The pace of market transformation and competitive market questions
2. Cost of installation
3. Equity of siting and charging rates
4. Integration of EVs' electricity load into the grid

Commissions have taken three general tracks when ruling about ownership (Figure 6). They might allow utility ownership of charging stations, disallow utility ownership of charging stations (through either a business as usual or utility incentive approach), or allow utilities to build make-ready infrastructure (i.e., the electrical infrastructure up to but not including the charger, such as wiring and conduit).

Table 2 summarizes the typical arguments proponents and opponents make for each of these approaches. The text that follows the table provides a more detailed discussion. It should be noted that decisions to allow or disallow utility ownership, incentives, or make-ready infrastructure are not necessarily binary choices. Many Commissions find hybrid solutions, where utility proposals and pilots are allowed in part and modified in part, or utility investments are focused mainly in underserved communities but not outright disallowed. Each decision will depend on context and local conditions.

Table 2: Summary of frequently cited reasons for Commission approaches to charging infrastructure ownership

Commission Decision	Argument			State Examples (see following text for more details)
	Consid-eration	Proponents' Rationale[73]	Opponents' Rationale[74]	
A. Allow Utility Ownership of Charging Stations	Market Transfor-mation	EV charger gap demands "all hands on deck," and involvement of utilities would speed charger deployment and solve "chicken or egg" problem.	Involvement of regulated monopolies is anti-competitive and would crowd out private investment.	• In May 2018, the Nevada PUC authorized NV Energy to build, own, and operate charging stations as part of a larger grid modernization effort.[75] • In 2016, the Washington Commission approved an Avista pilot program for Level 2 and DC fast charging to speed EV adoption. Charging stations can be owned by both Avista and customers.[76]
	Cost	Utilities could reduce installation costs through scale, access to low-cost capital, and existing expertise in installation and maintenance.	Utility cost recovery could lead to overbuilding, stranded assets, and higher overall costs.	

continued

73 Jones, Philip B. "The Future of Transportation Electrification: Utility, Industry and Consumer Perspectives." *Lawrence Berkeley National Laboratory*. 2018. http://eta-publications.lbl.gov/sites/default/files/feur_10_transportation_electrification_final_20180813.pdf

74 Levy, Jonathan. "The Future of Transportation Electrification: Utility, Industry and Consumer Perspectives." *Lawrence Berkeley National Laboratory*. 2018. http://eta-publications.lbl.gov/sites/default/files/feur_10_transportation_electrification_final_20180813.pdf

75 Docket No. 17-08021. "Rulemaking to Implement the Provisions of Senate Bill 145 (2017)." Public Utilities Commission of Nevada. May 11, 2018. http://pucweb1.state.nv.us/PDF/AxImages/DOCKETS_2015_THRU_PRESENT/2017-8/29834.pdf

76 Avista Corporation. Schedule 77: Electric Vehicle Supply Equipment (EVSE) Pilot Program. February 2, 2018. https://www.myavista.com/-/media/myavista/content-documents/our-rates-and-tariffs/wa/wa_077.pdf?la=en

Table 2 (continued)				
Commission Decision	Argument			State Examples (see following text for more details)
	Consid-eration	Proponents' Rationale	Opponents' Rationale	
A. Allow Utility Ownership of Charging Stations	Equity	Utility investment is subject to oversight by PUCs, which can enforce equitable charger distribution and rates.	Rate basing investments could lead to regressive cost allocation, where low-income ratepayers are forced to subsidize EV ownership.	• In February 2018, the Oregon PUC approved a pilot proposal by Portland General Electric (PGE) for PGE to own and operate up to seven public charging sites, which each have four Direct Current Fast Charging (DCFC) chargers and one Level 2 charger.[77]
	Integra-tion	Utilities are best able to plan and integrate charger loads to minimize negative grid impacts and the need for expen-sive grid upgrades.	Utilities might be less adept at keeping up with consumer preferences or technology innova-tions than startups and charging companies.	
B. Disallow Utility Ownership of Charging Stations	Market Transfor-mation	Monopoly utilities with a guaranteed rate of return do not belong in a pri-vate market; without their involvement, a robust private sector charging industry could flourish.	It is difficult to make money from chargers with low utilization rates, ensuring lackluster private investment and slow deployment rates in all but a few areas of the country.	• California PUC (CPUC) banned utility ownership in 2011 before deciding in 2014 to consider proposals on a case-by-case basis; the Commission cited the existence of underserved markets and market failures in its rescission.[78] • DC PSC in an April 2019 denied a request by Pepco to directly install and own charging stations, ruling that it could only sell electricity at charging stations through an affiliate; the PSC said that utility investment was not needed, citing sufficient EV charger buildout due to private investment and public incentives.[79]
	Cost	Utility ownership could lead to overbuilding and stranded assets, which would drive up costs.	Utilities have access to low-cost capital and have existing installation and maintenance expertise and capabilities, poten-tially leading to lower costs than third party installers.	

continued

77 Portland General Electric Company (PGE). RE: UM 1811 Transportation Electrification Compliance Filing. February 15, 2019. https://edocs.puc.state.or.us/efdocs/HAD/um1811had151943.pdf

78 Before the Public Utilities Commission of the State of California. Phase 1 Decision Establishing Policy to Expand the Utilities' Role in Development of Electric Vehicle Infrastructure. 12-079. December 18, 2014. http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M143/K682/143682372.PDF

79 Public Service Commission of the District of Columbia. Formal Case No. 1130 and Formal Case No 1155. April 12, 2019. https://edocket.dcpsc.org/apis/api/filing/download?attachId=84361&guidFileName=c302b307-c4b3-40e3-bf2e-3c8d9e064e64.pdf

Table 2 (continued)

Commission Decision	Argument			State Examples (see following text for more details)
	Consid-eration	Proponents' Rationale	Opponents' Rationale	
B. Disallow Utility Ownership of Charging Stations	Equity	If utilities own and rate base chargers, low-income ratepayers would be forced to subsidize EV charging for higher income EV early adopters; third-party ownership would shift costs to EV owners.	Private charging companies are likely to neglect low- and moderate-income communities, leading to inequitable siting outcomes.	• The PUC of Ohio opted for utility rebates instead of ownership, allowing American Electric Power (AEP) to reimburse up to $10 million in EV charging station installation costs.[80]
	Integra-tion	Market forces drive better outcomes; private charging companies rely on consumer demand to plan what types of char-gers are built and their location	Utility involvement would allow for better grid monitoring and distribution planning, which would help avoid negative grid impacts	
C. "Make-Ready" Approach	Market Transfor-mation	Make-ready investments would speed deployment, increase electricity sales, and leverage additional private capital without interfering with compe-tition.	Make-ready fails to fully take advantage of utility capital and maintenance expertise.	• In 2017, Massachusetts approved make-ready pilots to further encourage utility involvement with charging station manufacturers and vendors.81 • The DC PSC in April 2019 ruled that Pepco ought to assist with EV charger installation, including any electrical extensions behind the meter up to the charging station. This is to be paid for in full by Pepco through a revised tariff.82 • In 2018, CPUC approved make-ready and other investments by Pacific Gas & Electric (PG&E), Southern California Edison (SCE), and San Diego Gas & Electric (SDG&E) totaling more than $700 million for infrastructure, including fast chargers, the electrification of medium- and heavy-duty vehicles and fleets, and residential charging.[83]
	Cost	Utility involvement would decrease costs of installa-tion for third parties.	Make-ready investments do not go far enough, requiring host sites to purchase and operate charging stations them-selves.	
	Equity	Lower installation costs from utility investments in make-ready could improve the business case for chargers in low-income neighborhoods and areas with low EV adoption.	Would not ensure equitable charger siting or affordable charging rates, and does not provide a "turn-key" solution that is easy on underserved communities to implement.	

continued

80 The Public Utilities Commission of Ohio. Case No. 16-1852-EL-SSO and Case No. 16-1853-EL-AAM. Opinion and Order. April 25, 2018. http://dis.puc.state.oh.us/TiffToPDf/A1001001A18D25B43534I06271.pd

81 Walton, Robert. "In Massachusetts, Utilities Take a Collaborative Approach to EV Infrastructure." *UtilityDive*. May 10, 2017. https://www.utilitydive.com/news/in-massachusetts-utilities-take-a-collaborative-approach-to-ev-infrastruct/442047/

82 Public Service Commission of the District of Columbia. April 12, 2019.

83 California Public Utilities Commission. "Transportation Electrification Activities Pursuant to Senate Bill 350." *CA.gov*. https://www.cpuc.ca.gov/sb350te/

Table 2 (continued)				
Commission Decision	Argument			State Examples (see following text for more details)
	Consid-eration	Proponents' Rationale	Opponents' Rationale	
C. "Make-Ready" Approach	Integra-tion	Involvement of utilities in building EVSE would ensure utility awareness of charger locations.	Less capabilities for improved distribution planning and managed charging compared to utility ownership.	

Allowing Utility Ownership of Charging Stations

Many utilities around the country have begun to explore owning and operating EV charging stations to accelerate the growth of EVs and the corresponding growth in electricity sales. Proponents of utility ownership present several arguments in favor: Most experts agree that current EV charging infrastructure will need to grow dramatically to cover the expected growth of EVs.[84] This large "infrastructure gap" demands all hands on deck, including the participation of utilities. Furthermore, widespread charging infrastructure is a prerequisite for many consumers to consider purchasing an EV, but it is difficult for charging stations to be profitable without high usage from many EVs on the road. Utilities, which are rich in capital and can withstand initially low-usage rates, could solve this "chicken or egg" paradox. Utility involvement could speed up charger installations, especially in areas that are harder to reach, leading to increased EV adoption and all corresponding benefits, including lower rates for all ratepayers. (This phenomenon, discussed in the next box, occurs due to increased EV load itself and does not require utility ownership of charging stations per se.)

Utilities also argue that allowing utility involvement would force PUCs to closely regulate siting and alleviate equity and access concerns. Utilities could also use their access to low-cost capital, existing repair and installation capabilities, and scale to drive down the costs of charger installation and operation. The ownership of chargers by regulated utilities would also allow regulators to mandate certain equity standards, such as fair charging rates.

Siting for charging stations is a key issue facing Commissioners, including equitable access so that charging stations are not installed only in affluent neighborhoods, which are projected to have higher adoption rates of EVs. For these reasons, some Commissions require a certain percentage of utility investments to be deployed in disadvantaged communities. Finally, proponents say that utilities would be best able to site chargers in locations that would require fewer distribution system improvements, since the private market often does not have access to this information. Utility ownership could also make programs that beneficially shape EV load, such as managed charging (discussed more later), easier to implement.

Opponents of utility ownership contend that EV owners who charge their vehicles at charging stations that are owned and operated by utilities are being subsidized by ratepayers who do not and will not own EVs.[85] Opponents also contend that ownership of charging infrastructure by a monopoly utility with a guaranteed rate of return would crowd out investment from private companies and limit the growth of the EV charging industry.

Several PUCs have supported this model of charging infrastructure ownership, although PUCs have rarely approved the full investment amount proposed by the utility. In May 2018, the Nevada PUC authorized NV Energy to build, own, and operate charging stations as part of a larger grid modernization effort.[86] In the same ruling, the Commission created an Electric Vehicle Infrastructure Demonstration Program,

84 Jones, et al. "The Future of Transportation Electrification." 2018.

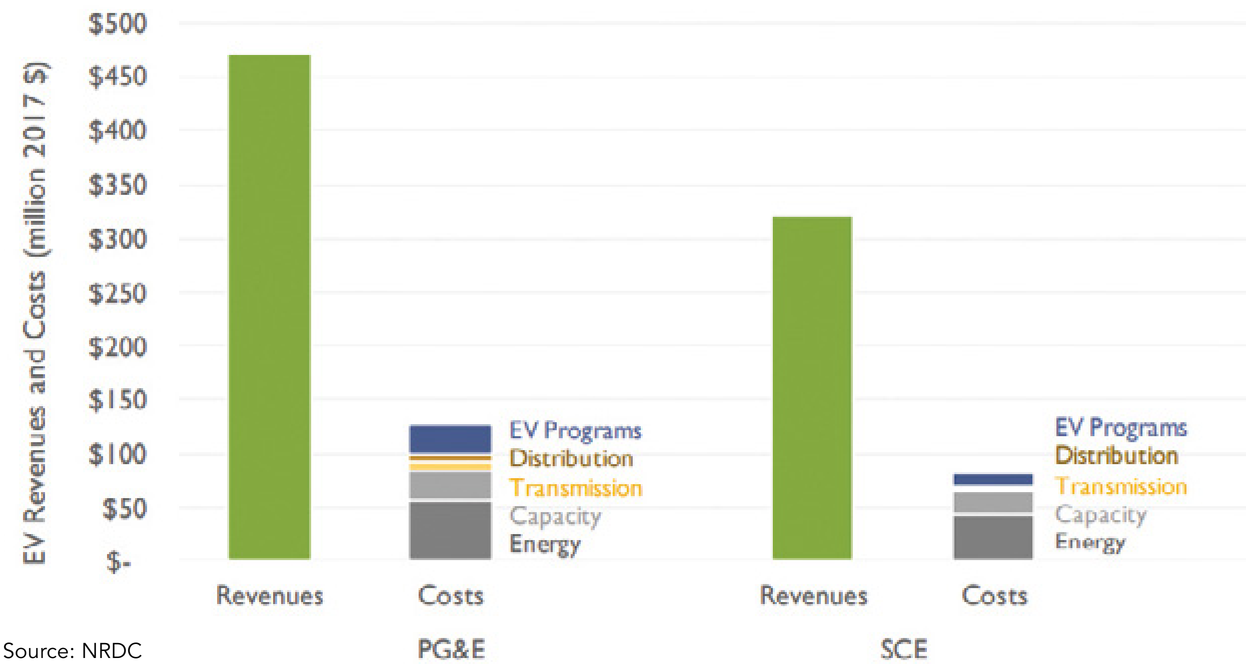
85 Tomich, Jeffery. "Big Oil looks to stop utilities' charging investments." *E&E News*. October 25, 2018. https://www.eenews.net/stories/1060104353

86 Docket No. 17-08021, "Rulemaking to implement the provisions of Senate Bill 145 (2017)." Public Utilities Commission of Nevada. May 11, 2018. http://pucweb1.state.nv.us/PDF/AxImages/DOCKETS_2015_THRU_PRESENT/2017-8/29834.pdf

EV Adoption Could Lead to Lower Rates for All Customers

A recent study by Synapse Energy found that in the territory of PG&E and SCE, the utilities with the highest EV adoption rates in the country, the revenue provided by EVs outnumbered the costs by more than 3 to 1 (Figure 7). This positive ratio is mostly due to EVs charging overnight during off-peak hours (requiring minimal costs for distribution improvements and capacity additions) while pushing EV owners into higher usage tiers (and creating higher marginal revenue).[87] This positive net revenue due to efficient use of the existing grid could lead to wider distribution of fixed costs across customers and—if Commissions choose to return the additional revenue to customers—could lead to lower rates for all ratepayers.[88]

Figure 7: Comparison of increased revenues and costs due to EVs in the two utility territories with the highest adoption rates shows that additional revenues outnumber costs more than 3 to 1 from 2012 to 2018.[89]



Source: NRDC

directing the utility to invest $15 million toward station development, including an attempt to complete the Nevada Electric Highway, a network of charging stations along interstate corridors.[90] However, NV Energy's investments will be reviewed for prudence in a future rate filing, and the utility agreed to Commission regulation on any EV charging rates—despite third-party stations not facing similar regulations in the state—providing an additional layer of consumer protection.

In August 2016, the Washington Utilities and Transportation Commission approved a two-year Avista pilot program for the installation of Level 2 and DC fast charging to speed EV adoption. Charging stations can be owned by both Avista and customers, with Avista allowed to own and operate no more than 265 Level 2 EV

87 Baumhefner, Max. "Electric Vehicles Are Driving Utility Rates Down." *Microgrid Knowledge*. June 24, 2019. https://microgridknowledge.com/electric-vehicles-utility-rates/

88 Jones, et al. "The Future of Transportation Electrification." 2018. For more information on how EVs might lower electricity rates, see Frost, Jason, Melissa Whited, and Avi Allison. "Electric Vehicles Are Driving Electric Rates Down." Synapse Energy Economics, Inc. June 2019 https://www.synapse-energy.com/sites/default/files/EV-Impacts-June-2019-18-122.pdf

89 Baumhefner, Max. "Electric Vehicles Are Driving Utility Rates Down."

90 Walton, Robert. "Nevada regulators allow utilities to own EV charging stations." (Brief). *UtilityDive*. May 15, 2018. https://www.utilitydive.com/news/nevada-regulators-allow-utilities-to-own-ev-charging-stations/523479/

chargers and seven DC fast chargers.[91] In 2017, the Commission issued an EV policy statement clarifying what utility EVSE investments are eligible for return on investment and how utilities must engage stakeholders to ensure that utility participation does not harm the competitive market.[92]

In February 2018, the Oregon PUC approved a modified Transportation Electrification Plan submitted by PGE.[93] The pilot plan includes the buildout (and PGE ownership) of up to seven Electric Avenue public charging sites, each having four DCFCs and one Level 2 charger. The PUC order approved the modified pilot program with the stipulation that it had not considered further EVSE ownership by PGE beyond the seven charging stations included in the pilot.[94]

Disallowing Utility Ownership of Charging Stations

Advocates that oppose utility ownership note that there is a risk to the health of the private market and that utility ownership of rate-based charging infrastructure may stifle innovation and crowd out private investment.[95] Additionally, the private market is beholden to the monopoly utility for interconnection and electric service and must compete with its power provider, who is often subsidizing charging at rates too low for the private market to compete. Opponents also note that, as utilities enjoy a publicly guaranteed rate of return on their investment regardless of usage of a given charger, utility ownership could lead to overbuilding of chargers and the potential for stranded assets.

Finally, they point to the fact that utilities generally do not have the relevant sets of expertise regarding development, purchasing, operations, or maintenance of the relevant chargers and that utilities would be effectively subsidized by the ratepayer to develop these skill sets that are already in the hands of third-party EV service providers. In addition, third-party EV service providers already have national and regional partnerships with site hosts, have data on where utilization is highest to avoid stranded assets, and possess the latest technology. Some opponents of utility ownership also contend that the benefits of utility involvement (such as ready access to capital and faster installation) could be accomplished through utility incentives or rebates for third-party charger installation without any negative impacts, such as the crowding-out effect.[96]

Several Commissions have taken steps to ban or disallow utility ownership of chargers. In 2011, the CPUC banned utility ownership of charging stations in the hopes of minimizing impacts on competition through the involvement of monopoly utilities. This policy changed after the state legislature passed SB 350, which set a metric of "widespread transportation electrification" for utilities.[97] Accordingly, the CPUC now considers applications through a case-specific approach that weighs any detrimental impacts on competition against the potential for utility ownership to support underserved markets and remedy any market failures.[98]

In April 2019, the DC PSC denied a request by Pepco to directly install and own charging stations and instead mandated Pepco to provide make-ready programs to accelerate the competitive marketplace to expand EV access to District residents. The PSC ruled that utility ownership was not needed, as there was sufficient charger buildout due to private investment and the existence of DC government incentives and rebates for charger installation. Pepco would be allowed to build chargers through an affiliate but would not be allowed cost recovery from ratepayers.[99]

---

91 Docket UE-160799. "Final Policy Statement." Washington Utilities and Transportation Commission. June 14, 2017, 5. https://www.utc.wa.gov/_layouts/15/CasesPublicWebsite/GetDocument.ashx?docID=147&year=2016&docketNumber=160799

92 Ibid, 8.

93 PGE. February 15, 2019.

94 Sanger Thompson PC. "Oregon PUC Approves PGE's Transportation Electrification Program." February 22, 2018. http://www.sanger-law.com/oregon-puc-approves-pges-transportation-electrification-program/

95 Levy. 2018, 20.

96 Ibid.

97 California Public Utilities Commission. "Transportation Electrification Activities Pursuant to Senate Bill 350."

98 Before the Public Utilities Commission of the State of California. Phase 1 Decision…. December 18, 2014.

99 Public Service Commission of the District of Columbia. Formal Case No. 1130 and Formal Case No 1155. April 12, 2019.

In the PUC of Ohio's (PUCO) PowerForward program, PUCO said in April 2018 that AEP Ohio could not own or receive a return on charging stations as part of the program, instead allowing AEP to create a rebate incentive program capped at $10 million to reimburse the costs of hardware, network services, and installation of Level 2 and DC fast charging stations.[100]

Allowing Utilities to Invest in Make-Ready Infrastructure

Even when utilities are not allowed to own the actual charging stations themselves, utilities can play a valuable role in the planning and infrastructure build-out up to the station (a make-ready role). Many consumer advocates and third-party EV service providers prefer make-ready investments. Make-ready avoids potential issues with ownership, such as the monopoly entity's ability to set its public pricing at rates too low for the private market to compete, which may undercut competition, while also allowing the utility to still rate base the electric infrastructure and other electrical components up to the charger.

Such work ensures that the utility is involved in planning for the stations, guarantees adequate local distribution infrastructure—such as peak capacity on the relevant substations—and involves installing the wiring and conduit necessary for the charger (including a 240V connection for Level 2 charging and a three-phase connection for DC fast charging[101]). Advocates for a make-ready approach tout that utility investment in this area can increase the speed and generally lower the costs of infrastructure investment without the negatives some associate with utility ownership.[102] Lower installation costs could also improve the business case for building chargers in low-EV adoption areas.

In this model, host sites (i.e., property owners of buildings or parking lots where stations are located) and charging station companies are responsible for charger installation, ownership, operation, and maintenance. Critics of this model say that it fails to go far enough to take advantage of utility maintenance expertise and capital, requiring host sites to research, purchase, and maintain charging stations and not providing a turnkey solution that is especially important in difficult-to-access market segments. According to their arguments, these responsibilities may create administrative inefficiencies and inconsistent charging station reliability.[103] There is also less oversight by Commissions that could help ensure equitable siting and fair rate setting. To mitigate these concerns, Commissions may require a certain percentage of make-ready stations to be deployed in disadvantaged communities or provide siting guidelines to help meet other state policy goals.

Massachusetts has used the make-ready approach in two different program approvals. In 2017, the Massachusetts Department of Public Utilities (DPU) approved a five-year, $45 million program from Eversource to install make-ready infrastructure on both sides of the customer meter, in which the utility owned everything up to, but not including, the charging station itself. The Commission stated in its ruling that "the program likely will help to boost the market size for the competitive EV charger suppliers."[104] The other involved a $25 million National Grid program in September 2018 that supported charging stations in areas deemed underserved or in low-income communities. The proposal was approved by the DPU after modification, with the DPU determining that the program would enhance the competitive marketplace.[105]

100 Williams, Mark. "Ohio Regulators Green-Light Utility's $10M Plan to Install More EV Charging Stations." *FutureStructure*. April 26, 2018. https://www.govtech.com/fs/transportation/Ohio-Regulators-Green-Light-Utilitys-10M-Plan-to-Install-More-EV-Charging-Stations.html

101 Vermont Energy Investment Corporation. "Electric Vehicle Charging Guidebook." June 2014. https://www.ccrpcvt.org/wp-content/uploads/2016/01/20140626-EV-Charging-Station-Installation-Guide.pdf

102 Allen, et al., 10.

103 Ibid.

104 EEI. "Customer Solutions: Electric Transportation. February 2018. 11. https://www.eei.org/issuesandpolicy/electrictransportation/Documents/Accelerating_EV_Adoption_final_Feb2018.pdf

105 Rivera-Linares, Corina. "Massachusetts regulators approve National Grid's proposed EV program, subject to modifications." *TransmissionHub. September 13, 2018.* https://www.transmissionhub.com/articles/2018/09/massachusetts-regulators-approve-national-grids-proposed-ev-program-subject-to-modifications.html

In April 2019 (in the same ruling that denied direct charger ownership), the DC PSC ruled that Pepco ought to assist with EV charger installation, including helping with any electrical extensions behind the meter that would allow EV owners to install chargers. The full cost to Pepco of make-ready infrastructure (not including the charger itself) is to be recovered in full through a revised tariff.[106]

In California in May 2018, the CPUC approved transportation electrification investments by PG&E, SCE, and SDG&E totaling $738 million, including make-ready investments to support fast charger deployment and the electrification of fleets and medium-duty vehicles and heavy-duty vehicles.[107] The CPUC allowed PG&E to spend $22 million on make-ready infrastructure for approximately 234 fast charging stations at more than 50 sites; the CPUC mandated that 25 percent of site hosts should be located in or adjacent to disadvantaged communities, and site hosts may receive an additional rebate for projects installed in these communities. Through this program, PG&E issues a Request for Proposals to collect sites from EVSPs that they then evaluate based on grid capacity and other considerations. The medium-duty and heavy-duty vehicle make-ready investments would support the charging of at least 6,500 and 8,490 vehicles by PG&E and SCE, respectively.[108]

For more detailed information on charging infrastructure ownership approaches and perspectives, see:

- **"The Future of Transportation Electrification: Utility, Industry and Consumer Perspectives"**
  Lawrence Berkeley National Laboratory, 2018
  - Three different perspectives on the most pressing issues, both current and future, behind transportation electrification
- **"Utility Investment in Electric Vehicle Charging Infrastructure: Key Regulatory Considerations"**
  Georgetown Climate Center and M.J. Bradley & Associates, 2017
  - Lays out market and policy context for EV regulation, including key considerations for regulators involving different utility investment models
- **"Getting from Here to There: Regulatory Considerations for Transportation Electrification"**
  Regulatory Assistance Project, 2017
  - Focuses on the opportunities provided by increasing EV penetrations and the regulatory principles and issues that they raise
- **"The 50 States of Electric Vehicles"**
  North Carolina Clean Energy Technology Center, 2019
  - Comprehensive and quarterly updated analysis and insight on state Commission actions and trends on EVs
- **"Accelerating Electric Vehicle Adoption"**
  Edison Electric Institute, 2018
  - Identifies key arguments for proponents of increased role for electric utilities in charging infrastructure, grid integration, and easing the transition to electric vehicles
- **"Electric Vehicles for All: An Equity Toolkit"**
  The Greenlining Institute, 2016
  - Describes tools that can be used to increase equitable access to EVs for underserved communities, including for low-income communities and communities of color

---

106 Public Service Commission of the District of Columbia. Formal Case No. 1130 and Formal Case No 1155. April 12, 2019.

107 California Public Utilities Commission. "Transportation Electrification Activities Pursuant to Senate Bill 350."

108 Walton, Robert. "California, New York, New Jersey see nearly $1.3B in new EV finding." (Brief). UtilityDive. June 1, 2018. https://www.utilitydive.com/news/california-new-york-new-jersey-see-nearly-13b-in-new-ev-funding/524757/

2.2. Impacts on the Grid and Rate Design

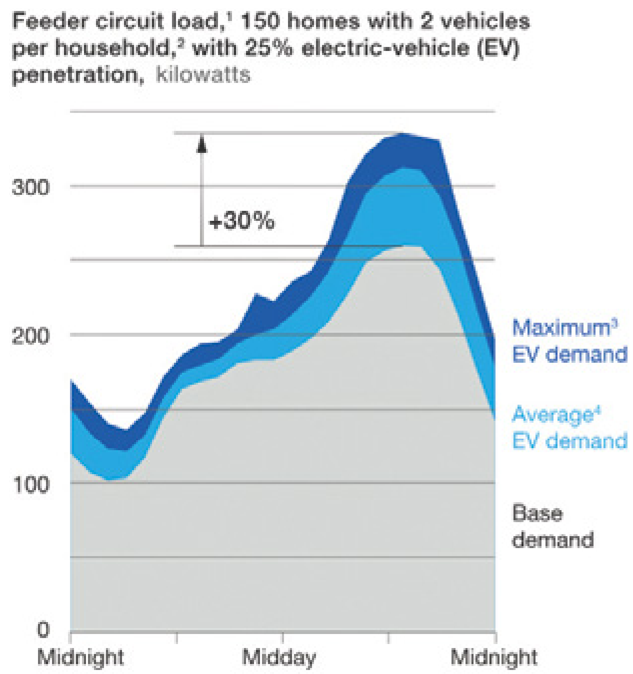
According to an August 2018 McKinsey estimate, EVs will likely not lead to enough additional power demand by 2030 to require new generation.[109] However, the authors anticipate a reshaping of the load curve, with an increase in evening peak loads being the most prominent, a direct result of EV drivers charging their cars when returning home from work.[110] If unaddressed, EV charging could strain local distribution networks, which may be exacerbated by the advent and further adoption of fast-charging systems that can magnify spikes in electricity demand. However, EVs also represent an opportunity for grid management. Because EV load is flexible, if charging can be moved to times of low demand or abundant renewable generation, EVs represent a significant opportunity for increased grid flexibility.

Rate design is one way to minimize any unintentional impacts to the grid and instead maximize benefits associated with this flexible new load, including through implementing time of use (TOU) rates and dynamic real time pricing (RTP). Through managed charging, sometimes called smart charging, negative impacts could be further minimized, and EVs could act as grid assets by serving as a demand response resource. In the future, EVs could provide additional grid services through Vehicle to Grid (V2G) services, which would leverage the onboard battery to discharge electricity back to the grid when needed or provide ancillary services like voltage regulation.

Analysis has shown that a typical residential feeder circuit of 150 homes at just 25 percent EV penetration would increase local peak load by nearly 30 percent (Figure 8).[111] There are concerns that if left unmanaged, substation peak-load increases from just a single fast charging station would exceed capacity of local transformers, requiring a rapid intensification of grid investment alongside the growth in the number of EVs.[112]

However, changes to the load curve and overall demand will likely be spread unevenly across geography, with regions with more EV adopters and fast-charging stations seeing changes before other areas. These conditions will also depend greatly on rate design, charging incentives, and characteristics of the local grid. Utilities will need far more visibility into their distribution system's operational constraints than they have historically had. Coincidentally, the advent of EVs is coming at the same time as growth in penetration of other distributed energy resources, so challenges and opportunities are complex and intertwined. Utilities and commissions can get ahead of these potential challenges by integrating EV load into distribution system planning.[113]

Figure 8: Load impacts of increased EV adoption[114]



¹Load shape for a typical feeder with 150 houses at 8 megawatt-hours per year; example shown for Midwestern US on typical September day.
²The average US household owns 2.1 vehicles.
³Statistically expected maximum EV demand—"peak day."
⁴Statistically expected average EV demand—"typical day."

Source: McKinsey & Company

109 Engel, Hauke, Russell Hensley, Stefan Knupfer, and Shivika Sahdev. "The Potential Impact of Electric Vehicles on Global Energy Systems." *McKinsey and Company.* August 2018. https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/the-potential-impact-of-electric-vehicles-on-global-energy-systems

110 Ibid.

111 Ibid.

112 Ibid.

113 See, Smart Electric Power Alliance. "Preparing for an Electric Vehicle Future: How Utilities Can Succeed." October 2019. https://sepapower.org/resource/preparing-for-an-electric-vehicle-future-how-utilities-can-succeed/

114 Engel et al. "The Potential Impact of Electric Vehicles on Global Energy Systems."

A common approach to avoid negative grid impacts and equitably allocate costs for supporting EVs is through rate design. The two main principles of EV-specific rate design are typically that:

- Rate design should be utilized to increase efficient usage of existing assets rather than undergoing expensive distribution system upgrades to serve EVs.
- Bill increases due to EV infrastructure upgrades should be kept to a minimum for customers who do not own EVs.

There are many methods to accomplish these goals. TOU rates are becoming a more common way to send price signals to customers in order to prevent peak-load spikes in demand. RTP and managed charging are approaches similarly employed to give consumers and utilities more control over when to efficiently charge EVs. The underlying logic of these systems is that if an EV owner wishes to charge their vehicle during peak demand periods, they will pay higher prices for electricity to reflect the higher system costs. This in turn benefits both EV owners with cheaper off-peak rates, or other discounts or incentives for participation in a managed charging program, and protects non-EV owners from the higher costs that are imposed by peak-load charging.[115] For any rate changes, there is an open question of whether to make the rate available to all customers, only optional, or mandatory for EV loads. If the tariff is EV-specific, a way to monitor, record, and bill the customer for the energy consumed by the vehicle (such as a secondary meter or submeter) would need to be installed, potentially leading to additional costs.

Demand Charges and Impact on EV Charging

Demand charges are additional charges or higher rates added to a customer's electricity bill based on the customer's peak capacity usage, traditionally used to recover the nonfuel costs of generation, transmission, and distribution. They are charged to commercial and industrial customers to incentivize these customers to level out their load and avoid steep increases in usage that could overload the distribution system. The charge often scales proportionately with the highest power capacity (kW) drawn by a user during any given 15-minute period over the course of a billing cycle and can depend on the time of day that the demand occurs (peak or off peak).[116] DC fast chargers (DCFCs), which can draw large amounts of power to quickly charge vehicles, are especially susceptible to high demand charges, which can make up large portions of electricity bills and are seen as a stumbling block for increased installation of EV chargers. For EVGo, a prominent owner-operator of EV charging infrastructure, demand charges can represent up to 93 percent of monthly electricity bills for a charger, depending on the charger's location and utilization rate, as well as rate design in the area.[117]

Demand charges are a particular issue for areas where EV system utilization is low. Many DCFC stations are currently characterized by having a low load factor, yet they are on the same commercial tariffs as commercial and industrial buildings. The combination of high power and extremely low load factor is atypical for commercial and industrial uses cases and can subject fast charging stations to significant demand-based charges. Without substantial utilization and sales, relatively high fixed demand charges inhibit the ability of charging stations to earn profits. The existence and cost of demand charges are important factors in whether a private charging company decides to build in an area or not. In order to improve charging economics, some utilities and Commissions are looking at revising demand charges or instituting special EV-specific commercial rates—at least until EV adoption is high enough to improve the business case for fast chargers.

continued

115 Regulatory Assistance Project (RAP). "Getting from Here to There: Regulatory Considerations for Transportation Electrification." May 2017, 26. https://www.raponline.org/wp-content/uploads/2017/06/RAP-regulatory-considerations-transportation-electrification-2017-may.pdf

116 Southern California Edison. "Electric Transportation and Rate Designs at SCE." June 7, 2018. http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=6442457678

117 Jones, et al. "The Future of Transportation Electrification." 2018.

The California legislature, for example, passed a bill ordering the CPUC to consider alternative rate designs that address the high demand charges to which commercially owned charging stations are subject (some utilities had included demand charge waivers in their EV pilot proposals).[118] SCE was the first investor-owned utility to have such a rate approved. SCE's new commercial EV rate schedules are all-volumetric TOU rates with strong price signals to consume energy in off-peak and super-off-peak periods and to limit charging between 4 pm and 9 pm. A key feature of the new SCE rates is a five-year holiday from all demand charges, with the expectation that EV penetration will be higher after the holiday, reducing the demand charge penalty at what are today low-utilization charging stations. In years six through ten, most of the demand charges from SCE's standard commercial rates will be phased back into the EV rates.[119] Where high demand charges remain, some companies have started investing in behind-the-meter energy storage or managed charging as a demand charge management strategy, but those opportunities can be costly or increase customer charge times.

The Pennsylvania PUC approved a PECO Energy Company proposal in late 2018 for a DCFC rider that offers commercial EV charging facilities a credit against any demand charges for up to 36 months.[120] The 36 months of demand credits will be available during a five-year program period, which began July 1, 2019 and will end June 2024. The credit is equal to 50 percent of the connected DCFC nameplate capacity. For example, a DCFC station with a nameplate charging capacity of 200 kW would receive a demand credit each month of 100 kW.

In order to alleviate problems that increased EV adoption may bring, some Commissions have declared that greater attention to transportation electrification is needed. The rationale is that as EVs gain a larger market share, growing load and greater peak-load strain on local distribution systems is possible.

Maryland's PC44 was one of the first such PUC initiatives to investigate potential grid impacts of EVs during a review of electric distribution systems in its state. In its concluding order in January 2019, the PSC agreed that increased EV adoption could put additional strain on local distribution systems but could be mitigated by incentivizing off-peak charging through either TOU rates or managed charging systems. The Commission also noted that those approaches were critical for preventing expensive distribution upgrades and maintenance that would impact every ratepayer.[121]

PUCO has taken similar steps to monitor grid impacts of EVs through its PowerForward grid modernization program. In its paper outlining the roadmap for future initiatives, PUCO concluded that EV market penetration has been too low for the Commission to immediately address any concerns relating to peak-load stresses. That said, the Commission will continue to monitor EV effects on distribution systems as growth rates increase.[122]

---

118 Trabish, Herman. "PG&E, SCE, SDG&E pursue subscriptions, time-of-use rates to drive more California EVs." UtilityDive. January 23, 2019. https://www.utilitydive.com/news/pge-sce-sdge-pursue-subscriptions-time-of-use-rates-to-drive-more-cali/545907/

119 Ibid.

120 Docket No. R-2018-3000164. "Pennsylvania Public Utility Commission v. PECO Energy Company – Electric Division." Pennsylvania Public Utility Commission. 22. https://www.puc.pa.gov/pcdocs/1599296.docx

121 Order No. 88997 - Case No. 9478 - EV Portfolio Order.

122 Ohio Public Utilities Commission. "PowerForward: A Roadmap to Ohio's Electricity Future," 22. https://www.puco.ohio.gov/industry-information/industry-topics/powerforward/powerforward-a-roadmap-to-ohios-electricity-future/

Heavy Duty and Fleet EVs' Load Impacts

Previous assumptions on the growth of EV adoption have usually concentrated solely on light-duty vehicles, but heavy-duty EVs and other fleets—whether public transit systems, school buses, trucks, or other larger vehicles—have been coming to market across the United States. Larger vehicles have larger batteries and could cause higher peak loads, drawing concerns that local distribution grids may not be ready for the sharp increases in peak loads that vehicles requiring frequent fast charging could bring, especially when that charging is concentrated, as could be the case with fleets.

Oncor Utilities recently estimated that if a local logistics company electrified its 325 fleet vehicles, it could add up to 40 MW of power demand, compared to the average 0.5 MW it usually sees from a commercial ratepayer. Providing this substantial amount of power may not be done quickly or easily and requires a new level of customer engagement between the utilities and fleet operators.[123]

Table 3 highlights three Commission approaches to EV rate design that can maximize grid benefits and minimize negative grid impacts: TOU rates, RTP, and managed charging.[124] The table includes pros and cons of each approach, broken down across three major considerations: success in reducing negative and maximizing positive grid impacts, rate of uptake by consumers, and costs involved. The table also includes a synopsis of state examples for each approach. The text that follows the table provides a more detailed discussion.

Table 3: Summary of frequently cited reasons for Commission approaches to EV rate design

Commission Approach	Argument			State Examples
	Consid-eration	Proponents' Rationale	Opponents' Rationale	
Time of Use (TOU) Rates	Grid Impact	Several pilots show price signals shift charging to off-peak periods.	Can create new secondary peaks at start of off-peak periods;[125] impact relies on uncertain customer response; sometimes the "peak" periods are not flexible to changing grid conditions	• The Maryland PSC approved a Baltimore Gas & Electric-run EV TOU pilot in 2015 that resulted in both shifts to off-peak charging and greater customer satisfaction.[126]

continued

123 Bade, Gavin. "How Oncor Is Preparing for a Wave of Large Electric Fleet Vehicles." *UtilityDive*. February 25, 2019. https://www.utilitydive.com/news/how-oncor-is-preparing-for-a-wave-of-large-electric-fleet-vehicles/549109/

124 Another rate structure not mentioned here is a subscription rate. Austin Energy has introduced an EV subscription rate, which allows unlimited off-peak charging for a flat monthly fee. See, Austin Energy. "Plug-in Austin Electric Vehicles." https://austinenergy.com/ae/green-power/plug-in-austin/home-charging/ev360

125 Myers, Erika. "Three Things You Think You Know about EVs Are Wrong." Smart Electric Power Alliance. July 26, 2018. https://sepapower.org/knowledge/three-things-you-think-you-know-about-evs-are-wrong/

126 Murach, John. "BGE Electric Vehicle Off Peak Charging Pilot." http://www.madrionline.org/wp-content/uploads/2017/06/BGE-EV-rate-design-pilot.pdf

Table 3 (continued)

<table>
<tr><th rowspan="2">Commission Approach</th><th colspan="3">Argument</th><th rowspan="2">State Examples</th></tr>
<tr><th>Consid-eration</th><th>Proponents' Rationale</th><th>Opponents' Rationale</th></tr>
<tr><td rowspan="2">Time of Use (TOU) Rates</td><td>Uptake</td><td>Simpler for customers to understand than hourly RTP rates, with potentially higher participation</td><td>Can be challenging to roll out in the face of customer disinterest[127]</td><td rowspan="2">• SDG&E's 2014 EV-specific TOU pilot shifted the majority of charging to "super off-peak" hours as participants learned how consumption affected rates.[128] The successful pilot led the CPUC to mandate the state's three IOUs to transition to default (or "opt-out") TOU rates by 2019 or 2020.[129]
• A January 2018 EV-specific TOU pilot by Arizona's Salt River Project found that TOU rates were successful in pushing EV owners to charge during off-peak periods. The Arizona Corporation Commission encouraged the further use of TOU rates for load shifting in a January 2019 ruling.[130]</td></tr>
<tr><td>Cost</td><td>Cost savings for consumers that successfully shift their load to lower cost periods</td><td>Low-income customers on whole-home TOU rates could pay more if unable to shift electricity load;[131] whole home TOU rates would require the installation of a smart meter (though EV-only rates could use a submeter).</td></tr>
<tr><td>Real-Time Pricing (RTP)</td><td>Grid Impact</td><td>Hourly prices more accurately reflect the cost of providing electricity, leading to more efficient outcomes.</td><td>Low customer adoption can lead to minimal benefits.</td><td>• Commonwealth Edison (ComEd) (Illinois) EV owners who opted into the utility's whole-home RTP, which was instituted in 2007, lowered average energy bills by 45 percent compared to standard rates and 38 percent compared to TOU rates by taking advantage of lower overnight rates for charging.[132] Low adoption of the rate, however, led ComEd to also propose a TOU rate to the Illinois Commerce Commission.[133]</td></tr>
</table>

continued

127 Ibid, 77–78.

128 Faruqui, Ahmad, Ryan Hledik, and John Higham. "The State of Electric Vehicle Home Charging Rates." October 15, 2018, 13. http://files.brattle.com/files/14717_the_state_of_residential_ev_electric_rates_10-15-2018.pdf

129 Trabish, Herman. "California Utilities Prep Nation's Biggest Time-of-Use Rate Rollout.: *UtilityDive*. December 6, 2018. https://www.utilitydive.com/news/california-utilities-prep-nations-biggest-time-of-use-rate-roll-out/543402/

130 Walton, Robert. "Time-of-Use Rates Can Manage EV Charging, New Report Says." *UtilityDive*. January 23, 2018. https://www.utilitydive.com/news/time-of-use-rates-can-manage-ev-charging-new-report-says/515284/

131 Jones, et al. "The Future of Transportation Electrification," 97.

132 RAP. "Getting from Here to There: Regulatory Considerations for Transportation Electrification." May 2017, 17.

133 Thill, David. "Illinois Groups Split on How to Balance Risk, Reward for ComED Time-of-Use Rates." *Energy News Network*. June 26, 2019. https://energynews.us/2019/06/26/midwest/illinois-groups-split-on-how-to-balance-risk-reward-for-comed-time-of-use-rates/

Table 3 (continued)

Commission Approach	Argument			State Examples
	Consid-eration	Proponents' Rationale	Opponents' Rationale	
Real-Time Pricing (RTP)	Uptake	Very low or negative overnight prices are quite attractive to EV owners or customers with flexible loads.	Lack of price certainty for consumers can lead to lower adoption rates than other rate designs;[134] requires that customers use an app to closely follow rate shifts or to automatically manage EV charging[135]	• Ameren (Illinois) maintains an hourly whole-home RTP rate, with more than 13,000 customers participating as of July 2019. According to a 2014 study, the average EV owner who participated saved $268.78 annually by taking advantage of cheaper overnight rates.[136]
	Cost	Can lead to large savings for consumers, especially EV owners[138]	Low-income customers or others could pay more if unable to shift electricity load;[139] would require installation of smart meter (unless the rate is EV-specific and relies on a submeter).	• In January 2016, the California PUC approved an SDG&E pilot EV-only hourly RTP called Power Your Drive that offers lower prices during grid-friendly times.[137] Customers can set a maximum price of electricity, and when the hourly price exceeds their maximum, the charger stops charging.
Managed Charging	Grid Impact	With more utility control over charging, utilities can better avoid load peaks at specific locations and times, including seasonal peaks, and have more certainty in EV load response; can both increase and decrease load.	Connectivity issues due to reliance on Wi-Fi or cellular may reduce benefit.	• In 2016, SCE (California) ran a CPUC-approved managed charging pilot using demand response technology in order to slow workplace charging during peak demand periods, with curtailment events occurring up to 10 days a year.[140]

continued

134 Walton, Robert. "ComEd Time-of-Use Pilot Will Test Importance of Price Certainty." *UtilityDive*. November 26, 2018. https://www.utilitydive.com/news/comed-time-of-use-pilot-will-test-importance-of-price-certainty/542838/

135 RAP. "Getting from Here to There: Regulatory Considerations for Transportation Electrification." 17.

136 Elevate Energy. "Hourly Pricing and Electric Vehicles." https://www.elevateenergy.org/wp/wp-content/uploads/Hourly-Pricing-and-EVs-050714.pdf

137 Public Utilities Commission of the State of California. "Electric Vehicle-Grid Integration Pilot Program." November 14, 2013. https://www.sdge.com/sites/default/files/regulatory/FINAL%20September%202018%20Power%20Your%20Drive%20Semi-Annual%20Rpt_0.pdf

138 Thill, David. "Illinois Groups Split on How to Balance Risk, Reward for ComED Time-of-Use Rates."

139 Jones, et al. "The Future of Transportation Electrification."

140 Hall, Dale, and Nic Lutsey. "Literature Review on Power Utility Best Practices Regarding Electric Vehicles." ICCT. February 2017. 19–20. https://www.theicct.org/sites/default/files/publications/Power-utility-best-practices-EVs_white-paper_14022017_vF.pdf

Table 3 (continued)				
Commission Approach	Argument			State Examples
	Consid-eration	Proponents' Rationale	Opponents' Rationale	
Managed Charging	Uptake	Easy on consumer, with no need for consumers to closely monitor rates	Concerns around customer privacy and lack of flexibility to charge when desired might lead EV owners to opt out	• Avista (Washington) implemented a voluntary managed charging program that curtailed evening peak charging by 75% until at least 8 pm, with participation rates of 84%. However, there were some issues with Wi-Fi connectivity, causing 30-45% of vehicles to be offline at any given time.[141] A final evaluation will be delivered to the Washington Utilities and Transportation Commission in fall 2019. • PG&E's 2016 i ChargeForward pilot, in cooperation with BMW and approved by the CPUC, was able to curtail on-peak charging and move charging load to times that would help prevent curtailment of abundant renewable energy.[142]
	Cost	Customers can receive savings for participating, utilities pay only for performance.	More expensive infrastructure required to enable two-way communication capabilities; lack of adoption of interoperability standards for communication can lead to higher integration costs.	

Time of Use Rates

TOU rates use a block rate structure with different rates for different periods, according to the time of day, season, and day type (weekdays and weekends/holidays). Higher rates are charged during peak demand hours, with the highest typically in the afternoon or evening, and lower rates during "off-peak" or overnight periods (Figure 9).[143] TOU rates are used for EVs to provide price signals that encourage consumers to charge vehicles at times that are most beneficial for the grid.

TOU rates, like other residential rates discussed in this section, can be either whole-home or EV specific. Historically, TOU rates relied on the adoption of the rate for the entire load (whole-home) or required installing separate electricity service and a secondary meter for the EV charger (to allow EV-specific rates). However, states such as California have begun to implement EV submetering, which utilizes the charging station, vehicle telematics, or third-party hardware to monitor the EV load exclusively.[144, 145] Submetering makes the implementation of EV-specific rates much more cost effective compared to secondary metering and eliminates the need to adopt whole-home TOU rates. According to a forthcoming report by the Smart Electric Power Alliance and the Brattle Group, as of September 2019, 43 utilities offer whole-home time-varying rates for EV users, 28 utilities offer EV-only rates using a secondary meter, five utilities offer an EV-only rate using a submeter, and two utilities use an EV charger for submetering.[146]

---

141 Smart Electric Power Alliance. "A Comprehensive Guide to Electric Vehicle Managed Charging." May 2019, 24. https://sepapower.org/resource/a-comprehensive-guide-to-electric-vehicle-managed-charging/

142 Ibid.

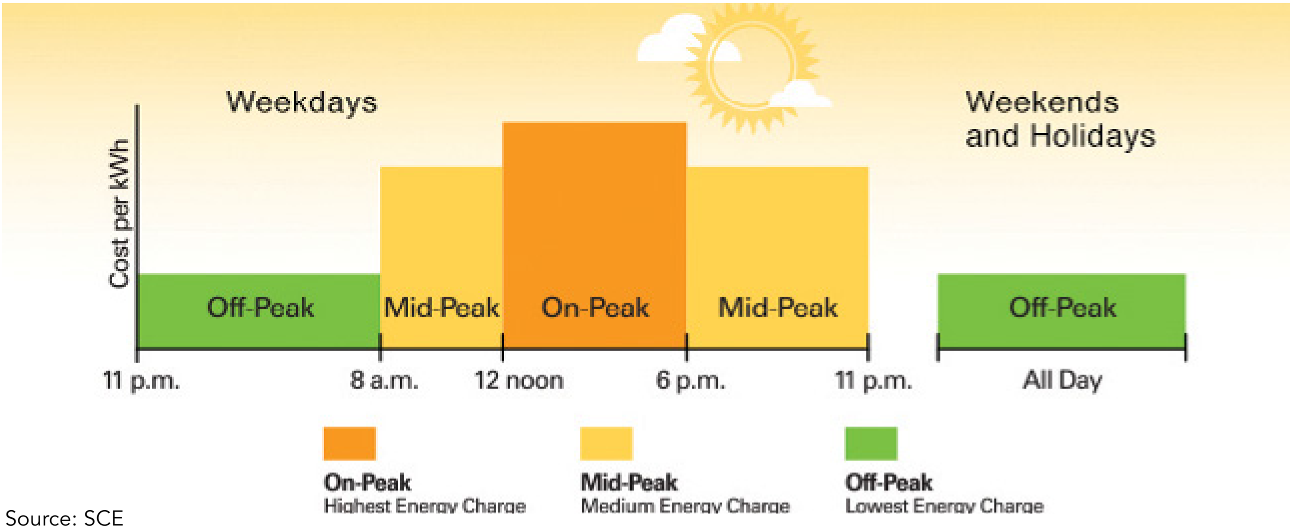
143 California Public Utilities Commission. "What Are TOU Rates?" http://www.cpuc.ca.gov/General.aspx?id=12194

144 California Public Utilities Commission. "Plug-in Electric Vehicle (PUV) Submetering." https://www.cpuc.ca.gov/general.aspx?id=5938

145 More information on EV submetering technology can be found at: Whited, Melissa, Avi Allison, and Rachel Wilson. "Driving Transportation Electrification Forward in New York." June 25, 2018, 3, 18. https://www.synapse-energy.com/sites/default/files/NY-EV-Rate-%20Report-18-021.pdf

146 Smart Electric Power Alliance. "Residential Electric Vehicle Rates That Work: Attributes That Increase Enrollment." November 2019. 30. https://sepapower.org/resource/residential-electric-vehicle-time-varying-rates-that-work-attributes-that-increase-enrollment/

Figure 9: Southern California Edison's previous summer TOU rate structure[147]



Source: SCE

TOU pricing is an important tool to encourage consumers to change their charging behavior so that it aligns with grid system needs. All levels of the electric system—generation, transmission, and distribution—exhibit loads that vary with time. The load flexibility that can come from TOU rates is particularly important in states with higher variable renewable energy generation (e.g., from wind and solar). If TOU rates successfully move EV load to off-peak hours, increased EV adoption could potentially lower rates for all customers (see box, page 21).[148] Proponents for TOU rates argue that without these price signals, charging of EVs could result in longer and higher peaks and will necessitate expensive upgrades to the distribution system, creating higher rates for all customers, rather than the decreased rates that some EV advocates promote.[149] McKinsey analysis shows that TOU rates could incentivize charging late at night rather than in the early evening, when most EV owners get home and plug in their vehicles to start charging. An EV penetration of 25 percent could lead to a 30 percent increase in peak load but that increase in peak load could be halved through the adoption of TOU rates (Figure 10).[150]

Baltimore Gas and Electric (BGE) ran a voluntary TOU pilot program for customers who owned EVs in 2015, resulting in an overall shift in charging behavior and demand to off-peak hours. The pilot found that customers decreased their peak demand energy usage by about 2.3 to 6 percent during the non-summer and summer billing periods respectively, with 58 percent of participants significantly changing charging behavior. BGE also reported that 91 percent of participants were either "satisfied" or "extremely satisfied" with the TOU rate program.[151] BGE made the program permanent in 2016.[152]

SDG&E found after its 2014 TOU rate pilot that the majority of participants shifted their charging behavior to late-night "super off-peak" hours. Their rates applied only toward EV charging instead of the entire residence, and all participants had Level 2 charging stations installed. SDG&E noted that participants increasingly shifted their charging to the cheaper periods as the pilot progressed, exhibiting learning behavior as they became more familiar with the rate program.[153]

---

147 California Public Utilities Commission. "What Are TOU Rates?"

148 Docket No. U-20134-0385, "In the Matter of the Application of Consumers Energy Company for Authority to Increase Rates for the Generation and Distribution of Electricity and for Other Relief," 3. *Michigan Public Service Commission.* January 9, 2019, https://mi-psc.force.com/sfc/servlet.shepherd/version/download/068t00000036VO3AAM.

149 RAP. "Getting from Here to There," 14.

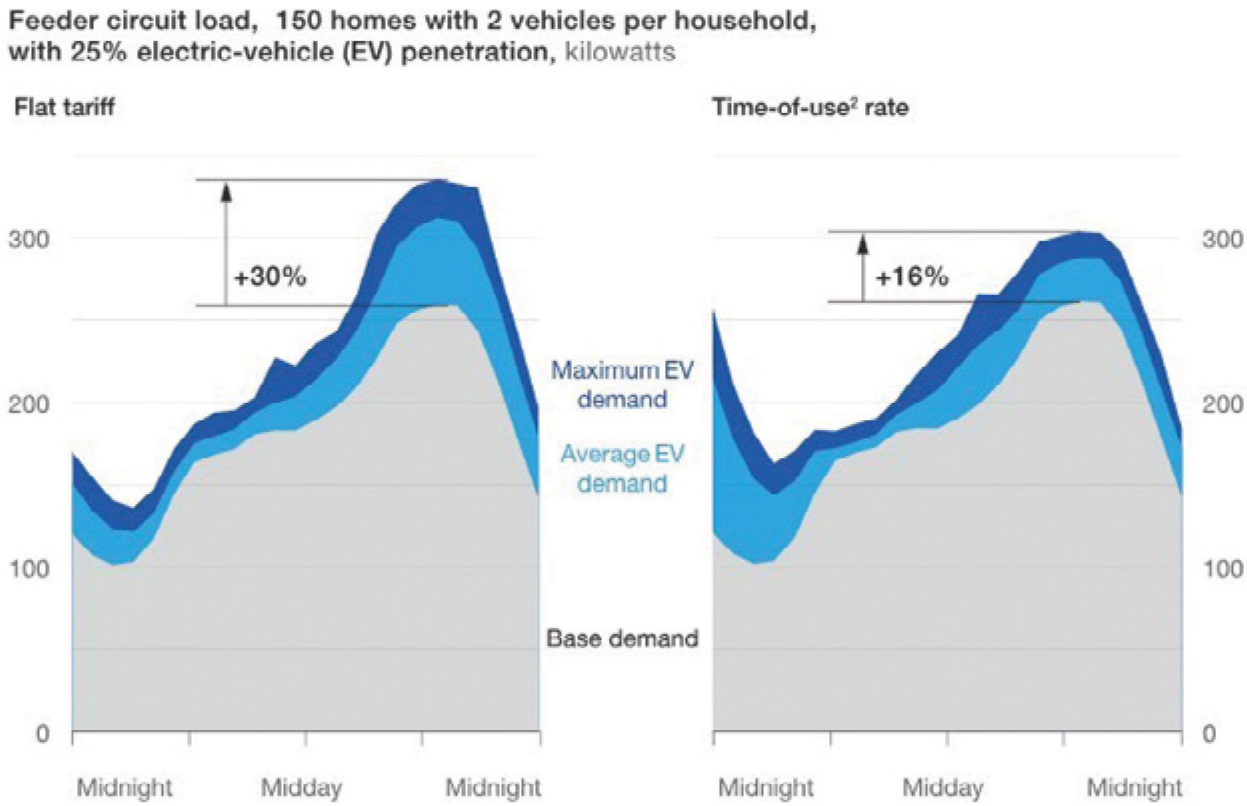
150 Engel, et al. "The Potential Impact of Electric Vehicles on Global Energy Systems."

151 Murach, John. "BGE Electric Vehicle Off Peak Charging Pilot," 11.

152 RAP. "Getting from Here to There: Regulatory Considerations for Transportation Electrification," 16.

153 Faruqui, et al. "The State of Electric Vehicle Home Charging Rates."

Figure 10: TOU rates could halve peak loads[154]



Source: McKinsey & Company

In Arizona, the Salt River Project teamed up with the Electric Power Research Institute in an 18-month-long study on influencing EV charging behavior through TOU rates. The utility had become concerned about potential grid impacts associated with the accelerating pace of EV adoption in its service area, as EV charging used more than 9,100 MWh each year (as of 2018). The study found that TOU rates were largely successful in pushing EV charging to off-peak hours, helping the utility to meet consumer demand without requiring the construction of new power plants.[155]

Opponents of TOU note that the effects of off-peak charging can have detrimental effects on the distribution system, as there are concerns that EV owners will all set their vehicles to charge as soon as off-peak rates take effect, creating "timer peaks".[156] Some worry that TOU rates (especially whole-home TOU rates) will adversely impact low-income customers who are unable to shift their charging times or other electricity load (if whole-home), potentially resulting in higher rates for those who can least afford them.[157] Critics of opt-in TOU rates cite that in jurisdictions where TOU rates are not mandatory, consumers are unfamiliar, not interested, or not financially incentivized enough to join such programs, which may limit their load-smoothing benefits.[158] The use of opt-out rates, where TOU is the default, could potentially remedy this issue. Finally, if the TOU periods are not regularly examined, peak load can move and become misaligned with the TOU rate structure (particularly in response to daytime solar generation). SCE recently changed its TOU peak period from 12-6pm (Figure 9) to the evening in response to solar penetration and shifting peak demand.[159]

---

154 Engel, et al. "The Potential Impact of Electric Vehicles on Global Energy Systems."

155 Walton, Robert. "Time-of-Use Rates Can Manage EV Charging, New Report Says."

156 Myers, Erika. "Three Things You Think You Know about EVs Are Wrong."

157 Jones, et al. "The Future of Transportation Electrification," 97.

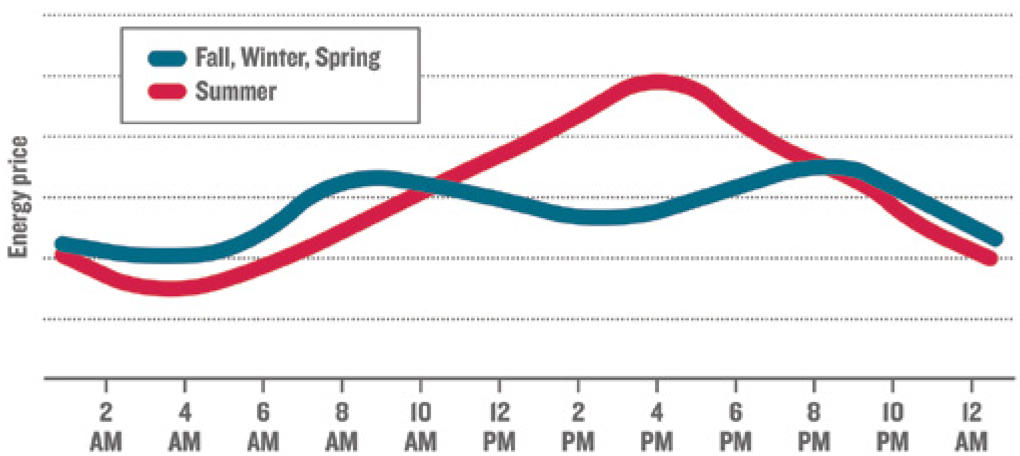
158 Ibid, 77–78.

159 Walton, Robert. "Time-of-Use Rates Can Manage EV Charging, New Report Says."

Real-Time Pricing

With RTP, charging rates vary each hour based on the actual, or wholesale, cost of energy during that hour (Figure 11).[160] Proponents of this approach argue that it provides a more effective and accurate price signal than TOU rates, as RTP reflects the actual cost of charging at any given hour, with more responsive consumers avoiding higher prices when they occur and lowering the potential for negative grid impacts. Critics of this rate design say it requires additional education and attention on the part of consumers as they have to actively monitor hourly prices and/or configure an app that will determine when their vehicle will be charged (or that they simply will not change their behavior in response to the price signal).[161] As with TOU rates, there is a concern that RTP rates (especially whole-home or mandatory rates) could lead to higher costs for low-income consumers or others who cannot shift their load. Additionally, there is a concern that uncertainty about how much it will cost to charge a vehicle could lead to low uptake of the rate (minimizing any benefits from load shifting) or could dissuade future EV purchases.[162] The installation of smart meters is crucial to whole-home RTP rates, which incurs an additional cost and has so far limited their use compared to other rate options.[163] However, EV-specific RTP rates could rely on submetering, as mentioned in the TOU section above.

Figure 11: Typical RTP patterns for ComEd customers[164]



Source: ComEd

ComEd in Illinois ran a study in 2013 on EV owners who use its optional RTP rate. The program encouraged overnight charging through lowered rates during overnight hours. Analysis found that participating EV owners reduced their average EV charging costs by 45 percent compared to a standard rate that did not vary and 38 percent compared to TOU rates.[165] Administrators for ComEd's RTP program noted that wholesale prices on rare occasions dip below zero dollars during overnight hours, enabling EV owners to be paid to charge their vehicles when this phenomenon happens.[166] Low adoption rates, however, led ComEd to propose a TOU price to the Illinois Commerce Commission (the TOU option is in addition to its RTP program, which is required statewide by Illinois law). The RTP program on average leads to lower rates for overnight charging than the TOU rate (40 percent lower according to a study by Elevate Energy, the third-party administrator).[167]

---

160 RAP. "Getting From Here to There: Regulatory Considerations for Transportation Electrification," 17.

161 Ibid.

162 Walton, Robert. "ComEd Time-of-Use Pilot Will Test Importance of Price Certainty."

163 Lydersen, Kari. "In Illinois, Real-time Pricing Saving Utility Customers Millions." *Energy News Network*. May 4, 2016.

164 ComEd. "Real-time Hourly Prices." https://hourlypricing.comed.com/live-prices/

165 RAP. "Getting from Here to There: Regulatory Considerations for Transportation Electrification," P. 17.

166 Elevate Energy. "Hourly Pricing and Electric Vehicles."
http://www.elevateenergy.org/wp/wp-content/uploads/Hourly-Pricing-and-EVs-050714.pdf

167 Ibid.

Ameren in Illinois also maintains an hourly RTP rate, with more than 13,000 customers participating as of July 2019. Taking advantage of overnight charging allowed EV owners on the RTP rate to save an estimated 30 percent on EV charging costs according to a study by Elevate Energy, the third-party administrator of the Ameren plan.[168]

In January 2016, the California PUC approved an SDG&E pilot program for an EV-specific hourly RTP called Power Your Drive that offers lower prices during grid-friendly times.[169] The pilot focuses on residential, multi-unit dwelling, and workplace charging and requires installation of an SDG&E-approved Level 2 charger. Customers can set a maximum price of electricity that they are comfortable paying, and when the hourly price exceeds the maximum, the charger stops charging.

Managed Charging

Managed charging, also known as "smart charging," is a system in which two-way advanced charging infrastructure, usually in residential or multifamily buildings, is actively used by utilities or other third parties to control when charging occurs, similar to traditional demand response programs.[170] Through managed charging, EV load can be decreased, increased, shifted, and curtailed. This approach can help avoid or reduce load spikes and potentially enable EV customers to take advantage of renewable power when it is at its highest generating levels, avoiding curtailments. The load control can occur through the charging device, through automaker telematics, or via a smart circuit breaker or panel.[171]

Proponents of managed charging think TOU (and RTP) rates do not go far enough with regard to consumer behavior, as customer response is uncertain and consumers under a TOU rate will wait until off-peak and then all charge their vehicles at once.[172] Additionally, insights from McKinsey have shown that charging is often done inefficiently, as EVs are frequently left connected to the grid while not actively charging. For private and residential charging, this can represent more than 80 percent of the time connected, and almost 25 percent when using public charging stations.[173] Managed charging allows utilities more control over EV charging, allowing them to slow or delay charging during peak-demand times or in certain locations. Managed charging is also convenient for consumers, with no need to closely monitor rates. Utilities do the work of monitoring prices and load while consumers can receive savings on their electricity bill for participation. Managed charging does have some detractors with concerns about cost: Networked charging stations are more expensive than those without communications capabilities. Active managed charging relies on two-way communications (such as Wi-Fi, cellular, or telematics), and some managed charging pilot programs have run into connectivity issues.[174] Another challenge exists in determining how information would be sent to and from the EV charger and grid operator. The Open Charge Point Protocol and Open Smart Charging Protocol are two attempts to create open communication standards for EV charging stations and EV managed charging.[175]

A similar infrastructure would be needed for V2G capabilities, where EVs discharge electricity back to the grid when needed. Currently, applications of V2G are limited due to concerns by some around the degradation of EV batteries.[176] Accordingly, V2G is less likely to see widespread use in the near future compared to unidirectional managed charging (sometimes referred to as V1G).

---

168 Ibid.

169 Public Utilities Commission of the State of California. "Electric Vehicle-Grid Integration Pilot Program."

170 In addition to *active* managed charging discussed here, there is also *passive* managed charging which relies on customer behavior to control load rather than utility communications. This is often encouraged through TOU rates and RTP as discussed previously.

171 Smart Electric Power Alliance. "Utilities and Electric Vehicles: The Case for Managed Charging," 11. https://sepapower.org/resource/ev-managed-charging/

172 Myers, Erika. "Three Things You Think You Know about EVs Are Wrong."

173 Engel, et al. "The Potential Impact of Electric Vehicles on Global Energy Systems."

174 Myers, Erika. "Three Things You Think You Know about EVs Are Wrong," 11.

175 Greenlots. "Open vs. Closed Charging Stations: Advantages and Disadvantages." https://greenlots.com/wp-content/uploads/2018/10/Open-Standards-White-Paper-compressed.pdf

176 European Commission. "Science for Environment Policy." March 27, 2019. https://ec.europa.eu/environment/integration/research/newsalert/pdf/understanding_degradation_battery_life_key_successful_v2g_523na1_en.pdf

One example of managed charging is SCE's demand response program that was incorporated into a 2016 workplace charging pilot. Customers in the program allowed charging of their EVs to slow or stop when demand hit a certain threshold, with curtailment events occurring up to 10 days a year; they received lower rates as compensation for their participation. The CPUC has gone one step further from this pilot by requiring all new public Level 2 chargers built in California to include demand response capabilities in preparation for widespread implementation of demand response in the future.[177]

Avista in Washington State implemented a voluntary managed charging program that curtailed evening peak charging by 75 percent until at least 8 pm, with participation rates of 84 percent. However, there were some issues with Wi-Fi connectivity, causing 30–45 percent of vehicles to be offline at any given time.[178] A final report on the project's impact will be delivered to the Washington commission in fall 2019.

PG&E and BMW's 2015 i ChargeForward program was able to curtail on-peak charging of BMW EV owners. The second phase of the pilot successfully curtailed on-peak charging and moved charging load to times that would help prevent curtailment of abundant renewable energy.[179] The program relied on the BMW i3 EVs' telematics to reduce charging load.[180]

For more detailed information and perspectives on EV rate design, see:

- **"Getting from Here to There: Regulatory Considerations for Transportation Electrification"**
  Regulatory Assistance Project, 2017
  - Focuses on the opportunities provided by increasing EV market penetration and the regulatory principles and issues that they raise, with examples of various rate design programs
- **"Utilities and Electric Vehicles: The Case for Managed Charging"**
  Smart Electric Power Alliance, 2017
  - An insight into managed charging and vehicle-grid integration as a possible alternative to TOU rate design programs
- **"A Comprehensive Guide to Electric Vehicle Managed Charging"**
  Smart Electric Power Alliance, 2019
  - A review of the state of the managed charging industry, utility case studies, a survey of utility interest in managed charging, and an overview of managed charging options
- **"Sacramento Municipal Utility District: Preparing its Distribution System for PEVs"**
  Electric Power Research Institute, 2013
  - An analysis of Sacramento Municipal Utility District's distribution system and upgrades that might be required to accommodate EV charging load, as well as how modifying charging load can reduce the need for costly distribution system upgrades
- **"The State of Electric Vehicle Home Charging Rates"**
  The Brattle Group, 2018
  - A summary of residential EV-specific rate offerings in the US, including the drivers and goals of EV-specific rates
- **"Residential Electric Vehicle Time-Varying Rates That Work: Attributes That Increase Enrollment"**
  Smart Electric Power Alliance, 2019
  - A look at utility time-varying rates and factors that affect their customer uptake

---

177 Hall, Dale, and Nic Lutsey. "Literature Review on Power Utility Best Practices Regarding Electric Vehicles," 19–20.

178 Smart Electric Power Alliance. "A Comprehensive Guide to Electric Vehicle Managed Charging," 24.

179 Ibid.

180 BMW Group and Pacific Gas and Electric Company. "BMW i Charge Forward: PG&E's Electric Vehicle Smart Charging Pilot." http://www.pgecurrents.com/wp-content/uploads/2017/06/PGE-BMW-iChargeForward-Final-Report.pdf

3. Future Gaps and Research Questions

As EV adoption continues to grow across the country, Commissions will face additional challenges beyond issues related to charging station infrastructure and rate design. Below are some topics that Commissions may be asked to address in the future, where state experience and information is currently limited.

Interoperability and Open Standards

Standardization and interoperability of EV infrastructure and software are important considerations for cost effectiveness, ease of operations, and avoiding obsolescence. Interoperability challenges exist across four prominent EV interfaces:[181]

1. Physical charging interface interoperability (i.e., plugs)
2. Charging network-to-charging network interoperability
3. Charge station-to-network interoperability
4. Vehicle-to-grid interoperabililty

Physical charging interface interoperability concerns are essentially restricted to DC fast charging. Level 1 and Level 2 charging plug interfaces use a single standard plug type (J1772) with Tesla vehicles requiring an adapter. However, DC fast charging in the United States currently uses three different plug types that are not generally interoperable: CHAdeMO, CCS, and Tesla (Figure 12).[182] Some measures are being taken to set standards across manufacturers of vehicles and charging stations. In October 2018, the eight signatory states of NASEO's Regional Electric Vehicle Plan for the West Memorandum of Understanding (REV West MOU) put out a Request for Information from the public and private sectors on how to tackle administrative and interoperability issues.[183]

Figure 12: The three varieties of direct current fast charging (DCFC) plug types[184]

Source: ChargePoint

181 Drawn from this EPRI report, which details interoperability challenges in more depth. Electric Power Research Institute (EPRI). "Interoperability of Public Electric Vehicle Charging Infrastructure." August 6, 2019. https://www.epri.com/#/pages/product/3002017164/?lang=en-US

182 ChargeHub. "2019 Guide on How to Charge Your Electric Car with Charging Stations." https://chargehub.com/en/electric-car-charging-guide.html

183 NASEO. "REV West RFI: Voluntary Minimum Standards for DC Fast Charging." October 24, 2018. https://www.naseo.org/news-article?NewsID=3339

184 Chargepoint. "Driver's Checklist: A Quick Guide to Fast Charging," 3. https://www.chargepoint.com/files/Quick_Guide_to_Fast_Charging.pdf

Charging networks might also differ across utility territories (with utility ownership) or be reliant on membership in a certain subscription charging service.[185] Many public charging stations maintain several different plug types (excepting Tesla stations), and many automakers provide adapters. As of July 2019, at least 28 different charging networks were operating across the United States, although increasingly, most of the major providers are turning to bilateral roaming agreements with other networks.[186] Tesla's Superchargers are among them and are free to use for some of its customers. Charging network memberships are generally structured with both pay-as-you-go and monthly subscription payment plans. It is still unclear what the future holds for charging station standards, although Commissions may be asked how to avoid obsolete and stranded assets.

Charge station-to-network interoperability addresses back-end communication protocols between EV chargers and network operators.[187] Much of the charging infrastructure deployed today uses proprietary communication methodologies, making customer switching difficult, costly, or impossible, while increasing stranded asset risk. Commissions can play a key role in supporting use of open technical standards, including Open Charge Point Protocol and OpenADR, to minimize these risks and better protect potential ratepayer investments.

Vehicle-to-grid integration and managed charging programs require an additional level of interoperability. Open standards such as the Open Smart Charging Protocol are important in ensuring that distribution system operators have more visibility into EVs and charging systems. The Electric Vehicle-Smart Grid Interoperability Center at Argonne National Laboratory is working to harmonize standards and technology at the EV-grid interface.[188]

Obsolescence

Decision makers naturally have concerns about obsolescence, as it is generally considered imprudent to invest in systems that could become obsolete or stranded assets in just a few years.[189] Considering the pace of technological advancement in the industry, it remains to be seen if there will be more consolidation of EV charging station companies with increased EV adoption, further standardization, or other advances that reduce the risk of stranded assets (lower voltage chargers and different plug types are frequently discussed contenders). While certain hardware may, over time, become less relevant, software will likely become more of a constant, with the ability to update, upgrade, and build in new functionality and compatibility with future charging methodologies. Commissions will need to collaborate with utilities and other private sector stakeholders on how to address these issues. One way to do this in the fast charging space is for make-ready investments to include "future proofing" that could enable higher power draws as technologies evolve.

Vehicle-to-Grid

The implementation of V2G services (involving bidirectional power flows to and from EV batteries) is currently limited by several unknowns, including the potential impact on EV battery health and longevity. Questions also remain about the economics of V2G, how much to compensate vehicle owners, and how to reduce impacts on vehicle owners who may need the battery charged for driving. Technological challenges related to software control, charging station hardware, and metering will also need to be addressed. Several of these questions are the subject of research at the National Renewable Energy Laboratory and numerous private companies.[190]

185 Jones, et al. "The Future of Transportation Electrification," 14–15.

186 Smart Electric Power Alliance. "A Comprehensive Guide to Electric Vehicle Managed Charging," 36.

187 Electric Power Research Institute (EPRI). "Interoperability of Public Electric Vehicle Charging Infrastructure." August 6, 2019 https://www.epri.com/#/pages/product/3002017164/?lang=en-US

188 Ibid.

189 Interview with Patricio Portillo, National Governors Association.

190 See, National Renewable Energy Laboratory (NREL). "Electric Vehicle Grid Integration." https://www.nrel.gov/transportation/project-ev-grid-integration.html

Cybersecurity

With increased reliance on internet-connected home charging and monitoring (smart chargers), the importance of cybersecurity for EVs has become more evident.[191] Commissions will be asked what they can do to assist stakeholders in preventing cyberattacks on commercial and residential charging and EVs. Idaho National Laboratory has embarked on a multi-year project investigating how hacking into charging stations may disrupt the quality and flow of electricity through a local grid.[192] Researchers are also studying the impact on distribution systems in a scenario where hundreds of stations are turned off simultaneously during a cyberattack.

Critical Infrastructure

As chargers become ubiquitous and relied upon for a significant percentage of transportation, questions arise over whether charging stations will become a public good that should be considered critical energy infrastructure. Emergency energy management scenarios and responses might also need to evolve. These possibilities could require additional utility involvement in the charging station industry. Commissions will be asked to consider how these advances affect emergency response plans and charging infrastructure ownership. The National Association of State Energy Officials' Initiative for Resiliency in Energy through Vehicles (iREV) program examines the intersection of EVs and emergency response.[193]

Mitigation of Lost Gas Tax Revenue

Gas taxes on the state and federal level are used to maintain public highway infrastructure, with state taxes ranging from 14.65 cents per gallon in Alaska to 58.70 cents per gallon in Pennsylvania as of July 2018.[194] About 40 percent of highway funding comes from fuel taxes. Currently, EVs make up only 0.25 percent of all vehicles on the road, so they likely will not noticeably impact highway funding for some time. An estimate by the University of Tennessee forecasts an 8 percent reduction in gas tax revenue due to EV adoption by 2050.[195] Nonetheless, as nonhybrid EVs do not consume any gasoline, there is a widespread concern that states could face a shortfall in funding for highway maintenance with growth in EV adoption. In response, 28 states have imposed EV registration fees or road user charges for EV owners as of September 2019.[196]

Although gas taxes are not under the purview of PUCs and likely will not be majorly affected by EVs in the short or medium term, state legislatures and consumer advocates are asking many questions about how best to structure gas taxes around EV programs approved by PUCs. Maryland PSC's PC44 is one example where the Commission included the state's Department of Transportation in its proceedings to investigate the impacts of EVs on future gas tax revenues.

---

191 Jones, et al. "The Future of Transportation Electrification," 42.

192 Lyngaas, Sean. "Power Struggle: Government-funded Researchers Investigate Vulnerabilities in EV Charging Stations." *Cyberscoop*. February 25, 2019. https://www.cyberscoop.com/ev-charging-stations-hacked-idaho-national-laboratory/

193 See, NASEO. "iREV – Initiative for Resiliency in Energy through Vehicles." https://www.naseo.org/irev; or iREV. "Electric Vehicles and Emergency Response." June 2016. http://naseo.org/data/sites/1/documents/publications/iREV%20EV%20Case%20Study.pdf for more information about NASEO's iREV program.

194 Tax Foundation. "State Gasoline Tax Rates as of July 2018." https://taxfoundation.org/state-gas-tax-rates-july-2018/

195 Greene, David, and Howard Baker, Jr. "Impacts on State Revenue." Presentation: Charging Electric Vehicles for Public Roads. March 12, 2019. https://www.nga.org/wp-content/uploads/2018/09/Impacts-on-State-Revenue.pdf

196 Rogotzke, Matthew, Garrett Eucalitto, and Sue Gander. National Governors Association. "Transportation Electrification: States Rev Up" (White Paper), 6. https://www.nga.org/wp-content/uploads/2019/09/2019-09-15-NGA-White-Paper-Transportation-Electrification-States-Rev-Up.pdf

Sources Cited

"2018 U.S. Models - BEV Range Comparison Infographic." InsideEVs.com. Accessed April 27, 2018. https://insideevs.com/2018-u-s-models-bev-range-comparison-infographic/

"Advanced Energy Year in Review 2018: Breakthroughs, Setbacks, and Holding Patterns." Advanced Energy Economy Webinar. December 18, 2018. https://info.aee.net/2018-year-in-review-breakthroughs-setbacks-and-holding-patterns

"December 2018 U.S. Plug-In EV Sales Report Card." Inside EVs. January 06, 2019. Accessed January 23, 2019. https://insideevs.com/december-2018-u-s-plug-in-ev-sales-report-card/

"Range Anxiety | Definition of Range Anxiety in US English by Oxford Dictionaries." Oxford Dictionaries | English. Accessed January 23, 2019. https://en.oxforddictionaries.com/definition/us/range_anxiety

"The Advantages of an Electric Forklift." Blog. NMC Hexbolt | NMC Inc. Accessed January 23, 2019. http://www.nmc-corp.com/lift-truck/advantages-of-an-electric-forklift/

Allen, Paul, Grace Van Horn, Matthew Goetz, James Bradbury, and Kathryn Zyla. Utility Investment in Electronic Vehicle Charging Infrastructure: Key Regulatory Considerations. M.J. Bradley & Associates and Georgetown Climate Center. November 2017. https://www.georgetownclimate.org/files/report/GCC-MJBA_Utility-Investment-in-EV-Charging-Infrastructure.pdf

Avista Corporation. Schedule 77: Electric Vehicle Supply Equipment (EVSE) Pilot Program. February 2, 2018. https://www.myavista.com/-/media/myavista/content-documents/our-rates-and-tariffs/wa/wa_077.pdf?la=en

Bade, Gavin. "How Oncor Is Preparing for a Wave of Large Electric Fleet Vehicles." UtilityDive. February 25, 2019. https://www.utilitydive.com/news/how-oncor-is-preparing-for-a-wave-of-large-electric-fleet-vehicles/549109/

Baumhefner, Max. "Electric Vehicles Are Driving Utility Rates Down." Microgrid Knowledge. June 24, 2019, 13. https://microgridknowledge.com/electric-vehicles-utility-rates/

Before the Public Utilities Commission of the State of California. Phase 1 Decision Establishing Policy to Expand the Utilities' Role in Development of Electric Vehicle Infrastructure. 12-079. December 18, 2014. http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M143/K682/143682372.PDF

Bernd Heid, Russell Hensley, Stefan Knupfer, and Andreas Tschiesner. "What's Sparking Electric-Vehicle Adoption in the Truck Industry?" McKinsey & Company. September 2017. https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/whats-sparking-electric-vehicle-adoption-in-the-truck-industry

Bloomberg NEF. "Electric Vehicles to Accelerate to 54% of New Car Sales by 2040." June 05, 2018. Accessed January 23, 2019. https://about.bnef.com/blog/electric-vehicles-accelerate-54-new-car-sales-2040

Bloomberg NEF. 2019 Sustainable Energy in America Factbook. "Deployment: U.S. Gasoline Consumption and Fuel Economy," 121. https://www.bcse.org/wp-content/uploads/2019-Sustainable-Energy-in-America-Factbook.pdf

BMW Group and Pacific Gas and Electric Company. "BMW i Charge Forward: PG&E's Electric Vehicle Smart Charging Pilot." http://www.pgecurrents.com/wp-content/uploads/2017/06/PGE-BMW-iChargeForward-Final-Report.pdf

California Public Utilities Commission. "Plug-in Electric Vehicle (PUV) Submetering." https://www.cpuc.ca.gov/general.aspx?id=5938

California Public Utilities Commission. "Transportation Electrification Activities Pursuant to Senate Bill 350." CA.gov. https://www.cpuc.ca.gov/sb350te/

California Public Utilities Commission. "What Are TOU Rates?" http://www.cpuc.ca.gov/General.aspx?id=12194

ChargeHub. "2019 Guide on How to Charge Your Electric Car with Charging Stations." https://chargehub.com/en/electric-car-charging-guide.html

Chargepoint. "Driver's Checklist: A Quick Guide to Fast Charging," 3. https://www.chargepoint.com/files/Quick_Guide_to_Fast_Charging.pdf

ComEd. "Real-time Hourly Prices." https://hourlypricing.comed.com/live-prices/

Docket No. 17-08021. "Rulemaking to Implement the Provisions of Senate Bill 145 (2017)." Public Utilities Commission of Nevada. May 11, 2018. http://pucweb1.state.nv.us/PDF/AxImages/DOCKETS_2015_THRU_PRESENT/2017-8/29834.pdf

Docket No. 32694. "Generic Proceeding to Determine the Commission's Jurisdiction Over Electric Vehicle Charging Stations, Request for Comments." Letter to the State of Alabama Public Service Commission. Greenlots, 3–4. December 15, 2017. http://www.psc.state.al.us/Greenlots%20Comments%20to%20AL%20PSC%2012.15.17.pdf

Docket No. E002/M-18-643. Great Plains Institute. "Stakeholder Process Clarification…." February 15, 2009. https://www.edockets.state.mn.us/EFiling/edockets/searchDocuments.do?method=showPoup&documentId={000EF368-0000-CF1A-9394-EBCD70494266}&documentTitle=20192-150340-01&userType=public

Docket No. E-999/CI-17-879. "In the Matter of a Commission Inquiry into Electric Vehicle Charging and Infrastructure." Minnesota Public Utilities Commission. February 1, 2019, 1–2. https://www.edockets.state.mn.us/EFiling/edockets/searchDocuments.do?method=showPoup&documentId={10BBAA68-0000-C413-9799-DF3ED0978E75}&documentTitle=20192-149933-01

Docket No. U-20134-0385, "In the Matter of the Application of Consumers Energy Company for Authority to Increase Rates for the Generation and Distribution of Electricity and for Other Relief," 3. Michigan Public Service Commission. January 9, 2019, https://mi-psc.force.com/sfc/servlet.shepherd/version/download/068t00000036VO3AAM

Docket UE-160799. "Final Policy Statement." Washington Utilities and Transportation Commission. June 14, 2017, 5. https://www.utc.wa.gov/_layouts/15/CasesPublicWebsite/GetDocument.ashx?docID=147&year=2016&docketNumber=160799

Douris, Constance. "The Bottom Line on Electric Cars: They're Cheaper to Own." Forbes. October 24, 2017. Accessed January 23, 2019. https://www.forbes.com/sites/constancedouris/2017/10/24/the-bottom-line-on-electric-cars-theyre-cheaper-to-own/#1a84e41e10b6

Doyle, Kevin. "Level Up Your EV Charging Knowledge." Chargepoint. March 23, 2017. https://www.chargepoint.com/blog/level-your-ev-charging-knowledge/

Edison Electric Institute (EEI)/IEI. EV Sales Forecast and the Charging Infrastructure Required through 2030. November 2018.

EDTA, "Electric Drive Sales Dashboard." https://electricdrive.org/index.php?ht=d/sp/i/20952/pid/20952

EEI. "Customer Solutions: Electric Transportation. February 2018. 11. https://www.eei.org/issuesandpolicy/electrictransportation/Documents/Accelerating_EV_Adoption_final_Feb2018.pdf

Electric Power Research Institute (EPRI). "Interoperability of Public Electric Vehicle Charging Infrastructure." August 6, 2019. https://www.epri.com/#/pages/product/3002017164/?lang=en-US

Elevate Energy. "Hourly Pricing and Electric Vehicles." https://www.elevateenergy.org/wp/wp-content/uploads/Hourly-Pricing-and-EVs-050714.pdf

Engel, Hauke, Russell Hensley, Stefan Knupfer, and Shivika Sandev. "The Potential Impact of Electric Vehicles on Global Energy Systems." McKinsey & Company. August 2018. https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/the-potential-impact-of-electric-vehicles-on-global-energy-systems

European Commission. "Science for Environment Policy." March 27, 2019. https://ec.europa.eu/environment/integration/research/newsalert/pdf/understanding_degradation_battery_life_key_successful_v2g_523na1_en.pdf

EV Hub. Electronic Trucks and Buses Overview. "Resource Description," July 5, 2019. https://www.atlasevhub.com/resource/electric-trucks-and-buses-overview/

EV Hub. VW Settlement. https://www.atlasevhub.com/materials/vw-environmental-mitigation-fund-tracking/

Evarts, Eric C. "2019 Is the Year of the Electric SUV." Green Car Reports. July 3, 2018. Accessed November 06, 2018. https://www.greencarreports.com/news/1117536_2019-is-the-year-of-the-electric-suv

Faruqui, Ahmad, Ryan Hledik, and John Higham. "The State of Electric Vehicle Home Charging Rates." October 15, 2018, 13. http://files.brattle.com/files/14717_the_state_of_residential_ev_electric_rates_10-15-2018.pdf

Gorzelany, Jim. "10 Most Fuel-Efficient Hybrid Cars Of 2018." Motor1.com. February 16, 2018. Accessed January 23, 2019. https://www.motor1.com/features/229073/most-fuel-efficient-hybrids/

Great Plains Institute. Minnesota Public Utilities Commission. "Summary of Stakeholder Meetings…." July 31, 2019. https://www.edockets.state.mn.us/EFiling/edockets/searchDocuments.do?method=showPoup&documentId={90A1A968-0000-CA1B-AF47-24D6EC828FED}&documentTitle=20191-149887-01&userType=public

Greene, David, and Howard Baker, Jr. "Impacts on State Revenue." Presentation: Charging Electric Vehicles for Public Roads. March 12, 2019. https://www.nga.org/wp-content/uploads/2018/09/Impacts-on-State-Revenue.pdf

Greenlots. "Open vs. Closed Charging Stations: Advantages and Disadvantages." https://greenlots.com/wp-content/uploads/2018/10/Open-Standards-White-Paper-compressed.pdf

Hall, Dale, and Nic Lutsey. "Literature Review on Power Utility Best Practices Regarding Electric Vehicles." ICCT. February 2017. 19–20. https://www.theicct.org/sites/default/files/publications/Power-utility-best-practices-EVs_white-paper_14022017_vF.pdf

Holley, Peter. "Death of Gas and Diesel Begins as GM Announces Plans for 'all-electric Future.'" The Washington Post. October 02, 2017. Accessed January 23, 2019. https://www.washingtonpost.com/news/innovations/wp/2017/10/02/death-of-diesel-begins-as-gm-announces-plans-for-all-electric-future/?noredirect=on&utm_term=.55a50bd7fcad

Jones et al. "The Future of Transportation Electrification: Utility, Industry and Consumer Perspectives." Lawrence Berkeley National Laboratory. 2018. http://eta-publications.lbl.gov/sites/default/files/feur_10_transportation_electrification_final_20180813.pdf

Jones, Philip, and Nick Nigro. "Utilities Have a Vital Role in Advancing Electronic Vehicle Infrastructure through the VW Settlement." NRRI Insights. September 2019, 3. https://pubs.naruc.org/pub/ADFADCB5-B5C7-92F8-E93F-927F3B045E39

Kane, Mark. "Toyota To Electrify Every Model By 2025: Video." Inside EVs. January 08, 2019. Accessed January 23, 2019. https://insideevs.com/toyota-electrify-every-model-2025-video/

Kraker, Dan. "Minnesota regulators press utilities to prepare for more electric vehicles in Minnesota." MPRnews. December 13, 2018. https://www.mprnews.org/story/2018/12/13/puc-electric-vehicles-pushes-utilities

Lambert, Fred. "Volvo Clarifies Electrification Plan, Aims for 50% of Sales to Be 'Fully Electric' by 2025." Electrek. April 25, 2018. Accessed January 23, 2019. https://electrek.co/2018/04/25/volvo-electrification-plan-fully-electric/

Loveday, Eric. "Top 6 Plug-In Hybrids Ranked by Electric Range." InsideEVs.com. Accessed July 03, 2018. https://insideevs.com/top-6-electric-range-phev/

Lydersen, Kari. "In Illinois, Real-time Pricing Saving Utility Customers Millions." Energy News Network. May 4, 2016.

Lyngaas, Sean. "Power Struggle: Government-funded Researchers Investigate Vulnerabilities in EV Charging Stations." Cyberscoop. February 25, 2019. https://www.cyberscoop.com/ev-charging-stations-hacked-idaho-national-laboratory/

McCarthy, Niall. "The Evolution of U.S. Electric Vehicle Charging Points [Infographic]." Forbes. April 09, 2018. https://www.forbes.com/sites/niallmccarthy/2018/04/09/the-evolution-of-u-s-electric-vehicle-charging-points-infographic/#7d77449c4164

McDonald, Loren. "US Electric Car Range Will Average 275 Miles By 2022, 400 Miles By 2028 - New Research (Part 1)." CleanTechnica. October 28, 2018. Accessed January 23, 2019. https://cleantechnica.com/2018/10/27/us-electric-car-range-will-average-275-miles-by-2022-400-miles-by-2028-new-research-part-1/

McDonald, Zach. "A Simple Guide to DC Fast Charging." FleetCarma. February 28, 2018. https://www.fleetcarma.com/dc-fast-charging-guide/

McMahon, Jeff. "Electric Vehicles Cost Less Than Half as Much to Drive. Forbes. January 14, 2018. https://www.forbes.com/sites/jeffmcmahon/2018/01/14/electric-vehicles-cost-less-than-half-as-much-to-drive/#61e6ef7f3f97

Moloughney, Tom. "Electrify America Progress Report: Over 100 Charging Sites Open." Insideevs.com., https://insideevs.com/electrify-america-progress-charging-stations/

Mraz, Stephen. "Are Off-Highway Equipment and Heavy-Duty Trucks Going All-Electric Soon?" Machine Design. May 09, 2018. Accessed January 23, 2019. https://www.machinedesign.com/mechanical/are-highway-equipment-and-heavy-duty-trucks-going-all-electric-soon

Murach, John. "BGE Electric Vehicle Off Peak Charging Pilot." http://www.madrionline.org/wp-content/uploads/2017/06/BGE-EV-rate-design-pilot.pdf

Myers, Erika. "Three Things You Think You Know about EVs Are Wrong." Smart Electric Power Alliance. July 26, 2018. https://sepapower.org/knowledge/three-things-you-think-you-know-about-evs-are-wrong/

NARUC. "CI-1/EL-2 Resolution Supporting Infrastructure Modernization Program." July 18, 2018. https://pubs.naruc.org/pub/09F5359D-C9ED-BCB3-EDF9-56B03A81F6D2

NARUC. "Resolution on Alternative Fuel Vehicle Development and Deployment." July 20, 2011. https://pubs.naruc.org/pub.cfm?id=539841D1-2354-D714-51B7-E8BBCD1055C8

NARUC. "State Commission Staff Surge Call: Electric Vehicles." June 25, 2018. https://www.naruc.org/default/assets/File/EV%20surge%20summary%20070618-final.pdf

NARUC. Winter Policy Summit. "Maryland PSC Presentation: Implementing an Electric Vehicle Charging Infrastructure in Maryland." February 10–13, 2019. https://pubs.naruc.org/pub/07E1A01F-9771-C47F-DDE9-0117AD703ED7

NASEO. "REV West RFI: Voluntary Minimum Standards for DC Fast Charging." October 24, 2018. https://www.naseo.org/news-article?NewsID=3339

NASEO. "Volkswagen Settlement – Environmental Mitigation Trust Training Update." March 21, 2017, 2. http://naseo.org/Data/Sites/1/vw_emt_timeline_032117.pdf

NASEO. "Volkswagen Settlement – Overview and Opportunities for State Energy Officials." July 21, 2016, 8. https://www.naseo.org/Data/Sites/1/documents/committees/transportation/volkswagen/Volkswagen-NASEO-Webinar.pdf

National Association of State Energy Officials (NASEO). "Volkswagen Settlement Beneficiary Mitigation Plan Toolkit," 4. https://www.naseo.org/Data/Sites/1/03-27-17_naseo-vw-beneficiary-mitigation-plan-toolkit-final.pdf

Nicholas, Michael, Dale Hall, and Nic Lutsey. "Quantifying the Electric Vehicle Charging Infrastructure Gap across U.S. Markets," ii. https://theicct.org/sites/default/files/publications/US_charging_Gap_20190124.pdf

Ohio Public Utilities Commission. "PowerForward: A Roadmap to Ohio's Electricity Future," 22. https://www.puco.ohio.gov/industry-information/industry-topics/powerforward/powerforward-a-roadmap-to-ohios-electricity-future/

Opalka, Bill. "Vermont Says Charging Stations Shouldn't Face Same Rules as Utilities." Electric Vehicles. January 25, 2019. https://energynews.us/2019/01/25/northeast/vermont-says-charging-stations-shouldnt-face-same-rules-as-utilities/; Commonwealth of Kentucky. Case No. 2018-00372. "Electronic Investigation of Commission Jurisdiction over Electric Vehicle Charging Stations." https://psc.ky.gov/order_vault/Orders_2019/201800372_06142019.pdf

Order No. 88997 - Case No. 9478 - EV Portfolio Order. https://www.psc.state.md.us/search-results/?keyword=9478&x.x=16&x.y=13&search=all&search=case

Plautz, Jason. "California to Require All-electric Buses by 2040." Smart Cities Dive. December 17, 2018. Accessed January 23, 2019. https://www.smartcitiesdive.com/news/california-to-require-all-electric-buses-by-2040/544462/

Portland General Electric Company (PGE). RE: UM 1811 Transportation Electrification Compliance Filing. February 15, 2019. https://edocs.puc.state.or.us/efdocs/HAD/um1811had151943.pdf

Public Service Commission of the District of Columbia. Formal Case No. 1130 and Formal Case No 1155. April 12, 2019. https://edocket.dcpsc.org/apis/api/filing/download?attachId=84361&guidFileName=c302b307-c4b3-40e3-bf2e-3c8d9e064e64.pdf

Public Utilities Commission of the State of California. "Electric Vehicle-Grid Integration Pilot Program." November 14, 2013. https://www.sdge.com/sites/default/files/regulatory/FINAL%20September%202018%20Power%20Your%20Drive%20Semi-Annual%20Rpt_0.pdf

Regulatory Assistance Project (RAP). "Getting from Here to There: Regulatory Considerations for Transportation Electrification." May 2017, 26. https://www.raponline.org/wp-content/uploads/2017/06/RAP-regulatory-considerations-transportation-electrification-2017-may.pdf

Rivera-Linares, Corina. "Massachusetts regulators approve National Grid's proposed EV program, subject to modifications." TransmissionHub. September 13, 2018. https://www.transmissionhub.com/articles/2018/09/massachusetts-regulators-approve-national-grids-proposed-ev-program-subject-to-modifications.html

Rogotzke, Matthew, Garrett Eucalitto, and Sue Gander. National Governors Association. "Transportation Electrification: States Rev Up" (White Paper), 6. https://www.nga.org/wp-content/uploads/2019/09/2019-09-15-NGA-White-Paper-Transportation-Electrification-States-Rev-Up.pdf

Sanger Thompson PC. "Oregon PUC Approves PGE's Transportation Electrification Program." February 22, 2018. http://www.sanger-law.com/oregon-puc-approves-pges-transportation-electrification-program/

Smart Electric Power Alliance. "A Comprehensive Guide to Electric Vehicle Managed Charging." May 2019, 24. https://sepapower.org/resource/a-comprehensive-guide-to-electric-vehicle-managed-charging/

Smart Electric Power Alliance. "Residential Electric Vehicle Rates That Work: Attributes That Increase Enrollment." November 2019. 30. https://sepapower.org/resource/residential-electric-vehicle-time-varying-rates-that-work-attributes-that-increase-enrollment/

Smart Electric Power Alliance. "Utilities and Electric Vehicles: The Case for Managed Charging," 11. https://sepapower.org/resource/ev-managed-charging/

Southern California Edison. "Electric Transportation and Rate Designs at SCE." June 7, 2018. http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=6442457678

Tannert, Chuck. "Will SUVs Breathe New Life into the Electric Car Market?" Forbes. November 27, 2018. Accessed January 23, 2019. https://www.forbes.com/sites/chucktannert/2018/11/27/will-the-suv-breathe-new-life-into-the-electric-car-market-dont-count-on-it/#1c2fb19517f9

Tax Foundation. "State Gasoline Tax Rates as of July 2018." https://taxfoundation.org/state-gas-tax-rates-july-2018/

The Public Utilities Commission of Ohio. Case No. 16-1852-EL-SSO and Case No. 16-1853-EL-AAM. Opinion and Order. April 25, 2018. http://dis.puc.state.oh.us/TiffToPDf/A1001001A18D25B43534I06271.pdf

Thill, David. "Illinois Groups Split on How to Balance Risk, Reward for ComED Time-of-Use Rates." Energy News Network. June 26, 2019. https://energynews.us/2019/06/26/midwest/illinois-groups-split-on-how-to-balance-risk-reward-for-comed-time-of-use-rates/

Tomich, Jeffery. "Big Oil looks to stop utilities' charging investments." E&E News. October 25, 2018. https://www.eenews.net/stories/1060104353

Trabish, Herman. "PG&E, SCE, SDG&E pursue subscriptions, time-of-use rates to drive more California EVs." UtilityDive. January 23, 2019. https://www.utilitydive.com/news/pge-sce-sdge-pursue-subscriptions-time-of-use-rates-to-drive-more-cali/545907/

U.S. Department of Energy. Alternative Fuels Data Center. "Developing Infrastructure to Charge Plug-In Electric Vehicles." https://www.afdc.energy.gov/fuels/electricity_infrastructure.html.

U.S. Department of Energy. Alternative Fuels Data Center. "Electric Vehicle Charging Station Locations." https://afdc.energy.gov/fuels/electricity_locations.html#/analyze?fuel=ELEC&country=US&ev_levels=all

U.S. Department of Energy. Alternative Fuels Data Center. "Maintenance and Safety of Hybrid and Plug-In Electronic Vehicles." https://afdc.energy.gov/vehicles/electric_maintenance.html

U.S. Department of Energy. Hydrogen & Fuel Cells Program. "2019 Annual Merit Review Proceedings." https://www.hydrogen.energy.gov/annual_review19_acceleration.html#acceleration

U.S. Department of Energy. Office of Energy Efficiency & Renewable Energy. "Saving on Fuel and Vehicle Costs." Accessed June 11, 2019. https://www.energy.gov/eere/electricvehicles/saving-fuel-and-vehicle-costs

Vermont Energy Investment Corporation. "Electric Vehicle Charging Guidebook." June 2014. https://www.ccrpcvt.org/wp-content/uploads/2016/01/20140626-EV-Charging-Station-Installation-Guide.pdf

Walton, Robert. "California, New York, New Jersey see nearly $1.3B in new EV finding." (Brief). UtilityDive. June 1, 2018. https://www.utilitydive.com/news/california-new-york-new-jersey-see-nearly-13b-in-new-ev-funding/524757/

Walton, Robert. "Colorado Passes Bill to Avoid Urban-Rural Divide on EV Chargers." UtilityDive. April 12, 2019. https://www.utilitydive.com/news/colorado-passes-bill-to-avoid-urban-rural-divide-on-ev-chargers/552561/

Walton, Robert. "ComEd Time-of-Use Pilot Will Test Importance of Price Certainty." UtilityDive. November 26, 2018. https://www.utilitydive.com/news/comed-time-of-use-pilot-will-test-importance-of-price-certainty/542838/

Walton, Robert. "In Massachusetts, Utilities Take a Collaborative Approach to EV Infrastructure." UtilityDive. May 10, 2017. https://www.utilitydive.com/news/in-massachusetts-utilities-take-a-collaborative-approach-to-ev-infrastruct/442047/

Walton, Robert. "Nevada regulators allow utilities to own EV charging stations." (Brief). UtilityDive. May 15, 2018. https://www.utilitydive.com/news/nevada-regulators-allow-utilities-to-own-ev-charging-stations/523479/

Walton, Robert. "Time-of-Use Rates Can Manage EV Charging, New Report Says." UtilityDive. January 23, 2018. https://www.utilitydive.com/news/time-of-use-rates-can-manage-ev-charging-new-report-says/515284/

Williams, Mark. "Ohio Regulators Green-Light Utility's $10M Plan to Install More EV Charging Stations." FutureStructure. April 26, 2018. https://www.govtech.com/fs/transportation/Ohio-Regulators-Green-Light-Utilitys-10M-Plan-to-Install-More-EV-Charging-Stations.html

NARUC
National Association of Regulatory Utility Commissioners

1101 Vermont Ave, NW • Suite 200 • Washington, DC 20005
www.naruc.org • (202) 898-2200