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# Zero-Emissions Vehicle (ZEV) Mandates Workshop: Research for Effective, Efficient, and Equitable Policy Implementation

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# About the Authors

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**Nafisa Lohawala** is a fellow at RFF. She earned a PhD in economics at the University of Michigan after receiving a BS-MS dual degree in economics with a minor in computer science and engineering (algorithms) from the Indian Institute of Technology, Kanpur. Lohawala's research lies at the intersection of industrial organization, energy economics, and public finance. She focuses on the effect of government policies on environmental and safety externalities generated by the transportation sector, as well as other transportation issues, including decarbonization strategies for medium- and heavy-duty vehicles.

**Emma DeAngeli** is a research analyst at RFF. She graduated from the University of Oklahoma in 2020 with a BA in mathematics and a BMA in cello performance. She then earned her master of environmental management degree with a specialization in environmental economics and policy from Duke University in 2022, focusing on community-based environmental management and climate change policy. Her previous research focused on incorporating equity into state regulatory impact analyses.

# About RFF

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# Sharing Our Work

# Executive Summary

This document is a report summarizing Resources for the Future's workshop: "Zero Emissions Vehicle (ZEV) Mandates Workshop: Research for Effective, Efficient, and Equitable Policy Implementation." The virtual workshop, held on June 12 and 13, included two fireside chats and five moderated discussion panels covering a range of different topics with over 25 panel participants. The objectives of the workshop were to explore the policies put in place by California and New York that require a rapid scale-up of electric vehicle (EV) adoption, both in the light-duty and medium- and heavy-duty sectors, and to understand the role that research has to play in helping states achieve their goals efficiently, effectively, and equitably. This report summarizes the insights and discussions held during the panels and fireside chats and elicits open questions on different topics. We provide the list of participants and the workshop agenda in the appendices to this report.

Throughout the workshop, many discussions overlapped across the panels and three themes emerged as key areas where researchers could help to inform policymaking. These include:

- **Equity**: Achieving an equitable transition to EVs is a shared goal amongst many communities and governments. The ZEV mandates provide a significant opportunity for local governments to increase equity outcomes of their communities. However, if policies are not structured carefully and intentionally, workshop participants noted that the ZEV mandates could possibly exacerbate inequities, leaving behind underserved communities who have been most affected by transportation pollution. The main issues include:
    - Given that electric vehicle adoption has been relatively concentrated within wealthier and whiter communities, achieving an equitable transition requires us to consider barriers to adoption in underserved communities. What policies, including public charging stations or EV subsidies, are most effective in accelerating adoption by these households?
    - How can we leverage the transition to EVs to improve mobility options for households, and to improve the electric grid in underserved areas?
    - How can we ensure that the transition to EVs does not negatively affect jobs and encourages workforce training in preparation for new jobs related to EV manufacturing and maintenance?
    - What policies can help ensure that charging stations are accessible and functioning properly in lower-income and racial/ethnic minority communities?
    - What policies and regulations could ensure an equitable distribution of air quality and economic benefits of the EV transition to underserved communities?
    - What policies can we implement to reduce any negative environmental impacts of EV manufacturing and critical mineral extraction and processing for batteries?

- **Charging stations**: Workshop participants described public charging stations as one of the most important investments that can be made to increase vehicle adoption. Given prevalent range anxiety concerns, more public charging stations can help alleviate these concerns and allow for greater adoption. Furthermore, more investments in these stations can also reduce the driving range and battery capacity necessary for incentivizing adoption, which has other benefits in terms of reduced critical minerals usage. Optimizing the placement of charging stations will be a key issue in bringing about an effective, efficient, and equitable transition to EVs. Some more specific research questions include:
    - How can charging station networks be structured in order to maximize societal benefits: from an equity perspective, a business investment perspective, a grid perspective, and to accelerate the adoption of EVs?
    - What are the best policies for bringing about compatibility in charging station networks, and what are the costs associated with having multiple standards?
    - How can we optimize charging station subsidies to achieve equity and efficiency in our investments?
    - What role do charging station investments play in accelerating EV adoption, particularly in low-income communities? What policies can help ensure that these investments result in accessible and affordable public charging?
- **Place-based research**: Centering a research question, data, methods, and framing around a specific geographic location or region will be key to answering all of the above questions in a way that makes sense for different locations. Each location is unique and faces its own challenges and characteristics. For example, electric distribution system investment costs may vary widely depending on location. Conducting research on tariffs in one utility service territory may have only limited applicability to other areas. This means that for policymakers to choose approaches, policies, and regulations that work well for their location, they will need significant support from the research community to create models and understandings that are specific to their needs. Some of the issues raised include:
    - Understanding local mobility needs and tailoring electrification solutions to these needs. In some places, expanding and improving public transit simultaneously with electrification can bring about improved equity and mobility, but in other areas, solutions such as increasing ride share accessibility may be cheaper and a better solution for improving mobility.
    - Identifying investments in charging stations (both location and speed of charging) that improve outcomes of interest (such as greater EV adoption, increased equity in access, etc.) will depend significantly on local conditions, including costs of investments, traffic flows, density of the area, business development opportunities, and so on. Place-based modeling can help local policymakers identify layouts that maximize the net benefits for their region.

- Quantifying price responsiveness to different tariffs requires a focus on local tariffs given the large differences in underlying costs. Furthermore, local regulators are hesitant to accept results from other service territories as applicable to their location. By conducting modeling and analyses on local electric tariffs, regulators and utilities can be better informed of the benefits of new rate designs.
- The benefits of grid injections vary significantly across location and time. Conducting place-based models at a fine geographic and temporal scale can help local utilities and regulators identify cost-reflective tariffs and payments for vehicle-to-grid injections (a technology that allows vehicles to send excess electricity from their battery back to the electric grid).

What is clear from the workshop discussions is that there is much more research that we can conduct to inform policymakers of how to ensure that the ZEV mandates are not just achievable, but also effective, efficient, and equitable.

# Contents

# Introduction

This document is a report summarizing Resources for the Future's workshop: "Zero-Emissions Vehicle (ZEV) Mandates Workshop: Research for Effective, Efficient, and Equitable Policy Implementation." The virtual workshop, held on June 12 and 13, included two fireside chats and five moderated discussion panels covering a range of different topics with over 25 panel participants. The objectives of the workshop were to explore the policies put in place by California and New York that require a rapid scale-up of electric vehicle (EV) adoption, both in the light-duty and medium- and heavy-duty sectors, and to understand the role that research has to play in helping states achieve their goals efficiently, effectively, and equitably. This report summarizes the insights and discussions held during the panels and fireside chats and elicits open questions on different topics. We provide the list of participants and the workshop agenda in the appendices to this report.

Achieving 100 percent electric vehicle adoption is an ambitious goal that will require a coordinated effort amongst many different stakeholders: the electric utilities, vehicle manufacturers, government, communities, and private investors. Importantly, researchers have a key role to play in helping illuminate challenges and opportunities for improving coordination amongst the stakeholders and identifying policies that can help states achieve their goals efficiently and equitably, all of which can be done through modeling, ex-post analyses, and community-engaged research.

It was clear from the workshop that there are many ways in which researchers can help shape policy, such as by working with utilities and city governments to create models and analytical tools, producing and sharing findings and analysis of outcomes for legislation and regulatory settings, and working with communities to improve their analytical engagement with policymakers.

In this paper, we highlight three overlapping themes that emerged from the workshop, which provide important considerations for policymakers in their quest to achieve widespread electric vehicle adoption: equity as a guidepost for policymaking around ZEV mandates, the importance of ensuring charging station accessibility, and the need for place-based research to help advance state ZEV goals.

# 1. On the Need for Equitable ZEV Adoption

Recent developments, such as the declining costs of batteries and a dedicated push by manufacturers to electrify both passenger vehicles and commercial trucks and buses, have been promising for an equitable adoption of zero-emission vehicles. In the public sector, targeted policies—including NYSERDA's policy to subsidize 100 percent of charging infrastructure costs in environmental justice communities—could further facilitate access to EVs that underserved populations would otherwise not have. Despite developing research, many uncertainties remain, including the effectiveness of various policy instruments to ensure an equitable distribution of the costs and benefits of the ZEV mandates, a balance of public transit and privately owned vehicles to optimize mobility, workforce shifts, and access and reliability of public charging. Additionally, panelists expressed concerns about the ZEV mandates' impact on industrial development and whether these shifts (e.g., more manufacturing plants, battery processing plants, etc.) may exacerbate air quality inequities across communities. More broadly, the panelists discussed the importance of focusing on whether the benefits of the EV transition will accrue to underserved communities, or whether they will be left behind.

## 1.1. EV Adoption by Underserved Communities

So far, EVs have been primarily adopted by wealthy and white drivers. One of the key ways to ensure that the ZEV mandates are equitable is by facilitating adoption by lower income and non-white vehicle owners. In addition to providing programs that support the adoption of EVs in underserved communities, Rory Christian, chair and CEO of the New York State Public Service Commission, emphasized during his fireside chat the importance of communication and education to ensure the incentives reach these communities. The path toward targeting these communities for EV sales could be through various rebates and financial mechanisms, particularly subsidies for used vehicles. One pilot program, as mentioned during a panel by Erich Muehlegger of the University of California, Davis, demonstrated that subsidies have a meaningful impact on adoption and benefit the owners of new vehicles, though the impact subsidies could have on adoption of used vehicles remains to be seen. Most low- and middle-income households purchase vehicles from the secondary market, making an accessible and robust used vehicle market a critical issue for helping to achieve equity in the EV transition. Although the used EV market could look substantially different from its internal combustion engine (ICE) counterpart in terms of what vehicles are offered, purchasing used EV could also result in savings from reduced refueling costs. However, to increase the number of vehicles in the secondary market, there must first be an increase in the number of new EVs on the road, necessitating incentives for new vehicles in tandem with those for older vehicles.

## 1.2. Mobility As a Way to Increase Equity in the Transportation System

According to the panelists on the Distribution and Equity panel, ZEV mandates and adoption should be framed within the context of mobility more broadly. Suzanne Russo, former CEO and current board member of Pecan Street, noted that the United States has a very inequitable transportation system, both in terms of owning personal vehicles and accessing public transportation. Since low-income people and people of color tend to have less access to personal vehicles and good public transportation options, improving mobility must be a key part of an equitable transition to EVs. To that end, panelists discussed solutions such as electrification of buses and other public transit options alongside increased adoption of personal EVs, with an eye toward leveraging the transition to improve community mobility. Furthermore, improving public transit agencies' ability to gain revenues from EVs and investing in a multi-modal public transit system to meet various needs could allow for a diversified transportation system that encourages mobility for those that currently lack access. Importantly, these improvements to the public transit system overall—jointly with electrification—can lead to even greater impacts on community wellbeing, not just by improving mobility and reducing travel times, but also by requiring electric distribution system upgrades. These electric system upgrades can have ancillary benefits to the community by creating a more resilient grid and avoiding blackouts.

## 1.3. Workforce Expansion and Transitions

As Mehri Mohebbi, director of the Transportation Equity initiative at the University of Florida, identified during the Distribution and Equity panel, a shift in the workforce would also be necessary for the expansion of the EV market. To ensure an equitable transition, retraining programs must be prioritized. Russo also identified an opportunity to expand the workforce within vehicle and charging station maintenance given low numbers of technicians who are trained to work with EVs. Retraining oil and gas workers could be a solution that provides a just transition. Fortunately, according to panelist Muehlegger of UC Davis, it wouldn't be a "day and night" transition for workers. In Norway, the transition to EVs has been slow, giving the workforce time to adjust to new needs.

## 1.4. Public Charging Station Investments to Increase Equity Outcomes

Public charging stations will be important for low-income communities and communities of color to adopt EVs, in large part due to a reduced likelihood of having a garage for home charging access. The literature has largely focused on developing charging networks for owners who likely have several charging options, but public charging stations would be important for adoption among several groups, including those who live in apartment complexes that may not have charging capabilities or

dedicated parking, as well as renters who are prevented from installing charging infrastructure. Targeted public charging station development in some areas could increase interest in EVs, and locations to maximize net benefits could be determined through a geographical study considering the local network and community needs.

Public charging stations will also be important for small fleets of medium- and heavy-duty vehicles used for long-distance transportation that may not have the capacity to build their own on-route infrastructure (e.g., PepsiCo's on-route **Tesla Semi chargers**). Panelist Elizabeth Stein, state policy director at the Institute for Policy Integrity at the New York University School of Law, flagged that since utilities do not provide reduced electricity prices for fleets in disadvantaged neighborhoods or those owned by lower-income drivers[1], challenges can arise for smaller fleets due to lack of sophistication or experience with complicated rates.

Once public infrastructure is installed, it poses additional uncertainty in the realm of ensuring equitable and reliable access to charging. According to Russo, researchers have shown that charging costs and reliability can vary across geographies; ensuring that charging stations in disadvantaged communities are affordable and in proper working condition will be a key aspect of an equitable transition to EVs. More research can be done to identify pricing structures, regulations, and incentives that ensure charging station investments and pricing occur in an equitable manner.

## 1.5. Air Quality Impacts of the Transition to EVs

While the transition to EVs can result in significant air quality improvements, there is more research that can be done to ensure that environmental justice is achieved through the transition to EVs. Several factors could impede an equitable distribution of air quality benefits, such as the differential uptake of EVs in underserved communities relative to other communities, the location of accessible and affordable charging stations, and a potential for increased grid emissions due to charging. Low-income communities and communities of color have disproportionately faced poorer air quality due to proximity to roadways, and as Regan Patterson, assistant professor of civil and environmental engineering at the University of California, Los Angeles (UCLA), mentioned, larger EVs that customers favor pose a concern with the potential for increased emissions of non-exhaust particulate matter.

1 In the residential sector, utilities generally provide favorable rates for low-income households in an attempt to improve equity outcomes.

## 1.6. Industrial Development Equity Impacts

Furthermore, there are several concerns with the increase of EV adoption related to industrial development. Low-income communities and communities of color are disproportionately located near industrial sites, and in the transition to EVs, the question of where the new vehicle and battery manufacturing and processing plants will be placed may exacerbate existing inequities unless special attention is placed on siting decisions. Similarly, the extraction of critical minerals on Indigenous land is another equity concern, as discussed by Patterson; indeed, a recent **report** demonstrated that the majority of critical minerals are located near Indigenous lands. To avoid exacerbating existing inequities in our transition to EVs, research can help by focusing on quantifying the potential for increased inequities due to more domestic manufacturing and the push to increase domestic battery material extraction and processing capacity, and by working to find solutions to these challenges.

# 2. On the Need to Facilitate Access to Charging Infrastructure

Another theme that emerged during panel discussions was the need to facilitate access to charging infrastructure for the widespread adoption of EVs. From a consumer's perspective, access to a robust and widespread high-speed public charging infrastructure is crucial to alleviate range anxiety and facilitate seamless long-distance travel. Its importance is well highlighted by HEC Montréal Assistant Professor of Applied Economics Katalin Springel's past **research** on Norway's EV market, which suggested that dollars spent on charging station subsidies were twice as effective in raising EV penetration in the early stage of the market than the dollars spent on consumer price subsidies. Among the different types of chargers, Cornell University's Shanjun Li pointed out that Level 3 (DCFC) chargers can be more effective in promoting EV adoption than Level 2 chargers. While Level 2 charging stations only spur adoption locally, Level 3 stations can also spur adoption more broadly by better facilitating long-distance travel.

## 2.1. Inequities in Access

Robust access to public charging infrastructure is essential for those living in apartments, condos, or other multi-dwelling units, where setting up personal charging stations is challenging. There are significant inequities across space in the cost to charge vehicles and the reliability of chargers. Both Russo and Li's works suggest that charging stations are primarily located in high-income zip codes. Muehlegger also pointed out meaningful differences in the electricity costs faced by people who can charge at home versus those who must rely entirely on the public charging infrastructure; thus, policies that work to keep public charging costs affordable will be key to ensuring equitable access to charging infrastructure.

## 2.2. Public Charging Station Investments and Subsidies

The Infrastructure Investment and Jobs Act of 2021 provides $5 billion in funding for public charging stations through the National Electric Vehicle Infrastructure Formula (NEVI Formula) Program and $2.5 billion through the Charging and Fueling Infrastructure Discretionary Grant Program (CFI Program). Conditional on such funding, station allocation can be designed for efficiency and cost-effectiveness. Developing efficient policies requires understanding the incentives of private investors and aligning them with socially desirable outcomes. One reason private investors' incentives may be suboptimal from a welfare perspective is that the placement of charging stations within a broader network can have positive spillovers for the incumbent charging stations. For instance, the placement of a new charging station could lead to increased utilization of other, existing charging stations if the new one helps fill a hole in a route that would otherwise not be viable for EV driving. However, private investors may not consider such spillovers when choosing the location of charging stations.

Moreover, ensuring cost-effectiveness would involve recognizing that an extra government dollar's marginal benefit is likely to differ across space. For instance, the greater availability of charging infrastructure in high-income areas suggests a high private incentive to invest in these areas. Thus, directing the funding to low-income areas where the private incentive to invest is low but the potential for EV adoption is high can get the best value for government money.

The panelists discussed geographically targeted subsidies, whereby the cost-sharing ratio is higher where the marginal benefit of government money is higher, as a promising solution to achieve efficiency and cost-effectiveness. Geographically targeted subsidies can be valuable if they allow investors to internalize the positive spillovers from investing in the holes in the charging network. They can also address some distributional concerns to the extent that they create an incentive to invest in low-income areas.

## 2.3. Charging Station Capability

The panelists also highlighted compatibility in the EV charging standards as an area that could bring significant social benefits by encouraging EV adoption and creating equitable access to charging. Yet, this issue may not be easily solved if left to private decisions and investments, as the private incentives toward compatibility are not always strong. For instance, Springel of HEC Montréal pointed out that for already established charging networks, a private investor may find it advantageous to restrict their charging station to only serve one standard in order to reduce congestion or provide exclusivity to the EV drivers charging at their station. Against this backdrop, Chris Smith from the Ford Motor Company discussed Ford's recent agreement with Tesla Motors to provide Ford EV customers access to the Tesla Supercharger network. Starting in 2025, Ford EVs will have a built-in North American Charging Standard (NACS) connector, eliminating the need for an adapter to access Tesla Superchargers. The discussion underscored the need to reduce charging time and make chargers broadly accessible.

## 2.4. Open Research Questions around Charging Stations

Research has a prominent role in helping policymakers take the most effective actions. The conversation with Christian (from the New York State Public Service Commission) nicely highlights how research helped the New York Public Service Commission identify the pressure points developers face in deploying charging infrastructure and designing incentives for intelligent deployment of EV charging across the New York State during their 2020 make-ready proceedings. Throughout the workshop, panelists identified several vital questions about charging infrastructure where future research can help.

First, how can government policies incentivize charging standard compatibility? One possibility is to mandate compatibility; another is to restrict the eligibility of subsidies only to stations that serve multiple standards. A vital puzzle piece and area for new research is to better identify how policies can incentivize already established charging networks to serve multiple charging standards.

Second, what would a charging network that maximizes net benefits look like as battery technology and consumer preferences change over time? Such changes can affect the optimal placement of charging stations in non-trivial ways. For instance, on the one hand, a higher battery range could allow for a less dense charging infrastructure because batteries can travel longer distances on a single charge. On the other hand, a higher battery range can also increase adoption, necessitating additional public infrastructure. Given the different moving pieces, the configuration of charging infrastructure would need regular assessment to adapt to the evolving conditions.

Third, when and where do consumers charge their EVs? Are they responsive to price signals? Understanding the charging behavior of consumers will be crucial to placing charging stations and designing electricity tariffs in locations that produce efficient, effective, and equitable outcomes.

Fourth, how will the charging station network affect drivers who will be very dependent on public charging? Most past literature examining how charging incentives affect adoption has focused on consumers who can charge at home and do not necessarily depend on public charging stations. Answering this question will be crucial to understanding how substantial this barrier is to adoption in different communities. Similarly, the effectiveness of consumer and charging station subsidies in future years, particularly once the market for EVs has developed to be truly competitive with gasoline vehicles, is an open question. Although past research indicates subsidizing charging stations to be much more cost-effective during the earlier years of EV adoption, it may not always be the case, as the incentives for adoption of early adopters may not necessarily be reflective of the needs of later adopters.

# 3. On the Need for Place-Based Research to Help Advance State Goals for 100-Percent EV Adoption

Place-based research is an approach to conducting research that centers the research question, data, methods, and framing around a specific geographic location or region. In the workshop, the benefits of engaging in this type of research emerged across multiple panels and within different types of discussions. Specifically, maximizing the benefits associated with the ZEV mandates requires research that is specific to a location; given the variation in each community, region, and state's unique setting, needs, and objectives, optimal solutions for one location will not necessarily be a silver bullet everywhere.

## 3.1. Place-Based Research for Equity in the EV Transition

Achieving an equitable transition is a key part of the states' ZEV goals. Yet it was clear from the workshop that a truly equitable transition requires policymakers to take into account existing and historical inequities across their state, and how these inequities vary across communities, cities, and regions within the state. In the Distribution and Equity panel, the panelists discussed the importance of place-based research in understanding broader transportation inequities, such as limited mobility options. As discussed earlier in this report, given the major inequities that currently exist related to the transportation systems and the importance on focusing on mobility as part of our clean vehicle transition, policymakers will need to understand the specific constraints and challenges of a location when designing mobility solutions.

More broadly, addressing equity concerns will require a better understanding of what the community needs and which types of transportation they prefer. Both Patterson from UCLA and Russo from Pecan Street discussed the importance of community-engaged research to identify how different communities would prefer to improve their mobility, whether through improved public transit options or through better access to private transit. As an example, EV Noir was highlighted by Patterson as an organization that engages in community focus groups and interviews to identify the best path forward for improved mobility and vehicle electrification. For communities whose mobility could be improved through better public transit options, electrifying buses or shuttles can be a great solution to ensuring both equity and environmental goals are met. However, in other locations, Kara Kockelman, a transportation engineering professor at the University of Texas at Austin, argued that the cost of extending public transit can be much more expensive than enabling ride-sharing options, which can also greatly increase mobility; thus, electrifying ride-sharing fleets like Uber and Lyft would be a better solution for these areas. Similarly, Russo spoke about Pecan Street's own research engaging with the community in Austin, Texas, to identify the demands, benefits, and willingness to pay for small electric shuttles that provide local on-demand service. For policymakers to achieve an equitable transition to EV adoption, it was clear from the workshop that they will have to take into account the specifics of each area in their planning decisions.

## 3.2. Place-Based Research to Help Plan for and Optimize Electric System Investments

Research plays a major role in understanding not just the mobility needs of the community, but also other issues such as costs and constraints on the distribution system that will determine which investments in public and private transit are most optimal. Understanding where to invest in charging stations to maximize benefits to EV adoption overall and to the community also requires place-based modeling. Multiple stakeholders are involved in these investment decisions including the electric utility, the charging station investors, and the government; their decisions and requirements for investment will be highly place dependent. Furthermore, local drivers will want to have a say in where these charging stations are placed in order to optimize routes, minimize charging time, and maximize external benefits from increased business activities near charging stations. Planning for these investments requires understanding these different points of views and incorporating the community's preferences for local development. Alan Jenn, an assistant professional researcher at the Institute for Transportation Studies at the University of California, Davis, discussed his own place-based **research** that identifies where on the system fast charging stations can be built to maximize the benefit for ride-sharing fleets within a region. Mehrnaz Ghamami, an associate professor in the College of Engineering at Michigan State University, highlighted her **work** in creating place-based models that can help minimize the total investment cost while also maximizing the benefits to society and the other stakeholders. For example, her research demonstrated that the benefit of including co-located solar and storage with charging stations would differ significantly depending on the location's existing rules, regulations, and solar irradiance throughout the year. This type of place-based modeling effort can lead to more carefully targeted investments, as it can highlight the specific issues of the city such as traffic flows, local pollution levels, highway placement, business development goals, and more.

Furthermore, it was clear from the fireside chat with Christian that regulators highly value place-based research. Extrapolating research findings from other locations and regions is a challenge and can raise concerns about validity for the regulators' specific service territory. In order for the utility to make prudent investments that will be approved by the regulators, the utility will need projections of EV adoption across both space and time; yet these will be highly dependent on local factors such as the location of fleet depots, the geographical distribution of population demographics (such as race and income), concentrations of urban areas, and so on. Place-based modeling identifying where EV adoption may occur and the best location of charging station investments can therefore help local electric utilities and regulators identify least-cost approaches to key electric grid investments to serve increased electric demands.

## 3.3. Electric Tariffs Based on Local and Real-Time Conditions

The importance of place-based research also emerged within the framework of quantifying price responsiveness of EV owners to electric tariffs. All panelists within the Electric Regulatory Decisionmaking panel discussed the importance of engaging in more research to test the responsiveness of EV drivers (within both the light-duty and medium- and heavy-duty sector) to new and proposed electric rates. Yet, because the electric tariffs proposed by a utility will reflect its own underlying costs, similar rate structures may yield very different responses in different locations due to the variations in rate levels brought about by variations in underlying costs. Furthermore, in many states across the country, customers are exposed to real time prices for their electric supply that reflect the wholesale market conditions in their region; as these vary over service territory, research will need to be conducted in different areas to ensure that the results are valid for those underlying costs. More broadly, any cost-benefit analysis of a specific utility policy or new tariff will, by definition, have to be done in a place-based manner to accurately reflect the local conditions faced by EV drivers. This type of work can help utilities and regulators improve tariffs for their specific location, and understand the costs and benefits associated with new regulatory policies.

Similarly, the specifics of a location will determine the benefits that an EV can provide to the grid. In certain neighborhoods where capacities are very constrained, having a network of distributed batteries through EVs can allow for these vehicles to provide grid services through energy injections into the grid. This is known as vehicle-to-grid technology (or V2G). Steve Letendre, the Vice President of Policy and Regulatory Affairs at Nuvve, discussed that payments for V2G will need to be structured based on location-specific information to be cost-reflective. Given how these costs vary over time and within and across service territories, much more place-based research will need to be conducted to help utilities and regulators identify the benefits that these injections have on the grid and thus accurately set tariffs and payment structures.

# 4. Conclusion

California and New York's ZEV mandates, which require 100 percent of new light- and medium-duty vehicles and 75 percent of medium- and heavy-duty EVs sold in these states to be zero emission by 2035, are an ambitious but significant step in facilitating transportation electrification. RFF's Zero Emissions Vehicle Mandates Workshop engaged over 25 participants across multiple panel discussions and fireside chats to discuss the many issues surrounding these mandates. What was clear from the workshop is that major momentum exists across multiple stakeholder groups to make this goal a reality. For example, the fireside chat with Ford's Chris Smith revealed the huge amount of investment that the private sector is making to push forward this goal. However, achieving and requiring such a rapid transition to an electric transportation sector raises numerous questions, highlighting the crucial role of research to help states effectively, efficiently, and equitably achieve their ZEV goals.

Three recurring themes emerged across multiple panel discussions: the need for a focus on an equitable transition to EVs that doesn't aggravate existing disparities and also helps improve mobility; the need for optimizing charging station investments to combat range anxiety, promote EV uptake, and ensure equitable outcomes; and the importance of place-based research, which acknowledges unique geographic nuances and can aid in crafting policies and solutions tailored to specific regions.

The workshop revealed an urgent need for more research to facilitate informed policymaking. RFF will use the insights from this workshop to explore new research ideas related to EVs broadly, particularly within the framework of the ZEV mandates, and we encourage other researchers to use these insights as inspiration for their future work.

# Appendix 1: Participant List

| Last name | First name | Affiliation | Title | Panel | Role |
|---|---|---|---|---|---|
| Borenstein | Severin | Energy Institute at Haas, University of California Berkeley | Professor of the Graduate School, E.T. Grether Chair in Business Administration and Public Policy, and Faculty Director | Electric Regulatory Decisionmaking | Panelist |
| Cappers | Peter | Electricity Markets and Policy Department at the Lawrence Berkeley National Laboratory | Research Scientist and Strategic Advisor | Electric Regulatory Decisionmaking | Panelist |
| Chakraborty | Debapriya (Priya) | Institute for Transportation Studies at the University of California, Davis | Research Faculty | Electric Loads, Grid Impacts, and Environmental Outcomes | Panelist |
| Christian | Rory | New York State Public Service Commission | Chair and CEO | Fireside chat, Day 2 | Interviewee |
| Ghamami | Mehrnaz | Michigan State University | Associate Professor | Charging Station  Network Development and Investments | Panelist |
| Gillingham | Kenneth | Yale University | Professor of Environmental and Energy Economics | Vehicle Demand and Supply | Panelist |
| Jenn | Alan | Institute for Transportation Studies at the University of California, Davis | Assistant Professional Researcher | Electric Loads, Grid Impacts, and Environmental Outcomes | Panelist |

| Last name | First name | Affiliation | Title | Panel | Role |
|---|---|---|---|---|---|
| Kates-Garnick | Barbara | Tufts University | Professor of Practice and Senior Research Fellow | Fireside chat, Day 2 | Interviewer |
| Kockelman | Kara | University of Texas at Austin | Dewitt Greer Centennial Professor of Transportation Engineering | Electric Loads, Grid Impacts, and Environmental Outcomes | Panelist |
| Leard | Benjamin | Howard H. Baker Jr. Center for Public Policy at the University of Tennessee | Assistant Professor | Vehicle Demand and Supply | Panelist |
| Letendre | Steve | Nuvve | Vice President of Policy and Regulatory Affairs | Electric Loads, Grid Impacts, and Environmental Outcomes | Panelist |
| Li | Shanjun | Cornell University | Professor of Applied Economics and Policy | Charging Station Network Development and Investments | Panelist |
| Linn | Joshua | University of Maryland and Resources for the Future | Associate Professor, Senior Fellow | Vehicle Demand and Supply | Moderator |
| Lohawala | Nafisa | Resources for the Future | Fellow | Charging Station Network Development and Investments | Moderator |
| Mann | Margaret | National Renewable Energy Laboratory | Group Manager Transportation Energy Storage and Infrastructure Analysis | Vehicle Demand and Supply | Panelist |
| Mohebbi | Mehri | Transportation Equity initiative at the University of Florida | Program Director | Distributional and Equity Concerns | Moderator |

| Last name | First name | Affiliation | Title | Panel | Role |
|---|---|---|---|---|---|
| Muehlegger | Erich | University of California, Davis | Professor of Economics | Distributional and Equity Concerns | Panelist |
| Newell | Richard | Resources for the Future | CEO and President | Fireside chat, Day 1 | |
| Palmer | Karen | Resources for the Future | Senior Fellow, Electric Power Program Director | Electric Loads, Grid Impacts, and Environmental Outcomes | |
| Patterson | Regan | University of California, Los Angeles | Assistant Professor of Civil and Environmental Engineering | Distributional and Equity Concerns | |
| Russo | Suzanne | Pecan Street, Inc. | Board Member and Former CEO | Distributional and Equity Concerns | |
| Smith | Chris | Ford Motor Company | Chief Government Affairs Officer | Fireside chat, Day 1 | |
| Spiller | Beia | Resources for the Future | Fellow, Transportation Program Director | Electric Regulatory Decisionmaking | |
| Springel | Katalin | HEC Montréal | Assistant Professor of Applied Economics | Charging Station Network Development and Investments | |
| Spurlock | C. Anna | Sustainable Energy and Environmental Systems Department at Lawrence Berkeley National Lab | Research Scientist and a Deputy Department Head | Vehicle Demand and Supply | |
| Stein | Elizabeth | Institute for Policy Integrity at New York University School of Law | State Policy Director | Electric Regulatory Decisionmaking | |

# Appendix 2: Agenda

California and New York recently adopted the Advanced Clean Cars II rule, requiring all new light-duty vehicle sales to be electric by 2035, and the Advanced Clean Trucks rule, which requires a ramping up of medium- and heavy-duty electric vehicle sales to 75 percent by 2035. Achieving and requiring such a rapid transition to an electric transportation sector raises a number of questions, such as:

- What will happen to the used gasoline vehicle market, new vehicle sales (both electric and gasoline), and vehicle imports?
- How can we ensure that this transition will be equitable?
- What is the optimal pathway for charging station investments?
- How will this expansion of new ZEV sales affect the electricity sector, and what rules and regulations within the electric sector can help support this transition?

There are multiple avenues to explore and lots of new research that can be done in this space to help the states effectively, efficiently, and equitably achieve their ZEV goals. To that end, we hosted a two-half day virtual workshop with leading researchers and policymakers in the ZEV space to examine the state of research on zero-emission transportation, identify new researchable questions, and explore the data still needed to answer these questions. Shortly, we will create a written communication summarizing the findings from the workshop and lay out a new research agenda related to the ZEV mandate.

### Day 1: June 12, 2–5 pm ET

2 pm: Introduction/welcome

2:05–2:35: Fireside chat with Chris Smith and Richard Newell

2:35–3:20: Distribution and equity concerns

- Moderator: Mehri Mohebbi
- Panelists: Regan Patterson, Erich Muehlegger, Suzanne Russo

3:20–3:30: Coffee break

3:30–4:15: Charging station network development and investments

- Moderator: Nafisa Lohawala
- Panelists: Shanjun Li, Katalin Springel, Mehrnaz Ghamami

4:15–5:00: Electric regulatory decisionmaking

- Moderator: Beia Spiller
- Panelists: Elizabeth Stein, Severin Borenstein, Peter Cappers

5:00: Close out, summary of first day

### Day 2: June 13, 11 am–2 pm ET

11 am: Welcome back

11:05–11:35: Fireside chat with Rory Christian and Barbara Kates-Garnick

11:35–12:30: Electric loads, grid impacts, and environmental outcomes

- Moderator: Karen Palmer
- Panelists: Alan Jenn, Steve Letendre, Priya Chakraborty, Kara Kockelman

12:30–1: Lunch Break

1–1:55: Vehicle demand and supply

- Moderator: Joshua Linn
- Panelists: Kenneth Gillingham, Anna Spurlock, Benjamin Leard, Margaret Mann

1:55–2: Close out