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EVs 101: A REGULATORY PLAN FOR AMERICA'S ELECTRIC TRANSPORTATION FUTURE

What utility commissioners need to know about the accelerating electric vehicle market

A 21st Century Electricity System Issue Brief

By Advanced Energy Economy

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ADVANCED ENERGY ECONOMY

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ABOUT ADVANCED ENERGY ECONOMY

Advanced Energy Economy (AEE) is a national association of businesses and business leaders who are making the global energy system more secure, clean and affordable. Advanced energy encompasses a broad range of products and services that constitute the best available technologies for meeting energy needs today and tomorrow. AEE's mission is to transform public policy to enable rapid growth of advanced energy businesses. AEE and its State Partner organizations are active in 26 states across the country, representing roughly 1,000 companies and organizations in the advanced energy industry. Visit www.aee.net for more information.

ABOUT THIS ISSUE BRIEF

The U.S. energy sector has entered a period of foundational change not seen since the electricity industry restructuring of the late 1990s. Change is being driven by new technologies and commercial opportunities, evolving customer needs and desires, environmental imperatives, and an increased focus on grid resiliency. With these developments come challenges, but also new opportunities to create an energy system that meets the changing expectations of consumers and society for the coming decades. We call this the *21st Century Electricity System:* a high-performing, customer-focused electricity system that is efficient, flexible, resilient, reliable, affordable, safe, secure, and clean. A successful transition to a 21st Century Electricity System requires careful consideration of a range of interrelated issues that will ultimately redefine the regulatory framework and utility business model while creating new opportunities for third-party providers and customers to contribute to the cost-effective management of the electricity grid.

To support this transition, Advanced Energy Economy (AEE) has prepared several issue briefs that are intended to be a resource for regulators, policymakers, and other interested parties as they tackle issues arising in the rapidly evolving electric power regulatory and business landscape.[1] This issue brief on **Electric Vehicles and Charging Infrastructure** describes the emerging electric vehicle market, electric vehicle taxonomy, and the use cases for electric vehicles and the associated charging infrastructure. It then poses questions for regulators to consider when developing electric vehicle policy and makes recommendations on how to maximize the benefits of electric vehicles to consumers, the electric system, and society. Topics include utility planning and operations, rate design, infrastructure ownership and financing, and unique considerations for fleets, including medium- and heavy-duty fleet vehicles.[2]

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EXECUTIVE SUMMARY

The future of America's transportation system is electric.

The market for plug-in electric vehicles (PEVs) is relatively small at the present time. As of 2018, passenger electric vehicles make up a little over 1% of new vehicles sold in the United States. Nevertheless, the PEV market is beginning to rev up – or perhaps more accurately, *charge up* – with compound annual sales growth of more than 50% since 2011.[3] This growth is not just in passenger cars, but in all sorts of vehicles, ranging from e-bikes and carts to delivery trucks, school buses, city transit buses, and semi-trucks.

A confluence of powerful trends is driving consumer interest in, and enhancing the value of, electric vehicles. These trends include:

- advances in technology – especially lithium-ion batteries – leading to falling upfront costs, declining total cost of ownership, increased range, and an improved driving experience;
- megatrends in transportation that are leading to connected, automated, and shared vehicle platforms; and
- societal trends, including renewed urbanization, changing views on car ownership, and growing environmental concerns.

These trends all point to the potential for rapid electrification of the vehicle fleet, ultimately raising some challenges but also significant opportunities, including, of course, for the electric power system. While investments in the electricity grid will be needed, if PEVs are properly integrated, they can help to increase electricity system asset utilization and provide grid support functions that will reduce customer costs and also yield a range of societal benefits. To address this market development, maximize the benefits, and mitigate potential challenges, a regulatory plan is needed as soon as possible. Specifically, utility regulators should:

- **Establish an electric vehicle regulatory framework.** Public utility commissions should use a collaborative process to gather information and then develop viewpoints on the key regulatory issues for PEVs to reduce uncertainty in the marketplace. The process should engage a broad cross section of stakeholders to surface the best information for decision-making and conclude in a white paper outlining the commission's views.
- **Consider roles for various stakeholders in electric vehicle charging infrastructure ownership and financing.** Both utilities and third-party companies have critical roles to play in PEV charging infrastructure. Third parties should be able to develop, own, and operate charging facilities, and regulators should make sure that companies are free to sell electricity to charge PEVs without triggering "sale for resale" issues. Utilities should likewise take an active role – up to and including ownership and operation of PEV charging infrastructure – under appropriate rules and market conditions when there is a failure of the marketplace to provide sufficient services, as is seen in today's PEV

charging infrastructure market. In designing the rules, the goal of regulators should be to eliminate market barriers and facilitate the development of an expanded competitive market while ensuring service provision in areas beyond the reach of the competitive market.

- **Adjust utility planning and operations to fully integrate electric vehicles.** As the PEV market grows, consideration should be given to the potential impacts and benefits of PEVs for utility operations. This includes incorporating PEV-related load forecasts into utility planning, preparing the grid for smart charging through modernization investments, adopting streamlined interconnection processes, and ensuring that industry interoperability standards are used for public charging stations.
- **Implement rate designs for an electric vehicle future.** The greatest benefits from PEV deployment will be achieved by optimizing charging behaviors and giving customers the ability to manage their energy usage and costs. Regulators should consider PEV-only tariffs and well-designed time-varying rates to encourage off-peak charging. In the early stages of market development, regulators should also provide relief from demand charges under PEV-only rates to support the use of chargers.
- **Ensure that vulnerable populations are not left behind.** As the PEV market unfolds, particular attention should be given to low-income and other vulnerable populations. PEVs offer these communities important potential benefits (e.g., air quality improvements for populations disproportionately exposed to poor air quality conditions) but the market, on its own, may be slow to provide them. Regulators should take steps to improve the ability of these communities to access the PEV market and apply longstanding principles of consumer protection to ratemaking decisions with cost implications.
- **Educate consumers.** Given the important role that consumer awareness plays in PEV adoption and utilization of the charging infrastructure that utilities support, regulators should allow utilities to use their unique relationship with customers to improve access to PEV information. There is substantial relevant experience in this type of customer engagement from utility energy efficiency programs.
- **Prioritize consideration of medium- and heavy-duty fleets.** Vehicle fleets have the potential to provide electrification at scale in the near term, with substantial benefits to the grid and society. Some operators are already starting to make large commitments to electrifying their medium- and heavy-duty fleets. These fleet vehicles are subject to many of the issues outlined in this paper pertaining to non-fleet vehicles but also have some unique characteristics. Commissions should explicitly look at fleets in the context of these regulatory issues.

In the end, there is no one-size-fits all solution for optimizing the benefits of transportation electrification. The elements at play are complex and interdependent, and will point to different solutions in different states. Nevertheless, the basic regulatory framework outlined in this brief provides states with a foundation for addressing the PEV market with a focus on maximizing the potential benefits from this transportation transition.

THE EMERGENCE OF ELECTRIC VEHICLES

Since its invention, the automobile has defined the American way of life, and the internal combustion engine (ICE) has allowed for the effective transport of goods, services, and people that has been key to American prosperity. However, despite tremendous improvements, the majority of our transport needs are still met with the same basic engine installed on Henry Ford's production line over 100 years ago. This is beginning to change as a confluence of trends, including advances in technology and cost reductions – especially in batteries – have led to the rise of plug-in electric vehicles (PEVs) as an important and transformational vehicle platform in the United States and globally.

Electric Vehicle Basics

THE ALPHABET SOUP OF ELECTRIC VEHICLES: EVS, PEVS, BEVS, PHEVS, AND REEVS

While most people use the term "electric vehicle" or "EV" to describe a vehicle that runs on electricity, a more precise term is "plug-in electric vehicle", or "PEV". PEVs include vehicles powered completely or in part by batteries (typically lithium-ion) that can be recharged with electricity from the electric grid. PEVs include 100% battery electric vehicles (BEVs) like the Nissan LEAF, Chevy Bolt, Tesla Model S, and Honda Fit EV, and plug-in hybrid electric vehicles (PHEVs) such as the Chevy Volt, Toyota Prius Prime and Honda Clarity Plug-in Hybrid. PHEVs contain both a battery with an electric motor and a gasoline-powered internal combustion engine.

PHEVs are different from hybrid-electric vehicles (HEVs) like the Toyota Prius in that PHEVs have larger batteries, can operate for some distance on electricity only, and can be plugged in to recharge. HEVs, by comparison, do not plug in and do not have batteries large enough to enable electric-only operation, but rather, use the combination of a gasoline engine and electric motor/battery system to increase overall fuel economy. BEVs typically have ranges of 80 to 300 miles, while PHEVs generally have electric-only ranges of about 20 to 40 miles, after which they operate on gasoline in a manner similar to HEVs, giving them an overall driving range equivalent to, or better than, comparable ICE vehicles.

Another type of PEV is a range-extended EV, or REEV. A common example of a REEV, is the BMW i3, that uses an ICE as a generator to recharge the battery when it is depleted. The pure electric battery range of a REEV generally falls between 30 and 90 miles (though some models can go further), before the vehicle switches to the range-extender mode to continue the journey. REEVs can be thought of as a subset of PHEVs but they are different in that the wheels are only driven by the electric motor, and the gasoline engine is only for recharging the battery and does not drive the wheels directly.

This issue brief only covers vehicles that can plug into the grid and can operate for some distance on electricity only. To describe these vehicles, the term PEV is generally used in the brief. However, there are a few instances of the term "EV", which in this brief also refers to all plug-in vehicles, whether they are BEVs, PHEVs, or REEVs.

PEV VEHICLE CLASSES

Like traditional vehicles, PEVs can be broken down into different vehicle classes by weight (Table 1). The U.S. Department of Transportation categorizes vehicles from Class 1 to Class 8 under a system called Gross Vehicle Weight Rating or GVWR.[4] At the lightest end of the spectrum, there are two-wheeled options, such as the GenZe 2.0 Electric Scooter and 200 series eBike, dockless electric bikes and scooters offered by ridesharing companies like Jump[5] and Bird,[6] and four-wheeled, low-speed personal transportation or neighborhood vehicles, including the Club Car Villager and Onward™. All of the lower weight options, including passenger cars, cross-overs, sport utility vehicles, and pick-up trucks, fall into the light-duty vehicle (LDV) classification.[7] As of January 2018, the top selling light-duty PEV car was the Nissan Leaf with over 300,000 units sold worldwide[8] with other top-selling models being the Chevy Bolt, Tesla Model S, and BMW i3.

The next classification of vehicles as size rises is medium-duty vehicles (MDVs)[9], which include city delivery trucks, such as the N-Gen trucks Workhorse has developed for UPS[10], as well as box trucks, beverage trucks, and school buses. That is followed by heavy-duty vehicles (HDVs)[11] that include city transit buses, such as the BYD K11, the Cummins EPB and HPP, and the Proterra Catalyst®, refuse trucks like BYD's 8R, and tractor trailer trucks like the Cummins AEOS and Tesla Semi.

Table 1 - PEV Vehicle Weight Classes

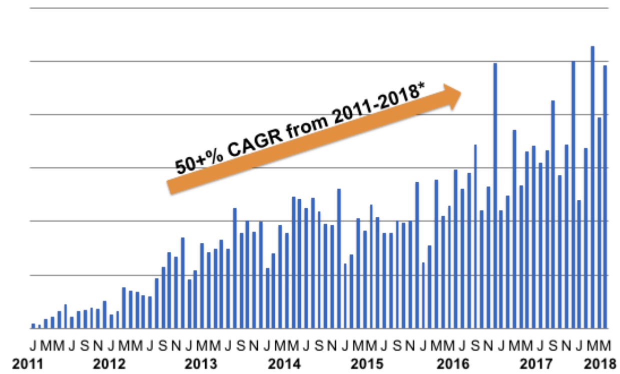
Vehicle Class	Gross Vehicle Weight Rating Category
Class 1: <6,000 lbs.	Light Duty < 10,000 lbs.
Class 2: 6,001 – 10,000 lbs.	
Class 3: 10,001 – 14,000 lbs.	Medium Duty 10,001 – 26,000 lbs.
Class 4: 14,001 – 16,000 lbs.	
Class 5: 16,001 – 19,500 lbs.	
Class 6: 19,501 – 26,000 lbs.	
Class 7: 26,001 – 33,000 lbs.	Heavy Duty > 26,001 lbs.
Class 8: >33,001 lbs.	

Snapshot of the PEV Market

Although sales of PEVs are relatively small as of 2018, the market is growing rapidly. U.S. sales were just under 200,000 units for LDVs in 2017, a 20% increase over 2016, and have grown at a compound annual growth rate (CAGR) above 50% since 2011 (Figure 1).[12] In 2017, PEVs represented over 1% of the total U.S. market for new LDVs for the first time.[13] These sales figures, although small on a percentage basis, represent a significant dollar value – U.S. PEV sales were $7.8 billion in 2016.[14]

Forecasters expect this growth to continue. Analysts estimate that U.S. PEV sales will increase by more than 50% in 2018, potentially exceeding 300,000 units for LDVs.[15] By 2035 global EV sales could reach 125 million units and 20% of car sales in the U.S. could be electric.[16]

Figure 1 - U.S. Plug-in Electric Vehicle Sales (units)[17]



Note: *Indicates that 2018 is based on data through May.

The medium- and heavy-duty PEV markets are also growing rapidly. Sales of plug-in electric buses increased 40% from 2016 to 2017, and analysts project a 19% CAGR over the next 10 years.[18] By 2030, forecasters anticipate that 84% of all municipal bus sales globally will be electric, such that 80% of the global municipal bus fleet will be electric by 2040.[19] Utilization of MDV and HDV PEVs more broadly, especially those used for commercial and public transportation fleets, has the potential to grow rapidly as the needed charging infrastructure is developed and smaller orders of vehicles give way to broader fleet conversions.[20]

Market Drivers

The growth of the PEV market is driven not by a single factor, but rather by a confluence of trends that collectively are accelerating consumer interest and accentuating the overall value provided by these vehicles.

VEHICLE PRICE

As of 2018, the upfront costs of PEVs are generally higher than comparable ICE vehicles, but the situation is changing as PEV prices are falling rapidly. Battery costs constituted approximately half of the cost of a PEV in 2017.[21] As battery manufacturing has scaled up, driven by demand – particularly in China[22] - and by the development of large-scale production through factories such as Tesla's $5 billion Gigafactory 1,[23] battery costs have declined faster than anticipated, such that battery pricing in 2017 was already lower than prices projected in 2012 for the year 2030.[24] All told, lithium-ion battery costs have dropped by 73% from 2010 to 2017, and prices are forecast to fall an additional 43% by 2021.[25] With battery demand, competition, and innovation driven not only by the growing market for PEVs, but also by the increased adoption of grid-level storage and portable electronic devices such as smart phones, tablets, and laptops,[26] the downward trend in pricing is expected to continue over the long-term. Some analysts predict that efficiency improvements will drive the price of a battery that cost $1,000 in 2010 to only $73 by 2030.[27] As a result, batteries are only expected to account for 18% of total PEV costs by 2030.[28,29]

As battery costs fall, the purchase price of a PEV will approach and eventually fall below that of a comparable ICE vehicle, with reports projecting a crossover sometime in the mid-2020s.[30] Already, based on all PEVs available in 2017, an electric car can be purchased for as little as $23,000 to $24,000 without incentives.[31] And low-speed neighborhood vehicles, electric scooters, and electric bikes are available, as of 2017, for as little as $8,500, $3,700, and $1,600 respectively.[32]

TOTAL COST OF OWNERSHIP

The price of a vehicle is not the only cost faced by a vehicles owner. Over the life of a vehicle, owners also pay for maintenance, fuel, and insurance. The total cost of ownership (TCO) for a vehicle incorporates all of these costs along with the vehicle's upfront cost into a single number representing a summation of all the costs associated with vehicle ownership. As such, the TCO is a more comprehensive long-term indicator of cost competitiveness than the purchase price.

Given some inherent operational advantages of PEVs, the TCO for PEVs is already beginning to drop below that of comparable ICE vehicles. The high efficiency of electric drivetrains, which can achieve gasoline-equivalent[33] fuel economy in excess of 100 mpg, significantly reduces fuel needs, providing fuel cost savings. PEVs also have lower maintenance costs resulting from the overall simplicity of an all-electric drive train, which for example, eliminates the need for transmission or exhaust systems. As a result, studies are showing that the TCO of PEVs is already competitive with comparable ICE vehicles in some geographies with high gas prices and/or low electric rates.[34]

TCO savings are especially compelling for the operators of high-utilization vehicles, such as those used for car sharing, commercial fleets (e.g., local delivery fleets), public transit, and heavy-duty uses.[35] These high-utilization vehicle owners drive more miles per year than average drivers, leading to increased fuel and maintenance costs. In fact, data shows that shared fleet drivers, such as those working for Uber and Lyft, can save $5,200 per year on average by owning a PEV rather than an ICE vehicle.[36] Depending on utilization rates, the TCO for shared fleets are already at cost parity in 2018 for some light-duty EVs.[37]

VEHICLE RANGE

Beyond costs, consumers have often looked at vehicle range when making buying decisions. Battery technology improvements, coupled with the aforementioned large declines in battery prices have allowed vehicle manufacturers to increase the range that a PEV can travel before recharging. While range has increased, the overall cost of PEVs has fallen, meaning that the number of longer range PEVs with moderate pricing is on the rise. The Chevrolet Bolt and Tesla Model 3 both offer a range greater than 200 miles on a single charge and a base list price of around $35,000 as of 2018. Nissan, Mercedes-Benz and other companies are all planning to release affordable vehicles with 200+ mile ranges by the end of 2018.[38]

In the heavy-duty category, Tesla announced in the fall of 2017 a new PEV semi-truck with a 300- to 500-mile range.[39] And, an electric city bus, Proterra's Catalyst E2 Max®, recently set the long-distance record for any PEV by driving 1,101 miles on a single charge. This represented an 83% increase from a test by Proterra only one year before.[40]

The trend toward higher vehicle ranges is an important market development. Historically, potential PEV buyers have frequently identified "range anxiety" – a concern about whether a vehicle will be able to travel far enough to reach its destination or the next charging point – as a source of worry. Rising vehicle range therefore offers a direct solution to a key factor in customer decision-making.

MODEL AVAILABILITY

The expansion in moderately priced PEVs providing 200+ mile ranges is indicative of a much wider rise in the number and variety of

PEV models entering the market. As of 2018, almost all automobile manufacturers had at least one PEV model on the market or have announced release dates, and some are starting to announce the development of electric versions of their entire model lineup. By 2020 analysts project that there will be more than 50 models of PEVs available in North America, with up to 70 models on the market by 2022 and up to 100 by 2022.[41,42,43] And the model availability is not just about cars. The market is now seeing the entrance of electric options across all vehicle types, from scooters to delivery vans and pickup trucks and all the way up to tractor trailers.

Rising model availability is important in part because studies have shown that model availability in a region is highly correlated with market growth. That is, states and/or cities with many models available, such as California, have a higher than average PEV market share.[44] Furthermore, as the proliferation of PEV options and overall production continues, it creates economies of scale that are expected to contribute to continued price declines in PEVs.

CONSUMER EXPERIENCE

Consumer surveys consistently indicate that PEV drivers like driving their vehicles. Electric drivetrains provide a smoother and quieter ride with faster acceleration[45] than ICE vehicles. In addition, electric motors have faster response rates than ICEs and therefore can increase, reduce, or even reverse torque more quickly.[46] These performance attributes, combined with declining purchase prices, favorable TCO, and driver interest in the societal benefits of PEVs, create a value proposition that appears to encourage PEV drivers to advocate for the technology. Consumer Reports ranked PEVs available in the market as of 2017, such as the Chevrolet Volt and Tesla Model S, on top of their owner satisfaction charts.[47] As a result, it is not surprising that surveys have found that consumers who drive PEVs are often their biggest advocates.[48]

TRANSPORTATION MEGATRENDS

The personal transportation market is evolving quickly and several associated "megatrends" have a reinforcing relationship with electrification. In particular, the move towards vehicles that are (i) connected, (ii) automated, and (iii) shared, has significant implications for electrified platforms.

The trend towards connected vehicles – i.e., those that connect to the Internet either directly or via connection to another device (e.g., a smartphone) – is well underway, as drivers demand continuous connectivity. Connected cars made up 35% of the car market in 2015, and analysts project that the share will hit 98% by 2020 and 100% by 2025.[49] At the same time, autonomous vehicles are on the horizon. Traditional auto manufacturers (e.g., BMW, GM, and Audi), new entrants (e.g., Tesla, Faraday, and Byton), Tier 1 suppliers[50] (e.g., Delphi, Continental, and Autoliv), technology companies (e.g., Google, Baidu, and NVIDIA), and ride-sharing companies (e.g., Uber and Lyft) all want a place in the autonomous driving age. One of the principal drivers behind vehicle automation is its potential to make roads safer. There were more than 34,000 fatal car crashes on U.S. roads resulting in over 37,000 fatalities in 2016.[51] While important strides have been made over the past decades to increase car safety, driving related fatalities remain a significant societal problem and have even risen recently.[52] New advances in technology, such as lane control and automatic breaking, have the potential to substantially improve public safety.

In the near future, car-sharing and ride-hailing, which are becoming ubiquitous tools of mobility, particularly in urban settings, will begin to combine with autonomous vehicle technology and connectivity to remake personal transportation. Given the natural relationship between connected and autonomous technologies, which both rely on electronic devices, and an electric drive platform,[53] the transportation network companies (TNCs) – and the automakers themselves – are exploring the combination of all three elements. Analysts predict that by 2040, 80% of all automated vehicles in car-sharing services will be PEVs given their reduced operating and maintenance costs.[54]

Already car-sharing operations, such as Maven Gig, Lyft, and Uber, are beginning to feature PEVs as emissions-free options for riders. Maven Gig rents Chevy Bolts to drivers in the "gig economy" (i.e., those offering driving as a service, ranging from pizza delivery to ride sharing services) in cities around the United States and has partnered with fast charging network provider EVgo to provide dedicated and public access to fast charging for those drivers. Uber has partnered with PEV manufacturer BYD to provide electric taxis in London and Chicago. In Chicago, Uber drivers will have the option to rent from the Green Wheels USA dealership for $200 a week, and Uber customers will be able to choose a PEV through their smartphone app when booking a vehicle. Meanwhile, Lyft has announced a goal of using autonomous PEVs to provide at least 1 billion rides per year by 2025,[55] and the company has a partnership with GM to deploy the world's largest test fleet of autonomous PEVs using the Chevy Bolt as a platform.[56]

SOCIETAL TRENDS

The fundamental changes in the way people move from point to point have been accompanied by changes in the way people think about car ownership. The Millennial generation's views on car ownership differ substantially from their parents and grandparents. A significant portion of Millennials have little interest in owning a vehicle, as they have grown up surrounded by ride sharing services and other more cost-effective forms of transportation.[57] For example, many buyers in master planned communities, cities, towns, and institutions are beginning to view low-speed personal transportation or neighborhood vehicles, as a cost-effective alternative. Reinforcing the trend is the fact that the population continues to gravitate towards urban centers,[58] where car ownership is more challenging and ride sharing is ubiquitous.[59] Given the aforementioned benefits of PEVs for car sharing and ride hailing fleets, these changes have important implications for the PEV market going forward.

As population patterns, driving attitudes, and the transportation industry shift simultaneously, interest has grown in encouraging the associated business innovation to occur at home, so that domestic businesses are poised to lead the mobility services industry of the 21st Century.[60] The drive for leadership in the space as a competitive economic advantage is found at the local level as well, where cities like Columbus, Ohio are undertaking "smart city" developments as a core economic growth strategy with transportation electrification serving as a key platform for the development of the overall smart city effort.[61,62]

Beyond economic development considerations, consumer interest in PEVs has grown through realized fuel cost savings. Not only have consumers expressed a strong interest in the aforementioned fuel cost savings, but they have also indicated interest in substantial reductions that PEVs provide in both the criteria emissions that cause local air quality problems and the CO_2 emissions that drive atmospheric greenhouse gas buildup.[63,64,65] Furthermore, given that 92% of the transportation-sector was powered by petroleum-based fuels as of 2017, the reduction in fuel consumption associated with PEVs has also created interest in PEVs as a tool for increasing U.S. energy security and protecting American consumers from the volatility of the global oil market. [66]

Based on the range of interests outlined above, policymakers have pursued a number of mechanisms for supporting PEV vehicles. As of 2018, a number of countries, including China, France, United Kingdom, India, and Norway, have even announced plans or the initiation of planning to phase out ICE vehicles from their vehicle markets, as early as 2025.[67] A summary of the different types of policies that have been pursued domestically can be found in the figure below.

PEV Policies Outside of Utility Regulation

- **Vehicle emission and fuel standards.** Federal and state vehicle emissions standards require automakers to meet fuel economy, GHG, and tailpipe emissions standards.[68]
- **Zero-Emission Vehicle (ZEV) mandates.** As part of its emission standards program, California adopted a ZEV mandate that requires automakers to sell a certain percentage of ZEVs as a portion of their overall sales within a state. California's program has been adopted by nine other states.[69]
- **Tax credits.** The credits reduce consumer taxes, lowering the up-front cost of the vehicle purchase.[70]
- **Rebates.** Rebates provide the consumer a financial incentive closer to the point of sale than a tax credit. Utilities sometimes offer these rebates on behalf of other entities.[71,72]
- **Purchase vouchers.** Voucher programs help cover the difference between the cost of standard and alternative fueled vehicles (typically heavy-duty vehicles) and are usually distributed in a first-come, first-served and non-competitive process.[73]
- **Grants.** Grants are one-time payments typically awarded through a competitive process that pay for the difference between standard vehicles and PEVs.[74]
- **Dealership incentives.** Monetary incentive and recognition programs for dealers are used to encourage dealerships to market and sell PEVs.[75]
- **Consumer benefit programs.** Smaller incentives and non-monetary benefits are sometimes offered to consumers (e.g., high occupancy vehicle (HOV) lane access, emissions inspection waivers, preferred or dedicated parking spots, toll holidays).[76]
- **Recognition and marketing programs.** Promotional programs are designed to recognize consumers from individuals to fleet buyers that adopt PEVs.[77]

PEVs and the Grid

The use of electricity to power vehicles has implications for both the vehicles themselves and the electricity grid.

PEV CHARGING BASICS

PEV charging infrastructure has expanded significantly over the past few years as the number of PEVs on the road has risen. For a sense of scale, as of 2018, there are more than 16,000 public charging stations offering 43,000 public charging outlets across the country.[78]

In broad terms, charging infrastructure includes chargers (called "electric vehicle supply equipment," or EVSE), the interconnection to the grid ("make-ready"), and the communications and information technology systems for managing EVSE and billing customers, when applicable. EVSE generally falls into three categories based on charging levels (TABLE 2). Level 1 EVSE uses standard 120 volt household outlets to "trickle charge" at slow rates (under 2 kW) – equivalent to running a hairdryer – generally requiring continuous charging whenever the vehicle is parked. The benefit of these chargers is the ability to use existing infrastructure – i.e., any standard electrical outlet. Level 1 chargers usually provide about 5 miles of range for every hour of charging, or about 40 miles of range after eight hours of charging.[79] Thus they can meet the needs of PEVs that are driven relatively short distances, whether daily or occasionally. As context, studies show that 78% of commuters drive less than 40 miles a day.[80]

Level 2 EVSE uses 240-volt outlets, providing approximately 7.7 kW at 32 amps, which is typical for a home 240 volt connection. This reduces charging time by as much as 75% compared to Level 1, but requires installation of dedicated equipment.[81] Level 2 chargers, especially those used in public-purpose charging applications, can operate at up to 80 amps and 19.2 kW. Level 2 chargers provide about 10 to 30 miles of range for every hour of charging.[82] Tesla's Level 2 charger, when equipped with optional dual chargers, can supply over 50 miles of range every hour per vehicle.[83] The cost of a Level 2 charger ranges from about $500 to $6,000 depending on the application and complexity of installation.[84] Level 2 chargers are well suited to PEVs with ranges of 80 miles or more and can completely recharge a 200-mile PEV in approximately 10 hours. Level 2 chargers are also conducive to home and workplace charging, as well as some public sites (e.g. shopping centers) for "topping-up" PEVs.

Direct current fast chargers (DCFC), or Level 3 chargers, are able to provide 25 to 75 miles of range in 10 minutes of charging (equivalent to charging at 50 to 150 kWs). They are best suited for public locations in cities, in retail locations and on heavy traffic corridors (e.g., highways) or in private commercial garages. Level 3 chargers are ideal (and indeed, necessary) for day-long or multi-day trips that extend beyond the range of a single charge. These fast chargers are the most expensive option, with DCFCs costing from $25,000 to over $100,000, depending on the make-ready and installation requirements. The ability for a vehicle to utilize fast chargers varies. As of 2018, the highest charging rate that a production LDV can utilize is 120 kW (Tesla Model S), with many PEVs topping out at around 50 kW (Chevy Bolt). Over time, both cars and EVSE will move to higher charging rates.

Table 2 – PEV Charging Basics

Type	Typical Voltage/Power	Typical Charging Time (LDVs)
Level 1	120 volt outlets at up to 1.9 kW	Provides 5 miles of range for every hour of charging
Level 2	240 volt outlets at up to 19.2 kW	Provides 10 to 30 miles of range for every hour of charging
Level 3 or DCFC (Direct Current Fast Chargers)	480 volt outlets at 50 to 150 kW	Provides 25 to 75 miles of range for 10 minutes of charging

As technology advances, other high capacity chargers are expected to be rolled-out in the coming years. For example, IONITY – a joint venture between BMW, Daimler, Ford and Volkswagen – has announced plans to build a network of 350 kW ultra-fast chargers across Europe by 2020.[85] As of 2018, the highest power that standard connectors can accommodate for the heavy-duty sector (e.g., mass-transit vehicles) is around 400 kW. It is likely that higher level chargers (500 to 800 kW and up) will appear soon given that the new long-range heavy-duty PEVs (e.g., buses, semi-trucks) may require higher charging rates to match their high duty cycles, including considerations of fleet schedules and driver shifts. New charging equipment to bridge this technology gap is under development and will likely lead to new charging options in the near future.[86]

Technology companies and manufacturers like Momentum Dynamics and WAVE are also developing wireless charging options for newer PEV models that are nearly 90% efficient (traditional plug-in chargers operate at around 95% efficiency).[87] Stationary and dynamic inductive charging options, which are already available for other consumer products such as smartphones, smart watches, and electric toothbrushes, have the potential to make charging a more seamless experience. Wireless charging kits have been developed by third parties to work with vehicles from manufacturers such as BYD, BMW, Mercedes-Benz, Nissan, GM, Ford and Tesla.[88] While wireless charging is generally not available in production vehicles yet, these technology developments along with pilot demonstrations point to a promising future.

CHARGING USE CASES

As of 2018, more than 80% of charging occurs at home for personal vehicles,[89] and while homeowners can opt to install a Level 2 charger, the lowest cost option is for homeowners to use an existing Level 1 outlet. Drivers who do not want to invest in the faster charger may choose to rely on public charging. Level 2 chargers are preferable for many homeowners – especially for those with 200-mile+ BEVs – to ensure a full charge regardless of vehicle usage patterns as well as to provide the potential for managed charging capability.

Level 2 chargers and DCFCs have critical roles to play in public, workplace, and fleet charging, especially as batteries increase in capacity and provide longer range between charges.[90] Level 2 chargers provide greater ability for utilities to manage load patterns due to their higher power rating and their use in "long-dwell" parking sites, where cars are parked for several hours. On the other hand, DCFCs are typically utilized for shorter periods of time and are generally perceived to be less flexible, since there appears to be less opportunity for managing the timing of charging to change load patterns. It is important to note that DCFC still potentially provides benefits in terms of organic load shifting that stems from the different demand pattern for PEV charging compared to other electricity consumption. For example, in California where there is a daytime valley in demand, the additional energy consumption driven by DCFC during the day as opposed in the evening can help to smooth out the demand curve.

The vast reduction in charging time for a DCFC makes those stations necessary for many applications, including long distance road trips, high volume driving conditions, and retail situations where a consumer wants to significantly charge their vehicle while running errands for 30 minutes. Additionally, as the market moves beyond the early adopter phase in PEVs, DCFC becomes an important option for those unable to charge in the workplace or at home. Thus, some combination of Level 2 and DCFC are best suited for meeting public charging needs.

IMPLICATIONS FOR THE GRID AND CUSTOMERS

PEV charging impacts the electricity grid in a variety of ways. In many areas of the country, overall annual energy use is declining (largely due to energy efficiency and the increase in DERs) while peak demand is increasing. While the majority of the U.S. electric grid is underutilized and has capacity to spare, there is the potential for added charging demand, particularly if it is added during periods of peak usage, to constrain the system. This is because the electricity system must be sized to accommodate the single largest hour of electricity use at the wholesale, regional, local, and customer levels. However, adding charging demand during off-peak hours (such as overnight hours, high-wind hours, or high-solar hours in some states) can help to increase electricity system asset utilization at the regional, and wholesale levels. In fact, studies have shown that rising PEV adoption coupled with smart charging patterns can actually reduce costs for all ratepayers while benefiting the grid and providing a range of societal benefits.[91,92]

When it comes to the local system, differing charging technologies have different impacts on the grid. Level 1 chargers have low impact on the local system because they are using smaller amounts of power over a longer period of time. Level 2 chargers have an increased impact on the system and customer's specific electric service, occasionally requiring customers to upgrade the size of their electric service – particularly in installations that may accommodate several accessible Level 2 chargers. DCFC chargers have the greatest impact on the local system and can require substantial upgrades to the customer's service line and possibly even the local distribution system because they are using a large amount of power instantaneously.

In all cases, it is valuable to smooth the occurrence of coincident charging, such that charging takes place during lower cost, off-peak times. Smart integration of PEV charging, for example by adoption of proper price signals through time-of-use rates, can optimize load profiles and utility system asset utilization, thereby driving down rates for all customers. This form of smart charging helps to avoid capacity shortfalls while adding load when there is significant excess capacity. This not only avoids the need for new resources that would normally be needed to meet increasing demand, but it also spreads out the existing costs over additional energy usage, thus reducing the average cost of each kWh and saving customers money. Co-located batteries, potentially in the form of other fully-charged PEVs, can also help to smooth the instantaneous impacts of charging.

PEVs can provide grid support functions such as peak shaving, load shape smoothing, renewables integration, and power quality services. As PEV market penetration grows, the ability to aggregate and manage PEVs in a coordinated fashion has the potential to amplify these benefits. In the future, with eventual full, bi-directional integration with the grid (so-called vehicle-to-grid, or V2G), some PEVs – taking into consideration the use case and potential customer impact – could become distributed storage devices providing a larger range of benefits. Some pilot projects around the country are beginning to test the use of PEV batteries as storage for grid support under certain circumstances, including work at Fort Carson, Colorado by the U.S. Army and the National Renewable Energy Laboratory.[93]

RECOMMENDATIONS: HOW TO MAXIMIZE THE BENEFITS OF ELECTRIFYING TRANSPORT

The Importance of Addressing Regulatory Policy Now

While PEVs are a small share of the total vehicle market as of 2018, PEV sales are growing quickly, and there are indications that adoption could accelerate beyond recent growth rates and current predictions. Most forecasts, including those of the U.S. Energy Information Administration, are based on individual car owners trading in their old cars for new cars over time.[94] This approach fails to take into account the adoption of PEVs in ridesharing and fleets, whose owners drive significantly more miles per year than the typical individual car owner and thus focus more on TCO, where PEVs often have an advantage.[95] Beyond the limitations of forecasting models, it is important to note that PEVs, unlike many other energy technologies, are essentially large consumer products that may follow the type of exponential technology adoption growth curves that have been seen in other consumer devices (e.g., smartphones).

In light of this rapid deployment potential and the associated significant electricity load growth, it is important for regulators to proactively address this developing market. As noted earlier, high levels of PEV adoption with intelligent charging behavior can provide benefits to all ratepayers – not just PEV owners - and the grid. At the same time, without smart PEV policies that consider higher levels of PEV market penetration in the future, issues around grid integration and load pockets could occur.[96] Proactively addressing the regulatory aspects of PEVs will help accelerate PEV adoption, enhance the benefits they provide, ensure utilities pursue system investments that seek to maximize benefits and limit costs, and mitigate any challenges that could arise as the number of PEVs on the road grows.

Questions for Regulators to Consider

Several key questions can help to shape this dialogue and ensure smooth implementation of PEV regulations:

- How should a public utility commission go about developing PEV regulations from a process perspective?
- What are appropriate roles for stakeholders, including the public utility commissions, other state agencies, utilities, vehicle manufacturers, EVSE developers, third-party service providers, and industry groups?
- What is the state of the market, including private investment levels and competition, in each segment of the PEV charging infrastructure market? How can collaboration between utilities, EVSE companies, and public entities accelerate charging infrastructure investment and reduce the overall cost of PEV ownership?
- How do PEVs fit into short- and long-term utility planning, including integrated resource planning, distribution system planning, and rate cases?
- What technical and payment standards are needed for public charging stations to minimize the risk of stranding EVSE assets, ensure public access, and improve the customer experience?
- How does rate design impact PEV adoption and use? Can rate design improve the utilization of charging infrastructure and ensure beneficial charging patterns?
- How can low- and moderate-income customers access the benefits of PEVs?
- How can market rules and programs allow for reliability, innovation, learning, and adjustment over time?
- Can utilities help improve consumer awareness of PEVs to help ensure PEV charging infrastructure utilization?
- What special considerations are there for fleets and medium- and heavy-duty vehicles?

Process for Establishing a PEV Utility Regulatory Framework

There is no one-size-fits-all PEV regulatory framework that will suit all parties and lead to success in all jurisdictions. PEVs will be adopted along different timeframes in different jurisdictions as each state or utility considers a range of questions unique to them. However, following a basic process in developing and implementing a PEV regulatory framework will help any state engage all stakeholders, surface the best information for decision-making, and reduce uncertainty in the marketplace. Such a regulatory process will improve the likelihood of maximizing the benefits of PEV market development while managing any risks associated with change.

Although the PEV market is still in its infancy, many states have already recognized the need to take action. As of June 2018, 15 states have or have had proceedings to consider regulatory issues regarding PEVs and PEV charging infrastructure deployment.[97] The best practice emerging from this work is for commissions to undertake a two-step process.

1. COLLECT INFORMATION COLLABORATIVELY

The PEV and PEV charging infrastructure markets are complex and evolving rapidly, and they are new to many utility commissions. As a result, at the start of the process, regulators should set out to collect information on PEV technologies, markets, and business models and their interactions with utilities and the electricity system. Since this information is spread across a community of stakeholders – including companies of various sizes, many types of non-profits, academic institutions, utilities, and other entities – and given the cross-cutting nature of these markets, regulators should host an open PEV technical conference/workshop as part of a non-adjudicated proceeding and invite broad stakeholder participation (including from other state agencies) as well as accept written commentary. The stakeholders should be asked to respond to the types of questions outlined above in the section "Questions for a Regulator to Consider." Regulators should also ask participants to bring forward lessons learned and emerging best practices from PEV pilots and programs that are underway around the country.

The open nature of this process, as opposed to a contested case, is key since stakeholders and regulators are free to share and openly discuss all types of information without the restrictions of *ex parte* rules. Importantly, this type of collaborative process greatly reduces the financial and legal barriers to participation relative to contested cases, as many of the organizations with the best information on PEV issues are small and have limited resources.

2. DEFINE THE RULES OF THE ROAD

Based on the information gleaned from the non-adjudicated proceeding on PEV issues, utility regulators should undertake an effort to define the rules of the road in a paper outlining the commission's viewpoint on the key regulatory issues related to PEVs. A case from the Washington Utilities and Transportation Commission (WUTC) offers an example of this two-step regulatory approach.[98] In June 2016, the WUTC opened a staff investigation to gather input from stakeholders in several ways, including written comments, testimony at public hearings, and an opportunity to respond to a draft policy statement. Then, on June 14, 2017, the WUTC issued a policy and interpretive statement to clarify its authority to regulate PEV charging services, adopt policies to support the PEV market through utility provision of PEV charging services, and lay out a framework for regulating utilities.

By clearly identifying the parameters under which utilities could provide PEV charging services to their customers, the WUTC was able to provide clear and concise direction and guidance to market participants that will both stimulate the adoption of PEVs and promote fair competition in the PEV charging services market for years to come. Based on the success of this model process, other states including Michigan,[99] Maryland,[100] Rhode Island,[101] and

New York[102] recently have undertaken or are about to undertake a similar process.

Stakeholder Roles in EVSE Ownership and Financing

THE ROLE OF UTILITY CAPITAL IN PEV CHARGING INFRASTRUCTURE

One particularly important issue that regulators will need to consider is the role that utilities have to play as it relates to EVSE deployment. We see five potential roles for the utility covering the range of possibilities: [103]

1. Utility as **Facilitator**: The utility treats PEV charging like any other potential load, providing nondiscriminatory electric service when and where requested, but not engaging directly in the business of vehicle charging.
2. Utility as **Enabler**: The utility deploys additional infrastructure up to the point of connection to the EVSE to proactively build out capacity in key areas to enable project development – also called the "make-ready" option – but does not take a direct role in installing, owning or operating the EVSE.
3. Utility as **Manager**: In addition to delivering electric service to the location of the vehicle charger, the utility manages the charging operation to better integrate charging with grid capabilities and grid needs.
4. Utility as **Provider:** (includes Manager role): The utility delivers electric service to the charging equipment, which the utility owns and is able to earn a return on, and the utility provides charging services.[104]
5. Utility as **Exclusive Provider:** (includes Manager role): Vendors other than the utility are prohibited from reselling electricity to the public, which could be inclusive of charging service, effectively extending the utility monopoly functions to PEV charging and EVSE deployment.

With the exception of the Exclusive Provider role, all options should be on the table at the present time. At this relatively early stage of PEV market development, all capital resources should be brought to bear, including but not limited to: private capital, utility investment, automaker and other partner direct support, public funds, and other sources of funding (e.g., Volkswagen settlement money via the Environmental Mitigation Trust). This approach will accelerate the deployment of charging infrastructure, in turn spurring PEV adoption, and improving the utilization of the aforementioned grid infrastructure. As such, both utilities and third-party charging infrastructure companies have critical roles to play in the deployment of EVSE. Third parties should be able to develop, own, and operate charging facilities. Utilities should likewise take an active role – up to and including ownership and operation of PEV charging infrastructure – under appropriate rules when there is a failure of the marketplace to provide sufficient services, as is seen in today's PEV charging infrastructure market. In particular, as of 2018, it is difficult for non-utility companies to make a business case for developing, owning and operating public EVSE under many circumstances, such as in low PEV penetration markets, owing mainly to relatively low EVSE utilization rates and challenges in certain aspects of the private market business case. Currently, the market by itself cannot deploy sufficient charging infrastructure for all customer classes, uses, and geographies. This in turn slows PEV adoption and the broad public benefits that it can provide.

The goals of regulators should be to eliminate underlying market barriers to facilitate the development of an expanded competitive market while simultaneously ensuring service provision in areas that are outside the reach of the competitive market. Third-party EVSE ownership and operation harnesses the power of the competitive market in a way that ultimately benefits consumers, while allowing for utility participation under appropriate market rules ensures that sufficient infrastructure will be deployed, particularly in the near term, to support market growth across all customer classes, uses, and geographies.

Regulators should foster an environment that allows for diverse stakeholder input into proposals for EVSE deployment, and regulators should encourage utilities and third parties to propose various solutions that include both private capital and utility capital. This way, multiple types of stakeholders, both public and private, can work with utilities to deploy EVSE, and different business models can be tested and refined.

In some cases, it may make sense for the utility to act as the Enabler and build out the infrastructure up to the EVSE (so-called "make-ready" investments) to facilitate the efforts of third-party EVSE companies. It should be noted that utility ownership of make-ready infrastructure can address some market challenges and can significantly reduce upfront costs for parties wishing to construct EVSE. In other cases, including some public DCFC and multi-unit dwelling deployments, there is wide support for the utility acting as a Provider. In these cases, utility ownership and management can help in ensuring equitable access to PEVs and that the full range of benefits discussed above accrue back to the grid and to all ratepayers.

Even in cases where the utility is only acting as Facilitator, utilities need to carefully plan for any major changes in the grid. Thus, regardless of ownership structure, regulators and EVSE providers should work closely with utilities on deployment to maximize the benefits that PEVs can provide to the grid and to ensure successful integration of the additional loads from PEV charging. This might include, but is not limited to, identifying preferred sites for EVSE to be located, including where there is a specific market need, such as for low-income customers, fleet owners, and rideshare drivers.

RECOVERING INFRASTRUCTURE COSTS

When considering how to support EVSE deployment, regulators have a few options. Given the foregoing discussion on the rationale for utility ownership of EVSE or make-ready investments, if regulators do permit such ownership, they need to further consider how to handle cost recovery of those investments.

1. One option, which is preferable given the foregoing discussion, is to allocate costs associated with EVSE, along with any additional grid investments, to customers within existing rate classes, consistent with the rationale that PEV deployment ultimately provides benefits to all customers, not just those with PEVs. This approach would also be consistent with the policy objective of accelerating PEV adoption and raising charging infrastructure utilization by lowering the cost hurdles associated with early EVSE deployment.
2. Another option is to allocate some of those costs more directly to EVSE users, via the

rates charged for use of the EVSE. Such an allocation could be based on a sufficiently detailed benefit-cost analysis (BCA) that seeks to quantify the benefits to EVSE users, all utility customers, and society as a whole, provided that the BCA process does not slow down deployment.

3. A third option would be to recover most or all of the incremental investments from EVSE users only, although this option would likely negate the primary benefit of utility participation, as it will mean much higher costs for charging.

Whatever option is chosen, regulators should revisit this issue periodically to see if conditions warrant a change in approach – while avoiding retroactive decisions that may negatively impact earlier investments. Note that utility participation that involves including EVSE costs in the rate base could take various forms, including direct ownership or utilities providing incentives to third parties.

THE ROLE OF PRIVATE CAPITAL

The private sector has an important role to play in accelerating adoption of PEVs. Regulators can help private investment accelerate this transition by 1) defining the stakeholder roles (as noted above), 2) allowing private companies to resell electricity as part of providing charging services, and 3) addressing rate design issues (as described below). Most utilities recognize that EVSEs are providing a service beyond the resale of electricity and regulators should explicitly allow resale in order to facilitate development of that business model. Such a determination has already been made by 20 states and the District of Columbia either by statutory amendment or regulatory clarification.[105]

These steps can help reduce investment uncertainty and support rising utilization rates for EVSE. Over time, the rising utilization rates will improve the ability of private investors to earn enough revenue to sustain private business models.[106] With the right conditions, private companies, retail and institutional investors, and EVSE developers will have a variety of financing options to grow the market and bring down the costs of PEVs and EVSE.[107]

PUBLIC-PRIVATE PARTNERSHIPS

The development of close coordination and formal partnerships between state and local governments and market actors is another key tool to promote private sector and utility EVSE investments. In a survey of cities, public-private partnerships were ranked as the most effective form of investment in PEV charging infrastructure, though the feasibility of these partnerships relies on able and willing partnerships within government.[108] For example, New York State's $250 million Evolve NY initiative with the New York Power Authority, is creating private sector partnerships to accelerate the adoption of PEVs.[109] These arrangements are particularly important as charging infrastructure is deployed in cities, where curbside charging can be critical to PEV deployment.

Adjusting Utility Planning and Operations to Fully Integrate PEVs

LOAD FORECASTING AND PLANNING

As PEV markets grow, consideration should be given to the impacts of PEV-driven load growth on the electricity grid. In order to make sure that utilities are properly considering the effect that PEVs will have on their load forecasts and to optimize (locationally and temporally) the charging of PEVs, utilities and regulators should incorporate PEVs into their local and regional planning efforts if they have not done so already.

Load forecasting is a key element that underpins a utility's investment plans. Forecasts should include granular projections of PEV potential and expected customer adoption on different parts of the system, and the resulting effects on load, including the effect on system-wide peak and distribution system peaks, especially when PEVs are clustered. These granular forecasts will also be of increasing importance to regional transmission and wholesale market capacity planning.

To inform load forecasting, regulators should take into consideration broad stakeholder input for setting scenario and forecast assumptions. For example, utilities may not have full, up-to-date information on PEV goals for transit agencies or large commercial and industrial customers in their service territory, which may significantly impact their forecasts. Stakeholder input may also help with development of the macroeconomic and other broad assumptions that help define different scenarios and with understanding how PEV customers' load shapes may differ from those of non-PEV customers. Regulators can also help ensure that assumptions are shared between different planning activities and planning bodies, within the utility and beyond, thus improving results.

PREPARING THE GRID FOR PEVs

At low levels of market penetration, the impact of PEVs on the grid are minimal.[110] But as deployment rises, and in order to integrate PEV loads into the system in a way that maximizes their benefits, reduces any impacts on the grid, and supports their potential future use as a resource, it is necessary to adequately prepare the grid by investing in advanced technology solutions. Investments that can help to manage and integrate these and other distributed assets include but are not limited to: advanced metering infrastructure (AMI), advanced and expanded supervisory control and data acquisition (SCADA) systems and sensors, advanced distribution management systems (ADMS), advanced communications systems, smarter and more automated distributed energy resource (DER) monitoring and dispatch systems (i.e., DER management systems or DERMS), and advanced and expanded asset management and predictive analytics tools. Through these technologies, PEVs can be used either directly or indirectly (i.e., incenting charging behavior) as a flexible load to reduce demand when needed or build load to use excess generating capacity (e.g., times of peak renewable generation). This not only improves the operational flexibility and utilization of the grid, but it also improves the utilization of vehicles themselves.

As PEVs grow in number, utility and grid operators will have tools for managing the incremental demand from vehicle charging. One of the foundational ways this can be accomplished is by encouraging smart charging behavior. Smart chargers, which include capabilities for remote communications and sub-metering of PEV charging consumption, facilitate this behavior. In its simplest form, smart charging involves incenting PEV owners to control when vehicles charge their batteries, either to reduce load during peak times or to add load during times of excess energy generation. For example, in regions with high solar penetrations such as the Southwest, PEV charging can be shifted to the middle of the day to soak up renewables that may otherwise be curtailed. Similarly, in regions with high wind penetration, such as the Midwest, PEVs can charge during the night to take advantage of abundant wind energy.

With smart charging, analyses have shown that PEVs can reduce their electricity use by between 65% and 95% during demand response events without impacting mobility, indicating that PEV load can be highly flexible.[111] In the future, the batteries in PEVs may also be used as dispatchable energy storage to optimize grid operations. As the size of the PEV fleet grows, the ability to aggregate and manage PEVs in a coordinated fashion has the potential to amplify these benefits. For example, as of 2017, eMotorWerks – a charging system operator – estimated that California's PEV market translates to 4 GWh of dispatchable energy storage resources or about 700 MW of peak-shifting load.[112]

INTERCONNECTION PROCESS AND STANDARDS

Installing public charging stations can be a time-consuming process, and "awaiting utility interconnect" is a pending state that delays when drivers can start using chargers. As many states have already done for distributed generation, regulators should develop standardized and streamlined service requests associated with PEV charging stations to help speed the process of connecting new EVSE to the grid, reduce interconnection costs, and avoid undue discrimination and expenses for charging infrastructure projects. Some recommendations include an expedited review process for PEV charging projects, standardized service agreements, and moving from paper to digital applications. For technical interconnection standards, well-developed guidance already exists. For example, the Institute of Electrical and Electronics Engineers (IEEE) series 1547 standards address interconnecting distributed resources with the grid, including allowing PEVs to be used as V2G resource in the future.

INTEROPERABILITY STANDARDS

To get the most out of PEVs as a resource, make the customer experience as seamless as possible, ensure equitable access to charging infrastructure that is funded with public money, and ensure the reliability of the grid, regulators should address interoperability issues. One way in which regulators can help prevent technological obsolescence is by requiring utilities to adopt industry interoperability standards for their investments in publicly-funded, publicly available EVSE equipment. Just as fleet operators see standards as critical for making investments in private EVSE equipment at scale across different utility service territories, states or even across international borders, so too should regulators when it comes to publicly-funded, publicly available EVSE equipment. Since regulators oversee the prudency of utility investments, they have an important role in ensuring that utility investments in PEV charging infrastructure meet industry standards, as is normal practice in other areas of investment. For example, IEEE series 2030 standards address smart grid interoperability, including specifications of a DCFC for use with PEVs, that may be appropriate for publicly-funded EVSE. As with interconnection standards, regulators should encourage adoption of these open standards without specifying the particular standards to use.

There are several elements of interoperability standards when it comes to PEVs and EVSE, but they generally fall into three categories: the physical connection between the EVSE and vehicle, payment systems, and data and communications protocols. Charging networks that have been deployed to date with public funds have too often lacked true payment system interoperability. For example, some require customers using a network to have a membership in a private network in order to pay for charging their vehicle. The resulting balkanized system makes it difficult for drivers to move from a charging station in one network to a station in another network. Requiring that payment systems for publicly-funded EVSE have standardized options, at the minimum having the ability to use credit cards via a card reader or mobile app or telephone option, will ensure that no PEV driver has the experience of pulling up to a station that is publicly-funded only to find themselves unable to charge their vehicle. Basic open standards for data communications ensure that publicly-funded, publicly available charging equipment from different vendors can communicate information in the same manner, which allows a network owner/operator to expand the network at any point using any vendor's equipment. At the same time, it reduces the risk for the investors in public networks in the event that a vendor goes out of business in the future because it allows for other vendors to take over the network and add new charging equipment, knowing that all the units on the system can still communicate.

DATA ACCESS

There is a strong need for utilities to make customer usage data available, to allow for personalization of products and services offered to PEV users. Customer-authorized third-party access to customer data, including information on charging behaviors, will allow for better service and a wider array of products offered to PEV consumers. Utilities should use the Green Button platform to provide customers the option to authorize third parties to access their consumption and billing data, including the data that will emanate from PEV usage. At the same time, utilities need appropriate levels of data access, including data on non-utility-owned charging station availability and type, to inform planning and operations.

Data is critical for both customer engagement and system design and operations to maximize the benefits of PEVs. Nevertheless, data should be shared in a way that ensures that sensitive system information, company trade secrets or individual customer personal identifiable information are protected.[113]

Rate Design for a PEV Future

The greatest benefits from PEV deployment will be achieved if charging is done in such a way as to minimize the need for building additional infrastructure, including generation, transmission, and distribution. It is important that utilities implement well-designed rates for PEV charging before adoption is too high because studies have shown that consumers are creatures of habit. San Diego Gas & Electric conducted a multi-year PEV pricing and technology study that concluded there is a learning curve for PEV customers on new rates and that in order to optimize charging, utilities should develop well-designed tariffs before customers adopt poor charging habits.[114] Moreover, if done right, the additional load from PEV charging can improve the utilization of existing utility assets and drive down rates for all customers. These benefits can be achieved by incenting charging behaviors through different rate designs.

PEV-ONLY TARIFFS

In general, rate designs should align with utility cost causation, incent charging behaviors that optimize the use of the grid, and ensure that customers have the ability to manage their energy usage and energy costs. As discussed above, the impacts of PEVs on the grid are largely dependent on the manner in which they are charged, and potentially in the future, discharged for grid support. One mechanism for moving in this direction is establishing PEV-only rates that can be implemented by installing a second utility meter or by utilizing a billing-quality sub-meter built into the EVSE. While the accuracy of the sub-meters needs to be ensured, the latter approach can be significantly less expensive as demonstrated through San Diego Gas & Electric's (SDG&E) program.[115] Importantly, national standards for such sub-metering already exist, including the NIST PC-44 standard.[116]

As of 2017, over 25 utilities offered EVSE tariffs; most of them incent charging during off-peak hours, with rate reductions of up to 95%.[117] Over time tariffs that rely on on-/off-peak hours should be revisited regularly as the power production profile of the grid changes. For example, in some regions, EVSE tariff design is likely to change with an increase in solar power penetration, allowing for lower rates during midday hours that coincide with peak solar production. In this case, PEV loads become valuable in that they provide demand for renewable energy that might otherwise be curtailed.

It should be noted that the design of PEV-only rates will differ by sector. A rate design that may work for home chargers may not be suitable for public charging or fleet infrastructure. For example, customers who primarily rely on home chargers or workplace chargers have a greater ability to manage their charging because their cars will usually be sitting idle for a longer period of time and are therefore more likely to be responsive to rates that vary throughout the day. On the other hand, customers charging at a public DCFC have a much smaller window during which to charge and therefore less ability to adjust their charging habits in response to price signals.

TIME-VARYING RATES

A key aspect of helping to align charging behavior with system needs is offering appropriately designed, optional time-varying rates (TVR). Well-designed TVR can encourage charging during off-peak hours (even if not a PEV-specific rate), aid with grid reliability, and prevent expensive transmission and distribution upgrades, which will benefit all utility customers. TVR encompasses a range of tariff design options, from simple time-of-use (TOU) rates with predefined peak and off-peak periods, to fully dynamic pricing, where rates vary by the hour (or more frequently) based on the actual market price for electricity. Dynamic rates based on day-ahead price forecasts are another option that can provide customers information in advance, allowing them to plan around times of high pricing.

Research has shown that TVRs are effective at changing charging behavior and can provide significant ratepayer benefits. An Idaho National Laboratory study found that 78% to 85% of owners on a PEV-specific TOU rate set their car to charge during off peak hours (usually in the middle of the night).[118] TOU rates have also been shown to save PEV customers and all ratepayers money. A study of the top five cities for EV sales in the United States (Los Angeles, San Francisco, Atlanta, San Diego, and Portland, Oregon) found that TOU PEV rates saved PEV customers between $116 and $237 per year.[119] Another analysis concluded that PEV TOU rates would save California customers $1.2 billion compared to a traditional flat-rate from 2015 to 2030.[120]

Given their effectiveness in managing PEV charging, regulators should pursue well-designed TOU rates for residential, workplace, and fleet charging and explore more granular TVRs options over time that include dynamic pricing elements. When coupled with smart, networked EVSE, TOU rates allow customers to respond automatically via pre-defined "set it and forget it" preferences. These capabilities may also facilitate an eventual move to bi-directional flow of electricity where PEVs could export electricity to the grid at times when it is most valuable to the electricity system.

In terms of specific design considerations, research shows that larger differentials between on-peak and off-peak rates, increase the likelihood of changing customer charging habits. A recent study by The EV Project and SDG&E found that a 2:1 price ratio between the peak and off-peak shifted 78% of charging to the off-peak period and a 6:1 price ratio shifted 85% to the off-peak period.[121]

Some utilities have also implemented more sophisticated real-time pricing (RTP) rates – prices that vary by the hour as determined by day-ahead market prices or real-time spot market prices for electricity. For example, a study of an hourly PEV charging program offered by Commonwealth Edison in Illinois found that participants reduced their energy supply costs by 45% when compared with a standard rate and 38% when compared with a TOU rate.[122] In a pilot in Washington D.C., low-income customers also achieved bill savings on RTP, with satisfaction levels of approximately 90%.[123] RTP has proven to be effective, compared to other, simpler TVRs, and smart, networked EVSE allows even the average customer to respond to such price signals easily and automatically.

DEMAND CHARGES

Demand charges, which usually apply to large commercial and industrial (C&I) customers (but not residential and small commercial customers), are an important consideration when it comes to PEV rate design. Demand charges are based on the highest level of electricity usage on a per kW basis for a certain time period during each billing cycle. Demand charges are intended to better align revenue collection with utility costs, because the electricity system is designed, built, and maintained to meet peak demands at the customer, local, and wholesale system levels. Demand charges provide a price signal to incentivize customers to adjust their usage decisions to account for their impacts on the grid. However, depending on its design and magnitude, a demand charge can significantly undermine the economics of PEV and charging station ownership.

Although demand charges are common for large C&I customers, which often have the tools for managing them, they present some unique challenges when it comes to PEVs, especially for charging station owners and operators. Demand charges, which can account for over 90% of a public charging station's electricity costs, can significantly increase costs for companies trying to establish PEV charging businesses.[124] The impact is especially pronounced at the current, early stages of PEV adoption when EVSE utilization rates (i.e., the time spent charging as a percentage of total time in a day) are quite low for public applications. As a result, demand charges translate into very high average per kWh rates and can stifle infrastructure investment, which is already lagging PEV deployment in many parts of the country and suppressing PEV adoption.

While there are tools like smart charging and energy storage available to help mitigate some of these costs (discussed more below), at this stage of the market's development in 2018, it is important to reduce the burden of demand charges on public charging retail accounts in the near-term, especially DCFC, and to evaluate appropriate rate design for public chargers in the long-term.

With respect to what types of installations should be eligible for demand charge relief, regulators should distinguish between public charging-dedicated retail accounts (i.e., PEV-only applications) and accounts where public charging demand is combined with the overall demand of the customer premises. Balancing general rate design principles with the needs of the nascent PEV industry, it is reasonable to grant relief for PEV-only retail accounts, while the applicability of such relief to standard retail accounts with behind-the-meter public charging is unclear.

Several utilities have begun experimenting with alternative demand charge approaches. The programs and proposals identified in the box below provide some examples of demand charge relief that are being explored.

Examples of Recent Alternative Demand Charge Approaches

- In April 2017, PacifiCorp in Oregon received approval in their transportation electrification proposal to implement a transitional demand charge approach for DCFC.[125] The tariff offers an initial 100% discount on demand charges that steps down to 0% by the end of the 10-year program to reduce barriers to DCFC deployment.
- Southern California Edison, in their 2017 transportation electrification program, implemented a moratorium on demand charges for their commercial rate program for the first five years, with a subsequent five-year phase-back. The demand charge at the end of the ten-year period will only be 60% of the current demand charge.[126]
- In June 2014, the Public Utilities Regulatory Authority approved a five-year PEV rate rider pilot for Connecticut Light & Power that replaces a demand charge with a higher per kWh charge.[127]
- In July 2013, the Hawaiian Electric Co.'s received approval to implement a five-year PEV charging pilot, Schedule EV-F, where the demand charge is replaced with a higher TOU per kWh charge.[128]
- In April 2018, the New York Power Authority proposed to move DCFCs to rates without demand charges in the short-term and requested a longer-term plan for DCFC rate modifications that align with their low load factors and sporadic usage.[129]

ROLE OF TECHNOLOGY IN PEV RATE DESIGN

Smart EVSE & Sub-metering. One element of tariff design that can facilitate PEV adoption is allowing for the use of two meters - one for the premise at which the EVSE is located and a separate meter for the EVSE – each with its own tariff. This approach enhances the ability of utilities and regulators to address PEVs via the types of PEV-only tariffs described above. Sub-metering to allow for separate treatment and billing can be achieved through the installation of a separate meter as part of the EVSE service upgrade and installation or through the built-in meter in a smart, networked EVSE charger, which is the method that SDG&E's effort is utilizing in its aforementioned pilot. The cost of a separate meter installed in front of the charger ranges between $500 and $1,500 (all in) as of 2018, while meters built into smart, networked EVSE can reduce that cost to less than $50 for volume deployment. In order for the utility to apply separate tariffs through the separate meter, three technological capabilities are necessary:

1. The reading of the EVSE and premise meters must be synchronized,
2. All of the meter data must be delivered to the utility's software system, and
3. The meter readings must be disaggregated for billing purposes.

As discussed previously, the use of smart, networked EVSE, which can support billing with embedded sub-meters, also provides a technological platform to support a variety of advanced rate structures, and managed charging programs and functionality. Deploying managed charging technology-enabled EVSE is therefore a key consideration and program design element to maximize the benefits of transportation electrification.

Metering requirements should not be used as a reason to slow down the adoption of PEV-only rates and therefore should be optional. Other programs can also be developed that allow customers to earn rewards for optimal charging behavior (e.g., charging during off-peak hours) in the absence of a separate meter for billing purposes. For example, Con Edison's Smart Charge New York program offers participants a module that plugs into the PEV's diagnostic port that provides valuable information to the driver via an online portal, including battery health and driving efficiency.[130] The module also tracks charging behavior – and this data can be sent to the utility for verification and rewards.

Distributed Energy Resources (DERs). DERs, especially energy storage, are also an option (instead of, or in addition to, altering rate design), either behind the meter to mitigate demand charges, or in front of the meter to help integrate charging station load. Onsite energy storage at public charging stations, particularly DCFC, would allow EVSE operators to ensure a consistent charging price for customers and help to reduce peak loads as seen by the utility. Onsite distributed generation coupled with storage would have the added benefit of ensuring power availability even during grid-wide power outages.[131]

As noted previously, managed charging with smart, networked EVSE can also act as a DER, and aggregated managed charging can be a resource for grid operators. In the California market, such aggregated EVSE is already providing peak load reduction services.[132]

Low Income and Vulnerable Populations

As the PEV market unfolds, particular attention should be given to low-income and vulnerable populations. Commissions should look to ensure that these communities can access the benefits that PEVs can provide and to mitigate any impacts for these households of rate design changes and the use of the rate base to finance EVSE buildout.

PEVs offer these communities some particular potential benefits – for example, low-income and disadvantaged communities on average have disproportionally worse air quality than other communities, so the transition to PEVs could provide an outsized impact.[133] However, these populations also face specific challenges utilizing PEVs. For example, low-income communities have a higher proportion of residents in apartments and other multi-unit dwellings, where the provision of PEV charging is a bigger challenge and will rely more heavily on public charging for PEVs. Even for residents of single-family homes, older homes and buildings in low-income communities may have inadequate electrical service capacity to support vehicle charging loads, requiring infrastructure investments to enable charging. Given the challenges, regulators should consider PEV programs that focus on alleviating specific problems (e.g., public charging initiatives, multi-unit dwelling projects) and achieving equity in access.

When it comes to protecting these communities from rate and any other cost impacts, commissions can build a foundation by focusing on rate designs that support smart charging behavior to smooth demand and improve asset utilization. Smart planning and energy efficiency programs can further reduce new capacity needs and efficiency programs can ensure that existing loads are cost-effectively minimized in conjunction with the addition of PEV loads to homes and businesses. Finally, commissions can apply approaches used for other programs to protect these communities, including low and moderate income (LMI) discounts and special programs for energy efficiency.

Consumer Education

Market data indicates that one of the biggest barriers to PEV adoption is lack of consumer awareness related to PEVs. Despite the fact that 91% of survey respondents believe it is important to buy a car that is inexpensive to operate (i.e., the car has low fuel costs), and over 60% think it is important to buy a car that has zero emissions or is eco-friendly,[134] a recent report found that 60% of survey respondents were unaware of the existence of PEVs.[135] In other words, when these individuals consider vehicle purchases, they do not even consider PEVs despite desiring the attributes provided by PEVs. Even in California, which has the largest PEV market in the country, the vast majority of car buyers are still unable to name a single PEV model.[136] There are a number of reasons for the lack of consumer awareness, including the relatively brief time that these vehicles have been available in the mass market, a shortage of automobile manufacturer marketing, unavailability of PEV models in specific markets, and a lack of market transparency in terms of the relative operational efficiency and emissions of vehicles across fuel and engine types.

Given the challenges, regulators should recognize that much of the evolution of transportation will depend on the choices of consumers and that consumers respond to better information when it is presented simply and clearly. Some market data suggests that when consumers are armed with a simple and credible way to choose vehicle models that are zero-emission, inexpensive to operate, and do not cost more to purchase, 84% would be likely (45% extremely likely) to opt for an electric over a conventional car model.[137]

Utilities are uniquely placed to provide information on the complex web of considerations that come into play with respect to PEVs. Consumers need not only to understand the PEV options available in the auto market, but also need information about:

- Charging options available for buyers and information on electrical installation options in residential situations,
- Public charging station locations,
- PEV-specific rate options and demand response programs,
- Financial incentives, and
- The benefits of PEVs.

In the interest of reaching higher levels of EVSE utilization quickly, regulators should look for ways to improve access to information and make it as easy as possible for individuals to research and purchase PEVs. One specific step for regulators to consider is leveraging the relationships that utilities have with their customers by encouraging utilities to improve market transparency and develop data-driven customer engagement programs that leverage behavioral insights, as has been done with utility energy efficiency programs.

Given the important implications of PEV rate designs for PEV adoption, utility customer education programs should include a significant emphasis on helping customers understand the different pricing schemes and the PEV charging products and services available to help customers respond. Under short dwell-time scenarios, such as shopping center parking lot charging, customers need to understand the benefits of adjusting behavior in response to dynamic rates. In long dwell-time scenarios however, such as in overnight garages, customers generally do not need to change their behavior at all. They just need a smart, networked charger programmed to their particular needs and preferences.

MEDIUM-AND HEAVY-DUTY VEHICLE FLEETS

While many of the recommendations put forth throughout this paper apply to medium- and heavy-duty fleet vehicle charging, there are a few special considerations that regulators should take into consideration. Many commercial and fleet vehicle operators are seeking opportunities to deploy PEVs for commercial purposes or to serve public transit fleets. These vehicles commonly travel significant distances – the average heavy-duty truck travels more than six times the annual average mileage traveled by a light-duty vehicle – and are in use daily. Electrifying such fleet vehicles can therefore provide immediate and substantial financial, environmental, and public health benefits.[138] Medium-and heavy-duty ICE vehicles are a large source of smog-forming emissions and fine particulates, particularly in urban areas, so electric buses, local delivery vehicles, and intermodal freight trucks have significant potential to improve air quality.[139]

Medium- and heavy-duty PEVs can also provide significant operational benefits. These benefits include:

- Fuel savings
- Improved traction and vehicle stability (as electric motors have faster response rates than diesel engines and can increase, reduce, or even reverse torque quicker),
- Regenerative braking, which can improve safety, especially when going downhill
- Improved safety designs that leverage the removal of the engine and reconfigure the vehicle to protect the driver
- Reduced chance of human error by eliminating the need for shifting
- Reduced maintenance costs because PEVs have fewer moving parts than diesel vehicles

Many cities are recognizing the benefits and taking action. For example, the largest municipal bus fleet in the United States, New York City's, recently announced a plan to transition its entire public bus system – 5,700 buses – to PEVs by 2040.[140] Converting the fleet to PEVs is equivalent to taking over 100,000 LDVs off the road, in terms of greenhouse gas emissions. A study by Columbia University found that each electric bus could reduce health costs by about $150,000, and that shifting the entire fleet to PEVs would cut CO_2 emissions by 575,000 metric tons per year and save the city $39,000 per bus per year on fuel and maintenance costs.[141] The city of Los Angeles (LA Metro) also has a goal of moving its entire bus fleet, about 2,300 buses, to PEVs by 2030, and the Los Angeles Department of Transportation (LADOT) approved a motion to electrify its roughly 350 buses by 2030.[142,143]

Utilities also have a lot to gain from transitioning their own fleets to PEVs. Not only do PEVs provide significant operating and maintenance savings, but utilities can utilize them as distributed storage devices – providing exportable power capabilities for emergency response crews that can provide new solutions and potentially reduce planned outages.[144] It is important to note that more work is needed to determine how first-responder PEV fleets would operate in the case of extended emergencies, such as blackout, large storm-related outages, or a terrorist attack.

Many commercial delivery companies have announced plans to electrify their fleets as well. For example, UPS recently announced plans to convert 1,500 of its class 5 delivery trucks in New York City to PEVs. UPS said these new vehicles cost about the same as their traditional delivery trucks and offer over 100 miles between charges – allowing them to deliver all day in congested urban centers and then charge overnight.[145,146]

The TCO for fleets and commercially owned vehicles varies across vehicle classes and by vehicles uses. Reports forecast that long-haul applications (over 500 km per day) are projected to reach break-even with ICE vehicles by 2025 for light-duty commercial applications, by 2028 for medium-duty vehicles, and by 2029 for heavy-duty trucks.[147] Regional haul applications (200 km per day) are already at cost parity for light-duty commercial applications and are projected to reach their break-even points by 2021 for medium-duty vehicles and by 2030 for heavy-duty trucks.[148] Finally, urban haul applications (100 km per day) are already at cost parity for city buses, and are projected to reach cost parity by 2021 for medium-duty vehicles, and by 2022 for light-duty commercial applications.[149]

RATE DESIGN FOR FLEETS

As discussed above, rate design not only affects customers' buying decision but also the business model for charging station operators. The effect of rate design on the cost effectiveness of PEVs for commercial fleets and medium-and heavy-duty vehicles can be significant. Specifically, many commercial operators currently have limited ability to manage their charging or spread them throughout the day to reduce the effect of demand charges, although technologies like building energy management systems and distributed energy management systems will evolve to incorporate this capability.

Take demand charges applied to electric transit buses for example. Electric buses and many other commercial fleet operators have two main options for charging – on-route and overnight. On-route charging allows buses or other commercial fleets to recharge in a short amount of time, a use case that requires high power demand in order to charge as quickly as possible – therefore increasing the likelihood of triggering a demand charge. Overnight charging will usually take place at a bus depot where an entire fleet will charge at a lower rate over a longer duration. In theory this should reduce any demand charge; however, having many buses charging at the same time will lead to a very high-power demand in one location, which can trigger demand charges at the bus depot – even though they are charging during off-peak times, depending on the particular rate design. Studies have shown that demand charges have a large impact on both on-route and overnight charging for bus fleets, more than doubling fuel costs – potentially eliminating the fuel cost savings of PEV buses over diesel-powered and compressed natural gas buses.[150] While the guidance provided in the Demand Charges section above applies to fleets, the unique nature and value of fleet electrification justifies a fleet-specific evaluation. The industry is beginning to discuss some potential approaches, such as utilities offering time windows, when there is excess capacity on the grid, to fleet customers where their loads would be excluded from demand charge calculations.

Given the relatively inelastic charging behaviors of many commercial fleets, having more than one rate option will benefit fleet operators, allowing them to choose the best rate for their needs. For example, fleets that utilize on-route charging either at a depot or through a travel corridor might benefit from adopting a flat rate for energy use while fleets that utilize overnight charging would benefit from a TOU or RTP rate to take advantage of off-peak pricing. At the same time, rates should also take into consideration the potential of commercial properties or warehouses having onsite solar and energy storage, which may impact the type of rate that is most beneficial. It is important to note that many fleet operators have the sophistication and financial incentive to manage complicated rates that allow them to reduce costs.

CONCLUSION

America's transportation future is electric. Although sales of PEVs are still relatively small when compared to ICE vehicles, the market is growing rapidly, driven by a convergence of powerful trends including advances in technology, the move towards connected, automated, and shared vehicle platforms, and societal trends of continued urbanization, changing views on car ownership, and rising environmental concerns. Jointly, these trends all point to the coming electrification of the vehicle fleet, which raises a number of opportunities and challenges, including, including, of course, those for the electricity grid.

To address this potentially disruptive market development, regulators should be proactive in developing a plan for PEVs, to enhance the benefits that PEV adoption can provide the grid and its customers and address any challenges that might arise. Each state is different, so there is no silver bullet for optimizing transportation electrification, but the aforementioned framework provides states with a foundation for maximizing the benefits of PEVs and making our energy and transportation systems more secure, clean, and affordable. Whether this future can ultimately be realized will depend on regulators, utilities, automobile manufacturers, third-party charging infrastructure providers and customers working together to create a clear vision and fostering a healthy, competitive, and dynamic environment for America's electric transportation future.

ENDNOTES

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[103] These are adapted from the paper, Electric Vehicles as Distributed Energy Resources, https://www.rmi.org/insights/reports/electric-vehicles-distributed-energy-resources/

[104] Utilities can also facilitate EVSE on customer premises via alternative payment methods such as on-bill financing, http://my.cleanenergyroadmap.com/ViewRoadmapGoal/207

[105] Arkansas Code § 23-1-101(9); Cal. Pub. Util. Code, § 216(l); Colo. Rev. Stat. § 40-1-103.3(2); CT Section 16-1 of the 2016 supplement to gen. statutes; D.C. Code §§ 34-207, 34-214; Fla. Stat. § 366.94; Haw. Rev. Stat. § 261-1(2); Idaho Code § 61-119; 220 Ill. Comp. Stat. §§ 5/3-105(C), 5/16-102; Me. Rev. Stat. Ann. Tit. 35, §§ 313-A, 3201(5), 3201(8-B); Md. Code Pub. Utils. §§ 1-101(J)(3), 1-101(X)(2); Minn. Stat.§ 216B.02 (Subd. 4); Missouri PSC File No. ET-2016-0246; NYPSC Case No. 13-E-0199; Or. Rev. Stat. § 757.005(1)(B)(G); PA PUC Order R-2014-2430058; Utah Code §§ 54-2-1(7)(C), 54-2-1(19)(J); Va. Code Ann. § 56-1.2:1; Wash. Rev. Code § 80.28.310; W. Va. Code § 24-2D-3.

[106] https://www.c2es.org/site/assets/uploads/2015/11/strategic-planning-implement-publicly-available-ev-charging-stations-guide-businesses.pdf

[107] http://www.ironoakenergy.capital/uploads/3/2/5/1/3251407/ev_leveraged_financing_-_by_ironoak_energy_for_vulcan_philanthropy.pdf

[108] https://www.bv.com/insights/expert-perspectives/data-and-planning-drive-growth-smart-cities-and-utilities

[109] https://www.nypa.gov/innovation/programs/evolveny

[110] Studies, such as the California Load Research Report, have shown that the impact to date has been minimal. From July 2011 to July 2017, the three large IOUs in California only spent $4.7 million on residential PEV related service or distribution system upgrades.
http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=6442455828

[111] http://papers.sae.org/2015-01-0304/

[112] https://www.rmi.org/wp-content/uploads/2017/04/RMI_Electric_Vehicles_as_DERs_Final_V2.pdf

[113] For more details on a recommended data access framework see our Issue Brief on Access to Data, available at http://info.aee.net/21ces-issue-briefs

[114] https://www.sdge.com/sites/default/files/SDGE%20EV%20%20Pricing%20%26%20Tech%20Study.pdf

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[116] https://www.nist.gov/pml/weights-and-measures/nist-handbook-44-2018-current-edition

[117] https://about.bnef.com/blog/u-s-utilities-offer-multiple-electric-car-charging-rates/

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[122] http://www.elevateenergy.org/wp/wp-content/uploads/Hourly-Pricing-and-EVs-050714.pdf

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[125] Docket UM 1810. http://apps.puc.state.or.us/edockets/docket.asp?DocketID=20572

[126] Application 17-01-021. http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M215/K380/215380424.PDF

[127] Docket 13-12-11. http://www.dpuc.state.ct.us/dockhistpost2000.nsf/8e6fc37a54110 e3e852576190052b64d/0fdcd8bddffdbfdc8525829c0073540c/$FILE/FINAL131211.docx

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