Utility Investment in Electric Vehicle Charging Infrastructure: Key Regulatory Considerations

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November 2017

Acknowledgements

The authors wish to acknowledge Vicki Arroyo, Georgetown Climate Center, for her review and guidance; Tanya Abrahamian, Georgetown Climate Center, for her research and contributions; Brian Jones and Dana Lowell, M.J. Bradley & Associates; for their review and helpful input; and Gabriel Pacyniak, University of New Mexico School of Law, for his initial scoping and guidance.

The authors are grateful for the expert review provided by Karsten Barde, National Grid; Erin Boyd, U.S. Department of Energy; Dave Farnsworth, Regulatory Assistance Project; Scott Fisher, Greenlots; Sarah Garman, U.S. Department of Energy; Marissa P. Gillett, Maryland Public Service Commission; Kathy Kinsey, NESCAUM; and Nancy L. Seidman, Regulatory Assistance Project.

M.J. Bradley & Associates and the Georgetown Climate Center would like to thank the Barr Foundation, the John Merck Fund, and the Rockefeller Brothers Fund for the support that helped make this work possible.

This report reflects the analysis and judgment of the authors only and does not necessarily reflect the views of the funders or reviewers of this report.

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The Georgetown Climate Center (GCC) is a non-partisan law and policy research center based at Georgetown University Law Center that serves as a resource to states to advance cleaner energy and transportation policies and to help communities prepare for climate change impacts. GCC worked with states, power companies, and non-profit organizations to inform the development of the Clean Power Plan, and continues to support the development and implementation of local, state, and federal policies. It facilitates the Transportation and Climate Initiative—a collaboration that seeks to improve transportation and reduce carbon emissions and other pollutants from the transportation sector across 11 states and Washington, DC. GCC also helps states and communities integrate adaptation planning into all levels of government decision-making.

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Utility Investment in the Electric Vehicle Charging Grid: Key Regulatory Considerations

The paper provides an overview of the accelerating electrification of the transportation sector and the role of utility regulators in ensuring that investments in the electric grid to accommodate widespread transportation electrification create benefits for customers and society. The paper summarizes options for more direct utility investment in plug-in electric vehicle (PEV) charging infrastructure and analyzes key considerations for utility regulators when assessing these potential investments by electric utilities. These considerations include:

- How much charging infrastructure is needed to support the anticipated level of electric vehicle penetration?
- What transmission and distribution system upgrades and investments will be needed to accommodate electric vehicles?
- How can regulators help ensure equitable access to charging infrastructure?
- How should the costs and benefits of utility investment in charging infrastructure be assessed, and how can programs be designed to maximize the benefits?
- How should utilities recover the costs of infrastructure investment?

Introduction

The widespread deployment of plug-in electric vehicles[*] and the role of the electric utility in providing the fuel source for electric transportation may open a new chapter in the evolution of electric markets and in the role of regulators tasked with overseeing them. Several states have set ambitious policy goals for PEV adoption and are taking steps to prioritize transportation electrification as a key strategy to reduce fossil fuel dependence, energy costs, air pollution, and greenhouse gas (GHG) emissions. As utilities, state public utility commissions, manufacturers of PEV technologies, and other stakeholders navigate this new terrain, there is an opportunity to align the deployment of this emerging technology with the interests of grid customers.

PEV adoption is projected to grow in the near- to medium-term given rapidly declining battery costs and the growing number of vehicle models—including the first extended-range vehicles with affordable purchase prices or leasing terms. When combined with federal, state, and local purchase incentives that are available in many jurisdictions, PEVs are quickly approaching cost parity with traditional internal combustion engine (ICE) vehicles and may provide a lower cost of mobility for drivers.

These factors all amount to increasingly attractive economics of ownership, and PEVs are now becoming a viable mass market option for consumers. Nevertheless, the lack of sufficient charging infrastructure remains a barrier to widespread PEV adoption in the U.S.[1] The buildout of a comprehensive charging infrastructure network, including public charging stations, is needed to address "range anxiety," wait times for charging, and other common consumer concerns. Additionally, providing sufficient public charging infrastructure may increase the rate of PEV adoption until it reaches a scale that significantly reduces vehicle costs, leading to genuine market transformation. Along the way, maintaining grid

[*] The term plug-in electric vehicle (PEV) is used for plug-in hybrid electric vehicles and battery electric vehicles.

reliability, reckoning with issues of social and demographic equity, and meeting the new electrical demand dynamics with intelligent rate design will all be vital issues for policymakers' consideration.

State public utility regulatory commissions must address the challenge of balancing multiple interests—reliability, cost effectiveness, technological advancement, and utility planning—as more PEVs enter the roadways and draw electricity from local distribution systems. Critically, many of these commissions are investigating the role of electric utility investment in providing the PEV charging infrastructure needed to enable an electrified transportation system that is optimal for the grid and utility ratepayers.

A key question to explore is whether "ratepayer money" should be used to build out PEV charging infrastructure. In other words, should utility regulators approve utility capital investment programs in which various elements of PEV charging infrastructure and alterations to the electric distribution system are placed in the rate base and the utility company is authorized to recover these costs and earn a rate of return on the investment? If so, what are the justifications for this approach: how should such investment programs be structured, how can regulators ensure more equitable access by all customers to charging infrastructure, and how should utilities allocate and recover the costs of investment?

To examine these questions, we identify key considerations for regulators in this evolving market. We also look to the experience in states where PEVs are being encouraged and where utilities are making investments in and experimenting with various models of meeting the new demand for PEV charging.

As we discuss in more detail below,[2] increasing PEV charging load has the potential to provide numerous benefits to the electric grid and customers: reducing all customer rates by spreading fixed distribution maintenance costs over more electricity demand; reducing emissions of greenhouse gases and local air pollutants, including around low- and moderate-income communities that are disproportionately burdened by vehicle pollution; lowering the cost of transportation and increasing equitable access to mobility; and providing grid management services that can help integrate renewables and other distributed and customer-located generation resources. However, there remain many unknowns regarding transportation technology developments and electric vehicle infrastructure needs, and investments now must be made based on assumptions with inherent uncertainty. Ultimately, utility regulators must determine whether, in aggregate, this collection of potential grid, customer, and societal benefits is sufficient to justify the costs and risks associated with utility investments in the buildout of PEV charging infrastructure.

Market and Policy Context: Why Now?

State of the Electric Vehicle Market

Total PEV sales in the United States since 2010 have grown to nearly 650,000 vehicles,[*] with a record 159,000 in annual sales in 2016.[3] Consumer demand for PEVs has risen due to increased availability of vehicles with significantly improved vehicle performance, as well as increased understanding of PEV ownership benefits: lower maintenance costs, falling retail prices, and cheaper per-mile travel, as well as the environmental benefits of low-emission transportation. Federal and state policies and incentives are encouraging investments in PEVs and infrastructure to support national and local climate goals while bringing economic benefits, and the state Zero-Emission Vehicle (ZEV) regulation, discussed in more detail below, requires increasing sales of PEVs across the country through 2025.

[*] As of August 2017.

While the current generation of PEVs has proven to be reliable and appealing to a number of early adopters, widespread consumer adoption has been hampered by comparatively high upfront costs of PEVs (despite an often lower total cost of ownership compared to gasoline vehicles), as well as perception of limited range and charging infrastructure. However, in response to growing consumer demand and federal, state, and local policy actions, the automotive industry in the last five years has made significant progress in developing better-performing, moderately priced PEVs from well-recognized brands. While there were only two fully electric or plug-in hybrid electric models commercially available from major auto manufacturers in 2010, more than 35 models are expected to be available by the end of 2017.[4] Moreover, car manufacturers, including BMW, Ford, General Motors, Hyundai, Jaguar, Nissan, Tesla, Toyota, Volkswagen, and Volvo, have announced investments in PEV research and development and additional releases of new electric models in the 2020-2025 timeframe, making a future centered on electric transportation a viable near-term reality.[5] For example, in October, 2017, GM Chairman Mary Barra announced the company's commitment to an "all-electric future," including plans to launch at least 20 all-electric vehicles by 2023.[6]

Rapidly improving battery technologies are further improving the performance of vehicles while reducing purchase costs, and many vehicle manufacturers and transportation analysts are projecting rapid adoption of PEVs.[7] For example, Bloomberg New Energy Finance projects that by 2040, electric vehicles will make up 35 percent of annual new vehicle sales in the United States and will cost less than $22,000, largely due to declining battery costs.[8] This trend toward electric transportation is global: China has surpassed the United States as the global leader in PEV sales, and in Norway PEVs made up nearly 30 percent of vehicle sales in 2016.[9] These trends are expected to continue, particularly in cities, which are setting the most ambitious goals: Los Angeles, London, Mexico City, and nine other major cities recently announced their commitment to only buy zero-emissions buses starting in 2025,[10] and other major cities have proposed bans on internal combustion engine vehicles.[11]

Transportation and the Grid

In the near term, the impacts of PEV charging on the electric grid are likely to be small, given the relatively low levels of deployment. However, as PEV penetration increases, the added demand for electricity could increase grid costs and introduce reliability challenges for the distribution system if certain locational concerns are not anticipated and addressed.

Even at lower vehicle penetration levels, the location of charging stations is an important consideration. Reliability or cost impacts could occur in locations where several PEVs are charging simultaneously (called "clusters"). These concerns increase as PEV battery sizes and PEV charging infrastructure power capacities increase over time. Additionally, as PEV technology advances, the market may also include a larger number of public fast charging stations (currently most fast chargers have a capacity of 50kW per port, but higher capacity chargers of up to 350kW are planned).[12] Because direct current (DC) fast charge stations draw significant power when charging vehicles, these stations can create challenging spikes in the electric system loads at host sites.

As utilities plan for increased PEV charging, they will need to incorporate these considerations into system planning processes. For example, Pacific Gas & Electric Company (PG&E) has initiated a DC fast charging initiative under its Electric Program Investment Charge (EPIC) program to identify optimal locations for fast charging stations based on, among other factors, the robustness of points on the secondary distribution system.[13]

Given the need to incorporate anticipated PEV charging loads into system planning, electric utilities will need to invest in overall grid infrastructure in response to transportation electrification, even if they do not invest in charging equipment itself. In addition, electric utilities may be able to bring about even greater customer and social benefits through more direct investment in the build-out of PEV charging infrastructure.

Air Quality and Climate Change: Critical Drivers of State Electric Vehicle Policies

States with GHG emission reduction goals on the order of 80 percent reductions by 2050 have determined that transportation electrification will play an indispensable role in meeting state targets.[14] Consequently, preparing and supporting the market transformation to PEVs has become a high priority for these states.

To date, significant carbon dioxide (CO_2) emissions reductions have been achieved in the power sector through energy efficiency and shifts from coal and oil to natural gas and renewables. As of August 2016, emissions from the transportation sector are now the leading source of CO_2 emissions in the U.S.[15] As the electric system continues to decarbonize, it will provide opportunities for achieving emissions reductions more broadly across the economy through electrification of key sectors such as transportation and buildings. Recent studies have concluded that deep reductions in transportation-sector emissions are only achievable through a dramatic shift away from gasoline vehicles to low-emitting plug-in hybrid electric vehicles or battery electric vehicles.[16]

In addition, states may look to PEVs to lower local criteria air pollutant levels by reducing the number of conventional vehicles on the road. Nationwide in 2014, 55 percent of all ozone-creating NOx pollution came from vehicles; in areas that have already pursued reductions from the electric sector, transportation's contribution level can be much higher.[17] About ten percent of nationwide fine particulate matter, and a much higher percentage of urban particulates, also comes from transportation.[18] More than a quarter of all anthropogenic volatile organic compounds are also from ground transportation.[19] Since these emissions can be fairly local in their effects, reducing transportation emissions can have a large impact on the health and well-being of communities in urban areas or around transportation corridors.[20] The criteria pollutant benefits of PEVs—particularly for SOx emissions—can be significantly greater when charging with electricity generated on cleaner grids.[21]

Existing State Policies Supporting Electric Vehicles

State governors and legislatures are taking policy action to enable PEV adoption and bring about the significant economic and environmental benefits associated with transportation electrification. States are implementing vehicle purchase and charging station incentives (among other policies) and establishing goals or binding regulatory targets to increase the number of PEVs on the road, at both the individual state level and through multi-state commitments.

One key policy supporting PEVs is the Zero-Emission Vehicle (ZEV) Standards first developed by California and then adopted by nine other states under Section 177 of the Clean Air Act. Under this program, large vehicle manufacturers must sell zero-emission vehicles (which include plug-in hybrid vehicles and fuel cell vehicles) to meet increasingly stringent ZEV credit requirements. The number of credits earned per vehicle depends primarily on electric range: for example, a 2017 Chevy Bolt earns four credits, and a 2017 Nissan LEAF earns three.[22] The California Air Resources Board estimates that total ZEV sales will need to be approximately 2 million by 2025 in order to produce enough credits for compliance in the10 participating states.[23]

In addition, governors from California, Connecticut, Maryland, Massachusetts, New York, Oregon, Rhode Island, and Vermont signed the Zero-Emission Vehicle Memorandum of Understanding (ZEV MOU) in 2013, committing to deploy 3.3 million ZEVs by 2025, along with the necessary charging and fueling infrastructure.[24] The governors established a multi-state ZEV Task Force to coordinate policies and programs to increase the sale of ZEVs, including vehicle purchase incentives, promoting public and workplace charging, and working towards equitable access to charging stations.[25] States also are collaborating to grow regional networks of charging infrastructure, through initiatives such as the West Coast Electric Highway and the Northeast Electric Vehicle Network.[26]

Several states, including California, Oregon, and Washington, have passed legislation to require or encourage electric utilities to support transportation electrification and PEV charging infrastructure investment. Some of this legislation directly requires utilities to submit comprehensive PEV charging infrastructure investment proposals to public utility commissions.[27] These utility transportation electrification proposals often combine customer incentives, charging and rate programs, customer education initiatives, and investment in charging infrastructure that together work to increase adoption and manage the costs and reliability impacts of electric vehicle charging.[28]

Due to these technology developments, federal and state incentives, and regulatory programs, PEV sales are projected to increase rapidly over the coming years. For example, to meet the vehicle adoption levels established in the multi-state ZEV MOU, PEV sales would have to increase 400 percent over 2014 levels over the next decade.[29] While the exact scale of infrastructure necessary to support this level of PEV penetration is not easy to predict with certainty, many companies and other stakeholders (including the authors of this paper) are continuing to study this question. For example, Bloomberg New Energy Finance projects that infrastructure necessary to meet current PEV sales projections (nearly 30 percent of new sales by 2030 and 35 percent by 2040) would require annual spending of more than $974 million by 2021, increasing significantly as sales increase year over year as projected. Importantly, this investment only includes the charging infrastructure itself, not any supporting distribution or transmission updates, or power purchases necessary to support increasing or changing electricity demand patterns.[30] At a minimum, meeting these goals will require a significant increase in the amount and pace of charging infrastructure construction over existing levels.

Why Infrastructure and Why Utilities?

While residential charging is likely foundational for an electrified transportation system, non-residential charging options will be necessary for widespread PEV adoption. Access to workplace charging can provide an alternative primary charging option for drivers and can significantly increase electric miles traveled for plug-in hybrid electric vehicles that begin running on gas after electric range is depleted.[31] Increased semi-public charging infrastructure is needed in apartment complexes and other multi-unit dwellings where drivers may not have dedicated parking spaces. Additionally, public charging infrastructure is needed to eliminate driver range anxiety, enable long-distance travel, and support drivers without dedicated home parking.

Utilities' involvement in infrastructure development can have numerous benefits, many of which are explored in more detail below. These can include:

- Increasing the pace and scale of infrastructure development by opening the market to utility capital, expertise, and other resources;
- Maintaining reliability and minimizing grid impacts and required distribution and transmission system upgrades by coordinating with existing utility investment and planning processes;
- Lowering the cost of infrastructure development through coordination with the distribution grid and building on utility experience with infrastructure development;
- Improving ability to communicate with customers through existing channels, developing customer pricing models, and creating incentives to promote vehicle charging at times that provide grid benefits—including load balancing and integration of renewable energy sources; and
- Providing more equitable access to charging infrastructure for all ratepayers and communities, and increasing mobility for all through utility partnerships with transportation programs focused on serving disadvantaged communities.

Regulators will need to balance these benefits—which will not always result from every project—against other risks and concerns. Regulators have an important role in ensuring that utility programs are well-designed and effectively implemented to address these concerns, including:

- Maintaining competitive access to charging infrastructure development for third parties;
- Developing infrastructure in a way that is accessible to low- and moderate-income communities;
- Protecting utility ratepayers and avoiding significant stranded costs; and
- Ensuring that electric infrastructure is capable of incorporating increased PEV charging load.

Careful planning and regulatory processes can take advantage of utilities' unique roles as critical partners in accelerating the development of infrastructure, while preserving the opportunity for non-regulated businesses to compete in the PEV charging infrastructure market.

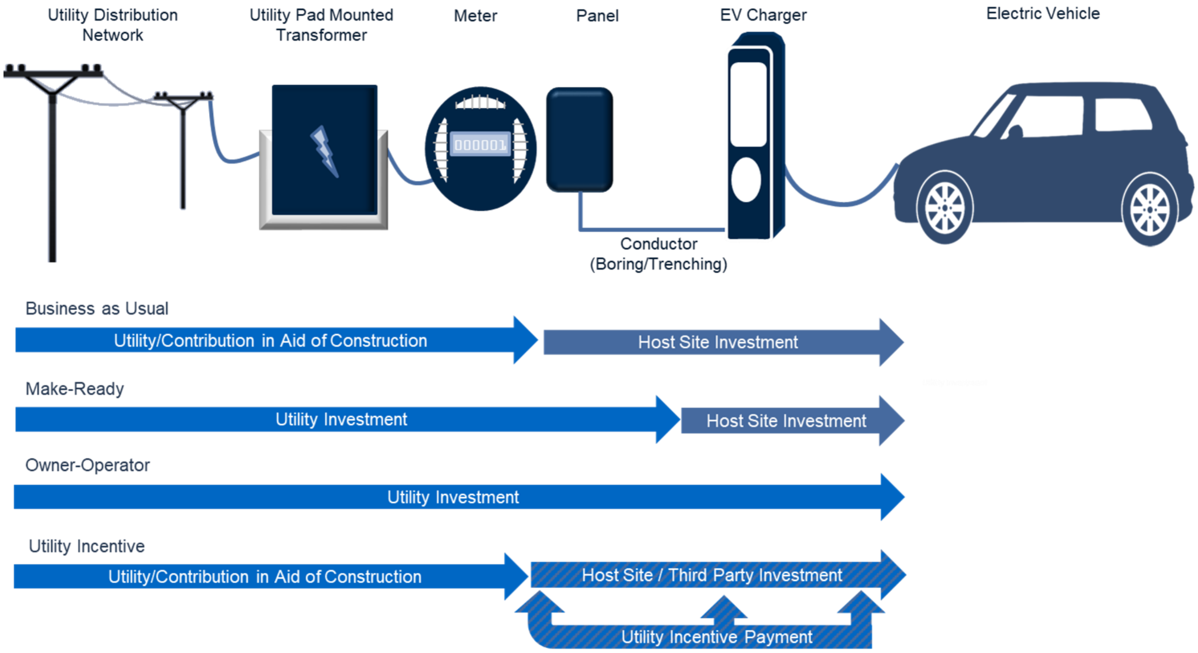
Utility Investment Models

Utilities' actions to assist in the development of PEV deployment and integration can take many forms, from offering new electric rate structures for PEV drivers to facilitating rebates for PEV purchases. For the purposes of this paper, however, we focus on the ways in which utilities can invest in charging infrastructure.[32] There are three primary models. First, a utility could invest in "make-ready" installations, which include the electrical infrastructure required up to, but not including, the actual PEV charging equipment.[*] Second, a utility could fully own and operate installations, which would include the make-ready components as well as the charging equipment itself, resulting in a single regulated entity building out and owning the electric infrastructure and vehicle charging equipment. Third, utilities could provide host sites with financial incentives, such as rebates for the costs of the PEV charging

[*] Note that charging infrastructure can be divided into three pieces: 1) secondary distribution infrastructure up to the customer meter to connect the new installation to the electric grid; 2) trenching and wiring to connect the meter to the charging infrastructure, as well as the foundation and insulating material for the charging infrastructure; and 3) the actual charging infrastructure, or electric vehicle supply equipment (EVSE) purchase and installation. Traditionally, responsibility for component one is split between the utility and the customer, depending on the interconnection requirements of the new equipment. Components two and three are typically covered by the customer. A make-ready investment by a utility could cover all of components one and two.

infrastructure and/or the make-ready portion of the infrastructure. Figure 1, below, illustrates the ownership of the components of the electric infrastructure and vehicle charging equipment under the different models.

Figure 1. Models of Utility Investment in Electric Vehicle Charging Infrastructure



Source: M.J. Bradley & Associates

There are many variables to consider when determining the most effective utility investment model for a given jurisdiction or site location. These variables may include location (e.g., site type, such as residential building or shopping mall; distance from existing infrastructure), the state of the existing distribution system, the state of the local PEV charging infrastructure market, and likely customer base characteristics (including income level). In addition, utilities and regulators may wish to pursue a mix of investment models; the best-fit model type may be different for specific locations across a utility's service area, or may vary as the charging infrastructure network develops over time. Parties may also wish to explore a variety of investment models in the early stages of utility investment as part of pilot testing.

As discussed in more detail throughout this paper, a key factor that utility regulators may wish to consider in determining an appropriate level of investment and investment model is the level of risk they will accept. A utility can play a critical role in jumpstarting the electric vehicle market, but such proactive investment requires a willingness to accept some degree of underused or unprofitable projects, or a lag between a project's inception and its full utilization. Further, these models are not mutually exclusive. A mixture of investment models, the use of a blend of utility customer and investor money, strategic use of diverse pilot projects, and phased project deployment are all viable strategies for balancing the potential risks and benefits of each approach.

Make-Ready Model

The make-ready model limits a utility's investment to the equipment necessary to connect the PEV charging infrastructure to the grid. This may include upgrades to transformers and service capacity and/or running new service drops. In some cases, it may also mean trenching and running conduit and cable to

specific areas of a host site, such as in a parking lot at a workplace. Since this can often be a large part of project costs, utility investment here can increase the pace and lower the costs of infrastructure investment by opening new sources of low-cost capital. The utility potentially could then recover some of these costs from all electricity customers, as is the case for other distribution system investment. Utilities can also use their familiarity with the design, operations, and maintenance of the distribution system, permitting requirements, and interconnection process to efficiently identify and develop appropriate connection infrastructure. In the make-ready model, the PEV charging infrastructure installation, ownership, operation, and maintenance are left to the host site and competitive marketplace, which may offer a wider range of pricing structures and other customer options.

A commonly cited downside of the make-ready approach is that it does not go far enough to take advantage of utility expertise and funding.[33] Critics of the approach argue that, in some situations, keeping utilities out of actual PEV charging infrastructure development puts inefficient and unnecessarily costly barriers between utility customers and PEV infrastructure—for example, by requiring the site host to research, select, and purchase the charging stations. Additionally, this model relies on a site host to operate and maintain charging infrastructure, and may not lead to consistent charging station reliability. Finally, the make-ready model may not be sufficient to meet the charging infrastructure gap in multi-unit dwellings. For example, in the Southern California Edison Charge Ready pilot program, which uses the make-ready model, less than four percent of charging stations have been installed in multi-unit dwellings.[34]

Utility Owner-Operator Model

Under the utility owner-operator model, a utility owns and operates all components of the PEV charging infrastructure. This could expand the primary benefits of make-ready utility investment (i.e., utility experience with infrastructure and access to capital) to streamline and increase the scale of PEV charging infrastructure development. A utility owner-operator may also oversee other program components, including marketing and host site recruitment, pricing and programs, and ongoing operations and maintenance—all areas in which utilities have operated for decades. In addition, utilities could be required to directly collect PEV charging infrastructure usage and charging data and transparently report this information to their utility commissions to inform future development efforts. Another important component is that utility operation of stations may provide additional opportunities for more sophisticated vehicle-grid integration and the use of dynamic and innovative rate designs to promote grid-optimized charging. For example, the San Diego Gas & Electric *Power Your Drive* program—through which the utility will install, own, and operate 3,500 charging stations—includes day-ahead, dynamic charging rates to promote charging during off-peak and high-renewable energy periods, and other pricing models aimed to create incentives for beneficial charging behavior.[35]

Critics of the utility owner-operator model argue that utility ownership of charging infrastructure may limit market competition. While it may be appropriate for utilities to directly develop PEV charging infrastructure in some situations, utilities could also offer site hosts with a choice of vendors and conduct competitive solicitations for charging equipment, software, and network services to avoid limiting the private market.[36] Ratepayer impacts are another important concern with utility investment in PEV charging infrastructure, one that is heightened when considering the potential for stranded assets, given the early stage of the market and the fast-paced evolution of charging technology. Utility investment programs could help to mitigate this concern through pilot programs with robust reporting requirements, phased deployment of infrastructure installation, and requirements that site hosts contribute towards the cost of the charging infrastructure. Additionally, utility ownership and operation of charging stations may

reduce the risk of stranded assets compared to other investment models because utilities may have greater capacity and expertise to maintain charging infrastructure across the service territory to ensure the ongoing reliability of the charging stations.

Rebates for Electric Vehicle Charging Infrastructure

Another way for utilities to support investment in charging infrastructure would be to administer and provide rebates for PEV charging infrastructure installation and make-ready investment costs in both public and private locations. For example, residential PEV charging infrastructure with Level 2[*] charging and networked "smart charging" capabilities can cost $1,200 or more for the hardware and installation. To mitigate these upfront costs, utilities can leverage their experience administering energy efficiency programs and incentives to develop and offer PEV charging infrastructure rebates. The rebates could be administered and paid for by the utility or with public funds such as state emission allowance auction proceeds. The rebate would have to be designed to allow the utility to recover costs.

Rebate programs can be structured to encourage installation at sites that are considered high priorities for additional investment or that offer certain benefits (such as Wi-Fi connectivity) to facilitate vehicle-grid integration and managed charging. These programs can also create incentives for development in areas of the grid with insufficient private investment in charging infrastructure or sites that are best suited to the additional load—or even limit rebates to those areas. This structure can increase a utility's ability to strategically plan locations or prioritize charging types that bring the rebate model more in line with the level of guidance a utility can provide under the other investment models. The rebate model is often deployed in conjunction with make-ready infrastructure investments, particularly to support the investment of charging equipment in low-and moderate-income or underserved communities.[†]

Key Considerations for Regulators

Utility regulators will play an important role in helping to ensure that PEV infrastructure investments are prudent, just and reasonable, aligned with other policy goals, equitable to ratepayers, and that they result in a fair return on investment for utilities. Utilities also play an important role by proposing investments that are most efficient and beneficial for the grid and all customers. Regulators must balance many factors in determining whether it is appropriate to approve the use of ratepayer funds to enable and support vehicle charging. Below, we highlight six key considerations for these regulators.

How Much Charging Infrastructure is Needed to Support the Anticipated Level of PEV Penetration?

States should expect increasing levels of PEVs due to both economic and policy factors. To support this growth, significant additional charging infrastructure will be required. Electric utilities and public utility regulators will need to engage in proactive planning to ensure that sufficient charging infrastructure is available to serve these vehicles and that it is successfully integrated with the grid. In states that have

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[*] "Level 2" or AC Level 2 charging equipment uses 240V or 208V electrical service and requires a dedicated 40 amp circuit. Level 2 charging is typically installed in long-dwell time locations (such as homes, workplaces, and hotels) and provides approximately 10 to 20 miles of range per hour of charge. U.S. Department of Energy, Alternative Fuels Data Center, "Developing Infrastructure to Charge Plug-In Electric Vehicles."

[†] For example, Southern California Edison's Charge Ready program includes rebates to offset some or all of the costs of charging station equipment and installation in conjunction with a commitment to install a minimum of five charging stations in disadvantaged communities.

adopted policy goals related to PEV adoption—for example, emissions reduction, utility rate mitigation, or transportation access—utility engagement in an integrated policy process may be critical to reaching these targets.

In order to gauge the level of PEVs anticipated in a state and the infrastructure needed to support it, utility regulators could work with a range of stakeholders (including state departments of transportation, environmental and energy agencies, utilities, federal agencies and national laboratories, and third-party groups) to conduct a three-step analysis.

The first step would be to study how many PEVs the state expects based on economic and policy factors. Even without state policy objectives to promote PEVs, many market forecasts project rapid adoption of PEVs in the next decade due to increasingly favorable economics, and regulators and other parties could conduct a market analysis that projects long-term adoption rates for PEV penetration. In states where climate or air quality targets are key drivers of PEV adoption, such an analysis could take into account the range of PEV fleet sizes that may be necessary, by certain dates, to achieve state goals[*] (in coordination with other projected strategies from transportation and other sectors).

The second step would be to determine how much public charging infrastructure would be necessary to support projected levels of PEV penetration, as well as the type of infrastructure (Level 2 or DC fast charging). Studies of this type are currently underway and take multiple forms. For example, the California Energy Commission and the National Renewable Energy Laboratory (NREL) developed the Electric Vehicle Infrastructure Projection Tool (EVI-Pro), which uses population density, PEV ownership rates, traffic patterns, and travel data to determine the total amount of infrastructure needed under various PEV adoption scenarios. This model has already been applied to model PEV infrastructure requirements in California, Massachusetts, and other jurisdictions. NREL recently published a nationwide assessment of charging infrastructure needs using the EVI-Pro model, that may provide a useful baseline for state- or utility service territory-level assessments.[37]

In addition to the total amount charging infrastructure required in metropolitan areas, utility service territories, and along corridors, it is important to better understand the locations where charging infrastructure is needed and whether the private market is providing charging infrastructure in these locations. The Georgetown Climate Center has been working with Northeast and Mid-Atlantic states to identify priority locations for fast charging infrastructure along major corridors in the region. This regional corridor analysis, conducted by M.J. Bradley & Associates, evaluates the existing public DC fast charging network along corridors, identifies gaps in charging infrastructure, and assesses highway exits for their level of priority for additional charging infrastructure investment.

Finally, regulators can assess the current competitive market for charging infrastructure in their state. This is a rapidly expanding sector that will be critical to increasing PEV penetration. However, in most if not all areas, this nascent business will not be sufficient to support the levels of charging infrastructure needed, especially on the relatively short timeframe driving many climate and air quality goals. Additionally, and as discussed further below, competitive market charging providers may not prioritize development in areas with low near-term utilization or other development barriers. Though regulators

[*] Such an analysis may consider, for example, the makeup of the anticipated fleet of PEVs (e.g., the relative number of PHEVs and BEVs, which may differ based on state incentives, consumer preferences, and model availability), the number of miles each car would likely be driven, the life-cycle emissions associated with the electricity used to power the vehicles, and more. Together, these factors could be used calculate the average emissions savings per vehicle.

will not be able to perfectly predict future development patterns, they can work with utilities, private charging companies, and other stakeholders to develop infrastructure proposals in which utility investment and private investment can complement each other. This could result in a plan for utility investment to be shared among a mix of "traditional" charging locations—single-family homes, commercial centers, and large office buildings—as well as those locations less likely to draw traditional private investment, such as multi-unit dwellings, low- and moderate-income areas, or relatively low-traffic volume areas that nevertheless are critical transportation corridors. This mix can be devised such that the total portfolio remains reasonably profitable for the utility (balancing the projected usage of both traditional and non-traditional locations), without limiting broader investment opportunities for non-utility businesses. Additionally, utilities could leave charging infrastructure selection decisions up to the site hosts or conduct competitive solicitations for PEV charging equipment to further enable development in the competitive market.

Phased or "iterative" approval of utility investment may also provide opportunities to update this assessment of charging infrastructure needs and existing private investment to ensure that regulators continue to allow competitive access to the market while helping to optimize utility investment. For example, the California Public Utilities Commission initially responded to an application from PG&E to invest over $650 million in PEV infrastructure and programming by instead asking for a "phased development approach" that would "provide an opportunity for the Commission to collect and evaluate data along the way to determine program effectiveness and allow for any modifications."[38] When the Commission just over a year later approved a first phase of $130 million PG&E investment, Commissioner Carla Peterman expressed her belief that the decision "strikes a good balance between consumer benefits and the promotion of competition in the PEV infrastructure marketplace."[39] In approving this investment level, the California Public Utilities Commission provided for a "hard stop" after three years to provide the Commission an opportunity to review and evaluate the initial results of the program before continuing with additional investment.[40]

This iterative approach can also help utility regulators manage the risk associated with developing infrastructure for an emerging technology that may not develop as anticipated. Phasing infrastructure deployment, with a commitment to keeping pace with vehicle adoption rates, can allow utilities to provide service in a timely manner—rather than waiting until needs are clear but overwhelming—while also limiting the instances in which infrastructure is used less than anticipated because of unpredictable but inevitable changing market conditions.

What Transmission and Distribution System Upgrades and Investments Will Be Needed to Accommodate Electric Vehicles?

Utilities have an obligation to serve all customers and all sources of electricity demand within their service area. This service requires a robust transmission and distribution system of wires and other equipment. Increases in transportation electrification have the potential to generate significant new electricity demand, which would require corresponding upgrades in utility transmission and distribution infrastructure. For example, a Bloomberg New Energy Finance analysis estimates that global electricity demand from electric passenger vehicles alone (not including transit, goods movement, or other transportation-sector components) could reach 2,700 TWh by 2040. This is more than 10 percent of current electricity usage.[41] In areas of particularly high adoption, such as those states that adopt aggressive electric vehicle targets in order to pursue air quality benefits and GHG emissions reductions,

vehicle electricity use could reflect an even higher percentage of total system load. This may require the upgrade of local electric distribution infrastructure and could trigger upgrades or additions of transmission-level infrastructure as well.

Even at lower vehicle penetration levels, the distribution system could see impacts from “clusters” of PEV home charging in early adoption neighborhoods or from public DC fast charging, which can draw as much electricity at a given time as an entire commercial complex. As more DC fast charging stations are installed, particularly when concentrated in charging hubs in downtown areas or along travel corridors, local distribution lines could experience significant local spikes in demand. Of course, these impacts will be highly dependent on the level of vehicle penetration, when charging occurs, and where public infrastructure for charging is developed.

The key implication of these infrastructure impacts of PEVs is that electric utilities will be responsible for some level of infrastructure investment to support charging, *regardless* of whether the utility is directly investing in the charging infrastructure. At a minimum, when conducting distribution and transmission system planning, utilities should be considering contingencies that include significant penetration of PEV charging.

Utility involvement in helping to identify and plan optimal locations for public infrastructure can help to spread out grid impacts across both time and space, yielding significant benefits for ratepayers. For example, utilities can work with regulators to identify distribution lines with unused capacity and support charging infrastructure in those areas. This utility involvement could come through a combination of sharing this data with stakeholders and potential site hosts, or through directly investing in infrastructure at key locations. For example, as described earlier, PG&E has identified in its service area key locations that can support DC fast charge infrastructure, taking into account traffic patterns, its distribution system, existing infrastructure, and other factors. The appropriate approach for a utility would likely be determined by the state of the competitive charging market in the area and the level of utility involvement needed to enable charging infrastructure investments in locations that optimize grid operations and create benefits for customers.

Regulators may also want to consider if there are benefits in aligning transmission and distribution system investment with charging infrastructure investment by having the same party—the utility—be responsible for both. For example, having the same developer for the charging infrastructure and the components necessary to serve that infrastructure could allow for streamlined integration of those elements' construction and operation. Similarly, utility development of charging infrastructure could help avoid delays in operation that may otherwise be caused by third party development that is not integrated with utility distribution system planning. For states that want additional clarity on the role of electric distribution utilities in PEV charging infrastructure investment, state transportation electrification legislation can provide direction.[42]

How Can Regulators Help Ensure Equitable Access to Charging Infrastructure?

Early adopters of PEVs have, to date, been wealthier and more likely to live in single family homes than the average U.S. resident. For example, a 2013 study from the University of California, Davis, found that during the early stage of the PEV market in California, 96 percent of PEV owners lived in a single-family home and 96 percent owned their home. This is compared to a rate of only 70 percent of households in single family homes nationwide.[43] Another national study noted that while the average household income

of a conventional Ford Focus purchaser in 2015 was $77,000, the household income of the average electric Ford Focus (a mid-price PEV) was more than double that, at $199,000.[44]

As PEVs quickly transition from the "early adopter" phase to mass market adoption, more charging infrastructure will be needed to ensure that all residents can take advantage of the benefits of electric transportation. In particular, PEVs can provide significant benefits to low- and moderate-income households. Lifetime cost savings can decrease the burden of transportation costs, and the reduction of vehicle air pollution can help address environmental justice concerns for communities along highways and major transportation routes, which are already facing inequitable environmental hazards. Access to PEV sharing programs can help increase mobility for communities that are otherwise substantially isolated from jobs, schools, and other services. Utility regulators, whose roles include ensuring access to electric service for all customers, are well placed to help shape infrastructure deployment to enable access to electric vehicles, and their many benefits, by low- and moderate-income customers.

One key barrier to increasing PEV usage in low- to moderate-income households is the relatively high number of such households living in multi-family and/or rental units, which often have limited PEV charging options. In 2015, only 49 percent of households with annual incomes less than $50,000 lived in detached single-family homes. This compares to 75 percent of households with annual incomes $50,000 and above (and 83 percent of households with incomes above $120,000).[45] In addition, only 13 to 17 percent of households with incomes below $50,000 owned the home they lived in, including single-family homes (nearly 50 million people in the United States live in rented single-family homes).[46] As a majority of PEV charging is currently conducted at home, residents without driveways, easy access to electrical infrastructure, or the ability to make modifications to existing structures may find it difficult to conveniently fuel a PEV.

Utility investment in PEV charging infrastructure could be used to help these communities benefit from broader PEV market trends by supporting public charging options in their neighborhoods. This could include semi-private charging available to residents of multi-family dwellings, or a focus on community-based public charging stations in locations that serve these communities. In some cases, PEV charging needs in these areas may not be sufficiently met by competitive charging companies that assess ideal locations on metrics such as past PEV purchasing patterns. In addition, competitive companies may struggle to make a business case to install charging equipment in rental or community areas that do not have a site host willing to pay for infrastructure installation or maintenance.

However, utility regulators preparing for an expanded PEV market may consider working with utilities that are pursuing charging infrastructure investment to ensure that utility investment programs increase equitable access to charging infrastructure among all communities. One mechanism to increase equitable access to infrastructure is to establish a minimum low- and moderate-income investment requirement in approved utility investment programs. For example, all California investor-owned utilities are required to deploy a minimum of 10 percent of their PEV charging infrastructure in disadvantaged communities; per a settlement agreement, PG&E will increase its target to 15-20 percent.[47] Two of Massachusetts' utilities, Eversource and National Grid, have submitted proposals for infrastructure investment that include

commitments to install at least 10 percent of total infrastructure in environmental justice communities and provide a full rebate for the cost of the charging infrastructure in these communities.[*]

This approach can work in conjunction with other programs that help overcome other barriers to PEV ownership, such as rebates and grants that help low- and moderate-income households to reduce the initial high cost of purchase. In addition to these purchase rebates, electric car-sharing programs are expanding access to electric mobility for low- and moderate-income customers, often in partnerships with electric utilities. For example, Pacific Power recently supplied charging infrastructure to support a PEV car sharing program at an affordable housing location in Portland, Oregon, in partnership with Forth and the Hacienda Community Development Corporation.[48] Similarly, the City of Los Angeles set up a pilot car sharing program for electric vehicles in disadvantaged communities that would serve over 7,000 residents.[49]

Utilities may also be able to provide charging infrastructure for electric transit buses, port electrification, and electric freight delivery—initiatives that can increase mobility options and reduce emissions in communities disproportionately impacted by air pollution. For example, investment proposals by investor-owned utilities in California include charging stations for electric buses and port electrification[50] and make-ready charging infrastructure for medium- and heavy-duty fleets.[51]

How Should the Costs and Benefits of Utility Investment in Charging Infrastructure Be Assessed, and How Can Programs Be Designed to Maximize the Benefits?

Increased penetration of PEVs can create broad benefits for drivers, utility customers, and society as a whole. PEV drivers will see annual savings as they spend less money to power their vehicles with electricity and save money on vehicle maintenance. As described in more detail below, under well-designed programs, utility ratepayers can see benefits from higher utility revenues due to increased electricity sales and improved overall system utilization, which puts downward pressure on electricity rates for all utility customers. These benefits increase if PEV charging is managed so that it occurs off-peak.[52] Health and societal benefits result from improved air quality as a switch to electric vehicles could dramatically reduce or eliminate tailpipe emissions of climate change pollutants and local air toxics.

Due to the uncertainty of charging infrastructure usage levels, a traditional cost-benefit analysis for utility infrastructure investment may show costs outweighing benefits. Furthermore, utility regulators may not typically account for additional benefits, including energy and maintenance cost savings for PEV drivers or the societal value of GHG and criteria pollutant emission reductions.

Additionally, as stated earlier, a utility can play a critical role in jumpstarting the electric vehicle market; however, such proactive investment necessitates a tolerance for risk in accepting some number of unprofitable or underutilized projects. Utility access to capital (and willingness to invest in infrastructure with a longer payback period), customer communications, and grid operations makes utilities potential strong and cost-effective investors, but their involvement does not mean that the full risk of failed projects lies with their customers. As discussed more below, some portions of costs could be recovered from users of infrastructure (drivers or host sites). Some can come from utility investors, or private partners

[*] Eversource and National Grid define environmental justice communities as meeting two of three criteria as defined under Massachusetts Executive Order 552, (1) 25 percent or more of the population in the communities must earn 65 percent or less than the Massachusetts median household income; (2) 25 percent or more of the population in the communities identify as minority; and/or (3) 25 percent or more of households lack a person over the age of 14 that speaks only English or speaks English very well.

involved in make-ready or rebate projects. And for funds that are provided from customer rates, utility regulators can establish cost recovery metrics and requirements to ensure that programs are run efficiently and appropriate steps are taken to manage (although not completely ameliorate) risks of project underperformance.

Some state commissions have taken action to establish standard guidelines for review of cost recovery for utility ratepayer portions of PEV infrastructure program proposals. The Massachusetts Department of Public Utilities issued an order that requires any utility submission for cost recovery of PEV infrastructure investments to meet the following terms: a) be in the public interest; b) demonstrate that the program will advance PEV deployment in the state that otherwise would not be met by the competitive PEV charging market; and c) not interfere with the growth of the competitive PEV charging market.[53] In other states, legislation has established guidelines for assessment. In Oregon, the state legislature required the Public Utilities Commission to direct utilities to file applications to accelerate transportation electrification that meet six key cost recovery factors.[*] Washington state legislation authorizes the commission to allow an incentive rate of return for utility investments in electric vehicle charging infrastructure "that is deployed for the benefit of ratepayers, provided that the capital expenditures do not increase costs to ratepayers in excess of one-quarter of one percent."[54]

In considering cost recovery and cost-benefit analysis models, the role of utility infrastructure investment can vary depending on the stage of market development. For example, during early stages of PEV market development, not all charging locations and models will be successful. However, utility-supported development and pilots can help to spur additional growth, gather important market information, and help drive market transformation that can ultimately support a broader range of charging models and locations. Regulators can also consider phasing investment approval, which could allow for the utility to adjust rates of return for future investment and to balance opportunities to maintain a competitive market for PEV charging equipment with the need to develop the required levels of infrastructure.

Utility regulators may also wish to explore how utility ratepayer investment can be combined with other sources of funds, especially in the earlier and riskier infrastructure development phases. System benefits charges (SBCs), for example, could be applied similarly to their use in supporting energy efficiency projects—i.e., by collecting general funds that are combined with other sources of funding (e.g., loan programs, tax incentives) and used to support investment in beneficial projects and infrastructure. In the case of electric charging infrastructure, these funds could be targeted at projects that would otherwise face cost-benefit hurdles. In the case of states with proceeds from the auctioning of emissions allowances, regulators could seek to provide access to proceeds (perhaps directly or through revolving loan funds) in order to secure some amount of funding to seed infrastructure projects that might face unique challenges and would otherwise not be pursued. These methods and others might be useful in addressing geographic constraints or helping provide low- and moderate-income regions access to charging.

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[*] *See* Section 20, chapter 28, subsections 3-4, Oregon Laws 2016: "…the commission shall consider whether the investments and other expenditures: (a) Are within the service territory of the electric company; (b) Are prudent as determined by the commission; (c) Are reasonably expected to be used and useful as determined by the commission; (d) Are reasonably expected to enable the electric company to support the electric company's electrical system; (e) Are reasonably expected to improve the electric company's electrical system efficiency and operational flexibility, including the ability of the electric company to integrate variable generating resources; and (f) Are reasonably expected to stimulate innovation, competition and customer choice in electric vehicle charging and related infrastructure and services."

Utility regulators may also consider whether they wish to promote certain charging models in order to optimize electric system infrastructure usage and maximize system benefits. For example, an analysis of New York price models to encourage off-peak charging of PEVs found that by 2030, if half of PEVs charged off-peak the state would see a 276 MW reduction in peak load and a savings of nearly $600 per vehicle due to reduced generation and infrastructure.[55] This period of peak demand is when electricity costs are generally at their highest. In many areas, charging incentives can help utilities flatten the daily load curve by shifting electric charging to fill in troughs in demand (and avoid stressing the grid or adding to existing peak demand).

This can be good for both the PEV customer (who may face lower charging costs) and all electricity customers, regardless of the type of vehicle they own. Properly managed, this added load on the system can improve overall utilization of the system, putting downward pressure on electricity rates. A report evaluating the effect of PEVs on California's electric system found that without pricing models that create incentives for certain charging behavior, PEVs could increase the afternoon ramp-up of demand by up to 1.6 percent in 2020; however, deploying demand control strategies such as time-based pricing could significantly or entirely mitigate PEV impact on afternoon ramp.[56] Numerous other studies have evaluated the potential impacts of electric charging on electricity load profiles and various strategies utilities can deploy to manage charging times and charging rates in residential and public settings.[57] Utility investment in infrastructure may give regulators and utilities more latitude to optimize charging infrastructure pricing to help achieve this load management.

How Should Utilities Recover the Costs of Infrastructure Investment?

The impact of charging infrastructure investment on electricity rates is a key concern of utilities, regulators, advocates, and consumers. There are several approaches to recovering the costs of infrastructure investments that are cautious about increasing electricity costs while also honoring the regulatory requirement that a utility earn a fair rate of return on its investment. For example, utilities could recover a portion of the investment costs from electricity customers, a portion from a charging infrastructure site host, and a portion from PEV drivers. Utility programs that recover costs from charging infrastructure users can use a variety of payment structures. These include:

- membership models that provide customers access to a network of charging locations for a fixed monthly or annual fee;
- fixed fee models, through which a driver pays a fixed amount to enter a charging location;
- usage-based fees that charge customers based on the amount of energy consumed, perhaps varying by time of day or location;
- free charging, most often associated with workplaces or other places that provide charging as a benefit to employees or customers; and
- additional hybrid models.

Each can have an impact on individual drivers' charging patterns. As mentioned above, utility investment in infrastructure may create additional and more effective opportunities for regulators and utilities to optimize charging infrastructure pricing in order to manage charging load. It may also allow for the creation of pilots or programs that help to expand access to disadvantaged communities. These pricing models can also be combined with other utility programs, such as dynamic, time of use, or subsidized rate programs that also target certain policy objectives.

California utilities have developed pilot programs to help accelerate the electrification of the transportation sector and deployment of PEV charging infrastructure, each with slightly different cost recovery models. For example, San Diego Gas & Electric (SDG&E) will predominantly recover the costs of its three-year, $45 million owner-operator "Power Your Drive Program" through general rates from all customers, although SDG&E will also charge a participation fee to third-party charging site hosts.[58] The projected increase in consumer electric bills is about 18 cents over the first year (about 0.02 percent), increasing to $2.75 annually by the end of the pilot period.[59] On the other hand, Southern California Edison's (SCE) $22-million "Charge Ready Pilot" will rate-base the cost of new utility service and make-ready installations located at the site of customer participants, while also providing rebates for installation of PEV charging infrastructure equal to 25 to 100 percent of the cost, dependent on charging station market and location.[60] SCE estimates that over the course of the five-year pilot, the cost of the Charge Ready program will result in a 0.1 percent to 0.3 percent increase on an average consumer's electricity bill, or about $0.001 per kWh.[61]

Utilities could recover a portion of the costs of utility investment in PEV infrastructure from all electric customers through standard rates, similar to how they recover costs for the development of renewable energy and energy efficiency markets. For example, many states collect funds through all customers' rates to provide rebates to customers who install energy efficiency technologies.[62] This technique is also used to help advance and explore new technologies. The Maryland Public Service Commission, for instance, just approved ratepayer funded subsidies that will help develop the state's offshore wind capabilities.[63] In all cases, the potential benefits of such investments must be weighed against the costs, including concerns about potential rate impacts for consumers.

In the near-term, cost recovery from all customers may be a useful tool to overcome uncertain revenue potential from charging site hosts and drivers. Recovering a portion of infrastructure costs through customer rates can help reduce costs for drivers and lower barriers to PEV adoption,[*] which can be critical for achieving other state environmental goals. Additionally, as discussed above, there may be significant benefits to all customers of increasing PEV adoption and managing vehicle charging, which can help justify ratepayer-recovered utility investment in charging infrastructure.[64]

Conclusion

Utility regulators have an opportunity to help shape the future grid by providing guidance for utilities investing in electric distribution infrastructure and the grid components needed to support plug-in electric vehicle charging infrastructure. In the same way that the advent of air conditioning and its corresponding demand for electricity reshaped the electric grid, PEVs may be central to a new era for electric utilities. Utility regulators can use existing practices, planning processes, and authorities to help guide and optimize infrastructure development; and support innovation and exploration while continuing the role of protecting customers and ensuring equitable treatment of all stakeholders. In considering utility investment in PEV charging infrastructure, utilities and their regulators will need to cautiously but proactively support developing PEV technology, taking reasonable risks to ensure that electricity customers cost effectively receive the energy services that they need while states are able to meet critical air quality, climate, community development, and equity goals.

[*] In particular, under low-gasoline-price conditions, PEV drivers may be less willing to pay a premium for charging.

Funding for this project was provided by the Barr Foundation, the John Merck Fund, and the Rockefeller Brothers Fund.
The Georgetown Climate Center is grateful for their support and the support from each of the funders who make our work possible: http://www.georgetownclimate.org/support.

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[1] Mark Singer, National Renewable Energy Laboratory, *Consumer Views on Plug-in Electric Vehicles– National Benchmark Report* (2016), http://www.afdc.energy.gov/uploads/publication/consumer_views_pev_benchmark.pdf.

[2] For more comprehensive state-specific analyses of the costs and benefits of transportation electrification, including ratepayer and societal benefits, *see* Dana Lowell, et. al, M.J. Bradley & Associates, *State-Wide Costs and Benefits of Plug-in Vehicles in Various States* (2017), http://www.mjbradley.com/content/mjba-analyzes-state-wide-costs-and-benefits-plug-vehicles-various-states.

[3] U.S. Department of Energy, Vehicle Technologies Office, *Fact of the Week #976* (May 8, 2017). https://energy.gov/eere/vehicles/fact-976-may-8-2017-china-has-highest-number-sales-plug-vehicles-world

[4] Zachary Shahan, *The 24 Plug-In Hybrid Electric Cars For Sale In The USA, Canada, &/Or Europe*, Clean Technica (January 4, 2017), https://cleantechnica.com/2017/01/04/24-plug-hybrid-electric-cars-sale-usa-canada-europe/; Zachary Shahan, *The 20 Electric Cars For Sale In The USA, Canada, &/Or Europe*, Clean Technica (January 3, 2017), https://cleantechnica.com/2017/01/03/electric-cars-for-sale-in-usa-canada-europe/.

[5] *See, e.g.*, Volkswagen, *New Group strategy adopted: Volkswagen Group to become a world-leading provider of sustainable mobility*, https://www.volkswagen-media-services.com/en/detailpage/-/detail/New-Group-strategy-adopted-Volkswagen-Group-to-become-a-world-leading-provider-of-sustainable-mobility/view/3681833/7a5bbec13158edd433c6630f5ac445da; Volvo Car Group, *Volvo Cars unveils global electrification strategy*, https://www.media.volvocars.com/global/en-gb/media/pressreleases/168142/volvo-cars-unveils-global-electrification-strategy; Daimler, *Daimler invests massively in green powertrain technologies: All Mercedes-Benz model series will be electrified*, http://media.daimler.com/marsMediaSite/en/instance/ko/Daimler-invests-massively-in-green-powertrain-technologies-All-Mercedes-Benz-model-series-will-be-electrified.xhtml?oid=11108480.

[6] General Motors, *GM Outlines All-Electric Path to Zero Emissions*, http://media.gm.com/media/us/en/gm/news.detail.html/content/Pages/news/us/en/2017/oct/1002-electric.html

[7] Henry Sanderson, *UBS takes apart Chevy Bolt, says electric vehicles will disrupt commodity markets*, The Financial Times (May 19, 2017), https://www.ft.com/content/f88292f9-ad32-3fbf-917f-2498fca4564a?mhq5j=e1.

[8] Tom Randall, *Here's How Electric Cars Will Cause the Next Oil Crisis*, Bloomberg New Energy Finance (February 25, 2016), https://www.bloomberg.com/features/2016-ev-oil-crisis/.

[9] Nic Lutsey, The International Council on Clean Transportation, *The rise of electric vehicles: the second million* (January 31, 2017), http://www.theicct.org/blogs/staff/second-million-electric-vehicles.

[10] Alister Doyle, *Twelve big cities to buy zero emissions buses, extend green areas*, Reuters (October 23, 2017), https://www.reuters.com/article/us-climatechange-cities/twelve-big-cities-to-buy-zero-emissions-buses-extend-green-areas-idUSKBN1CS13J.

[11] Brian Love, *Paris plans to banish all but electric cars by 2030*, Reuters (October 12, 2017), http://www.reuters.com/article/us-france-paris-autos/paris-plans-to-banish-all-but-electric-cars-by-2030-idUSKBN1CH0SI.

[12] Barney Carlson, Idaho National Laboratory, *DC Fast Charging Infrastructure 50 kW to 350 kW*, https://avt.inl.gov/sites/default/files/pdf/presentations/INL_DCFastChargerInfrastructure.pdf; *See also* Jay Cole, *EVgo Installing First 350 kW Ultra Fast Public Charging Station in The US*, InsideEvs (January 2017), http://insideevs.com/evgo-installing-first-350-kw-ultra-fast-public-charging-station-us/.

[13] Pacific Gas and Electric Company, *Site information for electric vehicle Direct Current Fast Chargers* (2017), https://www.pge.com/en_US/about-pge/environment/what-we-are-doing/electric-program-investment-charge/direct-current-electric-vehicle-fast-chargers.page.

[14] *See, e.g.*,

- Evolved Energy Research (prepared on behalf of the State of Washington office of the Governor and Office of Financial Management), *Deep Decarbonization Pathways Analysis for Washington State*, (December 2016), http://www.governor.wa.gov/sites/default/files/DeepDecarbonizationPathwaysAnalysisforWashingtonSt.pdf ("Passenger transportation, which is a disproportionate share of the state's current GHG emissions, must shift from internal combustion engine (gasoline) vehicles to a fleet almost entirely composed of electric vehicles by 2050").
- Minnesota Environmental Quality Board, *Climate Solutions and Economic Opportunities: A foundation for Minnesota's state climate action planning* (2016), https://www.eqb.state.mn.us/sites/default/files/documents/CSEO_EQB.pdf ("In order to meet the 2050 climate goal, Minnesota will need to significantly reduce gasoline and diesel consumption For example, a recent study conducted by Siemens for Minneapolis, estimates that for the city to meet its greenhouse gas reduction goals (also 80% by 2050) they would need to replace 65% of passenger vehicles with electric vehicles").
- Massachusetts Office of Energy and Environmental Affairs, *2015 Update of the Clean Energy and Climate Plan for 2020* (December 2015), http://www.mass.gov/eea/docs/eea/energy/cecp-for-2020.pdf ("Meeting the 2050 emission limit requires powering the transportation sector largely with electricity. This transition requires new infrastructure, incentives, and sustained policy over the 15–30 years it takes for the vehicle fleet to turnover.").

[15] U.S. PIRG, *New federal data show transportation sector now the largest source of carbon pollution in the United States, first time in nearly 40 years* (August 4, 2016), http://www.uspirg.org/news/usp/new-federal-data-show-transportation-sector-now-largest-source-carbon-pollution-united.

[16] Marco Miotti et al., *Personal Vehicles Evaluated against Climate Change Mitigation Targets*, Environmental Science & Technology (2016), http://pubs.acs.org/doi/full/10.1021/acs.est.6b00177; *See also* California Air Resources Board, *California's Advanced Clean Cars Midterm Review*, ES-34 (2017).

[17] U.S. Environmental Protection Agency, *2014 National Emissions Inventory Data* (2014), https://www.epa.gov/air-emissions-inventories/2014-national-emissions-inventory-nei-data.

[18] U.S. Environmental Protection Agency, *2014 National Emissions Inventory Data* (2014).

[19] Excluding soil and vegetation biogenic sources as well as wildfires. U.S. Environmental Protection Agency, *2014 National Emissions Inventory Data* (2014); *See also* U.S. Environmental Protection Agency, *Report on Environment: Volatile Organic Compounds Emissions* https://www.epa.gov/roe/ (citing National Emissions Inventory Data from 2011).

[20] Bonnie Holmes-Gen & Will Barrett, American Lung Association in California, *Clean Air Future Health and Climate Benefits of Zero Emission Vehicles,* 8-9 (2016); U.S. Environmental Protection Agency, *See How Mobile Source Pollution Affects Your Health*, https://www.epa.gov/mobile-source-pollution/how-mobile-source-pollution-affects-your-health.

[21] EV Smart Fleets, *Electric Vehicle Procurements for Public Fleets* (2017), http://evsmartfleets.com/materials/electric-vehicle-procurements-for-public-fleets/.

[22] Cal. Code Regs. 1962.1; Chevrolet, *Bolt EV*, http://www.chevrolet.com/bolt-ev-electric-vehicle-2# (estimating battery range to be up to 238 miles); Nissan, *2017 Nissan LEAF*, https://www.nissanusa.com/electric-cars/leaf/ (estimating battery range to be up to 107 miles).

[23] California Air Resources Board, *California's Advanced Clean Cars Midterm Review* (2017), https://www.arb.ca.gov/board/books/2017/032317/17-3-8pres.pdf.

[24] Multi-State ZEV Task Force, *About the ZEV Task Force*, https://www.zevstates.us/about-us/.

[25] Multi-State ZEV Task Force, *Multi-state Actions*, http://www.zevstates.us/multi-state-actions/.

[26] Washington State Department of Transportation, *West Coast Electric Highway*, http://www.westcoastgreenhighway.com/electrichighway.htm; Transportation and Climate Initiative, *The Northeast Electric Vehicle Network*, http://www.transportationandclimate.org/content/northeast-electric-vehicle-network.

[27] *See Clean Energy & Pollution Reduction Act*, Chapter 547, Statutes of 2015 (SB 350) (2015-2016), http://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB350.

[28] *See, e.g., Testimony of Southern California Edison Company in Support of its Application of Southern California Edison Company (U 338-E) for Approval of its 2017 Transportation Electrification Proposals* (January 20, 2017),

http://www3.sce.com/law/cpucproceedings.nsf/vwMainPage?Openview&RestrictToCategory=2017%20TE%20Application&Start=1&Count=25.

[29] B. Jones, G. Van Horn, K. Voellmann, and P. Allen, M.J. Bradley and Associates, *Accelerating the Electric Vehicle Market: Potential Roles of Electric Utilities in the Northeast and Mid-Atlantic States* (2017), http://mjbradley.com/reports/accelerating-electric-vehicle-market-potential-roles-electric-utilities-northeast-and-mid.

[30] Yayoi Sekine, Bloomberg New Energy Finance, *Electrified Transportation: Challenges and Choices For Grid And Transportation Markets And Policies* (Presented at Capture the Energy 2017) (March 8, 2017).

[31] The EV Project is a public/private partnership partially funded by the Department of Energy which involved the deployment of over 12,000 AC Level 2 (208-240V) charging units and over 100 dual-port DC fast chargers in 20 metropolitan areas over two years. Approximately 8,300 PEVs were enrolled in the project. During the data collection phase of the project (January 1, 2011- December 31, 2013), EV Project researchers collected and analyzed data from participant's vehicles and/or charging units, capturing almost 125 million miles of driving and four million charging events

[32] For more discussion of other possible utility actions in support of electric vehicles, *see, e.g.*, M.J. Bradley and Associates, *Accelerating the Electric Vehicle Market: Potential Roles of Electric Utilities in the Northeast and Mid-Atlantic States* (2017), http://mjbradley.com/reports/accelerating-electric-vehicle-market-potential-roles-electric-utilities-northeast-and-mid.

[33] *See, e.g., Reply Brief Of Greenlots On The Priority Review Project Applications Of San Diego Gas And Electric Company, Southern California Edison Company, And Pacific Gas And Electric Company, Greenlots*, in California Public Utilities Commission Docket A.17-10-20 (July 10, 2017), http://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M197/K132/197132656.PDF.

[34] Southern California Edison, *Charge Ready Pilot Program Q1/2017* (May 31, 2017), https://www.sce.com/wps/wcm/connect/1bba1dba-6614-45d4-aba6-9a0570bc6fef/Charge+Ready+Pilot+Program+2017+First+Quarter+Report.pdf?MOD=AJPERES&attachment=false&id=1496858361493.

[35] San Diego Gas and Electric Co., *EV Rates*, https://www.sdge.com/clean-energy/ev-rates.

[36] *See, e.g.*, the San Diego Gas & Electric Power Your Drive pilot, which allows site hosts to select from pre-approved charging equipment vendors and includes policies to avoid anti-competitive impacts. *In re San Diego Gas and Electric Co.*, Cal. P.U.C. Dec. No. 16-01-045, 110 (2016).

[37] Eric Wood, et. al., National Renewable Energy Laboratory, *National Plug-in Electric Vehicle Infrastructure Analysis*, U.S. Department of Energy (2017), https://www.nrel.gov/docs/fy17osti/69031.pdf.

[38] *In the Matter of the Application of Pacific Gas and Electric Company for Approval of its Electric Vehicle Infrastructure and Education Program (U39E)*, Application 15-02-009 at 7 (February 9, 2015), http://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M154/K290/154290929.PDF.

[39] California Public Utilities Commission, *CPUC Approves Plan for PG&E Electric Vehicle Program*, http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M171/K294/171294916.PDF.

[40] *In the Matter of the Application of Pacific Gas and Electric Company for Approval of its Electric Vehicle Infrastructure and Education Program (U39E)*, Decision Directing Pacific Gas and Electric Company To Establish An Electric Vehicle Infrastructure and Education Program (D. 16-12-065) at 72 (December 16, 2015), http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M171/K539/171539218.PDF

[41] Bloomberg New Energy Finance, *Electric vehicles to be 35% of global new car sales by 2040* (February 25, 2016), https://about.bnef.com/blog/electric-vehicles-to-be-35-of-global-new-car-sales-by-2040/.

[42] *See, e.g.*, the California Clean Energy and Pollution Reduction Act of 2015 (SB 350); Encouraging utility leadership in electric vehicle charging infrastructure build-out (HB 1853).

[43] Gil Tal et al., UC Davis Institute of Transportation Studies, *Who is Buying Electric Cars in California? Exploring Household and Vehicle Fleet Characteristics of New Plug-In Vehicle Owners* (2013), https://its.ucdavis.edu/research/publications/?frame=https%3A%2F%2Fitspubs.ucdavis.edu%2Findex.php%2Fresearch%2Fpublications%2Fpublication-detail%2F%3Fpub_id%3D1839; United States Census Bureau, *American Housing Survey*, https://www.census.gov/programs-surveys/ahs/data/interactive/ahstablecreator.html#?s_areas=a00000&s_year=n2015&s_tableName=Table1&s_byGroup1=a3&s_byGroup2=a7&s_filterGroup1=t1&s_filterGroup2=g1.

[44] Christoper DeMorro, *Who are Electric Car Buyers? Survey Says…*, Clean Technica (May 10, 2015), https://cleantechnica.com/2015/05/10/who-are-electric-car-buyers-survey-says/.

[45] United States Census Bureau, *American Housing Survey*, https://www.census.gov/programs-surveys/ahs/data/interactive/ahstablecreator.html#?s_areas=a00000&s_year=n2015&s_tableName=Table1&s_byGroup1=a3&s_byGroup2=a7&s_filterGroup1=t1&s_filterGroup2=g1.

[46] National Multifamily Housing Council, *Quick Facts: Resident Demographics*, http://www.nmhc.org/Content.aspx?id=4708.

[47] *In the Matter of the Application of Pacific Gas and Electric Company for Approval of its Electric Vehicle Infrastructure and Education Program (U39E)*, No. 15-02-009 at 33.

[48] Hacienda Community Development Corporation, *Forth: Electric Vehicle Program*, http://www.haciendacdc.org/forth-electric-vehicle-program/.

[49] The Greenling Institute, *L.A. Offered $1.6 Million for Pioneering Low-Income Electric Carsharing Program* (July 24, 2015), http://greenlining.org/issues/2015/l-a-offered-1-6-million-for-pioneering-low-income-electric-carsharing-program/.

[50] Southern California Edison, *SCE Files Plan for Expanding Electric Transportation* (January 23, 2017) https://newsroom.edison.com/releases/sce-files-plan-for-expanding-electric-transportation

[51] Pacific Gas and Electric, *PG&E Submits $250 Million Proposal Expanding Support for Electric Vehicles in California* (January 20, 2017) https://www.pge.com/en/about/newsroom/newsdetails/index.page?title=20170120_pge_submits_250_million_proposal__expanding_support_for_electric_vehicles_in_california.

[52] M.J. Bradley & Associates has published several cost-benefit analyses of PEV deployment scenarios. *See* M.J. Bradley & Associates, *Mid-Atlantic and Northeast Plug-in Electric Vehicle Cost-Benefit Analysis* (2016), http://www.mjbradley.com/reports/mjba-analyzes-state-wide-costs-and-benefits-plug-vehicles-five-northeast-and-mid-atlantic.

[53] Massachusetts 13-182-A, "Investigation by the Department of Public Utilities upon its own Motion into Electric Vehicles and Electric Vehicle Charging"

[54] RCW 80.28.360 (2015), http://lawfilesext.leg.wa.gov/biennium/2015-16/Pdf/Bills/Session%20Laws/House/1853-S.SL.pdf.

[55] Brian Jones and Dana Lowell, M.J. Bradley and Associates, *Electricity Pricing Strategies to Reduce Grid Impacts from Plug-In Electric Vehicle Charging in New York State* (2015), http://www.mjbradley.com/reports/electricity-pricing-strategies-reduce-grid-impacts-plug-electric-vehicle-charging-new-york.

[56] GTM Research, "The Impact of Electric Vehicles on the Grid: Customer Adoption, Grid Load and Outlook" (October 2016), https://www.greentechmedia.com/research/report/the-impact-of-electric-vehicles-on-the-grid.

[57] *See* Baumhefner et al., National Resources Defense Council, *Driving Out Pollution: How Utilities Can Accelerate the Market for Electric Vehicles* (2016); Chris Nelder, James Newcomb, and Garrett Fitzgerald, Rocky Mountain Institute, *Electric Vehicles as Distributed Energy Resources* (2016).

[58] SDG&E, *Power Your Drive*, https://www.sdge.com/clean-energy/electric-vehicles/poweryourdrive.

[59] *SDG&E*, Dec. No. 16-01-045 at 4.

[60] Edison International, *SCE Receives CPUC Approval for 'Charge Ready' Pilot Program; Will Install As Many As 1,500 Electric Vehicle Charging Stations in Southland* (January 14, 2016), http://newsroom.edison.com/releases/sce-receives-cpuc-approval-for-charge-ready-pilot-program;-will-install-as-many-as-1-500-electric-vehicle-charging-stations-in-southland.

[61] *Application of Southern California Edison Company (U 338-E) for Approval of its Charge Ready and Market Education Programs,* No. A.14-10-__ at 11.

[62] Galen Barbose, Charles Goldman, and Jeff Schlegel, Ernest Orlando Lawrence Berkeley National Laboratory, *The Shifting Landscape of Ratepayer-Funded Energy Efficiency in the U.S.* (2009) (finding that roughly 35 states implement some set of ratepayer-funded electric and/or natural gas energy efficiency programs and providing example of New Jersey which "approved expanded budgets for the state's ratepayer-funded energy efficiency programs").

[63] Maryland Public Service Commission, *Maryland PSC Awards ORECs to Two Offshore Wind Developers*, http://www.psc.state.md.us/wp-content/uploads/PSC-Awards-ORECs-to-US-Wind-Skipjack.pdf.

[64] *See* M.J. Bradley & Associates, *Mid-Atlantic and Northeast Plug-in Electric Vehicle Cost-Benefit Analysis* (2016).