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ARTICLE



Raceways, rebates, and retrofits: an exploration of several American cities' policies to facilitate electric vehicle purchase and usage

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ABSTRACT

Plug-in Electric Vehicles (PEVs) form a critical part of the infrastructure needed for sustainable transportation. Local governments are expected to play a key role in ensuring widespread adoption of PEVs by their residents. This study specifically investigates how large American cities have used the policy process to prepare for broader PEV usage. Based on a questionnaire sent to policy leaders in major American cities, this study investigates issues of building codes, city-utility relations, tax incentives for PEV users, and social equity. The study identifies and analyzes common and influential policies perceived as being most effective at advancing PEV adoption. Findings suggest that cities are either not preparing for PEVs at all, or are preparing in a very substantive and tech-savvy manner. Policymakers also highlight key areas of needed focus, and lay out ways in which regulators and electricity providers can aid in PEV adoption.

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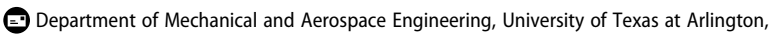
Introduction

Vehicular technologies in the United States are in the midst of a torrent of new ideas and new systems, particularly in the realm of alternative fuels and electrification. Alternative Fuel Vehicles (AFVs), which are generally powered by ethanol, hydrogen, or compressed natural gas, as well as Plug-in Electric Vehicles (PEVs) that must be plugged in to the electrical grid in order to recharge, have boomed in popularity among American consumers over the past two decades. This growth in demand has been fuelled by a host of personal and practical factors, ranging from a personal desire to reduce emissions, to federal and state tax incentives for purchasing such vehicles. [Figure 1](#) shows the dramatic increase in PEV sales in the US since 2011 (Edison Electric Institute, 2019). This rapid growth in PEVs on American roads is expected to continue in the future (Electric Vehicle Outlook, 2019).

The technology behind PEVs is based on energy conversion and storage in Li-ion batteries (Shah et al.

2017). When connected to a source of electricity during the charging process, the cells in a Li-ion battery are able to convert and store electrical energy in the form of chemical energy through a reversible electrochemical reaction (Beard 2019). Subsequently, the reverse reaction occurs when the vehicle moves, so the stored chemical energy is converted into electrical energy and used to run the electric motor, which propels the vehicle forward. The Li-ion battery pack of a PEV typically comprises thousands of cells, each capable of storing a small amount of energy.

While the departure from reliance on gasoline as a fuel represents a fascinating shift in energy consumption and vehicular pollution, PEVs do offer new technological and societal challenges. For example, the manufacturing of Li-ion batteries is an intensive process and has required manufacturers to develop brand new infrastructure, such as the Tesla Gigafactory. Similar infrastructure related to charging of PEVs on the road – akin to gas stations – is also

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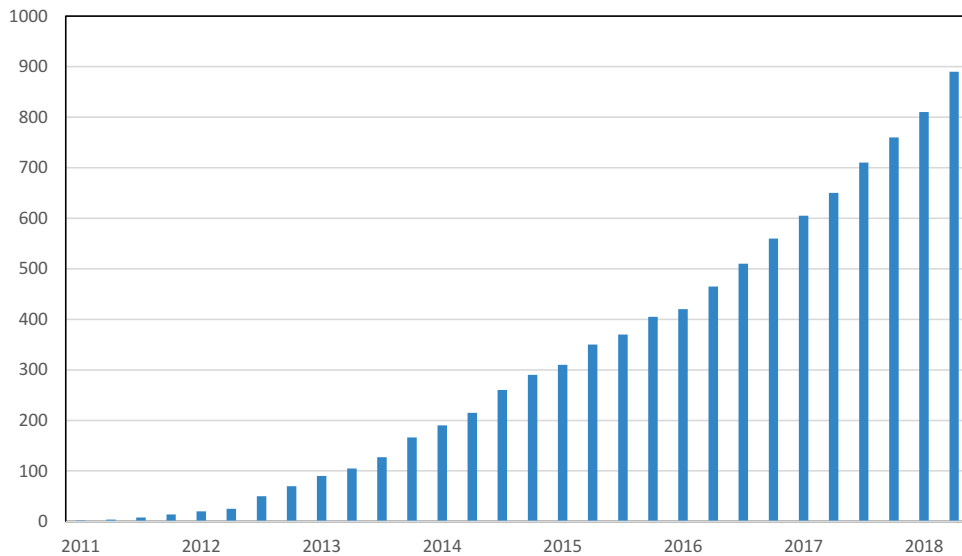


Figure 1. Cumulative PEV sales in the United States (in thousands of units sold).

under development. From a consumer's perspective, PEVs present challenges related to the need for retrofitting of homes and/or offices for charging infrastructure. The ability to rapidly charge a PEV – within a time that is competitive to the few minutes it takes to fill up a traditional vehicle at a gas station – is also an important consumer-related concern.

The physical infrastructure that accommodates the personal automobile in American cities has arguably not kept pace with the growing demand for these vehicles, particularly PEVs. The in-situ electrical equipment required to recharge PEVs has yet to be installed in many American parking lots, leaving PEV owners to charge their vehicles at home – provided they reside in a structure with the necessary electrical infrastructure installed. These critical issues have a significant and direct impact on the adoption and usage of PEVs by consumers on American roadways, and it remains unclear the degree to which local governments can (and do) address these issues through the regulatory process. As the authors will assert here, local governments have the explicit power to set and monitor land-use regulations, vehicle parking lot standards, and the rules governing the placement of critical infrastructure including electrical systems. Thus, the case can be made that a local government can influence, through action or inaction, the wider adoption and usage of PEVs by its residents and taxpayers. The

critical role that local governments will play in ensuring successful adoption of PEVs, with all its associated environmental and sustainability benefits, must be investigated.

The growth of PEVs as a segment of the American vehicle market has already compelled urban planners and policymakers to reconsider the existing ecosystem of fuelling stations, parking lots, and municipal electrical infrastructure. For example, a gasoline-powered vehicle is fuelled at a separate location from where it is usually parked, whereas a PEV can be refueled/recharged while parked. Two core needs of the vehicle (fuel and a place to park when not in use) are thus combined for PEVs. However, knowledge gaps remain among both practitioners and scholars. Studies have explored PEV adoption factors among American consumers (Soltani-Sobh et al. 2017; Kim et al, 2014) and the optimal models for constructing PEV charging infrastructure (Dong et al. 2014; Davidov and Pantos 2017). However, little attention has been paid in the literature to the specific actions local governments can take to promote PEV adoption and charging within their boundaries (ZEV Task Force 2018). In addition, studies that examine the government-EV relationship through a regulatory or policy lens are also lacking in the literature of both transportation planning and public policy. An exploration of this relationship – how it functions, how the parties

inform one another, and its various outcomes for the broader public – is thus badly needed for this growing body of literature. This study undertakes such an exploration, using a chiefly qualitative approach to understand not merely what American cities are doing to prepare their physical infrastructure for PEV usage, but also what factors are driving their decision to build (or not build) such infrastructure.

This study explores and compares the various methods by which several large American cities have sought to prepare their communities and physical infrastructure to service a growing number of PEVs. Previous studies, such as the one completed by Gomez San Roman et al. (2011), have attempted to illustrate the complex network of regulators, consumers, and physical infrastructure involved in city-dwellers using PEVs, but most are technical in tone and centred on innovations to make PEVs easier to charge and cheaper to own. The policy perspectives, and the regulatory frameworks necessary to influence long-range building code changes that might more easily accommodate PEV charging systems, remain missing. The literature also has little information on the public sector's internal attitudes towards PEV adoption, and the degree to which planners' views on the environment and technology might influence their job performance as regulators of both transportation and infrastructure assets in the community. This study sheds light on all of these aforementioned gaps by exploring attitudes as well as regulatory frameworks related to PEVs. The findings are expected to be useful to planners, energy providers, developers, and PEV manufacturers, all of whom may seek to better understand and formalise the local government's role in ensuring our cities are prepared for the full extent of PEV adoption predicted to occur in the coming decades.

Literature review

The literature surrounding PEV charging technology and adoption by consumers can readily be divided into a few distinct streams, three of which are relevant for the present work. The first stream is the robust and technically centred literature on the technology of PEV charging. Studies on the subject have evolved from general overviews a decade ago (Morrow et al. 2008; Botsford and Szczepanek 2009) to detailed evaluations of specific technologies and delivery

platforms (Budhia et al. 2011; Zheng et al. 2014). The focus of much of this research has been in improving the performance of charging technology, ostensibly for the benefit of manufacturers and the convenience of consumers (who might then become more likely to purchase an EV). This stream of literature, while at times dense with patents and equations, is essential for our shared understanding of what PEV charging systems require and what the manufacturers are capable of implementing as the machinery continues to mature.

The second relevant stream of literature focuses on the planning and siting of PEV charging stations. While this subset of studies moves somewhat away from technical analyses and more into questions of land use and community access, it lacks the policy focus necessary to truly understand all dimensions of this issue. Studies in this area have thus far focused on the optimal placement of PEV charging stations based on electrical grid capacity (Liu et al. 2012; Zheng et al. 2013) or "environmental and economic sensitivity," (Guo and Zhao 2015). However, investigations into the government's role in planning for PEV charging stations remain scarce. The authors feel it is vital for the growth of the PEV literature to better link these efficiency-focused studies to a better understanding of the decision-making processes in Western infrastructure planning, to better encapsulate how factors such as energy efficiency and carrying capacity mesh with issues of local politics and long-range regional planning.

The third stream of PEV literature, which helps to close the loop with the other two, centres on examining and evaluating the various government incentives and regulations offered by the public sector to boost PEV usage by consumers. Of the three streams, this one is the least technical and the most socially-focused, dominated by questions of economics, environmental justice, and public policy. It is also the stream with the least amount of published academic study behind it. The critical role of public policy on PEV adoption has been recognised in the context of US (Greene et al. 2014) and Europe (Tseng et al. 2012). Narassimhan and Johnson (2018) found a strong relationship between tax incentives, suitable charging infrastructure, and PEV adoption. Most literature in this direction, however, focuses on the role of the federal government in facilitating PEV adoption through tax rebates and other federal interventions. A summary of several studies in this direction has

been presented (Zhou et al. 2016). Specifically, federal tax credits have been shown to play a key role in encouraging PEV adoption, alongside High Occupancy Vehicle (HOV) lane access in many places (Clinton 2014; Jin et al. 2014). The role of other, non-federal financial incentives such as longer loan terms and securitisation has been discussed (Dougherty and Nigro 2014). A study of California's state-level PEV purchasing incentives, combined with the state's robust public PEV charging infrastructure (Greene et al. 2020), placed a dollar value on PEV drivers' willingness to pay for vehicle charging access in that state. Still, deeper study of local policies is needed.

The authors contend that there is indeed a vital role for local governments in encouraging (or at least allowing for) the charging infrastructure necessary in urban areas to facilitate PEV adoption by residents and public agencies. Urban planners and regulators are in a unique position to address the physical and regulatory barriers that make it difficult in many places to charge an EV, and they are also arguably in a position to set and enact policies that advance goals of environmental sustainability, cleaner air, and broader consumer choice. By exploring the policies and practices of PEV readiness set forth by many of America's largest cities, this work aims to contribute to a beachhead of scholarly knowledge regarding how local governments are preparing cities and the built environment for a growing number of PEVs adopted by consumers and businesses.

Methodology

This project addressed a sequence of three research questions: First, how have large American cities encouraged the adoption of PEVs through regulatory or economic means? Second, how have those efforts been enacted and received over time? And third, what best practices and broader policy lessons can be drawn from these cities' experiences in regulating and promoting the usage of PEVs?

The authors sought to investigate policies and their impacts in the nation's largest cities by population based on their assertion that larger cities would be reasonably more likely to have both the political incentive and financial means to promote PEV usage through formal policy. In order to capture a nationally relevant sampling of PEV policies and regulations, the authors developed a questionnaire on PEV issues and sent it to the 125 largest American cities by

population (according to 2017 Census Bureau data). The questionnaire was aimed specifically at city planners, transportation officials, sustainability officers, municipal utility directors, and anyone at the local level with firsthand knowledge of their city's experiences, needs, and capabilities with regard to electric vehicle adoption, charging, and usage. Contact information for city leaders was obtained from city websites. In some cases, when direct contact information was not available, the departments of Communications or Public Information or equivalent were contacted, which, in some cases were able to route our request to the appropriate city leaders. Multiple reminders were sent out in order to boost the response rate. Topics covered in the questionnaire included the specifics of a city's policies regarding PEVs, local efforts to build and manage charging infrastructure, financial incentives offered to PEV consumers, and the political lessons learned by each city's experiences in the realm of adapting policies to better serve the needs of PEVs and their drivers.

Responses to the questionnaire were analysed using a form of axial coding, with particular attention paid to text indicating long-term reforms to infrastructure, policy, or the management of transportation services. The study's research questions focused on policy changes over time, so the authors focused on those responses that described either a long-range policy action being established in the present or a present-day outcome of a years-active policy regarding PEVs and their supporting infrastructure. The unit of analysis is thus the policies themselves and their outcomes (where documented by respondents). The coding process generated numerous findings of note, and they are explored in the following section. These findings showcase several recurring trends in the landscape of PEV adoption and infrastructure adaptation in American cities, and each provides a clear indication of where major U.S. cities are in terms of infrastructure preparedness and the political/regulatory appetite for deeper adaptation.

Results

Of the 125 questionnaires sent to major American cities, a total of 31 were returned, indicating a response rate of roughly 25%, which the authors found acceptable for the purposes of this study. Responses were submitted from cities across the

mainland United States, with no specific pattern of geographic, political, or size clustering. The authors also found wide variety in response length and detail among the 31 participants. Some responding officials went into generous detail about the numerous programmes and policies their communities are offering in the realm of PEV adoption and adaptation, while others were vague or downright flip in their answers to the questionnaire. Still, several solid recurring themes emerged from the dataset, and the lessons derived from those themes inform the bulk of this section. The themes are ordered in rough correspondence to their position on the questionnaire, beginning with internal attitudes towards PEV policies and expanding outward into broader lessons for a national audience.

Cities' PEV policies vary widely, ranging from dense regulations to no regulation at all

Portland has adopted an Electric Vehicle Strategy with 49 specific action areas, a Green Building Policy to promote EV infrastructure in new construction, and a list of priority areas for PEV charging within city limits. We are actively working with community partners to encourage the installation of publicly accessible EV charging stations on private property at strategic locations in the metro area.

— An official in Portland, Oregon

The questionnaire's first question, and arguably the most foundational component, centred on what kind of policies related to PEV adoption and usage are present in respondents' local government. Roughly a quarter of respondents indicated their city had no written policies regarding PEVs, and had no plans to draft them in the near future. Among respondents whose cities did have active PEV policies on the books, the specifics varied considerably from place to place. Many city governments have internal policies to prioritise the purchase of PEVs and hybrids for city vehicle fleets, while other cities address the issue of PEV charging infrastructure by mandating and/or subsidising the installation of charging infrastructure in public places and residential developments. For example, the City of Seattle has an expansive plan for PEV adoption and infrastructure, with over 300 charging stations throughout the region and detailed requirements for all new parking stalls and residential driveways to be built to 'EV-ready' specifications. By

contrast, cities such as St. Louis, Missouri and Pittsburgh, Pennsylvania have no master plan for PEV adoption, but the city governments do purchase PEVs and AFVs as a matter of internal policy. At the far end of the regulatory spectrum are cities with no policies related to PEVs or AFVs at all, such as Arlington, Texas and Mesa, Arizona. While the authors expected to find a broad range of city policies regarding PEV adoption and infrastructure – indeed, the purpose of a national-scale questionnaire was precisely to capture this diversity of policies – it remains notable for its potential to inform the broader discussion over the relationship between municipal PEV policies and those vehicles' usage in American cities.

City efforts rely heavily on internal fleet policies rather than construction regulations

Our city has an alternative fuel vehicle acquisition policy in place, which replaces city vehicles with alternative-fuel vehicles wherever possible. This includes CNG, propane, and electric vehicles. In 2019, the city purchased nine PEV's for its fleet.

— A city staffer in Santa Ana, California

Related to the first finding, the authors found the PEV policies in the responding cities to be notably centred around internal policies for city vehicle purchases rather than broader or more intensive regulations regarding construction or municipal infrastructure. Fifteen of the 31 respondents indicated their cities had policies in place to prioritise the purchase of PEVs and AFVs for city fleets. By contrast, only eight respondents (most of whom are also in the prior group of PEV purchasers) stated that their communities have enacted any building codes or construction regulations to require PEV charging infrastructure in parking areas. Salt Lake City, for example, requires all new construction to incorporate EV-ready electrical infrastructure so that charging stations can quickly be added at a later date. Denver has a similar building code in force, with a particular emphasis on multifamily residential construction being ready for PEV charging stations in the future. This apparent focus on internal policies, which are arguably easier to set and manage than long-range construction codes and regulations, was noted by the authors and will be explored in greater depth later in this paper.

Cities view PEV infrastructure as the purview of utility companies, but remain supportive

Utilities in America are facing declining load demand due to the successful energy conservation measures of the past three decades. PEV's offer a great opportunity for revenue for utility companies, provided the charging is done off-peak and positioned smartly on the grid. Studies have shown our city's electric utility grid can handle a high number of PEV's without significant grid investments.

— A senior planning official in Seattle, Washington

The questionnaire did not ask specifically about cities' relations with their electric utility providers, but a number of responses described those relations in detail. In many cases, respondents discussed PEV charging infrastructure as being provided (built, operated, and in many cases funded) directly by private-sector utility companies operating in the region. Because electricity in many of these cities is purchased from private companies, city officials contend that the government's role in matching PEV users with suitable electrical infrastructure is limited. Electricity to charge PEVs is sold at market rates (or occasionally at a city-negotiated discount) directly to the owners of those vehicles. In Kansas City, Missouri, the city has no set of policies governing PEV adoption or charging, but officials have worked with the local utility provider (Kansas City Power & Light) to eventually install 1,000 PEV charging stations throughout the city. Attitudes towards utility providers as leaders of installing PEV infrastructure are generally optimistic and supportive in this set of responses. In cities such as Raleigh, North Carolina, and Phoenix, Arizona, city officials are working with utilities to help manage the demand for PEV charging on the electrical grid, encouraging consumers to charge vehicles during off-peak hours. An official with the City of Santa Clarita, California pointed out that PEV owners seeking to recharge their vehicle batteries may ultimately find themselves at the economic mercy of private utility companies that may or may not switch to a dynamic-pricing model as demand for EV-scale electricity rises in Southern California. The electrical infrastructure needed to supply power to PEV charging stations is generally quite expensive and complex to install, thus giving city governments reason to allow private utility firms to bear those costs and to recoup the investment directly from the consumers of the energy.

City officials are aware of the costs of PEV infrastructure, have ideas for innovations

Our main barrier to sustainable transportation is funding. Cities are expanding their transportation options – streetcars, light rail, bike-ped, and so forth – but the funding isn't keeping up. We have to do more with a shrinking share of the budget.

— An official in Tempe, Arizona

Related to the previous point, respondents in several cases noted the costs of PEV infrastructure and defended their cities' inaction on PEV issues in economic terms – for example, by claiming bike-ped infrastructure was both cheaper and better utilised by the public than any PEV infrastructure would be. The questionnaire also gave respondents the opportunity to recommend areas of future innovation and research focus at the intersection of PEV technology, infrastructure, and public policy. Respondents provided an extensive list of ideas, ranging from questions about fast-charging batteries for PEVs to the exploration of socioeconomic factors such as shared-use PEV networks and next-generation mechanical training for blue-collar workers. Several respondents also urged the authors to conduct deeper policy-oriented research into lowering the costs of installing and operating PEV infrastructure, while at the same time showcasing financial incentives for potential buyers. A curious but recurring stream of thought emerged on this issue among respondents, namely that the environmental case for PEV adoption has already been made for consumers and elected officials, but the consumer-scale micro-economics of PEVs have not been readily studied or publicised to that same audience.

Respondents view state/federal tax incentives as essential to broader PEV adoption

Beyond the existing federal purchase incentives, we should offer support to offset the costs of installing charging stations in homes and multi-family complexes. We could also offer guidance, information, and tax incentives for businesses converting their fleets to electric, and show developers how to safely and cheaply build 'EV-ready' parking lots for use at a later time.

— An official in Oklahoma City, Oklahoma

Tied to the issue of economics is the matter of tax incentives for the purchase of PEVs, ostensibly offered to reduce the cost of an PEV for consumers. As of

2019, the United States federal government offers a tax credit of between 2,500 USD and 7,500 USD per new PEV purchased in the U.S. The specific tax credit varies based on the vehicle purchased. In addition, several individual states offer supplemental tax credits and additional non-financial incentives (such as waived inspections and complimentary access to carpool lanes) to consumers purchasing an EV. These tax incentives can significantly reduce the initial costs of purchasing an EV, and are thus a visible and powerful tool in advancing PEV adoption nationwide. The questionnaire asked respondents what state or federal policies would help the most in increasing PEV usage in their city, and virtually all respondents mentioned the tax credit system as integral to achieving that goal. In many cases, respondents made the case for increasing the tax credit across the board, or boosting the credit for lower-income buyers specifically. Others argued for increasing the state and federal gasoline tax with the twin goals of raising short-term capital to fund PEV infrastructure and tax credits alongside a long-term goal of reducing demand for gasoline-powered vehicles over time. Geographically, the strongest proponents of increased tax credits were in the Western United States, where existing state tax credits for PEV purchases are already visible to consumers. Proponents of increased state and federal fuel taxes were dispersed roughly equally across the United States, with no discernible clustering in states with lower state fuel tax rates. Respondents also made the case for adding new incentives to help developers and homeowners reduce the costs of installing PEV infrastructure on their property and prepare more 'raceway' conduit for future PEV usage. Respondents here saw a clear and robust role for state and federal governments, and perceived the main power of those governments to be that of financial heft and consumer-friendly tax incentives to grow demand for PEVs over time.

Respondents list a range of obstacles to broader PEV adoption, but have solutions in mind

Battery capacity and efficiency play a key role in consumer adoption of PEVs. Range anxiety is a real thing, and it's doing great harm to PEV sales. Increasing their usable range while increasing performance characteristics would surely increase interest among younger consumers.

-A city staffer in Santa Ana, California

In describing what they perceive as the greatest obstacles to broader PEV adoption in their cities, respondents listed several specific factors that engineers and policymakers have the power to investigate and address over time. Common factors include battery capacity (the time an PEV can operate between charging events), battery material and electrical grid improvements (so PEVs can be charged more rapidly and in more locations), affordability (particularly for lower-income city-dwellers), and a broader catalogue of electric vehicles. Several respondents expressed a desire to see electrically-powered utility trucks, emergency service vehicles, taxis, and transit vehicles, rather than just personal automobiles. To address these, respondents recommend specific fixes from a technical as well as a policy perspective. To put more electric-powered service vehicles on the road, a few respondents suggested broadening the federal grant programmes used by cities to purchase fire engines and transit vehicles to more explicitly cover electric versions of those vehicles, which would optimally spur development of cheaper and more effective versions going forward. For lower-income residents, city employees recommend a mix of incentives and a shared-use model of PEVs. This latter idea was particularly popular among respondents, but evidence of local governments having success with such programmes is lacking. Improving battery capacity and charging station availability would aid the public image of PEVs and reduce discrete demand during charging events, but would also address a concept that emerged repeatedly throughout the questionnaires: 'Crowding at charging stations due to range anxiety.' This concept, loosely defined, refers to the tendency of some PEV drivers to underestimate their vehicle's remaining electric charge while driving. This supposed anxiety is said to lead many PEV drivers to plug in their vehicle for charging long before it truly needs it, which several respondents claimed can lead to congestion at public charging stations. and something that must be overcome through education and/or direct financial costs that compel PEV drivers not to recharge their vehicles until truly needed. One respondent further commented that consumer misunderstandings about range anxiety are likely deterring some consumers from buying PEVs, reinforcing the call for more education. The range of obstacles listed in the questionnaire responses, and the depth of participants' knowledge on the issue, reflects a growing technical and policy understanding of PEVs in American cities. Many

respondents used detailed technical terminology (such as range anxiety, raceways, and state of charge) in describing PEVs and charging infrastructure, while a few wrote in only general terms about electric vehicles. The authors did not expect such a detailed knowledge of PEVs among elected officials and generalist urban planners, and found the suggested policy solutions a colourful addition to this analysis.

Discussion

These findings indicate a broad diversity of policy with regard to PEV adoption and infrastructure in American cities. By allowing each respondent to describe not only their community's EV-related policies but also their origins and outcomes, the authors were able to capture the broader story of how these communities are grappling with the changes related to PEV usage by consumers, businesses, and government agencies. While this study did not incorporate an element of policy evolution or time-series progression simply because of how nascent this technology is, it is evident from the analysis that many of these policymakers are already conceptualising the future of PEVs on their own streets, with or without any broader guidance from industry or elected officials. Planners and policymakers (at least in the cities where PEV policies have been proposed or enacted) seem to the authors to be committed to the long-range goals of PEV adoption. Their questionnaire responses often rely on long-term language, and one gets the distinct impression of two forces at work: First, that many policymakers are aware of PEVs' present novelty and slow adoption, and second, that these officials are willing to wait a long time for PEVs to become widespread enough to justify their cities' investments on PEV-related infrastructure. The questionnaire gave respondents the opportunity to expound on what they wish their city had done earlier with regard to electrical infrastructure for transportation, and well over half of the respondents clearly stated a wish that their city government had installed this infrastructure sooner, as it might have spurred quicker adoption of PEVs by area consumers. The authors were intrigued by this optimism among policymakers, and were also surprised to observe the technical knowledge of respondents, many of whom wrote with clarity about specific technical components of PEV mechanics and charging.

The authors recommend deeper study into the economics of PEV adoption and infrastructure, both from a government perspective (for example,

incentives and public charging infrastructure) as well as from a consumer perspective (for example, questions of how lower-income families might have access to PEV technology, as well as PEV owners' willingness to pay for electricity to charge their vehicles). As electric vehicles mature and become more mainstream in the coming decade, it is recommended to analyse how transportation policies in major US cities have evolved over time in response.

Given the slow rise of PEV adoption among American consumers, as well as the uneven ways in which major American cities are adding PEV infrastructure, it remains unclear just how influential city-level policies can be on PEV adoption by consumers and businesses living in those cities. This study documented several ways in which individual governments are advancing political and environmental goals through PEV infrastructure and incentives, but deeper study is needed regarding the degree to which an EV-supportive (or an EV-sceptical) city government influences residents to buy a PEV rather than an AFV or gasoline-powered automobile. It is also not evident just how much power local governments have to launch structured tax incentives or shared-use PEV programmes, and the authors encourage deeper study on this topic. Still, the study remains highly relevant to those seeking to understand local governments' preparations and regulations for PEV infrastructure. It also represents a colourful glance into how several communities are working with utility providers, tax regulators, and the building-code process to prepare their cities for a wider national adoption of PEV technology that, in their eyes, is soon to come.

Conclusion

The results presented in this study represent one examination of the state of PEV adoption and infrastructure policies in America's largest cities. While a number of questionnaires were completed by representatives of several cities, much work remains to be done in truly capturing the spirit and scope of EV-related local government actions. This is arguably pressing, given the rate at which policies will need to adapt to coming changes. The expected growth in PEV usage among American consumers is sure to be a key motivator in reforming the nation's building codes, electrical infrastructure, parking regulations, and financial incentives packages

for vehicle purchase. This growth also represents a new challenge for infrastructure finance, as declining fuel tax revenues will be further impacted by a broader shift to electric vehicles. Regulators may need to formulate an alternative model of taxation/registration that captures revenue from PEVs as a parallel to fuel tax revenues from gasoline-powered vehicles. PEVs as an enduring component of American automobility is a relatively young concept, and regulations and building codes on the subject will arguably take time to mature.

The PEV literature, in all its streams and technical or policy directions, is growing but still largely unwritten. A tremendous amount of additional study is needed in order to fully flesh out the various angles and issues of this topic area. This study constitutes one small contribution to that broader goal. In the course of analysing questionnaire responses and cataloguing ideas for future research, the authors documented a few key concepts ripe for deeper study at a later point, and these are presented here for the benefit of other scholars. The authors also wish to point out that many of the boldest research ideas came directly from the audience of practitioners. First and most pressing is the need for deeper technical study into the time and usage aspects of PEV charging systems. For example, innovators must work towards fast-charging technology, so that PEVs can be recharged more expeditiously in public places. At the same time, social scientists must do more to investigate and ameliorate 'range anxiety' among PEV users, given its potential to deter potential PEV customers from purchasing an electric vehicle. Many city officials also expressed a desire to see more research and creativity in the area of electrically-powered service vehicles, such as fire engines and delivery trucks. Given those vehicles' size, expense, and capacity to pollute with diesel engines, efforts to electrify those vehicle fleets will arguably lead to cleaner air in the same way PEVs for personal autos would. One final area of deeper research recommended by this study is that of PEV accessibility for lower-income consumers. Several respondents described the concept of an 'electric carshare' programme as being ideal in this situation, as it would likely require far less financial investment on the part of individual drivers than buying a single PEV. Studying and implementing such a concept would be a complex undertaking from a research perspective, and a scholar wishing

to do so would likely have to work directly on a pilot project involving a local government as well as a manufacturer of PEVs. Still, the potential for a shared pool of PEVs for on-demand transportation is a captivating idea to reduce the ownership costs of PEVs while also providing vulnerable populations with a zero-emission means of transportation.

The authors also encourage the scientific community and the nation's urban policymakers to continue to work together in order to develop flexible best practices that can be adapted to virtually any cityscape contending with PEV adoption. At present, PEV adoption varies considerably across regions in the United States, and much of the work being done on best practices and infrastructure adaptation is being conducted within those regions with a large volume of PEV ownership. This leads to asymmetries in both policy preparation and electrification adaptations that will, in the short term, pose an obstacle to truly national-scale best practices. These asymmetries also impacted questionnaire responses in this study, and are arguably a limitation of this work but still instructional for future studies on the topic. The authors anticipate a greater degree of friction (chiefly motivated by financial concerns) between cities and utility providers with regard to PEV charging infrastructure. As it stands, many of the cities investigated in this study rely on utility companies to provide public charging stations at virtually no cost to the consumer. As more and more PEVs enter the nation's roadways, and demand for this accessible and 'free' electricity grows, cities and utility providers will be faced with the dilemma of how best to set a reasonable price for public charging infrastructure that formerly cost PEV drivers nothing. The potential role of private players such as parking garages offering PEV charging at no or reduced cost as an incentive to use their services is also worthy of investigation. The role of utility providers in setting policy is also an area that, while not explored in depth in this study, deserves richer exploration as PEV adoption grows nationally and local governments adapt to them. There must also be more explicit and detailed guidelines on universal building codes for PEV infrastructure in the construction industry. While only a handful of places in the US require newly-constructed dwellings to have EV-ready electrical infrastructure in place, the sooner the nation's homebuilders can develop safe and affordable best practices for installation and maintenance of such infrastructure, the easier it will be to adapt structures in

other parts of the nation at a later date. Another factor in the area of vehicle energy and infrastructure is the decline in fuel tax revenues, which will continue to cause a decrease in available funding for road construction and maintenance as vehicles grow more fuel-efficient. Furthermore, as PEV adoption grows, regulators will need to formulate fuel-tax alternatives that can be applied to drivers who operate vehicles that do not consume gasoline. As interest in PEVs continues to grow in American cities, the literature on the subject will no doubt mature and diversify, and the authors look forward to ways in which new knowledge can contribute to a cleaner transportation system.

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