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EXPANDING THE ELECTRIC VEHICLE MARKET IN U.S. CITIES

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

As of early 2017, global cumulative electric vehicle sales had surpassed 2 million units, with growth continuing in the major markets of China, Europe, and the United States. National and local governments in each of these markets continue to support this growth to help achieve energy conservation, climate change, local air quality, and industrial development goals. The United States provides a rich laboratory to analyze this market growth because of its position as the second largest national electric vehicle market and its large variation in local electric vehicle sales and support policies.

This paper assesses the U.S. electric vehicle market and the actions driving it. The assessment catalogues actions in place, identifies exemplary practices, and discerns links between various electric vehicle promotion actions and electric vehicle sales. The analysis focuses on the 50 most populous metropolitan areas, which together represented about 81% of the 2016 U.S. electric vehicle market. The work statistically analyzes the connections among various state and local policies, public and workplace charging infrastructure, consumer incentives, model availability, and the share of new vehicles that are plug-in electric (both fully electric and plug-in hybrid).

Figure ES-1 illustrates the share of new vehicle registrations that are plug-in electric across U.S. metropolitan areas in 2016. The 50 most populous metropolitan areas are labeled. The electric vehicle share tends to be highest in the major West Coast markets. The San Jose area had the highest share at 10%, followed by other California areas (4% to 6%) and markets in Colorado, Hawaii, Oregon, Vermont, and Washington (2% to 4%). Overall, the share of new vehicles that are plug-in electric in these 50 areas is 1.2%, about 3 times the proportion in the rest of the United States.

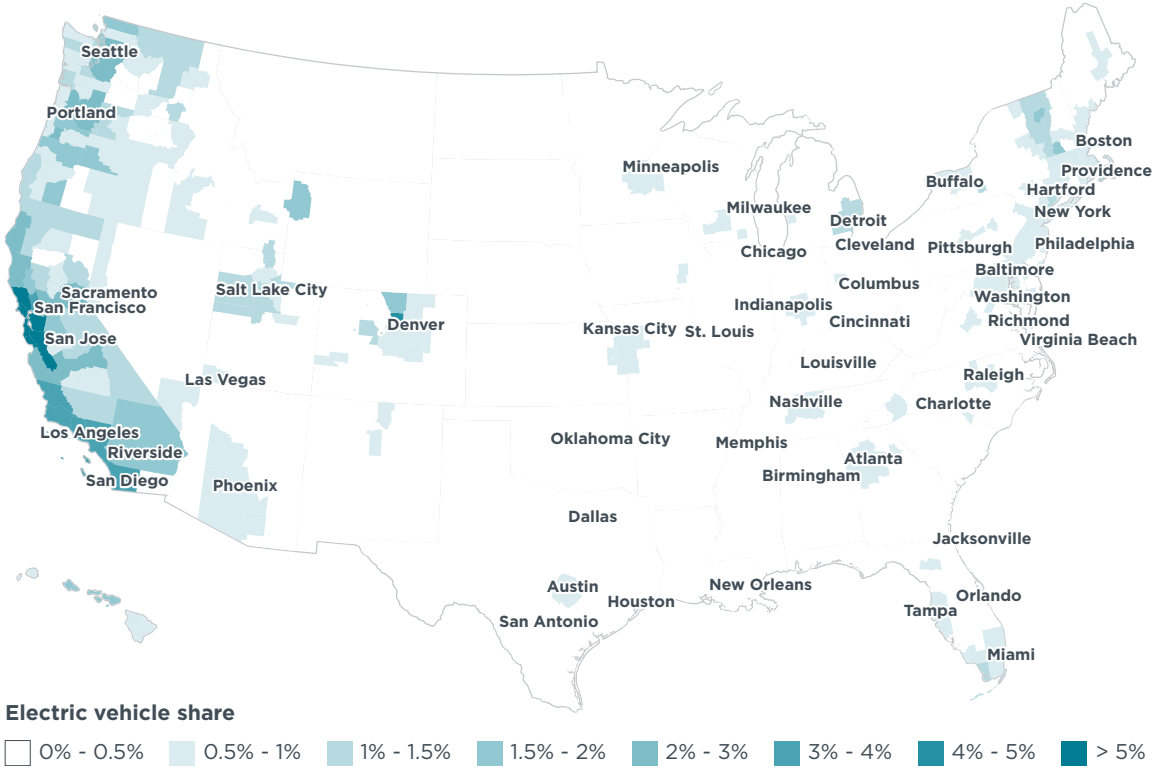

Figure ES-1. Electric vehicle share of new 2016 vehicle registrations by metropolitan area.

(New vehicle registration data from IHS Automotive.)

On the basis of extensive local-level data collection, we conducted a statistical analysis to assess the link between key electric vehicle support activities and market uptake at the metropolitan-area level. In particular, we analyzed whether electric vehicle market share is linked with the availability of more electric vehicle models, charging infrastructure, fiscal and nonfiscal incentives, high-occupancy vehicle lane access, and other activities. Our analysis leads us to the following four conclusions.

Growth in the electric vehicle market requires many actions by many players. Actions by various stakeholders are linked with electric vehicle uptake across U.S. markets. Actions by many local, state, and utility stakeholders work to reduce consumer barriers by means of policy, incentives, and awareness campaigns. Such a comprehensive approach is exemplified by California, where the Zero Emission Vehicle regulation helps to catalyze automaker marketing and model availability, complementary policy incentives, and sustained investment in charging infrastructure.

Expansion of electric vehicle options is a prerequisite to market growth. We find a link between electric vehicle model availability and uptake. The five leading electric vehicle markets by volume, representing nearly half of all U.S. electric vehicle sales, each had at least 24 available electric vehicle models in 2016. Yet across the major U.S. markets, about half of the population has access to 10 or fewer electric models, and many dealerships have very low inventories of those models. Availability of more models across vehicle types, offered at a range of price points and passenger capacities, is an essential precursor to more substantial market development.

Consumer incentives remain key to growing the electric vehicle market. Electric vehicle uptake is linked with incentives that reduce the effective electric vehicle cost. Ten of the top 12 major metropolitan areas with the highest electric vehicle uptake offered consumer incentives typically worth $2,000 to $5,000. Consumers in California markets and Salt Lake City were offered both consumer purchase incentives and carpool lane access, and those in Denver and Seattle had substantial purchase incentives. Such incentives increase awareness and reduce the initial cost barrier while electric vehicle range and cost improvements continue to expand the market, ultimately reducing the need for incentives.

Electric vehicle charging infrastructure remains a barrier in many markets. Our analysis finds that the availability of public charge points and workplace charging is linked with electric vehicle market uptake. The leading electric vehicle markets have at least 275 public charge points per million people; by contrast, half of the U.S. population lives in a market where public charging availability is less than one-third of that rate. The markets of Charlotte, Detroit, Kansas City, Minneapolis, Pittsburgh, Providence, and Virginia Beach showed charging infrastructure growth of approximately 30% to 80%, corresponding with at least a doubling of their electric vehicle uptake from 2015 to 2016.

I. INTRODUCTION

As the early electric vehicle market grows, many governments continue to implement policies to further expand the market. Governments at various levels seek to limit transportation carbon emissions, energy consumption, and local air pollution, and increasingly electric vehicles are central to each of these goals. Many governments are also interested in the economic and employment benefits that stem from local development and manufacturing of emerging technologies such as electric vehicles and their supporting infrastructure.

These efforts to support the electric vehicle market are beginning to take hold, as the early market steadily grows each year. The global electric vehicle market in 2016 exceeded 750,000 sales, versus approximately 550,000 in 2015, 300,000 in 2014, and 200,000 in 2013. Cumulative global electric vehicle sales since 2010 surpassed 1 million in September 2015, quickly reaching 2 million in January 2017 (Lutsey, 2017). The United States is a big part of this electric vehicle growth, accounting for about 30% of global electric vehicle sales since 2010, second only to China, making it a compelling region to analyze to better understand. The large variation of electric vehicle policy implementation and market development across the United States makes for an especially rich laboratory for further analysis.

Figure 1 shows annual electric vehicle sales in the United States since 2010. The figure illustrates electric vehicle sales in California, other states that also adopt California's Zero Emission Vehicle (ZEV) regulation, and the rest of the United States. California and the nine other ZEV-adopting states account for about 29% of the U.S. light-duty vehicle market. The ZEV regulation requires increasing numbers of electric vehicles to be sold annually through 2025. California has seen especially high electric vehicle uptake and accounts for approximately half of the national electric vehicle market. The nine other ZEV-adopting states account for approximately 15%. As shown, electric vehicle sales increased from approximately 115,000 units in calendar year 2015 to more than 150,000 in 2016, growing by about 30%.

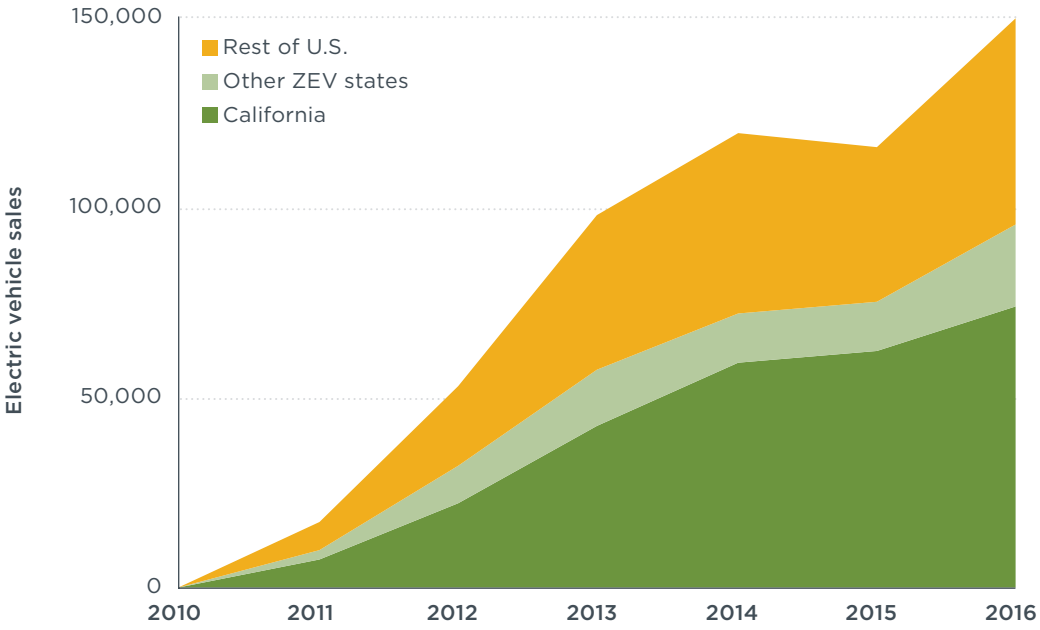

Figure 1. Annual electric vehicle sales in the United States from 2010 through 2016.

Automobile manufacturing companies are each charting somewhat different paths in their electric vehicle model offerings and annual production volumes. Figure 2 shows the eight companies with the most electric vehicle sales in the United States in 2016, including their previous 2013–2015 sales (based on HybridCars, 2016). These eight companies together represent 94% of the U.S. electric vehicle market in 2016. As shown, most companies had increased electric vehicle sales from calendar year 2015 to 2016. Electric vehicle sales growth among the companies shown in Figure 2 has generally corresponded with increased availability of new electric vehicle model offerings. For example, the growth in availability of the Tesla Model X was a large part of Tesla's 2016 growth; likewise, the second-generation Chevrolet Volt brought added sales to General Motors, and BMW offered several new plug-in hybrid electric models. Other new offerings such as the all-electric Chevrolet Bolt and the second-generation plug-in hybrid Toyota Prius (the Prius Prime) launched in the final months of 2016. A few companies sold fewer electric vehicles in 2016 than in previous years, including Nissan, which has begun shifting to a longer-range Nissan Leaf in 2016 and is expected to offer a second-generation Leaf in late 2017.

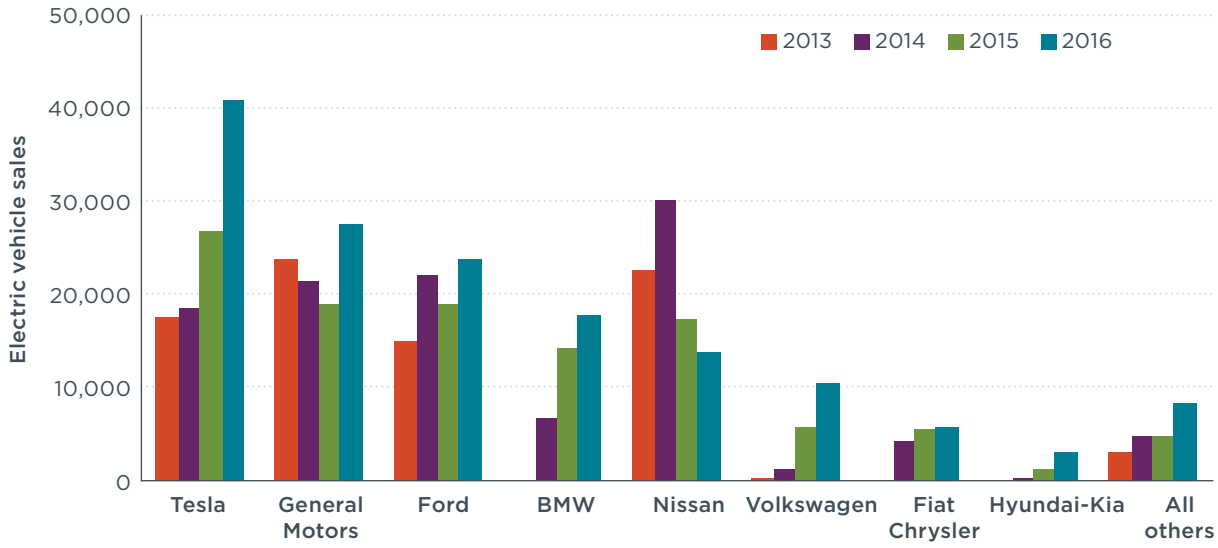

Figure 2. Automaker annual electric vehicle sales in the United States through 2016.

Most automakers have announced future electric vehicle offerings with lower cost and longer range in multiple vehicle classes, and there are some early indications that prospective consumers are awaiting the arrival of these next-generation technologies (Slowik et al., 2016). For example, when Tesla unveiled the all-electric Model 3 in March 2016, more than 300,000 prospective consumers reserved the vehicle by placing a $1,000 deposit. Several next-generation models with lower cost and longer range are available in 2017, such as the Ford Focus electric, Volkswagen e-Golf, and BMW i3. New model offerings available in 2017 include the all-electric and plug-in hybrid versions of the Hyundai Ioniq and the plug-in hybrid Chrysler Pacifica minivan. Dozens of additional electric vehicle models have been announced that are expected through 2020, indicating a general automaker trend toward greater offerings at higher volume (Slowik et al., 2016). Because these next-generation electric vehicle models are expected to enter the market at lower prices and higher volume, this is an important time for governments to consider their support policies and investments in charging infrastructure.

Electric vehicle uptake varies substantially across the United States, largely in parallel with the level of government action and support policies at the state, regional, and local levels (see, e.g., Jin et al., 2014; Lutsey et al., 2015, 2016). State and local government action on infrastructure, incentives, and information and awareness helps consumers to overcome barriers to electric vehicle adoption (NRC, 2015). Financial and nonfinancial incentives, public charging infrastructure, fleets, informational materials and tools, and public events help to overcome consumer barriers related to higher upfront costs, functional electric range and range anxiety, and an overall lack of awareness and understanding. As the market develops, leading governments are taking additional action to enhance policy effectiveness and capture a broader set of prospective consumers, beyond innovators and early adopters.

Here, we analyze the U.S. electric vehicle market in 2016, taking into account new market data, policy, and infrastructure developments. Previous analyses had identified several factors—including financial incentives, public and workplace charging infrastructure, model availability, access to high-occupancy vehicle lanes, and city actions—that are linked with higher electric vehicle uptake. In our data collection (section II), we highlight these previous studies to provide the background on factors that have driven 2010–2015 electric vehicle market growth.

We catalogue electric vehicle promotion actions, identify best-practice policies, discern statistical links between promotion actions and electric vehicle uptake, and evaluate major market trends between calendar year 2015 and 2016. In section III, we summarize and analyze all the data at a metropolitan-area level. Because the electric vehicle market is at an early stage of development, continued updates to these types of studies will reveal how the market evolves as new electric vehicles enter the market, new consumers are attracted to them, and new policy actions are implemented.

Relative to our own previous work (Lutsey et al., 2016), this analysis of the 2016 U.S. market includes more market uptake, more electric vehicle models on the market, greater local policy activity from state and city governments, and an expanded cataloguing of discrete electric vehicle promotion activities. In particular, we have expanded our assessment to include additional policies that are focused on broadening the electric vehicle market beyond early adopters.

Our final cataloging of local-level electric vehicle metrics and statistical analysis is based on the promotion actions and policies that were in place throughout the majority of calendar year 2016. A primary unit of analysis is “electric vehicle uptake”—the percentage of new vehicles registered that are plug-in electric vehicles. We also include separate statistics for battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs). The analysis is primarily focused on the 50 most populous U.S. metropolitan areas (U.S. Census Bureau, 2017), which accounted for 81% of the 2016 electric vehicle market and approximately 55% of the nation’s population. Where data are available, we also analyze the 200 most populous metropolitan areas. Ultimately, in section III, we summarize, compare, and present figures on local-level activities with electric vehicle market data, and statistically assess the relationship with a stepwise multiple linear regression analysis. We note that various consumer preference and demographic factors influence individual electric vehicle purchases; however, this study is focused on the narrower question of market response to targeted electric vehicle support activities at the metropolitan-area level.

II. DATA COLLECTION ON ELECTRIC VEHICLE PROMOTION ACTIVITIES

This section catalogues and summarizes data on state, city, charging infrastructure, and utility policies and activities that are supporting electric vehicles across major U.S. metropolitan areas. We collected information on dozens of such promotion actions that were in place in the 50 most populous U.S. metropolitan areas in 2016. When possible, we quantified the applicable data—for example, estimating the average consumer financial incentives and counts of charging infrastructure in place at the end for 2016. For discrete qualitative actions, such as electric vehicle outreach events, we simply catalogued the metropolitan areas in which the given actions or policies were implemented in 2016. The approach here follows that of three previous studies (Jin et al., 2014; Lutsey et al., 2015, 2016). We included several additional promotion actions, expanding the total tally from 33 to 43 electric vehicle promotion actions. We also clarified the definitions of several electric vehicle promotion activities to reflect the various actions that are under way. The Annex includes a list of the 43 actions and examples of metropolitan areas with those actions in place. These actions, and their implementation across the 50 most populous metropolitan areas, are summarized below.

CONSUMER INCENTIVES

Consumer incentives to promote the adoption of electric vehicles are in place in many states and metropolitan areas. Consumer incentives include purchase, operation, and parking incentives, as well as access to high-occupancy vehicle (HOV) lanes. Such incentives help consumers overcome key cost and convenience barriers, thereby giving impetus to the early electric vehicle market while technology costs fall and consumers become familiar with the technology (Slowik & Lutsey, 2016). Numerous studies have shown that purchase and other consumer incentives are linked to electric vehicle uptake (e.g., Jin et al., 2014; Lutsey et al., 2015, 2016; Tal & Nicholas, 2016; Vergis & Chen, 2014; Vergis et al., 2014; Yang et al., 2016; Zhou et al., 2016, 2017). Many state and local governments offer one or more consumer incentives, typically with the goal of reducing petroleum spending, enabling consumer fuel savings, improving local air quality, and reducing climate pollution. This section summarizes the state and local incentives in place across the 50 most populous metropolitan areas in 2016.

Purchasing incentives. State and federal incentives have been major components of electric vehicle promotion activities in the United States. At the federal level, plug-in electric vehicles are eligible to receive up to $7,500 in income tax credits for the purchase or lease of electric vehicles. This incentive applies uniformly across the metropolitan areas in this study and is not included in the city-specific analysis below.

State incentives such as rebates, tax credits, or substantial tax exemptions for the purchase or lease of an electric vehicle were available in 19 of the 50 metropolitan areas in this study. The value of incentives typically ranges from $1,000 (Utah) to as much as $6,000 (Colorado). Rhode Island began its state rebate program for up to $2,500 in January 2016. Similarly, the State of New York began offering rebates in early 2017. We include Maryland's excise tax credit in the analysis, although we note that the program funds were exhausted late in 2016. Conversely, Tennessee's rebate program expired early in 2016 and is not included here. Pennsylvania's rebate program was limited in number and availability during 2016 and is therefore not included in our analysis. In 2016, California modified its incentive program and, among other changes, increased

the rebate value for low- and moderate-income consumers by $2,000 (totaling up to $4,500 for BEVs and $3,500 for PHEVs). Purchase incentives from local governments are less common and typically of lesser value than state incentives; of the cities in this study, a $500 rebate is available in Riverside, and city and county tax exemptions are available in Seattle. The average purchase incentive value across the 50 metropolitan areas was approximately $790 for BEVs and $600 for PHEVs (excluding the federal credits). Averaging across only the areas that offered incentives, the average value was approximately $2,180 for BEVs and $1,880 for PHEVs. As done previously (Jin et al., 2014; Lutsey et al., 2015, 2016), our estimates include a population-based weighting of state incentives for the metropolitan areas that span multiple states.

Vehicle operation incentives. A few additional incentives are available after the initial purchase or lease of an electric vehicle. One or more vehicle operation incentives were available in 24 of the 50 metropolitan areas in 2016. These include exemptions from or reductions in state license and registration fees (5 areas) and emissions inspections (23 areas). Vehicle operation incentives tend to be worth approximately $100 over a 6-year ownership period. Arizona has a unique registration exemption program for BEVs that amounts to approximately $1,100.

Some states have implemented additional annual fees for electric vehicles, resulting in a disincentive in nine metropolitan areas: Colorado (Denver), Georgia (Atlanta), Missouri (Kansas City, St. Louis), North Carolina (Charlotte, Raleigh), Virginia (Richmond, Virginia Beach), and Washington (Seattle). A handful of other states have recently been considering similar legislation, in part as a means of offsetting decreased gasoline tax revenues (see, e.g., Office of the Governor of Massachusetts, 2017). However, we note that research has concluded that improved vehicle efficiency has had a much greater effect on depleting transportation budgets than electric vehicles (Vermont Agency of Transportation, 2016) at current levels of penetration, and this appears likely to be the case for several years to come (NRC, 2015).

Parking incentives. A range of state and local electric vehicle parking policies exist that provide benefits to electric vehicle drivers. Twelve of the 50 metropolitan areas in this study had some form of city-level parking incentive in place during 2016. Two states, Nevada and Hawaii, offer free parking for electric vehicles at eligible parking locations that are metered. Similarly, three cities (Cincinnati, Salt Lake, San Jose) provide free parking at all city parking meters and a limited number of participating garages. Eligibility varies by city; for example, Cincinnati's program only includes BEVs, whereas in Salt Lake City, free parking is available for all vehicles with a city-rated fuel economy above 41 miles per gallon. Vehicles displaying the Clean Air Permit in San Jose are eligible for free parking at all city parking meters and four participating parking garages that typically cost $100 for a monthly pass; the program has been funded through at least June 2018. Applying our previous methodology (Jin et al., 2014), we estimate that the 6-year value of parking incentives ranges from approximately $300 in Cincinnati to approximately $600 in Las Vegas and Honolulu. Sacramento, Nashville, and Orlando also provide local parking incentives; however, these programs are limited in number and availability, and therefore we do not quantify them here.

In addition to the direct financial parking perks described above, other examples of local parking support include policies that directly provide new designated parking for electric vehicles or policies that increase their number over time. For example, New York City's 2014 policy requires that 25% of new off-street parking be electric vehicle–ready. These types of policies typically mean that future parking facilities are equipped with the proper wiring and panel capacity to handle electric vehicle charging. As a co-benefit to

promoting electric vehicles, such forward-thinking policies are likely to provide additional financial benefits by avoiding timely and costly retrofits at a future date (CARB, 2015). There are also laws to discourage drivers of conventionally fueled vehicles from parking in designated spaces; Arizona, for example, has enacted a strong civil penalty of at least $350 for non–electric vehicle drivers parking in electric vehicle–designated spaces.

High-occupancy vehicle (HOV) lane access. Of the 50 metropolitan areas we studied, 18 allowed single-occupant electric vehicles access to HOV lanes. Our estimate of the value of HOV access is based on previous methodology (Jin et al., 2014), with updated congestion costs based on TTI's most recent Annual Urban Mobility Scorecard (Texas A&M Transportation Institute, 2015). Overall, the researchers at TTI found that annual congestion costs per auto commuter have increased modestly since 2014. As a result, our valuation of HOV access also increased. We estimate that the areas where HOV lanes have the highest 6-year ownership value are San Jose, Los Angeles, San Francisco, Nashville, and Raleigh (ranging from $3,350 in San Jose to $1,950 in Raleigh).

CHARGING INFRASTRUCTURE

Availability of charging infrastructure at home, at the workplace, and at public locations can support the adoption of electric vehicles by helping to overcome range and inconvenience barriers. A greater charging infrastructure network can increase driver confidence in the vehicle's range and expand the vehicle's operating functionality (NRC, 2015). Deployment of charging infrastructure can also offer supplemental benefits by increasing visibility and general awareness of the technology. Drivers of electric vehicles in the United States primarily charge at home, followed by the workplace and public stations (INL, 2015).

Multiple studies highlight the importance of home charging (Bailey et al., 2015; Lin & Greene, 2011; NRC, 2015). Workplace charging has been identified as statistically linked with electric vehicle adoption (Lutsey et al., 2016; Zhou et al., 2017). Furthermore, workplace charging has been reported as the most effective nonresidential charging investment for increasing electric vehicle adoption (Zhou et al., 2017). Similarly, the availability of public charging infrastructure is widely considered a key factor to encourage electric vehicle uptake (e.g., see Bakker & Trip, 2013; Li et al., 2016; Lutsey et al., 2015, 2016; Searle et al., 2016; Tietge et al., 2016).

Actions by governments, utilities, and industry are leading to a substantial increase in the size of the charging infrastructure network. Government support includes direct deployment, financial incentives for residential or commercial infrastructure, expediting of permitting and installation processes, and adoption of electric vehicle–ready building codes. Similarly, utility actions include direct installation as well as financial incentives for residential and commercial charging stations. Below, we qualitatively assess which actions are in place in each of the metropolitan areas. Multiple automakers (such as BMW, Nissan, Tesla, and Volkswagen) and partner equipment providers are also investing in charging infrastructure to support greater adoption of electric vehicles.

To quantitatively evaluate infrastructure availability across the 50 metropolitan areas, we analyzed the public and workplace charging infrastructure data from the U.S. Department of Energy (DOE) Alternative Fuels Data Center and U.S. DOE Workplace Charging Challenge (as reported by partners), respectively (U.S. DOE, 2016a; Heywood & Olexsak, 2017; U.S. DOE, 2016a). Figure 3 shows the public direct current (DC) fast charging points, public Level 2 charging points, and workplace charging points per million population in the 50 most populous metropolitan areas. In the left column, we show the relative deployment of the three most common types of DC fast charger (i.e.,

CHAdeMO, SAE Combo, and Tesla Supercharger). We note that more than 80% of the workplace charging infrastructure (right column) is Level 2, and the rest is a mix of Level 1 and DC fast (U.S. DOE, 2016b). Metropolitan areas are ordered from top to bottom according to the sum across the three columns.

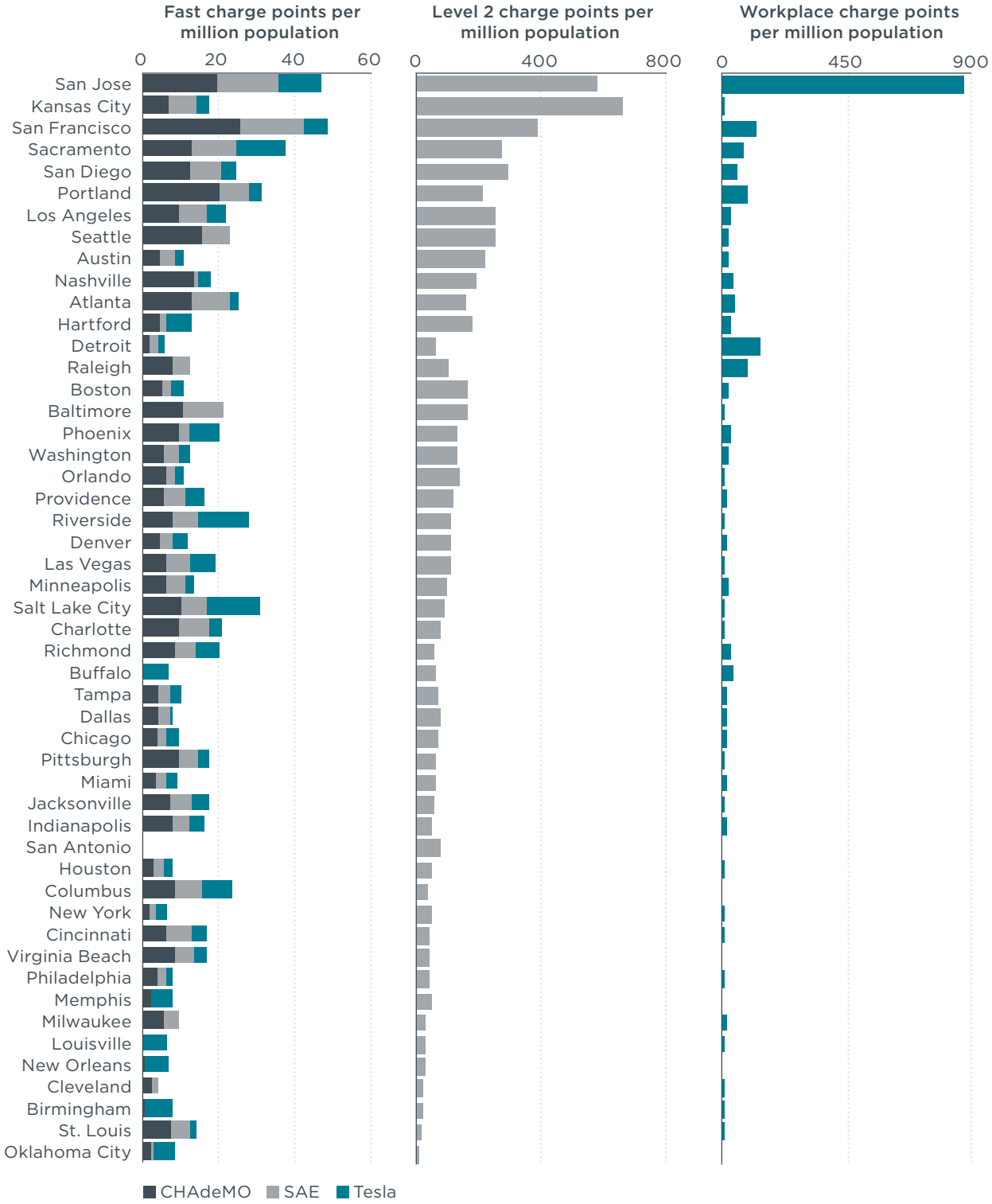

Figure 3. Public (DC fast and Level 2) and workplace charge points per capita in the 50 most populous U.S. metropolitan areas.

We make several observations from the Figure 3 data. Metropolitan areas with the most extensive charging infrastructure have roughly 30 to 40 DC fast charge points and 350 to 650 Level 2 charge points per million population. Many areas, however, had just a small fraction of that level of available public charging. Overall, the public charging infrastructure is 89% Level 2 and 11% DC fast. The 10 areas with the highest deployment of DC fast charge points per capita, in descending order, are San Francisco, San Jose, Sacramento, Portland, Salt Lake City, Riverside, Atlanta, San Diego, Columbus, and Seattle.

On average, the public charging infrastructure per capita of the top five metropolitan areas in Figure 3 exceeded that of the bottom five areas by a factor of 16. San Jose had more than 30 times the public charging infrastructure per capita of Oklahoma City. San Jose also stands out as having far greater workplace charging per capita than other cities. Several major technology companies in Silicon Valley have installed most of the workplace charging in the San Jose area; Google, for example, has installed more than 650 charge points (PEVC, 2013). Across the 50 metropolitan areas, the number of public DC fast and Level 2 charge points increased by about 60% and 30%, respectively, from the end of 2015 to the end of 2016. We investigate the potential relationship between charging infrastructure and electric vehicle uptake below.

State-level charging infrastructure actions. State governments have taken several specific actions that promote charging infrastructure. For example, low-carbon fuel standards (present in seven metropolitan areas) assist charging providers by incentivizing low-carbon transportation fuels and also provide a funding mechanism. Additional state actions include providing private charger incentives or support for residences and/or commercial businesses (20 areas) as well as providing public charger promotions such as financial incentives for charging stations at public locations or direct deployment of publicly available infrastructure (28 areas). Multiple state charging infrastructure policies directly address electric vehicles; however, a handful of state policies include "alternative fuel infrastructure" language, which could cover infrastructure for fuels such as hydrogen and natural gas (e.g., Louisiana). We continue to track these more general policies to learn whether they result in any relevant electric vehicle infrastructure developments.

City-level charging infrastructure actions. Numerous additional actions at the local level also promote charging infrastructure. At the city level, these include streamlined Electric Vehicle Service Equipment (EVSE) permitting processes (12 areas), electric vehicle–ready building codes (4 areas), EVSE financial incentives or support (2 areas), and city-owned chargers (38 areas). Select workplaces in 44 areas have made electric vehicle charging possible for employees while at work, although the availability of charging points per capita varies greatly. Electric utilities can also take action to promote charging infrastructure, as discussed below.

Chicago has streamlined the permitting process for home charger installations, enabling electricians to receive permit approvals in just 1 day (City of Chicago, 2017). Oakland, located in the San Francisco metropolitan area, has been especially forward-thinking in its implementation of electric vehicle–ready building codes. In February 2017, the city adopted standards that increase the number of plug-in–ready parking spaces for both multifamily dwellings and new commercial buildings (City of Oakland, 2016). Although the requirements differ according to the total number of parking spaces, at least 10% of parking must be fully electric vehicle–ready, and overall electric panel capacity must be capable of supporting electric vehicle charging in an additional

10% of parking spaces. Not only do such ordinances increase the feasibility of electric vehicle adoption, they also can avoid costly future retrofits, estimated at up to $6,975 per charging station (CARB, 2015).

PLANNING, POLICY, AND OTHER PROMOTION ACTIVITIES

States and cities have implemented a variety of policy and planning actions in addition to the consumer incentives and charging infrastructure actions described above. These policies and activities generally fall into areas that include state regulation, state and city policy planning, electric vehicle fleet initiatives, and other outreach and education awareness activities. Many electric power utilities also fill a role in this space and stand to benefit from greater electric vehicle adoption (Hall & Lutsey, 2017).

Zero Emission Vehicle regulation. The U.S. market as a whole is subject to vehicle efficiency and carbon dioxide emissions regulations that, to some extent, promote greater electric vehicle uptake. U.S. EPA estimates that about 5% of the national new light-duty vehicle sales in 2025 will need to be plug-in electric to comply with the standards (U.S. EPA, 2016). Ten U.S. states—California, Connecticut, Maine, Maryland, Massachusetts, New Jersey, New York, Oregon, Rhode Island, and Vermont—have adopted California's Zero Emission Vehicle (ZEV) regulation, which goes further by requiring incrementally greater electric vehicle sales over time. Of the 50 metropolitan areas in this analysis, 13 are in states that have adopted the ZEV regulation. The program requires at least 8% of new vehicle sales to be electric in 2025 in California (CARB, 2017). The ZEV regulation, in turn, pushes for greater electric vehicle model availability and greater marketing effort by automakers (NESCAUM, 2016, 2017).

The ZEV regulation currently differs functionally across ZEV states. For example, automakers can focus early electric vehicle deployment in California and delay efforts in other ZEV states to foster technology development and manage associated costs. This flexibility ends in 2018, and manufacturers will be required to offer increasing numbers of electric vehicles in ZEV states outside of California. To supplement the effectiveness of the ZEV regulation, many states have implemented a statewide or multi-state roadmap or action plan to help support ZEV deployment (see, e.g., California Office of the Governor, 2016; NESCAUM, 2013, 2014).

ZEV Alliance participation. Multiple states have taken additional steps to accelerate electric vehicle adoption by increasing collaboration and best-practice learning through information exchange with proactive governments around the world. The International Zero-Emission Vehicle Alliance is a 14-member consortium of eight U.S. states (California, Connecticut, Maryland, Massachusetts, New York, Oregon, Rhode Island, and Vermont), two Canadian provinces, and four European nations (International Zero-Emission Vehicle Alliance, 2017). Alliance members strive to make all new passenger vehicles in their jurisdictions zero-emission vehicles by no later than 2050; 13 of the 50 metropolitan areas in this analysis reside in states that participate in the ZEV Alliance.

Direct sales. One factor that affects electric vehicle sales is the ability for companies to sell new vehicles directly to customers, as opposed to the traditional automobile dealership franchising model used by conventional manufacturers. Different states have different rules that prohibit such direct sales, and this affects start-up companies such as Tesla (and potentially others). Tesla Motors emerged in 2003 and has since become one of the highest-volume electric vehicle automakers, with about 30% of the U.S. market (see Figure 2). For a variety of reasons (see Tesla, 2012), the company

chose not to pursue the traditional franchise dealership model to distribute and service its vehicles. In 2014, Michigan adopted legislation making it impermissible for vehicle manufacturers to "sell any new motor vehicle directly to a retail customer other than through franchised dealers" (Michigan Legislature, 2014). In contrast, Maryland in 2015 passed a law that, among other things, authorizes "a manufacturer or distributor to be licensed as a vehicle dealer if the manufacturer or distributor deals only in electric or nonfossil-fuel burning vehicles" (Maryland General Assembly, 2015). Laws such as those in Michigan hinder the direct sale of vehicles from automaker to consumer. We find that 11 states have blocked or significantly limited direct vehicle sales in their jurisdictions. Of the 50 metropolitan areas in this analysis, 36 allow direct sales.

City electric vehicle strategies. Many metropolitan areas have some form of local or regional electric vehicle strategy. These are commonly called electric vehicle "action" or "readiness" plans; many were supported by the DOE Clean Cities program (U.S. DOE, 2016c). Such strategies play an important role by creating a forum and network of local and state governments, utility companies, charging providers, auto dealerships, and other organizations to discuss common issues about the growth of the electric vehicle market. City electric vehicle strategies often have a dual purpose: to identify and shape local actions to overcome key barriers (e.g., cost, convenience, infrastructure, awareness) to electric vehicle adoption, and to prepare local infrastructure and utilities to support a substantial number of electric vehicles on local roads. We found that 25 of the 50 metropolitan areas had electric vehicle strategies in place.

Public outreach and awareness activities. Consumer awareness and education is key to widespread electric vehicle adoption; however, despite actions to date, the public lacks basic knowledge related to electric vehicles (Jin & Slowik, 2017; Kurani et al., 2016; NRC, 2015; Singer, 2015). A variety of actions can be taken to increase familiarity and general understanding of electric vehicles and their key features, such as available models, cost savings, available financial and nonfinancial incentives, charging infrastructure, and environmental benefits. We found that 28 of the 50 metropolitan areas provided online informational materials, and 46 areas hosted some sort of outreach event. Drive Electric Chicago is a particularly informative website, providing information about electric vehicle technology, the economic and environmental benefits it offers, a fuel cost savings calculator, installation instructions for single-family homes as well as apartment buildings and condos, a map of available public charging stations, and links to other additional resources (City of Chicago, 2017). Online resources offered by cities and utilities vary drastically in the type and level of detail they provide, as well as the accessibility of the information. Although we do not evaluate the differences quantitatively, we note that there is some evidence that comprehensive, locally focused information that is accessible within three or fewer clicks is best suited to support prospective electric vehicle buyers (Santini et al., 2016).

Outreach events are an effective way to raise awareness and increase familiarity. These include electric vehicle showcases, ribbon-cutting ceremonies for new public charging stations, and ride-and-drive events. National Drive Electric Week is one of the largest outreach programs, with 235 events in 212 cities. Many local governments participate in or support the events, which include proclamations by local officials, ribbon-cuttings for new public charging stations, charging station giveaways, ride-and-drives, technology demonstrations, and more (Plug In America, 2016). Although it is difficult to quantify the effectiveness of outreach events in spurring electric vehicle uptake, there is apparent evidence of success. For example, the California Plug-in

Electric Vehicle Collaborative reported that after attending the 2016 Best.Drive.EVer! ride-and-drive series, 9% of survey respondents purchased or leased an electric vehicle within 3 months (PEVC, 2017). Many others reported visiting dealerships (22%), talking to electric vehicle owners (34%), researching electric vehicles online (63%), or sharing their experiences with friends/family (83%) and co-workers (25%), enhancing the greater community network effect and increasing overall awareness.

In addition, some local outreach programs have especially been taking strides to expand the electric vehicle market beyond the early adopters. One element of California's ZEV Action Plan, for example, is to increase the visibility of electric vehicles through education and outreach programs to build awareness in disadvantaged communities that are subject to socioeconomic challenges and environmental pollution (California Office of the Governor, 2016). We identified 12 areas that held some sort of electric vehicle outreach event in low-income communities. The National Drive Electric Week event in Watts in Los Angeles, California, for example, included test drives as well as financing and rebate information to highlight the state financial incentives geared toward lower-income consumers (Sierra Club, 2016). Another action to expand the market is to educate prospective consumers in multifamily properties (commonly referred to as multi-unit dwellings), where a substantial share of major metropolitan area populations resides. The installation of charge points for multi-unit dwellings involves unique challenges and complications (CSE, 2016a), hence greater effort and understanding are needed to overcome these barriers. We found seven metropolitan areas where electric utilities provide information specific to multifamily properties or multi-unit dwellings.

Promoting local manufacturing of electric vehicle technology also contributes to consumer awareness by connecting communities with local businesses in the industry. Electric vehicle manufacturing incentives vary by state; some have offered direct funding and grants for electric vehicle manufacturing, whereas others provide incentives under broader green or clean manufacturing programs. We identified 15 metropolitan areas that reside in states with some sort of manufacturing incentive for electric vehicles or their components, such as Georgia, Louisiana, South Carolina, and Virginia (U.S. DOE, 2016d).

Fleets. Integrating electric vehicles into fleets directly increases their use while helping to overcome barriers to their wider adoption by increasing overall visibility and exposure (Jin & Slowik, 2017; NRC, 2015). There are many government fleet-based electric vehicle programs. The range of government actions related to electric vehicle fleets includes state fleet purchasing incentives (17 areas), local electric vehicle carsharing programs (16 areas), general municipal green fleet targets (37 areas), specific municipal electric vehicle fleet targets (17 areas), and use of electric buses in public transportation fleets (15 areas).

Multiple states offer financial incentives for electric vehicle procurement in fleets. Massachusetts, for example, has offered a fleet electric vehicle incentive program since 2014, which aims to increase the technology's visibility to the public (Commonwealth of Massachusetts, 2017). Public entities in the state, such as municipal governments, public universities, and state agencies, are eligible for incentives, which are worth $5,500 per PHEV, $7,500 per BEV, and up to $13,500 for dual-head charging stations. Colorado also offers financial incentives for fleets of electric vehicles and their

infrastructure and has made the program available to both the public and private sectors (Colorado Clean Air Fleets, 2017).

Fleet programs at the local level include carsharing programs, municipal green fleet targets, and municipal electric vehicle targets. In Indianapolis, the local carsharing program BlueIndy is expanding its program toward 500 all-electric Bolloré Bluecar vehicles and 200 charge points (BlueIndy, 2017). The City of Milwaukee has set alternative fuel targets for its municipal fleet; however, electric vehicles are not the primary technology of interest in the program (Wisconsin Smart Fleet, 2017). In contrast, some local governments have set explicit electric vehicle deployment targets for their municipal fleets. For example, Columbus plans to integrate 200 electric vehicles and their charging infrastructure into its municipal fleet (Clean Fuels Ohio, 2016). Indianapolis has also set goals to expand its municipal "Freedom Fleet" to 425 electric vehicles. Under the Freedom Fleet program, employees can take home and charge the municipally owned electric vehicles, providing direct experience, increased visibility, and general awareness of the technology (Vision Fleet, 2015).

A few cities have also taken steps toward launching dedicated electric carsharing programs in low-income communities. The largest is Los Angeles, where more than $10 million in state, local, and private-sector funding will go toward deploying 100 electric vehicles and 200 charging stations in disadvantaged communities that are subject to socioeconomic challenges and environmental pollution (City of Los Angeles, 2016). The project is expected to serve more than 7,000 unique users within 3 years. Low-income electric carsharing programs have also been announced in Sacramento and Portland. The pilot programs will begin with eight and three BEVs, respectively (Forth Mobility, 2017; Sacramento Metropolitan Air Quality Management District, 2017). These programs were not implemented by the end of 2016 and therefore are not included in the summary of promotion actions below.

Another local-level fleet program is use of electric buses in public transportation. Deploying electric buses in municipal transit systems directly increases their use while also enhancing overall visibility and awareness. The local transit authority in Louisville, for example, is investing $4.65 million to add six all-electric buses to its local fleet, expanding the fleet to include 15 all-electric buses (Proterra, 2016). One particularly active city in this space is Seattle. Following a feasibility study, King County Metro recommended that all new bus purchases be zero-emission (see King County Metro, 2017). Current electric bus technology can meet 70% of the agency's service needs, reaching 100% with continued expected advancements. Furthermore, the agency concluded that transitioning to a fully electric bus fleet (around 1,400 buses) will reduce Metro's emissions by 80% and advance social equity, while only increasing total lifecycle costs by around 6%. The feasibility report accompanies the agency's recent announcement to procure 120 all-electric buses by 2020.

Utility companies. Utility support of electric vehicles is becoming increasingly common in many areas throughout the United States. Research indicates that utilities stand to benefit from greater adoption of electric vehicles, such as their potential to increase revenue, reduce rates, and manage grid loads (see, e.g., Hall & Lutsey, 2017; Lowell et al., 2017; Ryan & Lavin, 2015; Salisbury & Toor, 2016). Early utility involvement in this area includes actions to educate and steer consumers toward electric vehicles and optimal charging practices. Such actions by utilities include charging pilot studies or research

(31 areas), offering time-of-use rates (39 areas), distributing informational materials or hosting outreach events (47 areas), providing a cost comparison tool (23 areas), and procuring electric vehicles in the utility fleet (34 areas).

Several especially forward-thinking utilities are exploring additional actions, such as offering preferential rates for electric vehicle charging (19 areas), electric vehicle or EVSE financial incentives (6 areas), and direct deployment of or investment in public charging infrastructure (15 areas). Some utilities are taking strides to expand the electric vehicle market by providing EVSE informational materials specific to multifamily properties (7 areas), deploying public charging infrastructure in low-income communities (4 areas), and offering increased financial incentives for semi-public EVSE at multifamily properties (1 area).

Procuring electric vehicles for a utility fleet can lower total fleet costs, improve safety, and reduce emissions while also enhancing consumer awareness, brand image, and public relations through community visibility and employee expertise with the technology and the benefits it offers (Edison Electric Institute, 2014). In late 2015, Pacific Gas & Electric in Northern California announced plans to invest 33% of its annual fleet budget (approximately $100 million over 5 years) in electric vehicle technology. The investment will grow the utility's electric fleet from around 1,400 to more than 2,150 vehicles (PG&E, 2015). Integrating electric vehicles into the utility fleet has helped to lower fuel and maintenance costs, extend vehicle operating life, and reduce emissions, and has positioned the utility to deliver electricity during emergencies (PG&E, 2015).

A few utilities offer some sort of financial incentive for electric vehicles or their infrastructure. The Orlando Utilities Commission, for example, offers a $200 rebate for the purchase or lease of an electric vehicle (Orlando Utilities Commission, 2017). Austin Energy provides incentives for both residential and commercial EVSE, valued at up to $1,500 for privately owned Level 2 residential stations and up to $10,000 for hosting a DC fast station. Several utilities in California launched rebate programs for electric vehicles or their infrastructure in early 2017, funded by the statewide Low Carbon Fuels Standard. Incentive values include one-time payments of $500 to $600 (e.g., PG&E, LADWP, SMUD) and annual $50 incentives for electric vehicle drivers (e.g., SDG&E) (Mulkern, 2017).

Some utilities are targeting barriers faced by particular housing types to help broaden the electric vehicle market. Electric utilities in Atlanta, Austin, and Seattle, for example, provide EVSE informational materials and instructions that are specific to multifamily properties as a first step to expand the market (Austin Energy, 2017; Georgia Power, 2016; Seattle City Light, 2017). Austin Energy also offers increased EVSE financial incentives ($4,000 versus $1,500) for Level 2 charging stations at multifamily properties if they are available to all residents (Austin Energy, 2017). In contrast, some metropolitan areas have heightened barriers for multi-unit dwellings. For example, First Energy Corporation in Ohio does not consider EVSE installations at multi-unit dwellings to be "standard installations" and has made these installations subject to additional costs (First Energy Corporation, 2016).

Utilities are increasingly investing in, or directly deploying, publicly available charging infrastructure. For example, Kansas City Power & Light's "Clean Charge Network" currently has more than 1,000 Level 2 charging stations (KCP&L, 2017). In California,

the state Public Utilities Commission has approved rate-based EVSE rollout plans by Southern California Edison, San Diego Gas & Electric, and Pacific Gas & Electric that will deploy 1,500, 3,500, and 7,500 charging stations in their respective service territories, with at least 10% located in disadvantaged communities (see CPUC, 2016; Edison International, 2016; SDG&E, 2016). Utilities in Oregon may soon be headed in a similar direction, now that Oregon has enacted laws allowing major utilities to submit plans for public EVSE deployment (Pacific Power, 2017). Missouri utility Ameren has submitted plans to build public charging stations along a heavily travelled interstate highway in order to accommodate electric vehicles (Ameren, 2016). Duke Energy is allocating $1.5 million to cities and organizations across North Carolina to install public charging stations and electric bus charging infrastructure as part of the utility's settlement with U.S. EPA. The project is expected to increase public charging infrastructure there by 30% (Duke Energy, 2016). There are also a handful of smaller programs in which utilities are co-funding or supporting state efforts, such as those by Jacksonville Electric Authority and NV Energy (see JEA, 2017; NV Energy, 2015).

EXPANDING THE MARKET BEYOND EARLY ADOPTERS

As the market develops, as indicated by the research above, proactive governments and utilities are increasingly looking to capture a broader set of prospective consumers beyond early adopters. The data suggest that innovators and early adopters of electric vehicles typically are educated, middle-aged, married, and male, and they typically have relatively high incomes and reside in detached homes (CSE, 2016b; NRC, 2015). As governments seek to develop the broader mainstream market, they continue to make efforts to reach prospective consumers outside of these categories.

As discussed above, several actions to date have worked to remove barriers and expand access to a broader set of prospective consumers. In Table 1, we summarize new actions that are designed to expand the market beyond early adopters that we are tracking in this report. As this constitutes a growing trend and a large set of additional actions for our annual electric vehicle report, we provide this additional summary of actions that cross-cut the above categories. As shown in the table, we are tracking several new actions: two at the state level, three at the city level, and three at the utility level. These actions help to promote the expansion of electric vehicles and to provide associated social, environmental, and economic benefits to residents, especially in low-income communities.

Table 1. Promotion actions and policies designed to expand the electric vehicle market.

Action	Description	Rationale	Example
State BEV (and PHEV) incentive increases for moderate- and low-income consumers	Increased rebate values for consumers who meet certain income criteria	Support the adoption of zero-emission vehicle technology by low- and moderate-income consumers	California Clean Vehicle Rebate
City outreach events in low-income communities	Outreach and education events, such as ride-and-drives and vehicle showcases	Increase consumer awareness and understanding about the multitude of benefits electric vehicles offer, as well as available incentives, perks, and programs	National Drive Electric Week, Watts, California
City electric buses in public transportation	Electrification of municipal transit buses	Lower total cost of operation, reduce climate and air pollution, and raise awareness of clean transportation	Transit Authority of River City, Louisville, Kentucky
City electric vehicle carsharing programs in low-income communities	Deployment of an electric carsharing fleet and infrastructure	Provide affordable zero-emission transportation options to communities that may otherwise lack equitable access	City of Los Angeles (forthcoming)
Utility public charging infrastructure in low-income communities	A percentage of utility-deployed public charging in low-income communities	Support electric vehicle adoption by expanding access to charging infrastructure in underserved communities	San Diego Gas & Electric
Utility incentive increases for EVSE at multifamily properties	Greater rebates available for charging stations at multifamily properties	Support the adoption of electric vehicles and expand access to charging infrastructure	Austin Energy
Utility EVSE informational materials for multifamily properties	Consumer-oriented information that details the process for installing EVSE	Overcome unique challenges and complications related to installing EVSE at multifamily properties	Seattle City Light

We identify several actions specifically targeted at expanding access to electric drive. As shown, these actions include state BEV and PHEV incentive increases for moderate- and low-income consumers (6 California areas), city targeted outreach events in low-income communities (12 areas), city electric buses in public transportation (15 areas), city electric vehicle carsharing programs in low-income communities (pending, but no areas launched as of January 2017), utility public charging infrastructure in low-income communities (4 California areas), utility incentive increases for EVSE at multifamily properties (1 area), and utility EVSE informational materials for multifamily properties (7 areas). We also note that lack of consumer awareness and knowledge is one of the primary barriers to expanding the market to widespread adoption (Kurani et al., 2016; NRC, 2015) and is a key factor in any effort to broaden the adoption of electric vehicles.

SUMMARY OF ACTIONS

The implementation of the actions described above is summarized in Table 2, categorized across columns into state, local, and utility areas of action. The cataloging of actions shown in Table 2 includes only those that were in place throughout the majority of 2016. The 50 metropolitan areas are ordered from top to bottom by total number of electric vehicle promotion actions. As shown, the level of policy action varies greatly across the 50 areas. Six areas in California have adopted the most actions, implementing 30 to 36 of the 43 actions that we discuss in this paper.

Table 2. Electric vehicle promotion actions across major U.S. metropolitan areas.

Metropolitan area	State action															Local action																						Utility action									Total actions (out of 43)
	State ZEV program	State international ZEV Alliance participation	State low carbon fuel policy	State BEV purchase incentive	State PHEV purchase incentive	State increased BEV incentive for low-income	State increased PHEV incentive for low-income	State fee reduction or testing exemption	No state annual electric vehicle fee	State private charger incentive, support	State public charger promotion	State parking benefit	State fleet purchasing incentive	State manufacturing incentive	State allows direct sales to consumers	City electric vehicle strategy	Streamlined EVSE permitting process	EV-ready building code	City vehicle purchase subsidy	City parking benefit	City EVSE incentive, support	City carpool lane (HOV) access	City-owned EV chargers	US DOE EV Project key area	Workplace charging	City car sharing program link	City informational materials	City outreach events	City outreach events in low-income communities	City green fleet target	City electric vehicle fleet target	City electric buses in public transportation	Utility charging pilot or other research	Utility public charging infrastructure	Utility public charging infrastructure in low-income communities	Utility time of use rates offered	Utility preferential EV rates	Utility EV or EVSE incentive, support	Utility increased incentives for EVSE at multifamily properties	Utility info materials or outreach events	Utility EVSE informational materials for multifamily properties	Utility cost comparison tool	Utility electric vehicle fleet	
Los Angeles	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X					X	X	X	X	X	X	X	X	X	X	X		X	X	X		X	X		X	36
San Francisco	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X						X	X	X	X	X	X		X	X	X		X	X	X	X	X	X		X		X	X	34
San Jose	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X			X			X	X		X		X	X		X	X		X	X	X	X	X	X		X		X	X	32
Sacramento	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X				X			X	X		X		X	X	X	X	X		X	X		X	X			X		X	X	31
Riverside	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X		X				X	X		X		X			X			X	X	X	X	X			X	X	X	X	31
San Diego	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X							X	X	X	X		X	X		X	X		X	X	X	X	X			X			X	30
Portland	X	X	X	X	X			X	X	X	X		X		X	X	X						X	X	X	X	X	X	X	X	X	X		X	X		X				X		X	X	29
New York	X	X		X				X	X	X	X		X		X	X	X	X		X		X	X		X	X	X	X		X	X		X			X	X			X		X		26
Seattle				X	X			X		X	X		X	X	X	X	X		X				X	X	X	X	X	X		X	X	X									X	X	X	X	24
Denver				X	X			X		X	X		X		X	X		X		X			X		X	X	X	X		X	X	X				X					X		X	X	22
Atlanta								X			X			X	X	X	X					X	X	X	X		X	X		X	X		X	X		X	X	X		X	X		X		22
Baltimore	X	X		X	X			X	X	X	X		X		X								X		X		X	X	X	X		X	X			X	X			X			X	22
Boston	X	X		X	X			X	X	X	X		X		X					X			X		X		X			X			X			X				X		X	X	21
Philadelphia				X					X		X		X		X	X				X			X	X	X	X	X	X	X	X	X	X		X			X		X		X		X		21
Chicago								X	X				X	X	X		X				X			X	X	X	X	X		X		X				X				X	X	X	X	19
Austin								X	X							X				X			X		X			X		X	X		X	X		X	X	X	X	X	X	X		18
Washington				X	X			X	X	X	X		X		X						X	X		X	X	X		X							X					X			X	18
Raleigh								X		X	X		X		X	X	X					X	X		X		X	X	X	X			X			X				X			X	18
Charlotte					X			X		X	X		X	X		X	X					X	X		X		X	X		X			X			X				X			X	18
Salt Lake City				X	X				X		X							X		X		X	X		X		X	X		X			X			X				X		X	X	17
Houston								X	X							X	X						X	X	X	X	X	X		X	X					X	X			X		X	X	17
Phoenix								X	X	X		X										X	X	X	X		X	X					X			X	X			X		X	X	16
Indianapolis									X					X	X	X							X		X	X		X		X	X	X	X	X		X	X			X				16
Hartford	X	X		X	X			X	X		X												X		X			X					X			X				X		X	X	15
Minneapolis									X						X								X		X	X	X	X		X			X			X	X			X		X	X	14
Richmond													X	X	X	X						X	X		X		X	X		X			X				X			X			X	14
Orlando									X						X	X				X			X		X		X	X		X	X			X				X			X		X	14
Las Vegas								X	X			X			X					X			X		X			X						X			X	X			X		X	13
Providence	X	X		X	X			X	X		X		X		X										X			X															X		X	13
Kansas City										X	X				X	X							X		X	X	X	X		X				X			X				X				13
St. Louis								X		X	X		X	X	X										X	X		X		X							X				X		X		13
Miami									X						X	X						X			X			X				X				X				X		X	X	12
Jacksonville									X						X								X		X		X	X	X				X	X				X			X			12
Cincinnati									X		X				X					X			X		X		X	X					X			X						X		12
Cleveland								X	X		X				X	X									X			X					X			X				X		X	X	12
New Orleans				X	X			X	X					X												X		X	X	X	X		X					X						12
Nashville									X						X					X		X	X	X	X					X	X	X						X						11
Pittsburgh									X		X		X		X								X		X			X	X	X	X					X								11
Dallas								X	X														X	X	X			X		X		X				X				X		X		11
Buffalo	X	X						X	X	X	X		X		X										X	X										X									11
Oklahoma City									X	X	X																	X	X	X		X			X				X		X	X	11
Tampa									X						X	X							X		X		X	X											X		X	X	10
Memphis									X						X							X	X	X				X				X		X					X			X	10
San Antonio									X							X							X				X	X	X	X		X						X				X		10
Detroit								X	X														X		X			X		X						X	X							9
Columbus									X		X				X	X							X				X	X		X			X										9
Milwaukee								X	X														X		X		X	X		X						X								9
Virginia Beach													X	X	X							X					X					X				X						X		9
Louisville									X																X		X	X		X		X				X								8
Birmingham									X																X								X				X	X			X	X			7

"X" denotes an electric deployment action in place in the metropolitan area in 2016. ZEV = Zero Emission Vehicle; BEV = battery electric vehicle; PHEV = plug-in hybrid electric vehicle; HOV = high-occupancy vehicle lane; EVSE = Electric Vehicle Service Equipment.

III. ANALYSIS OF ELECTRIC VEHICLE MARKET

This section evaluates the electric vehicle market and the underlying factors that affect its growth. We analyze electric vehicle uptake, measured as the percentage of new light-duty vehicle registrations that were plug-in electric vehicles in calendar year 2016. Vehicle registration data are from IHS Automotive. We then compare the data on electric vehicle uptake and public charging infrastructure, model availability, policy incentives, and promotion actions across the major cities. The relationship between electric vehicle uptake and these factors is analyzed and further discussed in the statistical analysis below.

ELECTRIC VEHICLE UPTAKE

The U.S. electric vehicle market surpassed 150,000 new registrations in 2016, up approximately 30% over 2015. As a percentage of all U.S. light-duty vehicle registrations, electric vehicles accounted for around 0.9% of the market. Electric vehicle registrations in the 50 metropolitan areas in our study account for about 81% of the total market; these areas constitute about 61% of the total light-duty vehicle market and 55% of the U.S. population. Electric vehicle uptake in these 50 metropolitan areas exceeds the rest of the country by a factor of 3 (i.e., 1.2% versus 0.4%). In 2016, the U.S. electric vehicle market was about evenly split between BEVs and PHEVs.

Figure 4 shows the share of new vehicles that are plug-in electric across the more than 900 metropolitan statistical areas. The 50 most populous areas are labeled. Electric vehicle uptake tends to be highest in major metropolitan areas on the West Coast. California alone accounted for about half of the total U.S. electric vehicle market in 2016. San Jose had the highest share at 10%, followed by a handful of other California cities at 4% to 6%.

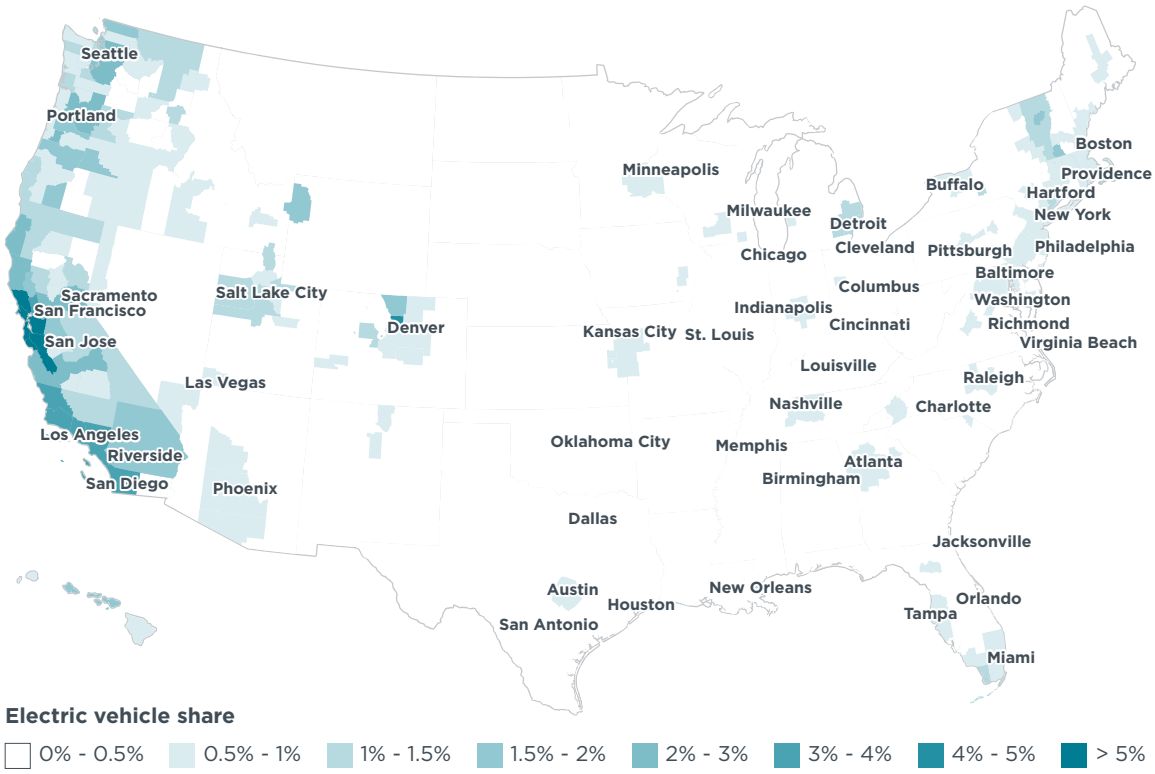

Figure 4. Electric vehicle share of new 2016 vehicle registrations by metropolitan area.
(New vehicle registration data from IHS Automotive.)

We analyzed the data to identify major changes from 2015 to 2016. Overall, the national electric vehicle market increased approximately 30%. We note several areas that experienced substantial growth. In terms of number of new electric vehicle registrations, the three areas with the largest annual increases were Los Angeles (from about 23,600 to more than 30,000), New York City (from about 4,500 to more than 8,000), and Detroit (from about 1,200 to more than 4,500). In addition, electric vehicle registrations increased by more than 1,000 units in San Diego, Washington, DC, and San Jose relative to 2015. Only one of the 50 most populous metropolitan areas, Atlanta, experienced a decrease in new electric vehicle registrations (from about 6,500 to 2,300); 2016 was the first full year without the consumer incentive and with the annual electric vehicle fee in Georgia.

In terms of percent growth from 2015 to 2016, several metropolitan areas stand out. Detroit experienced more than 280% growth in new electric vehicle registrations from 2015 to 2016. Charlotte, Kansas City, Minneapolis, Pittsburgh, Providence, and Virginia Beach saw 100% to 130% year-over-year growth. In addition, Memphis, Jacksonville, Richmond, New York City, and Salt Lake City grew 99% to 76% from 2015 to 2016. (These and other high-growth areas are discussed in Table 3 below.) Year-over-year electric vehicle registration growth was 50% or greater in 24 of the 50 most populous metropolitan areas. Similarly, 38 of the 50 areas experienced more than 30% growth from 2015 to 2016. There were also many smaller cities with high percent increases between 2015 and 2016. In the opposite direction, new electric vehicle registrations fell 64% in Atlanta, reflecting the absolute value decrease noted earlier.

Although our focus is on the most populous metropolitan areas, Figure 4 also reveals relatively high electric vehicle sales in a number of smaller metropolitan areas (as defined by the U.S. Office of Management and Budget; see U.S. Census Bureau, 2017) in Colorado, Hawaii, Oregon, Vermont, and Washington. Electric vehicle shares in these markets were typically several times higher than their region's average. In particular, Fort Collins (2% electric share) and Boulder (4%) in Colorado were 2.7 to 5.6 times, respectively, the Mountain region's average electric vehicle uptake. In the Northwest, Corvallis (and many other Oregon areas) and Bremerton, Washington, are similar to Portland and Seattle, with approximately a 2% electric vehicle share. Several Hawaii communities had electric vehicle shares around 1.5%, and Juneau, Alaska (not pictured) had a 2.6% electric vehicle share. In the Northeast, Barre and Burlington (Vermont), Keene (New Hampshire), Bridgeport (Connecticut), and Ithaca (New York) led the region with 1.3% to 1.8% electric vehicle shares, which amounted to 2.5 to 3.5 times the regional average. In Michigan, Ann Arbor had an electric vehicle share of 1.3%, 2.6 times the Midwest regional average. Key West (Florida) and Durham–Chapel Hill (North Carolina) led in the South with about a 1% electric vehicle share, which was about 3 times the regional average.

PUBLIC CHARGING INFRASTRUCTURE

As mentioned above, charging infrastructure at public locations supports the adoption of electric vehicles. Our analysis of public charging infrastructure across the metropolitan areas is based on the U.S. Department of Energy Alternative Fuels Data Center database (U.S. DOE, 2016a). We evaluate public charging infrastructure per million population in each area. Figure 5 shows how the public Level 2 and DC fast charging infrastructure corresponds to electric vehicle uptake in the 200 most populous metropolitan areas. The horizontal axis shows the public Level 2 and DC fast charging infrastructure per million population; the vertical axis shows electric vehicle uptake in

2016. The size of each data circle represents the electric vehicle market size in each area; the largest data circle is Los Angeles, with more than 30,000 new electric vehicle registrations in 2016. The U.S. average is shown as approximately 0.9% electric vehicle uptake and 110 public Level 2 and DC fast chargers per million population.

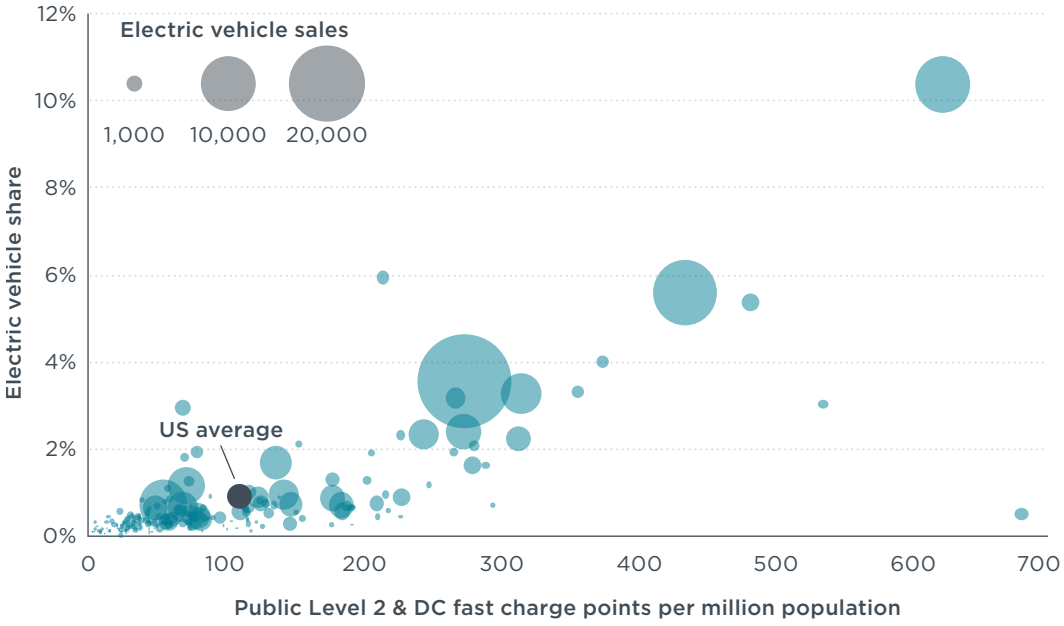

Figure 5. Electric vehicle share of new vehicles versus public charge points per population in the 200 most populous metropolitan areas.

As shown in Figure 5, many areas with the highest electric vehicle share also had relatively high deployment of public charging infrastructure. Areas with the highest electric vehicle uptake tended to have 2 to 6 times greater than average public charging infrastructure. Of the 20 areas with the highest electric vehicle share, 18 had greater than average charging availability. Six of the 10 areas with the highest electric vehicle share had public charging infrastructure availability that was more than 3 times the national average. Averaging across the 200 areas, DC fast charge points account for approximately 16% of the total public charging infrastructure; however, the deployment of DC fast and Level 2 charging stations varies greatly across the areas. Figure 3 provides more details regarding the breakdown of DC fast and Level 2 charge points per capita across the 50 most populous metropolitan areas. The potential link between charging infrastructure and electric vehicle uptake is further explored in the statistical analysis below.

Several additional observations stem from the analysis shown in Figures 3 and 5. The data suggest near-term benchmarks of at least 25 DC fast and 250 Level 2 charge points per million population are sufficient for higher electric vehicle uptake at this point in the market development through 2016. High electric vehicle uptake areas also appear to deploy roughly 10 public Level 2 chargers for each DC fast charger. There are several areas clustered around 245 to 320 public charge points per million population and about 2% to 4% electric vehicle uptake, including Seattle, Portland, Honolulu, Fort Collins, and several California cities. This approximate level of charging is also seen in Austin, Nashville, and Durham, which are starting to develop the infrastructure to support

market growth but still have electric vehicle uptake that is around the national average. Emerging markets continue to build out their charging infrastructure. From the end of 2015 to the end of 2016, the number of the 200 most populous metropolitan areas with more than 200 public charge points per million residents increased from 18 to 29. Many cities, however, have much lower charging availability than those benchmarks. Whereas the leading cities offer at least 275 public charge points per million residents, more than half of the U.S. population lives in an area that has 70% lower public charging availability than the leading-city benchmark.

We also investigated relationships in the charging infrastructure data other than those discussed above. For example, the relationship between cumulative electric vehicle sales (since 2010) and charging infrastructure was similar to the data on charge points per capita shown in Figure 5. The data suggest that leading electric vehicle markets tend to have above 20 electric vehicles for each public charge point in 2016. This includes areas such as Seattle, Portland, Honolulu, Ann Arbor, Boulder, Burlington, and several California cities with relatively high electric vehicle uptake. We are reluctant to suggest any such electric vehicle-to-charge point benchmarks. It is unclear if any conclusion regarding whether there is a relative oversupply or scarcity of public charging per electric vehicle can be determined from these early market developments. We also analyzed the relationship between electric vehicle uptake and public charge points per light-duty vehicle. The result was again similar to the data in Figure 5, as new vehicle ownership patterns tend to be relatively similar when assessing large populations across major U.S. metropolitan areas.

MODEL AVAILABILITY

Consumer vehicle make and model preferences vary widely, so the availability of a range of electric vehicle models is a key factor in the broader adoption of electric vehicles (see, e.g., NRC, 2015). Electric vehicle model availability tends to be much lower outside of California (NESCAUM, 2017; Reichmuth & Anair, 2016). Since 2012, when there were just a handful of smaller car models on the market, electric vehicle offerings have greatly expanded. Although the number of non-electric models is in the hundreds, the proliferation of electric models is greatly expanding the market to more prospective customers. As of the end of 2016, there were a variety of available BEV and PHEV vehicle models, including subcompacts and minis (e.g., Smart ForTwo, Fiat 500e), hatchbacks (e.g., Nissan Leaf, Ford C-Max Energi), smaller luxury cars (e.g., BMW i3, Audi A3), midsize cars (e.g., Ford Fusion Energi, Toyota Prius Prime), luxury sport utility vehicles (e.g., Tesla Model X, BMW X5 xDrive40e), and now a minivan (Chrysler Pacifica).

Figure 6 shows additional detail regarding the number of available models (horizontal axis), electric vehicle share (vertical axis), and total sales (bubble size) across the 50 most populous metropolitan areas. Several of the areas are labeled. We analyze model availability as the number of electric models that had at least 20 new registrations in 2016, in order to better distinguish models that were available beyond a few select showrooms. As shown, areas with high adoption, in terms of both overall sales and sales share, tended to have many available models. The five leading electric vehicle markets by volume, representing nearly half of all 2016 U.S. electric vehicle sales, were also the leading markets in terms of model availability, with 24 to 30 models offered.

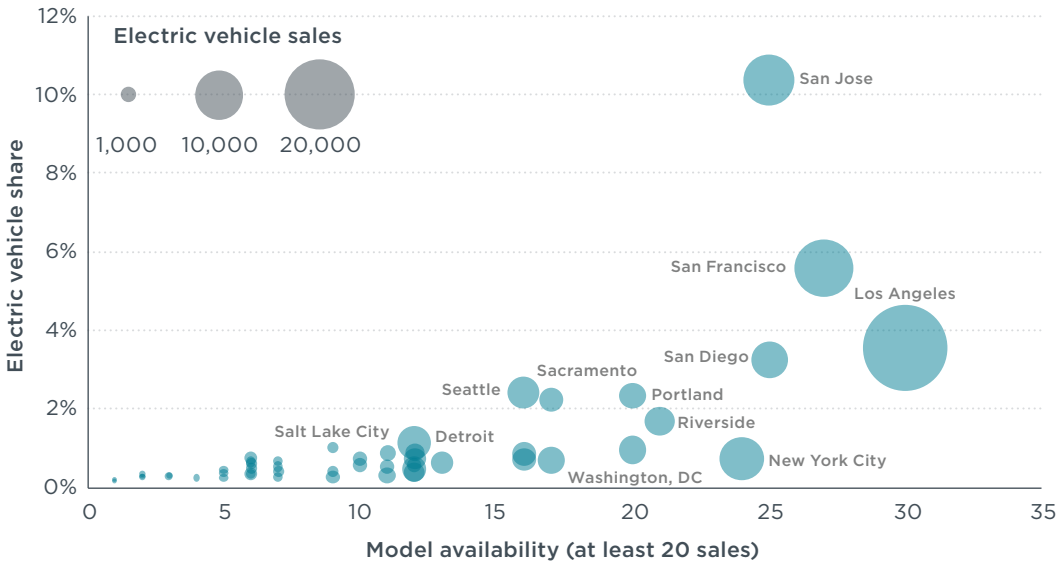

Figure 6. Electric vehicle share of new vehicles versus model availability in the 50 most populous metropolitan areas.

In terms of sales share, each of the areas with more than 2% uptake (more than twice the national average) had 16 or more models available in 2016. The areas with the highest electric vehicle share tended to have 20 to 30 electric vehicle models, namely Portland, San Diego, Los Angeles, San Francisco, and San Jose. Uptake in these five areas was between 2.5 times the national average (Portland) and 11 times the national average (San Jose). Many models were also available in New York City and Washington, DC, and both are relatively strong electric vehicle markets. New York City had the fourth highest electric vehicle sales volume in 2016, and Washington (1% share) is a regional leader relative to surrounding areas in the South and Northeast. As compared to 2015, 43 of the 50 most populous metropolitan areas saw an increase in model availability. The average increase across the 50 cities was about three electric vehicle models.

We also analyzed model availability among the 200 most populous areas. Based on the 20–electric vehicle threshold, we find that 88% of the 200 most populous metropolitan areas had no more than 10 electric vehicle models available to consumers. In terms of population in these areas, we find that about half (48%) of the population was in an area that had 10 or fewer models available in 2016. Prospective consumers in markets with high electric vehicle uptake had about 2 to 3 times this availability. Many cities, such as Birmingham, Buffalo, Cleveland, Jacksonville, Louisville, Memphis, Milwaukee, New Orleans, Oklahoma City, Richmond, and Virginia Beach, had five or fewer models available. Electric vehicle uptake in each of these cities was less than half of the national average. The potential link between model availability and electric vehicle uptake is explored in more detail in the statistical analysis below.

POLICY INCENTIVES

As discussed above, financial and nonfinancial incentives support electric vehicle market growth by lowering upfront cost barriers and by providing additional convenience during their use. Figure 7 shows the value of consumer incentives (vertical bars, right axis) across the 50 cities. Also shown is the electric vehicle uptake in 2016 (black curve, left axis). The

50 cities are ordered from left to right according to uptake. As shown, incentives include state purchase incentives, city purchase incentives, the estimated value of HOV lane access, and "other" incentives, which include exemptions from state and local fees and emissions inspections. Also shown are "fees," which generally come in the form of state annual license fees. Building on our previous work, we have made small updates in the data for estimating HOV lane access, parking incentives, exemptions, and fees. The incentive values shown are the average of BEV and PHEV incentives in each area. Incentives and fees that occur for future years after the point of sale are evaluated over a 6-year vehicle ownership period with a 5% annual discount rate. The potential link between consumer incentives and electric vehicle uptake is explored in more detail in the statistical analysis below.

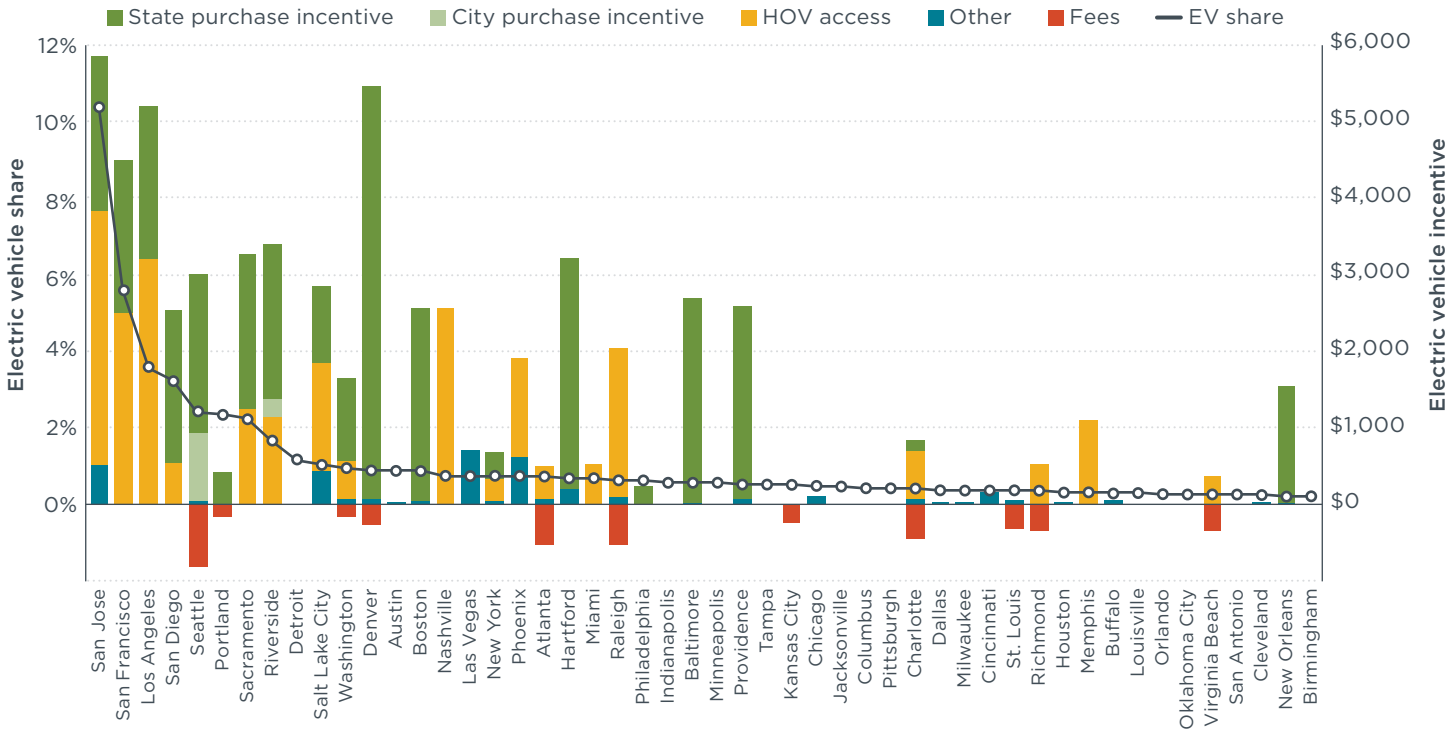

Figure 7. Electric vehicle share of new vehicles and available consumer incentives.

The figure shows how most of the areas with high electric vehicle uptake are those where substantial incentives are available. Many of these areas tend to offer multiple incentives. For example, electric vehicle drivers in the California cities, Salt Lake City, and Washington, DC can benefit from financial incentives and HOV access. Those in Denver receive substantial state purchase incentives, and those in Seattle receive both state and city financial tax credits. However, there are also examples with relatively high incentives but low uptake (e.g., Baltimore, Providence, New Orleans).

The Atlanta case demonstrates the importance of incentives. Through mid-2015, Georgia offered an incentive that was generally valued at $5,000. In 2014, the electric vehicle share in Atlanta was 3.5%, more than 4 times the national average. Since the expiration of the state incentive (and the introduction of a $200 annual fee for electric vehicles), electric vehicle registrations have fallen dramatically, and in 2016, the electric vehicle share in Atlanta was approximately 0.7%, below the national average of 0.9%.

Counterexamples of areas with low incentives and relatively high uptake tend to have several other electric vehicle promotion actions in place to support the market. Electric vehicle drivers in the Portland area, for example, benefit from a broad array of local and utility actions, a highly active outreach and awareness association (Forth Mobility), and extensive charging infrastructure; some drivers also benefit from Washington's state vehicle purchase tax credit. In addition, Oregon's adoption of the ZEV mandate helps ensure relatively high model availability in the Portland area.

Detroit is another example with relatively high uptake but low incentives. Nearly 95% of the area's electric vehicle registrations in 2016 were PHEVs, with relatively high volumes of the Chevrolet Volt, Ford Fusion Energi, and Ford C-Max Energi models. Although there is generally a lack of incentives or other promotion actions in the area, model availability in the Detroit area is higher than in most of the 50 most populous metropolitan areas in this study. The relatively high model availability is likely due to the rich dealership network, and individuals employed in the local auto industry benefit from greater awareness and potentially also from employee purchase discounts (Kwan et al., 2016). Furthermore, the Detroit area has the second largest workplace charging network per capita of the 50 cities.

ELECTRIC VEHICLE PROMOTION ACTIONS

As identified previously (Lutsey et al., 2015, 2016), a comprehensive package of policy and promotion actions by state, local, utility, and other private stakeholders is a key for developing the electric vehicle market. Figure 8 displays the number of state, city, and utility promotion actions (from Table 2) in each of the 50 markets (vertical bars, right axis) as well as the electric vehicle share (black curve, left axis). The areas are ordered from left to right according to uptake.

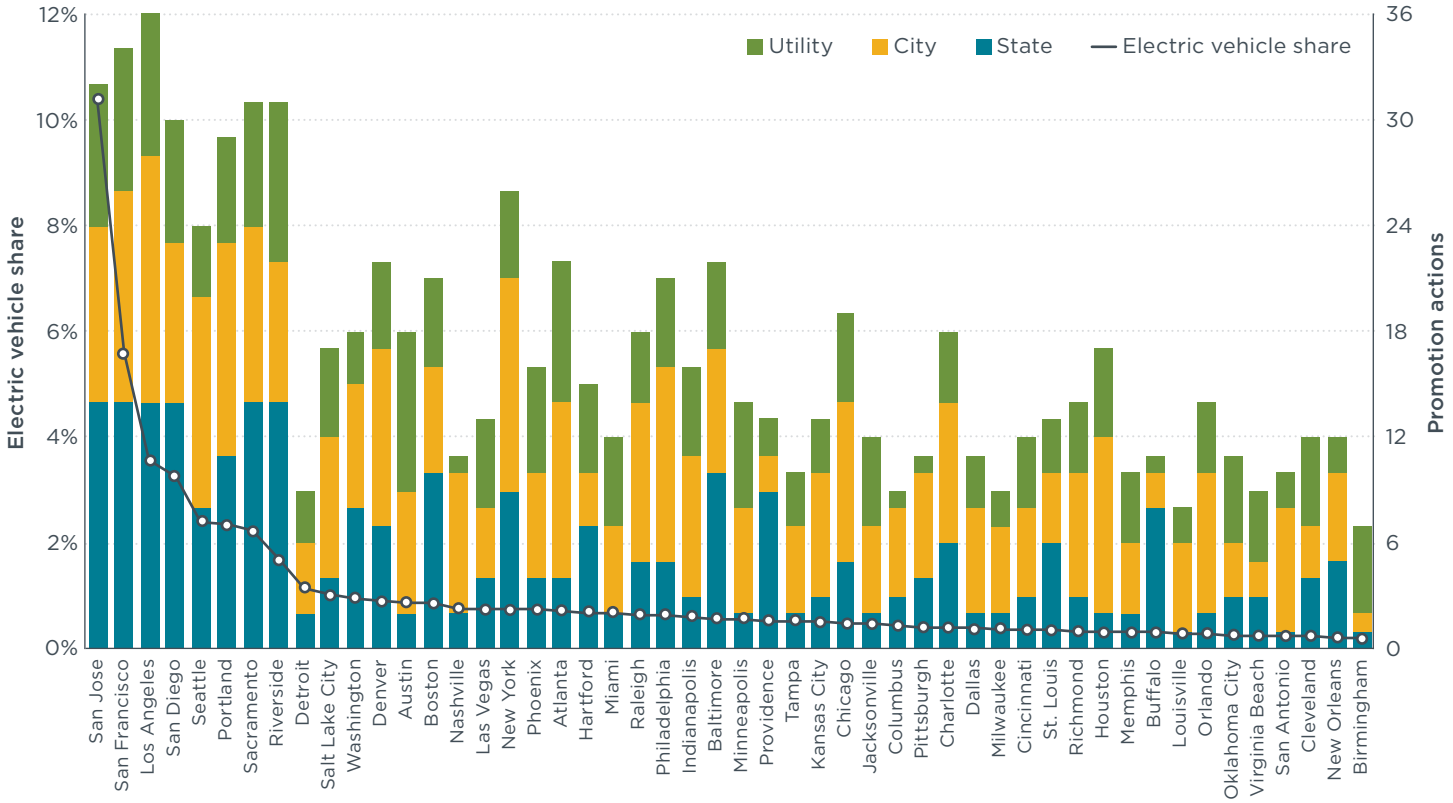

Figure 8. Electric vehicle promotion actions versus electric vehicle uptake.

As shown in Figure 8, the eight areas with the highest uptake—the six California cities, Seattle, and Portland—have adopted 24 to 36 actions. These areas tend to have a strong mix of state, city, and utility actions. As mentioned above, the Detroit market stands out as a relative electric vehicle share leader but with relatively few state, city, and utility actions. The New York area, on the other hand, has a strong mix of promotion actions but remains in the middle of the pack in terms of electric vehicle share. Markets with the lowest uptake tend to have 15 or fewer actions. The potential link between promotion actions and electric vehicle uptake is explored in more detail in the statistical analysis below.

The relative breakdown of state, city, and utility actions in each of the markets is shown in the figure. For example, areas with the greatest number of city actions include several California cities, Portland, Seattle, New York City, and Philadelphia. Austin has an especially active utility, but promotion actions at the state level are generally lacking. State electric vehicle promotion actions are very limited in Michigan, Tennessee, Texas, and Florida. Areas where several local actions are in place, such as Austin, Nashville, Houston, and Orlando, could benefit from greater support at the state level. Utility involvement appears to be quite limited in Detroit, Nashville, Columbus, Pittsburgh, and Buffalo.

COMPARISON OF 50 MAJOR METROPOLITAN AREAS

This section compares the 50 metropolitan areas to further investigate how electric vehicle uptake relates to several of the factors identified above. Figure 9 shows how charging infrastructure, promotion actions, and model availability relate to electric vehicle uptake. The horizontal axis displays total promotion actions (from Table 2 above), the vertical axis illustrates the total public charging infrastructure per million population, the color of the bubbles indicates the number of available electric vehicle models, and the bubble size represents the share of new vehicles that are electric. Several of the 50 areas are labeled, as well as the 50-city average. As shown, areas with the highest electric vehicle share tend to have the most extensive infrastructure deployment, many promotion actions, and high model availability.

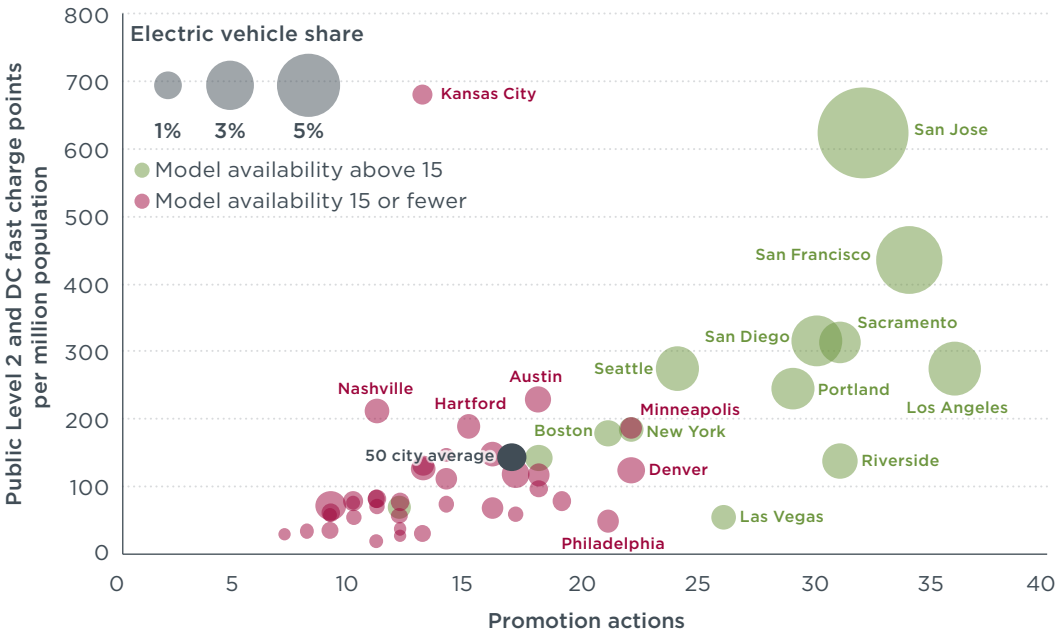

Figure 9. Electric vehicle public charging availability, promotion actions, and share of new vehicles.

Several observations can be made from a close look at Figure 9. Viewing the figure as four quadrants around the 50-city average data point reflects relative gaps. Areas in the lower left quadrant lack sufficient charging infrastructure, promotion actions, and model availability, and these areas tend to have less electric vehicle uptake than the U.S. average. In contrast, the largest bubbles (highest uptake) are all green and clustered in the upper right quadrant, reflecting high model availability, strong public charging infrastructure, and many promotion actions. Areas in the upper left quadrant (e.g., Kansas City, Nashville, Hartford) are behind in promotion actions. Areas in the lower right quadrant (e.g., Philadelphia, Denver, Las Vegas) are behind in public charging infrastructure. The relationships between these variables and electric vehicle uptake are further investigated in the statistical analysis below.

Figure 10 summarizes electric vehicle uptake and several other variables discussed above across the 50 metropolitan areas, namely public charging infrastructure per million population, model availability, consumer incentives, and number of promotion actions. The data for the 50 metropolitan areas are ordered from top to bottom according to their 2016 electric vehicle share. The figure shows a general link between electric vehicle share and several of the variables. Overall, the areas with the highest uptake also tended to have more extensive public charging infrastructure; more electric vehicle models available; consumer incentives; and numerous state, city, and utility actions. The top 10 areas in terms of electric vehicle share tend to greatly overlap with the top 10 areas for public charging infrastructure (7 of top 10), model availability (7 of top 10), incentives (6 of top 10), and promotion actions (8 of top 10).

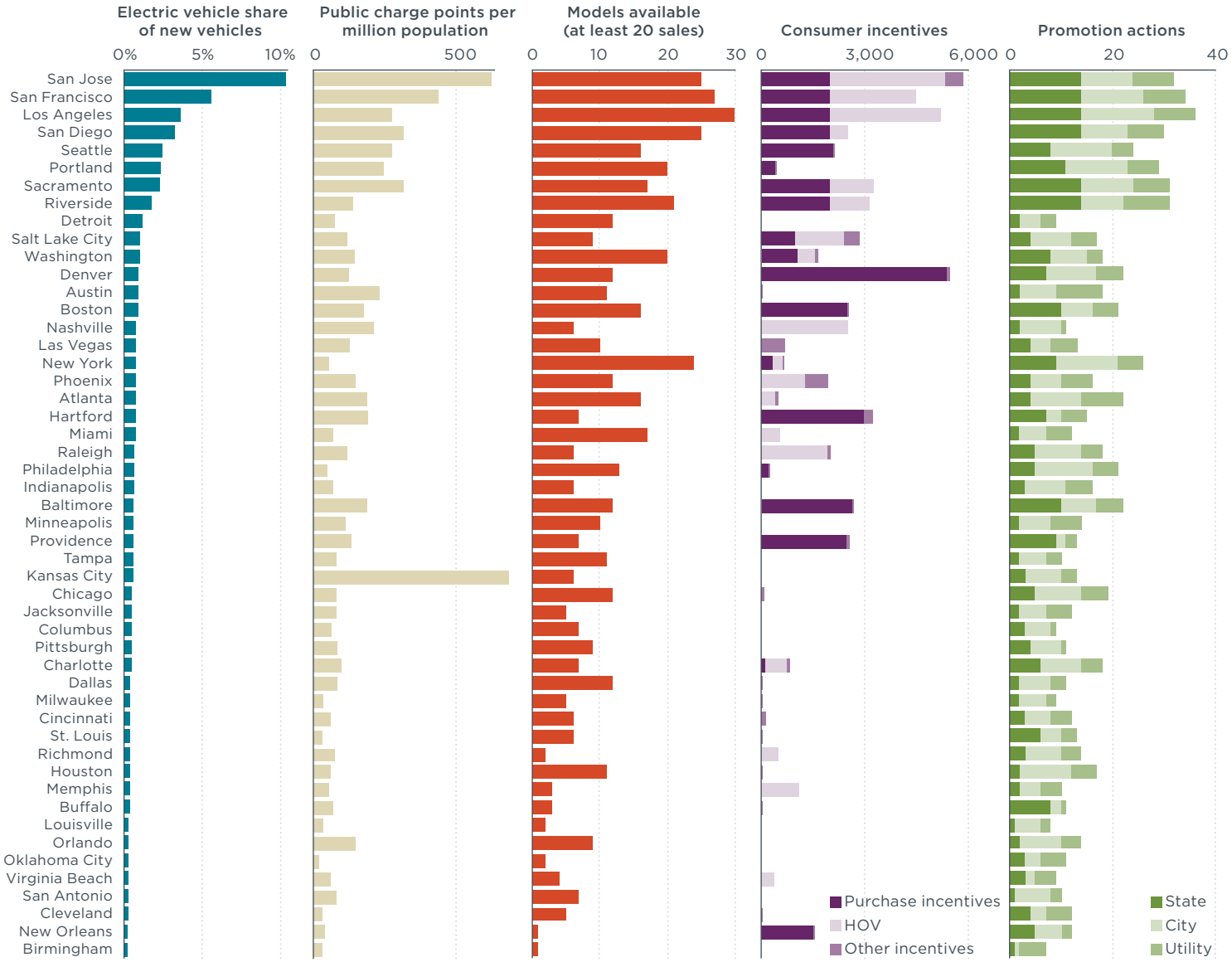

Figure 10. Electric vehicle sales share, public charging infrastructure, model availability, incentives, and promotion actions in 2016 in the 50 most populous U.S. metropolitan areas.

There are also some anomalies in Figure 10, where variables do not visibly follow the generally positive trend with higher electric vehicle uptake. Kansas City stands out as an area with the highest public charging infrastructure per capita, yet low uptake. Model availability, consumer incentives, and promotion actions are each limited in Kansas City. New York City, which has the fourth highest electric vehicle sales in terms of volume, has high model availability and a moderate number of promotion actions yet relatively low uptake; prospective consumers could benefit from a greater network of public charging infrastructure as well as consumer incentives. In 2017, New York recently launched a $70 million state rebate and outreach campaign (New York State, 2017).

A handful of cities stand out as having significant consumer incentives with relatively low uptake, such as Hartford and Providence. These areas appear to especially be lacking in model availability. Detroit and Nashville stand out as examples with relatively high uptake despite limited public charging infrastructure and promotion actions. In

Detroit's case, there is high workplace charging availability, and strong auto industry presence could greatly increase consumer awareness and also perhaps include potential employee discounts. Model availability in Nashville is quite low, but there are perks such as HOV access and free electric vehicle parking in downtown Nashville. The Nissan Leaf makes up roughly half of Nashville's electric vehicle sales, so consumer awareness may be high due to Nissan Leaf manufacturing in the state.

These examples demonstrate how no single factor is likely to drive significant electric vehicle market growth. Rather, a comprehensive package of high model availability, extensive public and workplace charging infrastructure, attractive financial and nonfinancial consumer incentives, and numerous promotion actions is the key to increasing electric vehicle adoption. The examples also suggest a high degree of experimentation with various types of local policies and practices as each area tailors its actions to the local conditions.

ELECTRIC VEHICLE SALES GROWTH FROM 2015 TO 2016

This section discusses the 50 most populous metropolitan areas that experienced the highest growth in electric vehicle sales from 2015 to 2016. As mentioned above, electric vehicle registrations across the United States increased by 30% from 2015 to 2016, surpassing 150,000 units in 2016. Table 3 shows the 15 markets (among the 50 most populous) that had the highest electric vehicle market growth in 2016. As shown, each had at least 66% growth in electric vehicle registrations, and each also had substantial growth in public charging infrastructure and model availability. For example, the major growth markets of Charlotte, Detroit, Kansas City, Minneapolis, Pittsburgh, Providence, and Virginia Beach each had 29% to 83% charging infrastructure growth and 40% to 300% model availability growth, corresponding with at least a doubling of their electric vehicle uptake from 2015 to 2016.

Table 3. Change in electric vehicle registrations, charging availability, and model availability for metropolitan areas with the highest electric vehicle growth from 2015 to 2016.

Metropolitan area	Change in number of electric vehicle registrations	Change in number of charge points per million people	Change in number of models available
Detroit	283%	45%	71%
Kansas City	130%	83%	50%
Virginia Beach	123%	50%	300%
Pittsburgh	115%	40%	80%
Minneapolis	107%	36%	67%
Providence	106%	29%	75%
Charlotte	100%	30%	40%
Memphis	99%	72%	200%
Jacksonville	94%	65%	400%
Richmond	88%	33%	100%
New York	79%	38%	41%
Salt Lake City	76%	18%	50%
Boston	73%	14%	23%
Miami	73%	54%	42%
Washington	66%	22%	25%

In addition to substantial growth in public charging infrastructure and model availability, there were also some notable policy and promotional developments among these year-on-year growth leaders. Rhode Island launched a state incentive program in 2016 that provided rebates up to $2,500 for purchases of BEVs or PHEVs, likely supporting market growth in Providence (Rhode Island, 2016). A multistate awareness and outreach campaign in several Northeast states was initiated in mid-2015 and active throughout 2016, increasing awareness among prospective consumers in the Boston, New York, and Providence areas (Prebo, 2016). The 15 markets in Table 3 show that even in markets with relatively low sales shares of less than 1%, increased deployment of charging infrastructure and increased model availability tend to result in an uptick in electric vehicle sales—sometimes at especially high year-on-year rates.

STATISTICAL ANALYSIS

We conducted a statistical analysis to discern links between the potential electric vehicle market drivers analyzed above and electric vehicle uptake. The statistical analysis was based on the 200 most populous metropolitan areas, where data are available, as well as on the 50 most populous metropolitan areas, for which we have more detailed data. The 50-area analysis included additional variables of workplace charging, HOV lane access, and local electric vehicle promotion actions. For the analysis below, we conducted a stepwise multivariate linear regression using StatPlus software to identify the best statistical fits among the factors researched above with electric vehicle uptake (see AnalystSoft, 2017).

The results from the statistical analysis are summarized in Table 4, showing relationships between the variables to discern the strongest fits at both the 200– and 50–metropolitan area level. We report six statistically significant fits; each column represents a unique statistically significant regression with three to five independent variables (each marked with "X") regressed against electric vehicle share. We conducted the analysis for BEVs and PHEVs; we also provide results for both types combined as electric vehicles (EVs), because this revealed additional statistically significant regressions with additional nuanced differences that might be useful for comparison with other data analyses for which separate BEV and PHEV data were unavailable.

For the regressions of the data for the 200 most populous metropolitan areas, we find statistical fits for BEVs, PHEVs, and EVs, each with four independent variables. Each includes model availability, consumer incentives, Level 2 public charging, and DC fast public charging, and each has adjusted R-squared values of 0.61 to 0.64. For the 50 most populous metropolitan areas, model availability remains significant in the PHEV and EV cases, and public charging infrastructure is significantly linked with market share in the BEV and EV cases. The regressions of the 50 areas also show significant links with workplace charging, HOV access incentives, and city promotion actions. For the six separate statistically significant regressions, all the variables' *p*-values were less than 0.05. As shown, the statistical fits help to explain more of the variability in the 50–metropolitan area regressions (adjusted R-squared = 0.89 to 0.94).

Table 4. Summary of significant independent variables for six statistical regressions on electric vehicle share in U.S. metropolitan areas.

Variable	200 U.S. metropolitan areas			50 U.S. metropolitan areas		
	BEV	PHEV	EV	BEV	PHEV	EV
Model availability, BEV	X			X		X
Model availability, PHEV		X			X	
Model availability, EV			X			
BEV incentive	X					
PHEV Incentive		X				X
EV incentive			X			
Public charging per capita (Level 2)	X	X	X			
Public charging per capita (DC fast)	X	X	X	X		X
Workplace charging per capita				X	X	X
High occupancy vehicle lane incentive					X	
City promotion actions					X	
Regression adjusted R-squared	0.61	0.63	0.64	0.92	0.89	0.94

BEV = battery electric vehicle; PHEV = plug-in hybrid electric vehicle; EV = electric vehicle (including BEV and PHEV); X = significant variable (p-value < 0.05).

The statistically significant regressions shown in Table 4 show links between the independent variables and electric vehicle uptake. The three separate 200 metropolitan area regressions suggest that incentives, infrastructure, and model availability are key factors for the growth in the electric vehicle market. The results of the separate analyses for BEVs, PHEVs, and EVs are similar. Each of the 200 metropolitan area regressions indicate that both Level 2 and DC fast charging are significant. The regressions with 50 metropolitan areas are more granular. As noted above, we were able to collect more data on more dimensions, especially on local promotion actions, in the 50 areas. As shown, workplace charging, HOV lane access, and city promotion actions are significantly linked with electric vehicle uptake in each of the 50–metropolitan area regressions, and consumer incentives were not identified as the strongest statistical fit when these variables were included. Overall, these relationships suggest that greater model availability, consumer incentives, public and workplace charging, carpool lane access, and city promotion actions have been important ingredients in the growth of the electric vehicle market. The information on actions underway in major electric vehicle markets in the sections above help to provide a template for actions that could be more widely deployed by cities, states, and other actions to enable more growth.

IV. CONCLUSIONS

Many factors are helping to spur electric vehicle growth in markets across the United States. The activities and policies analyzed in this report help to explain why the electric vehicle market is growing more quickly in some areas than others. We catalogued dozens of unique electric vehicle actions and found statistically significant relationships between the electric vehicle share of new light-duty vehicle sales and model availability, consumer incentives, public charging infrastructure, workplace charging, HOV lane access, and city promotion actions. The markets across the United States that are seeing more of the underlying support activities are seeing results in the form of greater electric vehicle market growth.

Growth in the electric vehicle market requires many actions by many players. Actions by many policy and industry stakeholders are key to reducing consumer barriers related to electric vehicle uptake with supporting policy, incentives, infrastructure, and consumer awareness. States develop policy and implement incentive programs, whereas cities focus more on local policies and nonfinancial consumer programs, and utilities increasingly are engaged in infrastructure deployment and consumer education. Such comprehensive efforts are exemplified by California, where the Zero Emission Vehicle regulation helps to catalyze automaker marketing and model availability, complementary policy incentives, and sustained charging infrastructure investment. The markets of Seattle, Portland, Denver, Austin, Boston, and New York are seeing the development of their own playbooks with emerging combinations of state, city, and utility policies and incentives to help address consumer barriers to electric vehicle uptake. The above text and additional Annex provide tangible examples where such actions are being implemented.

Several markets especially make it clear that no one or two actions are sufficient to grow the electric vehicle market. Kansas City, which has the most extensive public charging infrastructure per capita, lacks consumer incentives, model availability, and promotion actions, and the area's electric vehicle uptake is below the national average. The Hartford and Providence markets, also below the national average, have strong financial incentives but sparse model availability. Houston and Philadelphia have adopted several local promotion actions, but incentives and public charging infrastructure are especially lacking in these areas.

Expanded electric vehicle model offerings and greater availability of those models are prerequisites to market growth. The five leading electric vehicle markets by volume, representing nearly half of all U.S. electric vehicle sales, each had at least 24 available electric vehicle models available in 2016. Our analysis of major U.S. markets shows that about half of the population had 10 or fewer electric models available. Many markets outside of California have had very low electric vehicle inventories at dealerships (Reichmuth & Anair, 2016). Availability of more models in a wide range of vehicle types—from low-cost to luxury, from subcompact to three-row passenger capacity—is an essential precursor to more substantial market development. Where there are more models, there also tends to be more automaker marketing effort (NESCAUM, 2017). The primary policy driver that increases model availability is the Zero Emission Vehicle program, which has been adopted by California and nine other states, representing 29% of the U.S. auto market. This ZEV policy is expected to increasingly support the northeastern markets due to changes in the 2018 model year, including those in the

ZEV-adopting states of New York, Massachusetts, Connecticut, Maryland, and Rhode Island, which have lagged California markets in numbers of available models.

Consumer incentives remain a key to growing the electric vehicle market. Ten of the top 12 major metropolitan areas with the highest electric vehicle uptake offer significant consumer incentives typically worth $2,000 to $5,000. Consumers in California markets and Salt Lake City had both consumer purchase incentives and carpool lane access, and those in Denver and Seattle had substantial purchase incentives. These incentives increase awareness and reduce the initial cost barrier while electric vehicle battery costs continue to decrease to enable lower-cost and higher electric range vehicles. The abrupt repeal of the Georgia tax credit in 2015 and subsequent drop in electric vehicle sales clearly demonstrates the importance of financial incentives. In the future, governments would more ideally gradually phase down fiscal incentives while continuing complementary policy, nonfinancial perks, charging infrastructure, and regulatory policy to support the transition to electric drive (see Slowik & Lutsey, 2016).

Electric vehicle charging infrastructure remains a barrier in many markets. This research finds that public charging (and especially public fast charging) and workplace charging are significantly linked with electric vehicle uptake. The leading electric vehicle markets tend to have at least 275 public chargers per million people, whereas half of the U.S. population lives in a market where available charging is less than one-third of that rate. The markets of Charlotte, Detroit, Kansas City, Minneapolis, Pittsburgh, Providence, and Virginia Beach each had approximately 30% to 80% charging infrastructure growth, corresponding with at least a doubling of their electric vehicle uptake from calendar year 2015 to 2016.

This work has implications outside the United States as well. Markets in Europe and China, especially, are experimenting with similar and even bolder policies that explicitly promote electric vehicles. For example, the leading cities in this report are in the middle of the pack among the world's electric vehicle capitals that are developing their own electric vehicle market growth playbooks to move beyond early adopters (Hall et al., 2017). This analysis also offers an early look into actions, including incentives for low-income consumers and charging infrastructure support for multi-unit dwellings, that are designed to expand the market beyond early adopters. Additional research is needed to more comprehensively understand policies that have the potential to further broaden electric vehicle adoption to the mainstream market.

More electric vehicle models with lower cost and longer electric range keep coming (Slowik et al., 2016), and governments around the world stand to gain from learning from each other's policy and market experiences. The collective adoption of similar actions to help overcome barriers and develop electric vehicle markets will help all regions around the world achieve their air pollution, climate, and fuel saving benefits. The more markets that are embracing the leading electric vehicle policies, the faster the transition to an electric vehicle fleet will occur.

REFERENCES

Ameren (2016). "Ameren Missouri Pilots Electric Vehicle Charging Corridor for I-70 Connecting Jefferson City and St. Louis"; http://ameren.mediaroom.com/2016-08-15-Ameren-Missouri-Pilots-Electric-Vehicle-Charging-Corridor-for-I-70-Connecting-Jefferson-City-and-St-Louis.

AnalystSoft (2017). "Forward Stepwise Regression"; www.analystsoft.com/en/products/statplus/content/help/analysis_regression_forward_stepwise_regression_model.html.

Austin Energy (2017). "Plug-In Austin: Multifamily Properties: Rebates Available to Install Charging Stations for your Residents"; http://austinenergy.com/wps/portal/ae/green-power/plug-in-austin/multifamily-properties/!ut/p/a1/jZHBTsMwEES_pQcfU29dASk3E6oQSsmJNOSCDNoklhLb2jhU5etx1QuqKGRvq3mj0c7yipe8MupTN8pra1R33KvrNxCxeEhAZOmNiEGmyd3mqnherLJFAF5_Avk6v4esyAuZbxJlk-VE_4WR8J__cUKAoG2ybXjllG8jbWrLy37svK5Vr7tD5Mg6JK9xOMLSvC_jABPWSEjzkUILrffulgEDNQ5eGzRIzWH-YXsGezcwcJa86oKMDBpCNJGze6QgdGMTIqOTj8H03NYOnpfneXzHq78ulmtxDvzykhNwuXPXv5RfT7iL_SrTcjb7Bn752hU!/dl5/d5/L2dBISEvZ0FBIS9nQSEh/.

Bailey, J., Miele, A., & Axsen, J. (2015). Is awareness of public charging associated with consumer interest in plug-in electric vehicles? *Transportation Research Part D, 36,* 1–9; www.sciencedirect.com/science/article/pii/S1361920915000103.

Bakker, S., & Trip, J. J. (2013). Policy options to support the adoption of electric vehicles in the urban environment. *Transportation Research Part D, 25,* 18–23; www.sciencedirect.com/science/article/pii/S1361920913001065.

BlueIndy (2017). www.blue-indy.com/benefits.

California Air Resources Board (CARB) (2015). *Electric Vehicle Charging Infrastructure*. California Environmental Protection Agency; www.documents.dgs.ca.gov/bsc/2015TriCycle/CAC/GREEN/Exhibit-B-CARB-Cost-Analysis-and-Technical-Report.pdf

California Air Resources Board (CARB) (2017, January 18). *California's Advanced Clean Cars Midterm Review: Summary Report for the Technical Analysis of the Light Duty Vehicle Standards*; www.arb.ca.gov/msprog/acc/mtr/acc_mtr_finalreport_full.pdf.

California Office of the Governor (2016). *2016 ZEV Action Plan: An Updated Roadmap Toward 1.5 Million Zero-Emission Vehicles on California Roadways by 2025*; www.gov.ca.gov/docs/2016_ZEV_Action_Plan.pdf.

California Plug-in Electric Vehicle Collaborative (PEVC) (2013). *Amping Up California Workplaces: 20 Case Studies on Plug-in Electric Vehicle Charging at Work*; www.pevcollaborative.org/sites/all/themes/pev/files/WPC_Report4web.pdf.

California Plug-in Electric Vehicle Collaborative (PEVC) (2017). *California Plug-In Electric Vehicle Statewide Ride-and-Drive Series Best.Ride.Ever! 2016 Final Report*; www.pevcollaborative.org/sites/all/themes/pev/files/PUBLIC_PEVC%20Best.Ride.EVer!%202015%20Final%20Report.pdf.

California Public Utilities Commission (CPUC) (2016, December 21). *Decision Directing Pacific Gas and Electric Company to Establish an Electric Vehicle Infrastructure and Education Program*; http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M171/K539/171539218.pdf.

Center for Sustainable Energy (CSE) (2016a). *Electric Vehicle Charging Station Installation Best Practices: A Guide for San Diego Region Local Governments and Contractors*; https://energycenter.org/sites/default/files/docs/nav/transportation/plug-in_sd/Plug-in%20SD%20Installation%20Best%20Practices%20Report.pdf.

Center for Sustainable Energy (CSE) (2016b). *Zero-Emission Vehicle (ZEV) Markets in California: Disadvantaged Communities & the State Overall*; https://energycenter.org/sites/default/files/docs/ext/transportation/2016-02-03%20EUEC-J2-CSE-Williams-handout.pdf.

City of Chicago (2017). Drive Electric Chicago; www.cityofchicago.org/city/en/progs/env/drive_electric_chicago.html.

City of Los Angeles (2016). *Recommendation for Contract Award to BlueCalifornia, LLC, for Electric Vehicle Carshare Operations Using Grant Funds from the California Air Resources Board (CARB) Fiscal Year 2014-15 Targeted Car Sharing and Mobility Options in Disadvantaged Communities*; http://clkrep.lacity.org/onlinedocs/2015/15-1227_rpt_DOT_11-23-2016.pdf.

City of Oakland (2016). Oakland City Council ordinance of 17 February 2016; https://oakland.legistar.com/View.ashx?M=F&ID=4972530&GUID=FF34BA14-ECC4-4AD6-BC6A-A32968FC24B2.

Clean Fuels Ohio (2016). "Obama Administration Announces New Actions to Accelerate the Deployment of Electric Vehicles and Charging Infrastructure"; www.cleanfuelsohio.org/single-post/2016/11/08/Obama-Administration-Announces-New-Actions-to-Accelerate-the-Deployment-of-Electric-Vehicles-and-Charging-Infrastructure.

Commonwealth of Massachusetts (2017). *Massachusetts Electric Vehicle Incentive Program (MassEVIP): Fleets*; www.mass.gov/eea/agencies/massdep/air/grants/massevip-municipal.html.

Colorado Clean Air Fleets (2017). Charge Ahead Colorado; http://cleanairfleets.org/programs/charge-ahead-colorado.

Duke Energy (2016). "Duke Energy Project to Increase Public EV Charging Stations in N.C. by 30 Percent"; https://news.duke-energy.com/releases/duke-energy-project-to-increase-public-ev-charging-stations-in-n-c-by-30-percent.

Edison Electric Institute (2014). *Transportation Electrification: Utility Fleets Leading the Charge*; www.eei.org/issuesandpolicy/electrictransportation/fleetvehicles/documents/eei_utilityfleetsleadingthecharge.pdf.

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

First Energy Corporation (2016). "EV Charging Station Terms and Conditions"; www.firstenergycorp.com/content/dam/customer/products/files/EVSE-Plan-TCs-12012016-rev7-V3.pdf.

Forth Mobility (2017). "First-of-Its-Kind Program Brings Electric Vehicle Car Sharing to Lower-Income Community"; https://forthmobility.org/our-work/mobility-innovations.

Georgia Power (2016). "Charging EVs at Home"; www.georgiapower.com/about-energy/electric-vehicles/charging-at-home.cshtml.

Hall, D., & Lutsey, N. (2017). *Literature Review on Power Utility Best Practices Regarding Electric Vehicles*. International Council on Clean Transportation; http://theicct.org/literature-review-power-utility-best-practices-regarding-EVs.

Hall, D., Moultak, M., & Lutsey, N. (2017). *Electric Vehicle Capitals of the World: Demonstrating the Path to Electric Drive*. International Council on Clean Transportation; www.theicct.org/EV-capitals-of-the-world.

Heywood, P., & Olexsak, S. (2017, March 10). Personal communication. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy.

HybridCars (2016). "December 2016 Dashboard"; www.hybridcars.com/december-2016-dashboard/.

Idaho National Laboratory (INL) (2015). *Plugged In: How Americans Charge Their Electric Vehicles*; https://avt.inl.gov/sites/default/files/pdf/arra/SummaryReport.pdf.

International Zero-Emission Vehicle Alliance (2017). "The ZEV Alliance Participation Statement"; www.zevalliance.org/members/.

Jacksonville Electric Authority (JEA) (2017). "Plug-in Electric Vehicles"; www.jea.com/Ways_to_Save/Go_Green/Plug-in_Electric_Vehicles/.

Jin, L., & Slowik, P. (2017). *Literature Review of Electric Vehicle Consumer Awareness and Outreach Activities*. International Council on Clean Transportation; http://theicct.org/literature-review-EV-consumer-awareness-and-outreach.

Jin, L., Searle, S., & Lutsey, N. (2014, October). *Evaluation of State-Level U.S. Electric Vehicle Incentives*. International Council on Clean Transportation; http://theicct.org/evaluation-state-level-us-electric-vehicle-incentives.

Kansas City Power & Light (KCP&L) (2017). KCP&L Clean Charge Network; www.kcpl.com/about-kcpl/environmental-focus/clean-charge-network.

King County Metro (2017). *Feasibility of Achieving a Carbon-Neutral or Zero-Emission Fleet*; http://kingcounty.gov/~/media/elected/executive/constantine/news/documents/Zero_Emission_Fleet.ashx?la=en.

Kurani, K. S., Caperello, N., & TyreeHageman, J. (2016). *New Car Buyers' Valuation of Zero-Emission Vehicles: California*. California Air Resources Board; www.arb.ca.gov/research/apr/past/12-332.pdf.

Kwan, I., Lutsey, N., Slowik, P., & Jin, L. (2016). *Identifying the Leading Regional Electric Vehicle Markets in the United States*. International Council on Clean Transportation; www.theicct.org/regional-us-city-electric-vehicle.

Li, S., Tong, L., Xing, J., & Zhou, Y. (2016, May). "The Market for Electric Vehicles: Indirect Network Effects and Policy Design"; http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2515037.

Lin, Z., & Greene, D. (2011). Promoting the market for plug-in hybrid and battery electric vehicles: Role of recharge availability. *Transportation Research Record, 2252,* 49–56; http://trrjournalonline.trb.org/doi/pdf/10.3141/2252-07.

Lowell, D., Jones, B., & Seamonds, D. (2017). "MJB&A Analyzes State-Wide Costs and Benefits of Plug-in Vehicles in Five Northeast and Mid-Atlantic States." M. J. Bradley & Associates; www.mjbradley.com/reports/mjba-analyzes-state-wide-costs-and-benefits-plug-vehicles-five-northeast-and-mid-atlantic.

Lutsey, N. (2017, 31 January). "The Rise of Electric Vehicles: The Second Million." International Council on Clean Transportation; www.theicct.org/blogs/staff/second-million-electric-vehicles.

Lutsey, N., Searle, S., Chambliss, S., & Bandivadekar, A. (2015). *Assessment of Leading Electric Vehicle Promotion Activities in United States Cities (2015)*. International Council on Clean Transportation; www.theicct.org/leading-us-city-electric-vehicle-activities.

Lutsey, N., Slowik, P., & Jin, L. (2016). *Sustaining Electric Vehicle Market Growth in U.S. Cities*. International Council on Clean Transportation; www.theicct.org/leading-us-city-electric-vehicle-2016.

Maryland General Assembly (2015). House Bill 0235; http://mgaleg.maryland.gov/webmga/frmMain.aspx?pid=billpage&stab=02&id=HB0235&tab=subject3&ys=2015rs.

Michigan Legislature (2014). House Bill 5606; www.legislature.mi.gov/(S(udlbis5czbmyivc1tr3dqu3j))/mileg.aspx?page=GetObject&objectname=2014-HB-5606.

Mulkern, A. (2017, February 23). "Utilities paying EV drivers 'climate credits'." Environment & Energy Publishing; www.eenews.net/climatewire/stories/1060050446.

National Research Council (NRC) (2015). *Overcoming Barriers to Deployment of Plug-in Electric Vehicles*. National Academies Press; www.nap.edu/catalog.php?record_id=21725.

New York State (2017). "Governor Cuomo Launches $70 Million Electric Car Rebate and Outreach Initiative"; www.governor.ny.gov/news/governor-cuomo-launches-70-million-electric-car-rebate-and-outreach-initiative.

Northeast States for Coordinated Air Use Management (NESCAUM) (2013). *State Zero-Emission Vehicle Programs: Memorandum of Understanding*; www.nescaum.org/documents/zev-mou-8-governors-signed-20131024.pdf/.

Northeast States for Coordinated Air Use Management (NESCAUM) (2014). *Multi-State ZEV Action Plan.* ZEV Program Implementation Task Force; www.nescaum.org/documents/multi-state-zev-action-plan.pdf/.

Northeast States for Coordinated Air Use Management (NESCAUM) (2016). *Electric Vehicle Marketing Analysis*; www.nescaum.org/documents/nescaum-elec-vehicle-marketing-analysis-20161219.pdf/view.

Northeast States for Coordinated Air Use Management (NESCAUM) (2017). "Driving ZEV Success in the Northeast." Presented to California Air Resources Board, March 24.

NV Energy (2015). "Nevada Electric Highway to Link Northern and Southern Nevada with Electric Vehicle Charging Stations Along U.S. Route 95"; http://energy.nv.gov/uploadedFiles/energynvgov/content/Programs/Nevada%20Electric%20Highway%20Fact%20Sheet.pdf.

Office of the Governor of Massachusetts (2017). "Governor Baker Signs Electric Vehicle Promotion Legislation"; www.mass.gov/governor/press-office/press-releases/fy2017/gov-baker-signs-electric-vehicle-promotion-legislation.html.

Orlando Utilities Commission (2017). "Electric Vehicles at Home"; www.ouc.com/residential/save-energy-water-money/electric-vehicles-at-home.

Pacific Gas & Electric (PG&E) (2015). "PG&E to Step Up the Addition of Electric Vehicles to its Fleet"; www.pge.com/en/about/newsroom/newsdetails/index.page?title=20151015_pge_to_step_up_the_addition_of_electric_vehicles_to_its_fleet_.

Pacific Power (2017). "Oregon Clean Electricity & Coal Transition Law." Berkshire Hathaway Energy; www.pacificpower.net/env/oregon-clean-energy/oregon-law-details.html.

Plug In America (2016). "Record Number of Cities Celebrate Sixth Annual National Drive Electric Week"; https://pluginamerica.org/press-release/ndew-2016-record-number-cities/.

Prebo, B. (2016). "Plug-in hybrid electric vehicle demonstration program and social media campaign"; http://energy.gov/sites/prod/files/2016/06/f33/ti064_ardisana_2016_o_web.pdf.

Proterra (2016). "TARC Rolls Out Six New Proterra Battery-Electric Buses"; www.proterra.com/press-release/tarc-rolls-out-six-new-proterra-battery-electric-buses/.

Reichmuth, D., & Anair, D. (2016). *Electrifying the Vehicle Market: Evaluating Automaker Leaders and Laggards in the United States*; www.ucsusa.org/sites/default/files/attach/2016/08/Electrifying-Vehicle-Market-full-report.pdf.

Rhode Island (2016). "Rhode Island Office of Energy Resources Launches 'Charge Up!' Public Sector Vehicle Electrification Incentive Program"; www.energy.ri.gov/documents/News/OER_chargeup_PR_FINAL.pdf.

Ryan, N. E., & Lavin, L. (2015). Engaging utilities and regulators on transportation electrification. *Electricity Journal, 28,* 78–91; www.sciencedirect.com/science/article/pii/S1040619015000755.

Sacramento Metropolitan Air Quality Management District (2017). Community CarShare Program; www.airquality.org/residents/incentive-programs/community-carshare-program.

Salisbury, M., & Toor, W. (2016). *How Leading Utilities Are Embracing Electric Vehicles.* Southwest Energy Efficiency Project; www.swenergy.org/data/sites/1/media/documents/publications/documents/How_Leading_Utilities_Are_Embracing_EVs_Feb-2016.pdf. UScityEV2017-jec_JF_PS_NL.docx

San Diego Gas & Electric (SDG&E) (2016). "SDG&E to Install Thousands of Electric Vehicle Charging Stations"; www.sdge.com/newsroom/press-releases/2016-01-28/sdge-install-thousands-electric-vehicle-charging-stations.

Santini, D. J., Zhou, Y., Rood, M., & Vazquez, K. (2016). Effects of Utility Outreach on Plug-in Electric Vehicle Market Success. Argonne National Laboratory.

Searle, S., Pavlenko, N., & Lutsey, N. (2016, September). *Leading Edge of Electric Vehicle Market Development in the United States: An Analysis of California Cities*. International Council on Clean Transporation; www.theicct.org/ev-markets-calif-cities-sept2016.

Seattle City Light (2017). Electric Vehicle Service Equipment for Multi-Family Housing; www.seattle.gov/light/electricvehicles/docs/Electric_Vehicle_Service_Equipment_for_Multi.pdf.

Sierra Club (2016). "Record Number of Cities Celebrate Sixth Annual National Drive Electric Week"; http://content.sierraclub.org/press-releases/2016/09/record-number-cities-celebrate-sixth-annual-national-drive-electric-week.

Singer, M. (2015). *Consumer Views on Plug-In Electric Vehicles—National Benchmark Report*. National Renewable Energy Laboratory; www.afdc.energy.gov/uploads/publication/consumer_views_pev_benchmark.pdf.

Slowik, P., & Lutsey, N. (2016). *Evolution of Incentives to Sustain the Transition to a Global Electric Vehicle Fleet*. International Council on Clean Transportation; www.theicct.org/evolution-incentives-electric-transition.

Slowik, P., Pavlenko, N., & Lutsey, N. (2016). Assessment of next-generation electric vehicle technologies. International Council on Clean Transportation; www.theicct.org/next-generation-electric-vehicle-technologies.

Tal, G., & Nicholas, M. (2016). *Exploring the Impact of the Federal Tax Credit on the Plug-In Vehicle Market*. University of California, Davis; https://trid.trb.org/view.aspx?id=1392922.

Tesla (2012). "The Tesla Approach to Distributing and Servicing Cars"; www.tesla.com/blog/tesla-approach-distributing-and-servicing-cars?redirect=no.

Texas A&M Transportation Institute (2015). *2015 Urban Mobility Scorecard*; https://mobility.tamu.edu/ums/report/.

Tietge, U., Mock, P., Lutsey, N., & Campestrini, A. (2016). *Comparison of Leading Electric Vehicle Policy and Deployment in Europe*. International Council on Clean Transportation; www.theicct.org/sites/default/files/publications/ICCT_EVpolicies-Europe-201605.pdf.

U.S. Census Bureau (2017). Metropolitan and Micropolitan; www.census.gov/programs-surveys/metro-micro.html.

U.S. Department of Energy (DOE) (2016a). Alternative Fuels Data Center: Electric Vehicle Charging Station Locations; www.afdc.energy.gov/fuels/electricity_locations.html.

U.S. Department of Energy (DOE) (2016b). *Workplace Charging Challenge: Progress Update 2016: A New Sustainable Commute*; https://energy.gov/sites/prod/files/2017/01/f34/WPCC_2016%20Annual%20Progress%20Report.pdf.

U.S. Department of Energy (DOE) (2016c). Electric Vehicle Community Readiness Project; https://cleancities.energy.gov/partnerships/search?project_search=Electric+Vehicle+Community+Readiness.

U.S. Department of Energy (DOE) (2016d). State Laws and Incentives; www.afdc.energy.gov/laws/state.

U.S. Environmental Protection Agency (EPA) (2016). *Draft Technical Assessment Report: Midterm Evaluation of Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards for Model Years 2022-2025* (EPA-420-D-16-900); https://nepis.epa.gov/Exe/ZyPDF.cgi/P100OXEO.PDF?Dockey=P100OXEO.PDF.

Vergis, S., & Chen, B. (2014). *Understanding Variations in U.S. Plug-In Electric Vehicle Markets*. University of California, Davis, Research Report UCD-ITS-RR-14-25.

Vergis, S., Turrentine, T., Fulton, L., & Fulton, E. (2014). *Plug-In Electric Vehicles: A Case Study of Seven Markets*. University of California, Davis, Research Report UCD-ITS-RR-14-17.

Vermont Agency of Transportation (2016). *Sec. 15. 2016 Plug-In Hybrid and Electric Vehicle Registration Fees: Legislative Report December 2016*; http://legislature.vermont.gov/assets/Legislative-Reports/2016-Legislative-EV-Study-FINAL-formatted.pdf.

Vision Fleet (2015). *Indianapolis Freedom Fleet: 2015 Annual Report*; www.scribd.com/document/265995007/Indianapolis-Freedom-Fleet-2015-Annual-Report.

Wisconsin Clean Cities (2017). Milwaukee County. http://www.wicleancities.org/wisconsin_smart_fleet/Milwaukee_County.php.

Yang, Z., Slowik, P., Lutsey, N., & Searle, S. (2016). *Principles for Effective Electric Vehicle Incentive Design*. International Council on Clean Transportation; www.theicct.org/principles-for-effective-EV-incentive-design.

Zhou, Y., Santini, D., Rood, M., Bluestein, L., Mitchell, G., Stephens, T., & Ward, J. (2016). *An Assessment of Causes of PEV Success Across U.S. Metro Areas*. Argonne National Laboratory; https://anl.app.box.com/s/u3jnk1mwsbt3c406ielw0h1zbwy42wh1.

Zhou, Y., Santini, D., Vazquez, K., & Rood, M. (2017). *Contributing Factors in Plug-In Electric Vehicle Adoption in the United States: A Metro/County Level Investigation*. Argonne National Laboratory; https://trid.trb.org/view.aspx?id=1439160.

ANNEX

Table A1. Representative electric vehicle promotion actions.

Action	Level	
State ZEV program	State	California – Zero Emission Vehicle Program
State International ZEV Alliance participation	State	Multiple – Zero Emission Vehicle Alliance
State low-carbon fuel policy	State	California – Low Carbon Fuel Standard
State BEV purchase incentive	State	Colorado – Innovative Motor Vehicle Tax Credit
State PHEV purchase incentive	State	Massachusetts – MOR-EV
State increased BEV incentive for low-income	State	California – Clean Vehicle Rebate
State increased PHEV incentive for low-income	State	California – Clean Vehicle Rebate
State fee reduction or testing exemption	State	Arizona – Reduced Vehicle License Tax
No state annual electric vehicle fee	State	California – Zero-emission vehicle fee beginning 2020
State private charger incentive, support	State	Missouri – Alternative Fuel Infrastructure Tax Credit
State public charger promotion	State	Ohio – Alternative Fuels Transportation Program
State parking benefit	State	Hawaii – Free Parking for Electric Vehicles
State fleet purchasing incentive	State	Massachusetts – Electric Vehicle Incentive Program: Fleets
State manufacturing incentive	State	California – Sales and Use Tax Exclusion Program
State allows direct sales to consumers	State	Maryland – House Bill 0235
City electric vehicle strategy	Local	Portland, Oregon – 2017 City of Portland Electric Vehicle Strategy
Streamlined EVSE permitting process	Local	Chicago, Illinois – Drive Electric Chicago
EV-ready building code	Local	Denver, Colorado – Municipal building code
City vehicle purchase subsidy	Local	Riverside, California – Alternative Fuel Vehicle Rebate Program
City parking benefit	Local	Cincinnati, Ohio – Free Parking for All-Electric Vehicles
City EVSE incentive, support	Local	Washington, DC – Alternative fuel infrastructure credit
City carpool lane (HOV) access	Local	Nashville, Tennessee – HOV Smart Pass
City-owned EV chargers	Local	Raleigh, North Carolina – Electric Vehicle Charging Stations
U.S. DOE EV Project key area	Local	Multiple – The EV Project
Workplace charging	Local	Multiple – Workplace Charging Challenge Progress Update 2016
City car sharing program link	Local	Indianapolis, Indiana – BlueIndy
City informational materials	Local	Chicago, Illinois – Drive Electric Chicago
City outreach events	Local	New Orleans, Louisiana – National Drive Electric Week
City outreach events in low-income communities	Local	Watts, Los Angeles, California – National Drive Electric Week
City green fleet target	Local	Milwaukee, Wisconsin – Smart Fleet
City electric vehicle fleet target	Local	New York, New York – OneNYC
City use of electric buses in public transportation	Local	Louisville, Kentucky – Transit Authority of River City
Utility charging pilot or other research	Utility	Birmingham, Alabama – Alabama Power Electric Transportation
Utility public charging infrastructure	Utility	Kansas City, Missouri – Clean Charge Network
Utility public charging infrastructure in low-income communities	Utility	San Diego, California – SDG&E to install thousands of EV chargers
Utility time of use rates offered	Utility	Detroit, Michigan – DTE Energy Rate Options
Utility preferential EV rates	Utility	Atlanta, Georgia – Georgia Power Plug-in Electric Vehicle Rate
Utility EV or EVSE incentive, support	Utility	Austin, Texas – Austin Energy – Plug-in Austin
Utility increased incentives for EVSE at multifamily properties	Utility	Austin, Texas – Austin Energy – Multifamily Properties
Utility info materials or outreach events	Utility	Baltimore, Maryland – Baltimore Gas and Electric – Electric Vehicles
Utility EVSE informational materials for multifamily properties	Utility	Seattle, Washington – EV service equipment for multi-family housing
Utility cost comparison tool	Utility	Dallas, Texas – Oncor – EV Savings Calculator
Utility electric vehicle fleet	Utility	San Francisco, California – PG&E to Step Up Addition of EVs