

Fuels Institute

Electric Vehicle Adoption

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FOCUS ON CHARGING



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Abbreviations

ACS	American Community Survey	ISO	Independent System Operator
ARC	Atlanta Regional Commission	kW	Kilowatt
BEV	Battery Electric Vehicle	kWh	Kilowatt-Hour
CALeVIP	California Electric Vehicle Infrastructure Project	LA Metro	Los Angeles Metropolitan Transportation Authority
Capital Metro	Capital Metropolitan Transportation Authority	MARTA	Metropolitan Atlanta Rapid Transit Authority
CARB	California Air Resources Board	MSA	Metropolitan Statistical Area
CBG	Census Block Group	MUD	Multi-Unit Dwelling
CVRP	Clean Vehicle Rebate Program	MY	Model Year
DAC	Disadvantaged Communities	NAS	National Academies of Science
DART	The Des Moines Area Regional Transit Authority	NREL	National Renewable Energy Laboratory
DC	Direct Current	NYSERDA	New York State Energy Research and Development Authority
DER	Distributed Energy Resource	PHEV	Plug-in Hybrid Electric Vehicle
DEP	Department of Environmental Protection	PUC	Public Utility Commission
DOT	Department of Transportation	RMI	Rocky Mountain Institute
EPA	Environmental Protection Agency	SCE	Southern California Edison
EPRI	Electric Power Research Institute	SEPTA	Southeastern Pennsylvania Transit Authority
EV	Electric Vehicle	TAZ	Traffic Analysis Zone
EVI	Electric Vehicles Initiative	TCEQ	Texas Commission on Environmental Quality
EVSE	Electric Vehicle Supply Equipment	TCO	Total Cost of Ownership
GHG	Greenhouse Gas	TOU	Time of Use
HEV	Hybrid Electric Vehicle	UC Davis	University of California, Davis
HOT	High Occupancy Toll	V2G	Vehicle-to-Grid
HOV	High Occupancy Vehicle	VW	Volkswagen
ICCT	International Council on Clean Transportation	ZEV	Zero Emission Vehicle
IEDA	Iowa Economic Development Authority		
INL	Idaho National Laboratory		
IOU	Investor-Owned Utility		

Executive Summary

Electric Vehicle Adoption: Focus on Charging

Electric vehicles (EVs) have garnered considerable interest and support from a variety of stakeholders. New EV sales increased from 1.1% to 2.1% of total light-duty vehicle sales in the U.S. from 2017 to 2018; while official sales numbers are still forthcoming, the nationwide market for new EVs stalled in 2019. This sales growth is moderately promising considering that most EV models available today are sedans and hatchbacks in a period when new car buyers have increasingly turned to sport utility vehicles, crossovers, and light trucks.

The EV market is developing and changing rapidly, as evidenced by charging infrastructure deployment and the increasing number of EV models available to consumers, such as the Chevrolet Bolt and the Tesla Model 3, which have reasonably attractive price points and much greater ranges than models introduced in the last five years. However, the market for EVs is small, and the potential headwinds of low gasoline prices and increasingly efficient

conventional vehicles will present challenges to increased EV deployment.

In this report, ICF focuses on the main drivers for EV deployment, including the economics of owning a car (considering both the vehicle and the fuel), consumer behavior, and the availability of charging infrastructure—and how these drivers might change over time. Unsurprisingly, these drivers are inter-connected and can be difficult to parse; however, areas of overlap have been identified where appropriate.

Ultimately, this report presents a measured view of the EV market. Proclamations of tipping points and rapid market evolution are distracting given the amount of work and planning required to achieve higher levels of EV penetration. For instance, EV sales figures stagnated most of 2019 compared to sales in 2018; however, rather than overreact to near-term market realities, ICF takes a broader view of the market and the drivers that influence EV adoption. Generally speaking, the current economic, policy, and technology trends are positioning EVs to comprise a significant share of the American light-duty vehicle market in the long-term future. There are notable near-term hurdles that will temper large-scale EV growth, including battery prices, charging infrastructure and model availability,

federal policy outlook, and consumer awareness levels. However, it is not a question of if but when these barriers will be addressed. Many consumers will rely on conventional petroleum-based fuels for the foreseeable future, but electricity will become an increasingly important transportation fuel. Although there is ample time for the fuels community to prepare for a landscape with widespread transportation electrification, relevant stakeholders should take a proactive approach to assess how they can continue to serve future fueling needs and evaluate opportunities to incorporate electricity into an increasingly diverse suite of modern transportation fuels.

This report focuses on the EV market and its potential evolution over time with a focus on EV charging infrastructure. More specifically, this report posits that the market needs to prioritize developing a much clearer picture of several key issues with respect to EV charging infrastructure, most notably where, when, and for how long consumers are going to charge their EVs. Without responding to these basic consumer needs, the EV market could stall and charging infrastructure investments may not be optimally utilized.

This report considers other critical aspects of the EV market, including total cost of vehicle ownership and consumer acceptance. The findings presented mirror those stated elsewhere in the literature: EVs have the potential to reduce the total cost of ownership compared to conventional vehicles, and lack of consumer awareness around critical issues such as incentives, vehicle models available, and charging infrastructure availability are barriers to broader EV adoption. This report also concludes that consumers continue to be hesitant about EVs because of the higher costs of EVs, the availability of charging (at home or in public), and the uncertainty around battery technology (as indicated by driving range and to some extent the time to recharge).

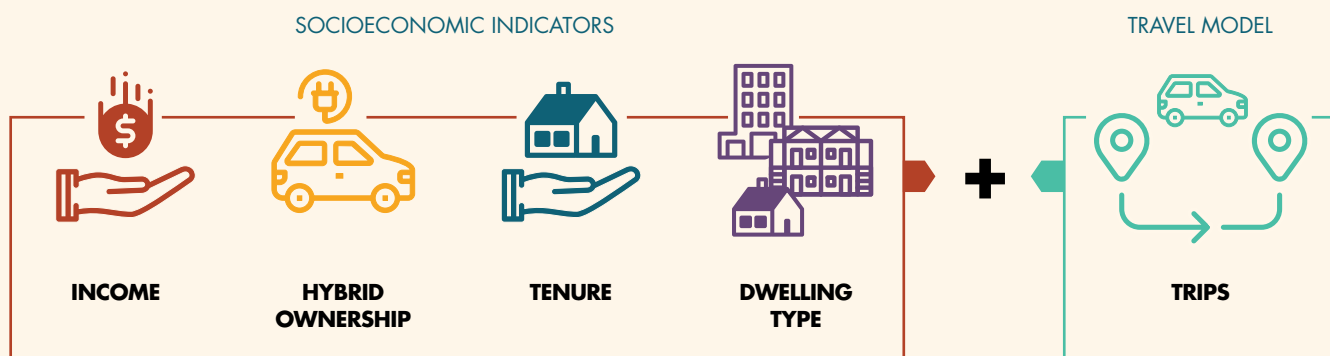


THIS REPORT FOCUSES ON EV CHARGING INFRASTRUCTURE BECAUSE IT IS A PLANNING AND INVESTMENT CONSTRAINT, WHICH IS DEPENDENT ON ENGAGEMENT AND COORDINATION OF A BROAD STAKEHOLDER COMMUNITY IN ORDER TO ADDRESS.

On the other hand, infrastructure availability is dependent on engagement and coordination of a broad stakeholder community, with a focus on utilities, charging station providers, site hosts, and government agencies. When solely considering revenues from EV charging services (i.e., “charging for charging”), EV charging stations may also operate under challenging economic conditions while EV adoption remains low.

The rapid entry of utilities into the EV charging market across the U.S. has spurred unprecedented levels of investment to support vehicle fueling. Many utilities have submitted investment plans to facilitate EV charging infrastructure deployment, seeking permission from utility commissions to recover the costs of transportation electrification programs from all utility customers, not just EV owners. While the long-term value of EVs has the potential to increase utility revenues, improve the

FIGURE 1. OVERVIEW OF ICF EV CHARGING INFRASTRUCTURE SITING ANALYSIS METHODOLOGY



efficient use of the electricity grid, and potentially lower utility rates for all customers, the near-term focus is on improving utility understanding of where, when, and how EVs are charged. Utility investments reflect the uncertainty in the EV charging market—utilities are investing equally in different places for charging (e.g., public, workplace, at multi-family units) and using different funding mechanisms (e.g., own and operate or so-called make-ready investments). Utilities are currently focused on Level 2 charging stations; however, this is likely a short-term focus rather than an indicator of long-term plans for EV charging infrastructure.

These various considerations were bundled into a series of case studies to examine how demand for EV charging infrastructure varies across geographies as the market evolves. This report presents a siting analysis to visualize and explore the demand for EV charging infrastructure at different locations based on a combination of socioeconomic indicators for EV ownership and travel patterns in and around each metropolitan area. [Figure 1](#) summarizes the approach that was used to characterize the demand for EV charging infrastructure.

The data on income, tenure, and dwelling type are from the American Community Survey, an ongoing

survey conducted by the U.S. Census Bureau.

Hybrid ownership data were collected from motor vehicle registration information provided by IHS Markit. This information helps characterize the likelihood that a region will adopt EVs. While all regions are expected to adopt EVs, this analysis quantifies the likelihood of EV adoption based on our current understanding of EV ownership. The likelihood of EV adoption is paired with origin-destination trip information extracted from the transportation models.

While we understand much about how people travel and use conventional vehicles today, we understand very little about how people will drive EVs—including where they will charge, when they will charge, and for how long. The case studies provide an opportunity to explore how the deployment of EV charging infrastructure might change as a function of various parameters across different geographies. The analysis is informed by a web-based mapping tool that ICF developed and is complemented by ICF analysis of various sources, including the National Renewable Energy Laboratory’s (NREL) [Electric Vehicle Infrastructure Projection Tool \(EVI-Pro\) Lite](#) to estimate the amount of charging infrastructure needed to support the EVs in a given metropolitan area.¹

¹ EVI-Pro estimates the number of public and workplace charging stations needed to support a given quantity of EVs in a defined metropolitan area or state. It does not provide estimates on station utilization, operational costs, or profitability.

ICF reviewed the current market for EVs in 10 metropolitan regions: Atlanta, GA; Austin, TX; Chicago, IL; Columbus, OH; Denver, CO; Des Moines, IA; Los Angeles, CA; Orlando, FL; Philadelphia, PA; and Portland, OR. These regions were selected because of their diversity, not only in terms of geography but also in terms of EV market readiness and penetration. And through a series of assumptions about potential changes to the EV market, the analysis considered changes to demand for EV charging infrastructure with a focus on the following issues:

The demand for charging at home. As much as 80% of EV charging today occurs at home. This has led to a market dominated by buyers with easy access to charging at home, typically single-family homeowners that have access to a garage. Charging at home is likely the most cost-effective way to reduce the operating costs of owning an EV. And when combined with the potential for attractive time of use (TOU) electricity rates from utilities, whereby it is cheaper to charge during the night for example, at-home charging is even more attractive. Moving forward, however, the EV market will have to expand beyond the single-family homeowner and serve a broader socioeconomic base. ICF developed a methodology to consider this shift and how it may affect EV charging infrastructure demand.

Potential for decreased vehicle ownership. Recent economic growth has spurred new vehicle sales, and vehicle miles traveled are on the rise in the U.S. However, there is increasing evidence to suggest that vehicle ownership may decrease in the future as new mobility options present themselves to consumers, such as through car-share, ride-sharing, ride-hailing applications, expanded public transit, or improved focused on non-motorized modes like walking or biking. ICF considered the potential for decreased vehicle ownership in each region and what that might mean for EV charging infrastructure demand.

Transitioning from early adopters to the mass market. ICF's base analysis for EV charging demand is focused on likely EV owners. Our current understanding of EV owners is focused on high-income individuals who own a single-family home and have likely owned a hybrid vehicle. As EVs become more affordable over time, this profile will likely change as middle-income car buyers, renters, and consumers who live in multi-family units consider purchasing an EV. ICF considered this transition and its impact on EV charging infrastructure demand.

Consumer preference for vehicle architecture. Today, the market for EVs is split between plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs). PHEVs are typically a combination of a smaller battery hybridized with a gasoline engine to address potential range concerns. BEVs are powered exclusively by electricity from the grid and have ranges of up to 350 miles, depending on driving conditions. The charging infrastructure solutions for these EV architectures is considerably different. Most PHEVs, for instance, cannot use direct current (DC) fast charging equipment. BEVs have larger batteries and will likely need to be charged at more places than just homes. ICF considered the potential shifts in demand for EV charging infrastructure depending on consumer preference for PHEVs versus BEVs.

Achieving decarbonization targets. While federal policies to mitigate greenhouse gas (GHG) emissions have stalled, many states and regions have enacted policies to help achieve decarbonization. Transportation accounts for a significant share of GHG emissions—more than 30% nationally and a higher share than that in some regions (typically depending on the proximity of regional industrial activity). As such, transportation is often a key focus of metropolitan areas' decarbonization efforts, and in some cases, cities seek aggressive adoption of lower carbon transportation solutions, including the rapid deployment of EVs.

ICF's siting analysis across multiple cities and regions reinforces the notion that the transition to mass EV adoption will require a mix of EV charging solutions, with a focus on convenient and ubiquitous access to EV charging. The quantitative determination of convenient and ubiquitous EV charging, however, remains difficult to ascertain. This will be even more difficult absent a more concerted effort across the industry to make data accessible regarding EV drivers' charging and driving behavior. ICF finds that outside of initial reporting by federal laboratories, the industry lacks a clear picture of how much charging infrastructure will be required because there is limited and disparate data sets available to market analysts. These data sets are increasingly proprietary, thereby limiting strategic planning for EV charging infrastructure deployment. This is being reinforced by public agencies' lack of data collection: ICF found that there is limited data collection regarding matters such as station utilization and total station installation costs across more than 35 government incentive programs. Moving forward, utilities and other EV charging program administrators will be important resources for assessing EV charging market dynamics to the extent those entities are required to provide publicly available data and reports on program performance. This information could help guide investment toward stations with the greatest economic potential, support the entry of new vehicles in the market, and facilitate the decarbonization of the transportation sector.

There is no single ratio that accurately captures the relationship between EV charging stations and EVs, but charging infrastructure deployment has historically been viewed as lagging behind EV sales, meaning that EV sales were growing faster than the amount of available charging infrastructure. However, over the next several years, this relationship will likely reverse as stakeholders seek to address infrastructure-related barriers

to EV adoption. More specifically, ICF anticipates that increases in charging station deployments may outpace EV sales growth in the near-term, particularly for publicly accessible Level 2 charging. The increased deployment of EV charging stations during a period of low EV sales growth may initially produce headwinds for EV charging service providers looking to increase utilization and revenues at the station level. Nonetheless, this anticipated short-term shift in charging station deployment dynamics is likely necessary to build out the backbone of a reliable, accessible charging infrastructure network that will improve consumer understanding of the technology and lay the foundation for future EV growth.

Lastly, the research conducted for this report indicates that there are likely to be more aggressive opportunities in the residential charging market in the near-term future, including both single-family housing units and multi-unit dwellings, as market participants seek to capitalize on growing customer acceptance of EV technology and focus on low-cost charging solutions. The increased growth and investment will be linked to the value proposition of managed charging where EV drivers are likely to continue to charge most frequently: at home. This does not diminish the importance of public charging. To the contrary, as EVs become increasingly attractive to a broader set of customers without access to home charging, greater access to public charging, like DC fast charging, will see opportunities for growth. Proliferation of electrified shared mobility options will also rely heavily on public DC fast charging, creating new revenue opportunities for entities positioned to attract high volumes of customers.

Introduction

Electric vehicles (EVs) have garnered considerable interest and support from a variety of stakeholders.² Even as gasoline prices have remained relatively low between 2015 and the summer of 2019,³ EV sales have held steady and gained momentum in many regional markets while stalling slightly at the outset of 2019. The market is developing rapidly, as evidenced by charging infrastructure deployment and the increasing number of EV models available to car buyers, including EVs with much longer ranges than models introduced in the previous five years.

However, the market for EVs is still emergent and the headwinds of low gasoline prices and increasingly efficient conventional vehicles could present significant challenges to increased EV deployment.

The objective of this report is to deliver the main drivers for EV deployment, including the economics of owning a car (considering both the vehicle and the fuel), consumer behavior, and the availability of charging infrastructure, and how these drivers might change over time. Unsurprisingly, these drivers are interconnected and can be difficult to parse; however, areas of overlap have been identified where appropriate.

ICF's analysis relies on a combination of analysis and literature review. With respect to the literature review, ICF considered the following:

- **Techniques for market assessment:** How are EV market status, key challenges, and benefits considered? Are there appropriate niche applications considered?
- **Policy and regulatory frameworks:** What are the scopes of the applicable regulatory frameworks? How do they address the core elements of market intervention?
- **Survey methodology:** How were consumer acceptance surveys conducted? What markets were addressed?

Section 2 provides a brief overview of the EV market, with a critical review of cost of vehicle ownership, consumer acceptance, and anticipated EV charging infrastructure requirements. Ultimately, the focus turns to understanding how the demand for charging infrastructure may evolve and its role in the development of the EV market. This report addresses EV charging infrastructure by reviewing the market today and the emerging role of electric utilities, and by identifying critical market indicators that will determine the future of EV charging infrastructure deployment.

The final section provides an overview of how EV charging infrastructure may evolve in the context of demographics, the movement of EVs into the broader consumer market, changes in how people travel or drive, consumer choice with respect to EV architecture, and achieving deep decarbonization targets—all against the backdrop of specific metropolitan areas in the U.S.

² A note on nomenclature: In this report, the term *electric vehicle (EV)* is used to represent both plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs). When needed, EV architectures are distinguished accordingly.

³ For instance, see information from the U.S. Energy Information Administration regarding weekly gasoline prices at https://www.eia.gov/dnav/pet/pet_pri_gnd_dcus_nus_a.htm.

Electric Vehicle Market Overview

The EV market has achieved significant progress over the last several years. In fact, EV enthusiasts and market observers alike cheered the sale of the one-millionth EV in the U.S. market in October 2018.⁴ Each of the major automobile manufacturers has made a substantial commitment related to transportation electrification.

Some market analysts are forecasting dramatic decreases in battery prices, leading to EVs being at purchase price parity with conventional vehicles in the 2023-2025 timeframe (without subsidies like the federal tax credit included).⁵ Utilities and third-party charging infrastructure providers like ChargePoint, EVgo, Greenlots, and Electrify America have announced billions of dollars of investment in charging infrastructure over the next several years.⁶

Congress' overhaul of the federal tax code in 2018 showed that the federal EV tax credit very likely will remain available until each automobile manufacturer reaches the 200,000-vehicle phase-out cap. The House of Representatives' version of the tax bill would have repealed the tax credit, but

the Senate did not follow suit and in conference committee reconciled the two chambers' bills. Passage of the bill by the Senate suggests (1) the EV tax credit had support from senators on both sides of the aisle, and (2) even with what was a Republican-controlled Congress and a Republican administration, which typically have not supported the credit, the credit cannot easily be eliminated. In other words, there is a combination of technical, economic, and regulatory reasons to be bullish on EVs. In April 2019, Sen. Debbie Stabenow (D-MI) introduced S. 1094, the Driving America Forward Act, to expand the existing federal tax credit for EVs by increasing the sunset threshold of 200,000 vehicles per automaker to 600,000 vehicles per automaker.⁷ Rep. Dan Kildee (D-MI) introduced a companion bill in the House of Representatives: H.R. 2256.⁸ This legislation would also have decreased the maximum tax credit amount from \$7,500 to \$7,000 before automakers reach the 600,000-vehicle threshold, after which point the tax credit would decrease quarterly until it is phased out completely. As leading EV manufacturers have recently reached the 200,000-threshold, the legislation suggested that some members of Congress are interested in supporting policies that would make EVs more accessible to middle-income consumers.⁹

⁴ Maxine Joselow, "The U.S. Has 1 Million Electric Vehicles, but Does It Matter?," *Scientific American*, October 12, 2018, <https://www.scientificamerican.com/article/the-u-s-has-1-million-electric-vehicles-but-does-it-matter/>

⁵ Nic Lutsey and Michael Nicholas, *Update on Electric Vehicle Costs in the United States through 2030* (International Council on Clean Transportation, April 2, 2019), https://theicct.org/sites/default/files/publications/EV_cost_2020_2030_20190401.pdf

⁶ Electrify America, *National ZEV Investment Plan: Cycle 2*, February 4, 2019, <https://www.epa.gov/sites/production/files/2019-02/documents/cycle2-nationalzevinvestmentplan.pdf>

⁷ Driving America Forward Act, S.1094, 116th Cong. (2019). <https://www.congress.gov/bill/116th-congress/senate-bill/1094>

⁸ Driving America Forward Act, H.R.2256, 116th Cong. (2019). <https://www.congress.gov/bill/116th-congress/house-bill/2256>

⁹ Following the completion of this report, the Fuels Institute noted that the current administration did not extend the EV credit, under H.R. 1865 - Further Consolidated Appropriations Act, 2020, which became law on December 20, 2019, for OEMs that have reached their 200,000 ceiling. A series of legislative proposals have been submitted to expand this credit.

Other members were less supportive of the tax credit: On October 9, 2018, Sen. John Barrasso (R-WY) introduced a bill that would repeal the federal EV tax credit and instead impose a fee on alternative fuel vehicles.¹⁰ Regardless, the spending bills that Congress passed in late 2019 did not include any provisions for expanding the EV tax credit.

Despite the preservation of the EV tax credit, there are also several reasons for pause with respect to unrealistic assumptions regarding rapid and unprecedented adoption of a new technology. EVs represent about 2% of domestic light-duty vehicle sales, with crossovers, sport utility vehicles, and light trucks gaining market share compared to smaller passenger cars. In its annual *Global Automotive Executive Survey*, KPMG International reports that “of the executives surveyed, 55% still believe that pure battery electric vehicles will fail due to the challenge of setting up the required infrastructure.”¹¹ Two automobile manufacturers, Tesla and General Motors, surpassed the Section 30D federal tax credit threshold of 200,000 EVs sold by the end of 2018, which triggered a sunset of the availability of the federal tax credit for EVs sold by those manufacturers. Furthermore, Nissan and Ford have surpassed 135,000 and 115,000 EVs sold as of June 2019, respectively; and Toyota is not that far behind with nearly 105,000 EVs sold as of June 2019. Absent an extension of the tax credit, EV sales could slow in the short-term as more automakers reach the sales threshold specified in the current tax code.

The policy support for EVs could be diminished slightly by the U.S. Environmental Protection Agency’s (EPA) new mid-term evaluation



determination that the greenhouse gas (GHG) emission standards for model years (MY) 2022-2025 light-duty vehicles, which EPA promulgated in October 2012, “are not appropriate” and warrant revision.¹² EPA has since collaborated with the National Highway Traffic Safety Administration on a joint rulemaking to propose amended (i.e., less stringent) GHG emission standards and corresponding corporate average fuel economy standards for light-duty cars and pickup trucks manufactured in MYs 2022-2025. The joint proposed rule was issued in August 2018 as the Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for MYs 2021-2026.¹³ The rule identifies California’s GHG standards and zero emission vehicle (ZEV) mandate as an “unnecessary complication” and outlines EPA’s proposal to “withdraw the waiver granted to California in 2013 for the GHG and ZEV requirements of its Advanced Clean Cars Program.” A final rule has not been adopted at the time this report was written.

10 Fairness for Every Driver Act, S.343, 116th Cong. (2019). <https://www.congress.gov/bill/116th-congress/senate-bill/343>

11 “Electric Mobility Is Still Far Away from Being Hassle-Free and Seamless,” KPMG International Cooperative, <https://automotive-institute.kpmg.de/GAES2019/product-value/electric-readiness>

12 Mid-Term Evaluation of Greenhouse Gas Emissions Standards for Model Year 2022–2025 Light-Duty Vehicles, 83 Fed. Reg. 16077 (Apr. 13, 2018), available at: <https://www.govinfo.gov/content/pkg/FR-2018-04-13/pdf/2018-07364.pdf>. See also: Environmental Protection Agency, “EPA Administrator Pruitt: GHG Emissions Standards for Cars and Light Trucks Should Be Revised,” April 2, 2018, <https://archive.epa.gov/epa/newsreleases/epa-administrator-pruitt-ghg-emissions-standards-cars-and-light-trucks-should-be.html>.

13 The Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021–2026 Passenger Cars and Light Trucks, 83 Fed. Reg. 42986 (August 24, 2018), available at: <https://www.govinfo.gov/content/pkg/FR-2018-08-24/pdf/2018-16820.pdf>.

Stronger GHG emission and fuel economy standards could encourage EV adoption among car buyers and pave the way for transportation electrification. But even with retention of the existing standards, those federal standards themselves are unlikely to serve as the primary drivers of electrification. Rather, California’s ZEV program that is currently followed by 10 other states, as well as the federal tax credit (and various state and local incentives)¹⁴ for EV purchases, could help serve as key drivers for greater EV adoption.¹⁵ Furthermore, the efforts being made to electrify the Chinese vehicle fleet cannot be overlooked: What happens in the world’s largest automobile market, coupled with automakers’ desires to remain globally competitive, could help to ensure that the long-term trend towards electrification continues in the U.S., irrespective of the revised MYs 2022-2025 standards.

This report is presented using a measured view of the EV market—most notably, this report avoids proclamations of tipping points and rapid market evolution that are otherwise distracting due to the amount of work and planning required to achieve higher levels of EV penetration. Generally, this report concludes that there are enough market and policy indicators pointing toward widespread

transportation electrification in the long-term. How quickly electrification materializes will be dependent on stakeholders’ ability to overcome near-term hurdles such as upfront purchase price, model availability, and consumer awareness. Policy uncertainty at the federal level may slow the growth of the EV market, but ICF does not recommend relying on business-as-usual federal and state policy as a long-term approach to electrification. ZEV programs, which have helped contribute to greater EV adoption and cover roughly one-third of the country’s auto market, may become a less significant driver of EV adoption toward the second half of the coming decade as EVs become increasingly cost competitive and automakers begin to realize returns on investment from EVs.

The following sub-sections outline three key elements of the EV market: cost of ownership, consumer acceptance, and charging infrastructure requirements. Our analysis demonstrates that charging infrastructure will be the most significant hurdle to overcome in the next 10 years. More specifically, ICF posits that the market needs to prioritize developing a much clearer picture of several key issues with respect to EV charging infrastructure, most notably where, when, and for

¹⁴ see: https://afdc.energy.gov/laws/matrix?sort_by=incentive

¹⁵ Colorado became the eleventh U.S. state to adopt a ZEV standard in August 2019. “Zero Emission Vehicle Mandate Proposal,” Colorado Department of Public Health and Environment, <https://www.colorado.gov/pacific/cdphe/zero-emission-vehicle-mandate-proposal>



how long consumers are going to charge their EVs. The more the market struggles to respond to these basic consumer needs could increase the likelihood that EV adoption stalls and potentially flounders and that the market will make ill-informed and potentially costly investments in charging infrastructure.

In the following sub-sections, ICF's analysis is structured as follows: introduce findings from credible, EV-focused studies; review some of these key findings in the context of what is known about the EV market today; and provide an analysis to formulate an updated view on the market. For instance, this report introduces many key findings from *Overcoming Barriers to Electric Vehicle Adoption*, published by the National Academies of Science (NAS) in 2013, reviews them in the context of today's market, and provides commentary on how things may have changed or in some cases held the same since that report was published.

EV COST OF OWNERSHIP

With respect to owning an EV, many of the key findings of the NAS study are largely true today:

- **To overcome the expensive prices of EVs, the federal government would need to “continue to provide economic incentives,” increase gasoline taxes, reduce license fees, and provide parking benefits and access to carpool lanes.**
- **Rate structures available to most commercial and industrial customers and some residential customers provide an incentive to EV owners and utilities in that they encourage charging at times when lower-cost generating capacity is available.**

The total cost of ownership (TCO) continues to be a challenging area for EVs—the savings potential requires access to competitive electricity rates (presumably via residential charging), driving a certain number of miles over the life of the vehicle, and a combination of higher conventional vehicle pricing and gasoline pricing.¹⁶ Despite the potential for lifetime savings, however, consumers continue to struggle with the upfront vehicle costs. The issue of the federal tax credit for vehicle purchase will become more acute over the next one to three years as certain manufacturers approach the initial limit of the tax credit (200,000 EVs sold) before the credit phases out, based on time, not volume. Tesla and General Motors passed the 200,000-vehicle threshold in mid-2018 and early 2019, respectively.^{17,18} Furthermore, as of June 2019, Nissan and Ford have surpassed 135,000 and 115,000 EVs sold, respectively; and Toyota is not that far behind with nearly 105,000 EVs sold. There are many market analysts predicting significant battery price reductions in the near-term future (e.g., by 2023), enabling a lower price for most EVs. This will be essential as the federal tax credit is likely going to be phased out or in the process of phasing out for the top three manufacturers (by way of sales) by then.


EVs currently cost more on an upfront basis than their conventional counterparts. However, there are cases when the TCO of an EV may be less than a conventional vehicle after accounting for incentives, the lower cost of electricity compared to gasoline, and lower maintenance costs. There have been a variety of studies reviewing the costs of owning an EV versus other types of vehicles—typically conventional internal combustion engine vehicles and hybrid gasoline-electric vehicles.¹⁹

16 This report did not consider the end-of-life for EV batteries. While there may be costs associated with the disposal of batteries at the end of their useful life, this cost is unlikely to be incurred by consumers. Rather, batteries will likely have useful life (e.g., for energy storage resources on the electrical grid) after the end of their useful life in an automotive application—and a secondary market will likely develop, thereby improving the long-term value proposition of EVs.

17 Tesla notes eligibility for the federal income tax credit on its own site at <https://www.tesla.com/support/incentives>. That site indicates the reduced value of the federal tax credit starting January 1, 2019, which indicates that they have surpassed the 200,000 vehicle threshold.

18 Mark Kane, “November Update - 4 Automakers Closest To Losing Federal Tax Credit,” *InsideEVs*, December 5, 2018, <https://insideevs.com/top-6-automakers-200000-federal-tax-credit-limit/>.

19 TCO is one metric upon which consumers may evaluate vehicle purchase decisions, but it is not the only metric. Other factors that may influence vehicle purchase decisions include size and technology features, among others.



The TCO continues to be a challenging area for EVs—the savings potential requires driving a certain number of miles over the life of the vehicle, among other things.

The cost of vehicle ownership is considered a function of the following parameters: acquisition costs, vehicle operation costs, and maintenance costs. For the sake of reference, there are competing theories regarding consumer behavior in car buying scenarios.²⁰ For instance, economic theory suggests that rational consumers would use the TCO approach; however, the little empirical evidence that does exist suggests that consumers rarely behave according to theory. Conversely, behavioral economics posits that because future fuel savings are highly uncertain, consumers discount them heavily compared to known initial costs (i.e., vehicle acquisition costs). Oak Ridge National Laboratory research prepared for the EPA found that there is “very substantial uncertainty about how consumers make decisions about fuel economy, as well as

how much they value expected future fuel savings.” Because of this limitation, this review seeks to consider multiple aspects of vehicle ownership consideration.

There are too many TCO calculators and TCO approaches available in the public domain to review in their entirety for this report. To that end, this report limits its consideration to an approach developed by the Electric Power Research Institute (EPRI) and one by researchers at the University of California, Davis (UC Davis).

EPRI compared the lifetime costs of EVs and hybrid or conventional vehicles.²¹ Although somewhat dated (2013), the study differentiates itself by examining various purchase options (e.g., cash purchases and financed purchases), compared

²⁰ Oak Ridge National Laboratory, *How Consumers Value Fuel Economy: A Literature Review* (Assessment and Standards Division, Office of Transportation and Air Quality, U.S. Environmental Protection Agency, March 2010). Available online: <http://www3.epa.gov/otaq/climate/regulations/420r10008.pdf>

²¹ Electric Power Research Institute, Total Cost of Ownership Model for Current Plug-in Electric Vehicles, June 10, 2013, <https://www.epri.com/#/pages/product/3002001728/?lang=en-US>.

the EVs to comparable conventional vehicles (e.g., models that have the amenities of EVs, such as smooth driving and low noise), and took into account realistic driving patterns. EPRI did not account for EV benefits or incentives that are more difficult to monetize, such as high occupancy vehicle (HOV) lane access or driver experience, and assumed that drivers only have access to home charging. EPRI reports that total lifetime costs and monthly outlay are within 10% of comparable hybrid and conventional vehicles. The study suggests that changes in gasoline prices will significantly affect the total lifetime costs of EVs, and that financial incentives (state or federal) have a large impact on cost and help make EVs cost competitive. Despite changes in the market over the last several years, the findings of this study hold up in part because of the different options that can be considered as part of the analysis. From ICF's standpoint, the only aspect that does not hold up over time is EPRI's conclusion that financial factors should not be a deterrent to an EV purchase. Generally speaking, this is a common misconception and misuse of the TCO modeling. As noted previously, consumer behavior with respect to new vehicle purchasing is rarely perfectly rational, and concluding that financial factors should not be a deterrent to EV ownership ignores the importance of upfront vehicle pricing in consumer decision making.

UC Davis researchers developed a lifecycle or TCO model that provides guidance to EV practitioners on factors that affect EV purchase decisions and ownership costs in California.²² The model considers cost parameters/variables for fuel, vehicle, maintenance, and parking and generates cost distribution and variations results for three models: Nissan LEAF, General Motors Volt, and Chevrolet Cruze. UC Davis' findings vary depending on location-specific drive cycle. The researchers suggest that there are public benefits from the information this tool can provide, including an "accumulated cost of ownership savings of roughly \$35 million"

with increased EV sales in California. Again, ICF finds that these types of conclusions with respect to TCO modeling are misplaced and presume to some extent that consumers are both interested in and capable of conducting complicated TCO calculations. In reality, the car-buying experience differs considerably from a spreadsheet analysis and involves a variety of lifestyle and hedonistic decisions that are difficult to capture in a TCO model.

Of note, UC Davis research suggests that "vehicle depreciation for EVs is likely to be similar to that of conventional vehicles"—this has not been borne out in the market. One major factor is the fact that the federal tax credit for the purchase of an EV does not apply to the second owner. And, with some notable exceptions, many EVs in the secondary used market can be more than 20% lower than their conventional counterparts. The study also noted that driving conditions have a large effect on the TCO calculations—including "driving cycle, grade, and accessory loads."

ICF finds that TCO calculations are best used to compare the costs of different fuel types within a vehicle class size, and it is especially useful in modeling state and federal policy, fuel pricing, and vehicle technology scenarios. However, that does not mean that these are particularly powerful guides for driving consumer decision-making in the car-buying process. ICF developed a TCO tool as part of our analysis to estimate the cost of owning and operating BEVs, PHEVs, and conventional vehicles in the U.S. Vehicle modeling is available for nine size classes defined by the EPA: subcompact, compact, midsize, large, small station wagon, small sport utility vehicle, standard sport utility vehicle, large sport utility vehicle, and minivan. ICF developed the tool to account for the state in which drivers might reside, the vehicle class, payment type (e.g., cash/check or financed), and vehicle lifetime. In the case of financed vehicles, ICF also developed the tool to modify the loan term. While ICF developed the tool with default values for each of the key parameters, all input fields can be modified to reflect more

²² Andrew Burke et al., *Analytical Tool to Support the Implementation of Electric Vehicle Programs* (Davis, CA: University of California-Davis, Institute of Transportation Studies, March 2013).

Because the tool calculates total lifetime cost of ownership, it provides a useful and holistic view of the cost of EVs. The tool allows users to compare how fuel and maintenance costs compare across different vehicle types over the expected vehicle lifetime. While the TCO tool defaults to general reference data, all assumptions can be modified. This allows many scenarios to be considered and more accurate TCO determinations to be made based on specific consumer behavior considerations and conditions.

The primary value of our TCO calculations is to update consideration of how different parameters and variables can impact the results. The following subsections highlight some key considerations when evaluating TCO calculations with a focus on charging incentives, publicly available charging, the impact of time of use (TOU) rates, and variations in vehicle technology. Specific states are used in the estimates presented below to illustrate the differences, which were selected for illustrative purposes only and are not meant to favor one region over another.

VEHICLE INCENTIVES

Elimination of federal tax credit

The federal tax credit for EVs serves as a financial incentive, with available credits ranging from \$2,500 to \$7,500 for the purchase of a new EV, depending on battery size. The incentive is scheduled to phase out when manufacturers sell a minimum of 200,000 qualified EVs. Using the tool, the user can explore the different impacts that a phased-out federal tax credit will have on a driver’s TCO.

With the current federal tax credit (as of January 2020), the purchase price of a midsize BEV (\$23,200) or PHEV (\$22,600) in New Hampshire is comparable to that of a conventional vehicle (\$23,100), with a 22% and 20% reduction in TCO for BEVs and PHEVs as compared to conventional vehicles, respectively. However, if the federal tax credit is eliminated or phased out, the purchase prices for BEVs and PHEVs increase, and the reductions in TCO decrease to 8% and 12%, respectively. In this scenario, TCO for a BEV is higher than a PHEV (Figure 2).

FIGURE 2. TCO FOR A MIDSIZE BEV AND A CONVENTIONAL VEHICLE IN NEW HAMPSHIRE WITH (L) AND WITHOUT (R) THE FEDERAL TAX CREDIT

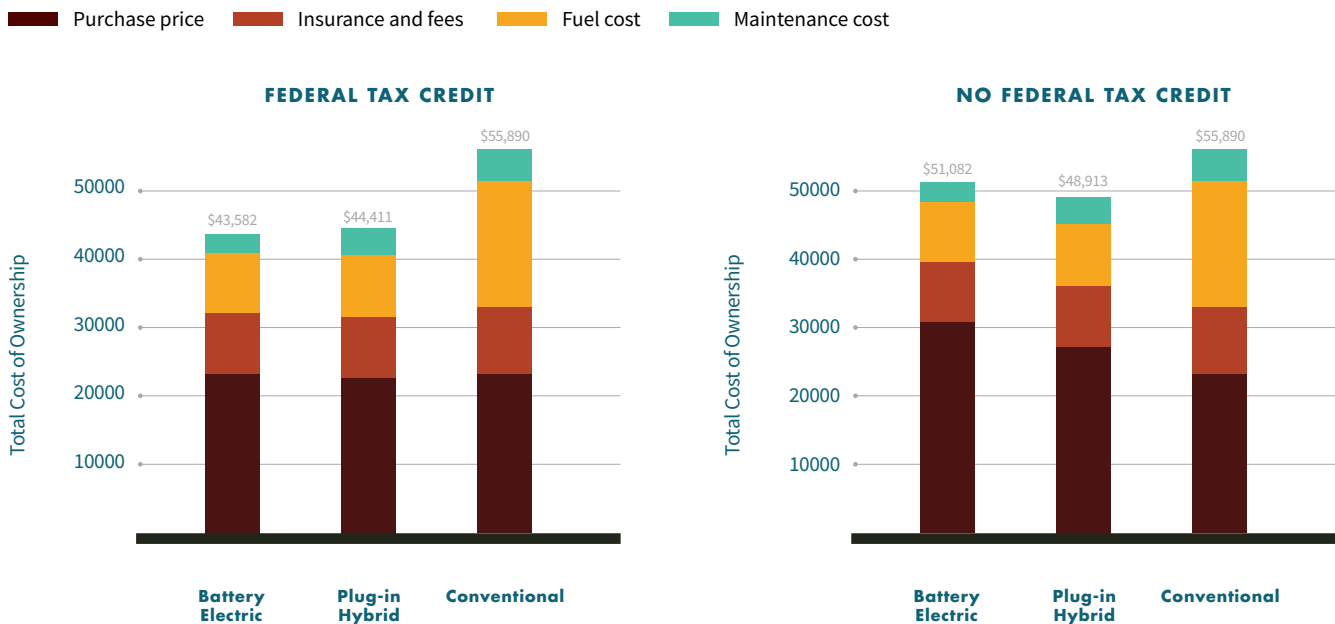
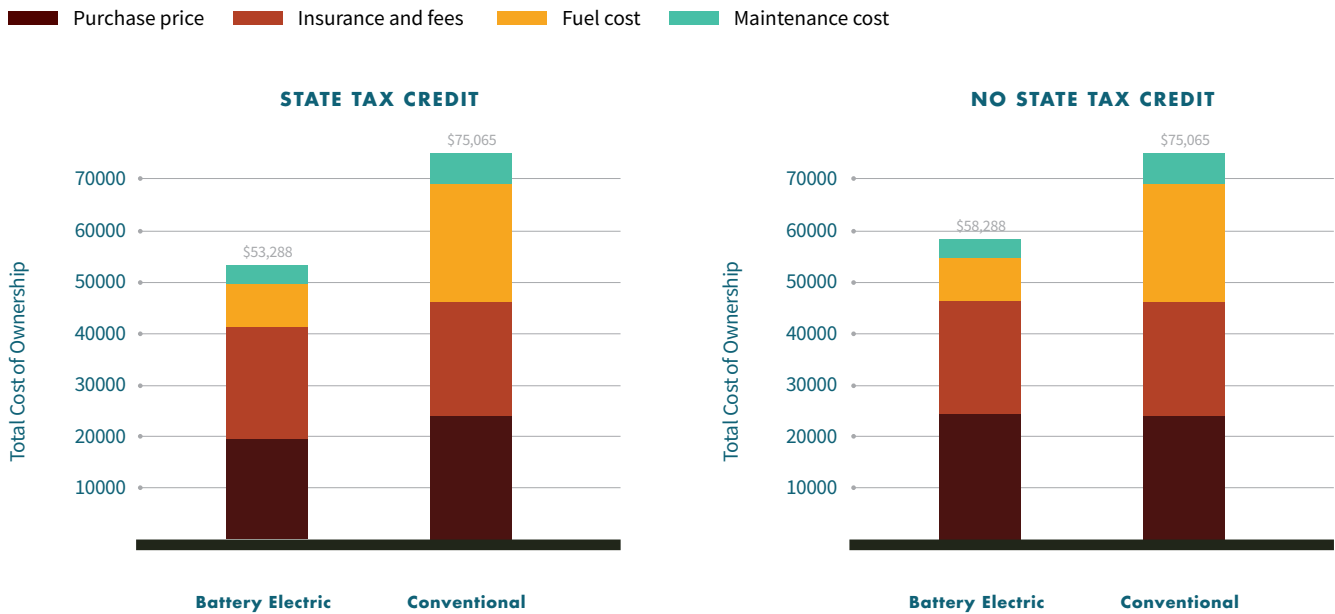


FIGURE 3. TCO FOR A MIDSIZE BEV AND A CONVENTIONAL VEHICLE IN GEORGIA WITH (L) AND WITHOUT (R) THE STATE TAX CREDIT



Elimination of a state tax credit

Changes in state incentives affect the purchase price of a vehicle and the vehicle’s TCO. One example is Georgia, where the state offered a tax credit equivalent to 20% of the MSRP of a ZEV, up to \$5,000. However, in 2015, the state legislature eliminated the tax credit to offset a transportation spending bill (Figure 3).²³

With the \$5,000 tax credit, the purchase price of a midsize BEV was \$19,400 (as compared to \$24,000 for a comparable conventional vehicle). The TCO of a midsize BEV for a 10-year lifetime would be \$53,300, nearly 30% lower than that of a conventional vehicle (\$75,100). However, with the elimination of the \$5,000 tax credit, the purchase price of a midsize BEV is \$24,000 (higher than a conventional vehicle) and the TCO increases to \$58,300 (20% lower than a conventional vehicle).

EVEN THOUGH THE TCO IS POTENTIALLY LOWER WITHOUT THE FEDERAL TAX CREDIT, CONSUMER SURVEYS (DISCUSSED IN MORE DETAIL LATER) DEMONSTRATE THAT UPFRONT VEHICLE PRICING REMAINS A BARRIER TO EV ADOPTION.

This highlights the importance of incentives, despite a potentially competitive TCO. The uncertainty of future fuel cost and maintenance savings, as well as factors such as charging infrastructure availability, continue to be a significant deterrent to EV adoption, despite TCO calculations suggesting otherwise.

²³ Alternative Fuels Data Center, “Expired, Repealed, and Archived Georgia Incentives and Laws,” U.S. Department of Energy, https://www.afdc.energy.gov/laws/laws_expired?jurisdiction=GA.

VARIABLE ELECTRICITY PRICING

Public charging

Residents in multi-family housing or multi-unit dwellings (MUDs) often face an additional barrier to EV adoption: lack of access to residential charging. Therefore, these EV owners rely on workplace and public charging. Station hosts can charge fees for station use, and these fees may be higher than the residential cost of electricity. Because of this variable cost, the TCO tool allows users to select what percentage of time they use public charging stations and modify what price, on a kilowatt-hour (kWh) basis, they pay for public charging.

For example, a Walgreens in San Francisco charges \$0.30 per kWh for use of its charger.²⁴ If a midsize BEV charges at home at the residential electricity rate, it has a lifetime fuel cost of \$9,200 (as compared to \$20,400 for a conventional vehicle). If, however, the vehicle owner lives in an apartment in San Francisco and uses the local Walgreens charger as the primary



power source, the vehicle’s lifetime fuel cost will be \$15,100. This still represents a fuel cost savings over the conventional vehicle, but it increases the TCO by about \$8,000, substantially narrowing the difference between the TCO of a BEV compared to a conventional vehicle (Figure 4).

24 Plugshare. Accessed February 2018. <https://www.plugshare.com/location/5645>.

FIGURE 4. TCO FOR A MIDSIZE BEV AND A CONVENTIONAL VEHICLE IN CALIFORNIA WITH BEV CHARGING AT \$0.18/KWH (L) AND \$0.30/KWH (R)

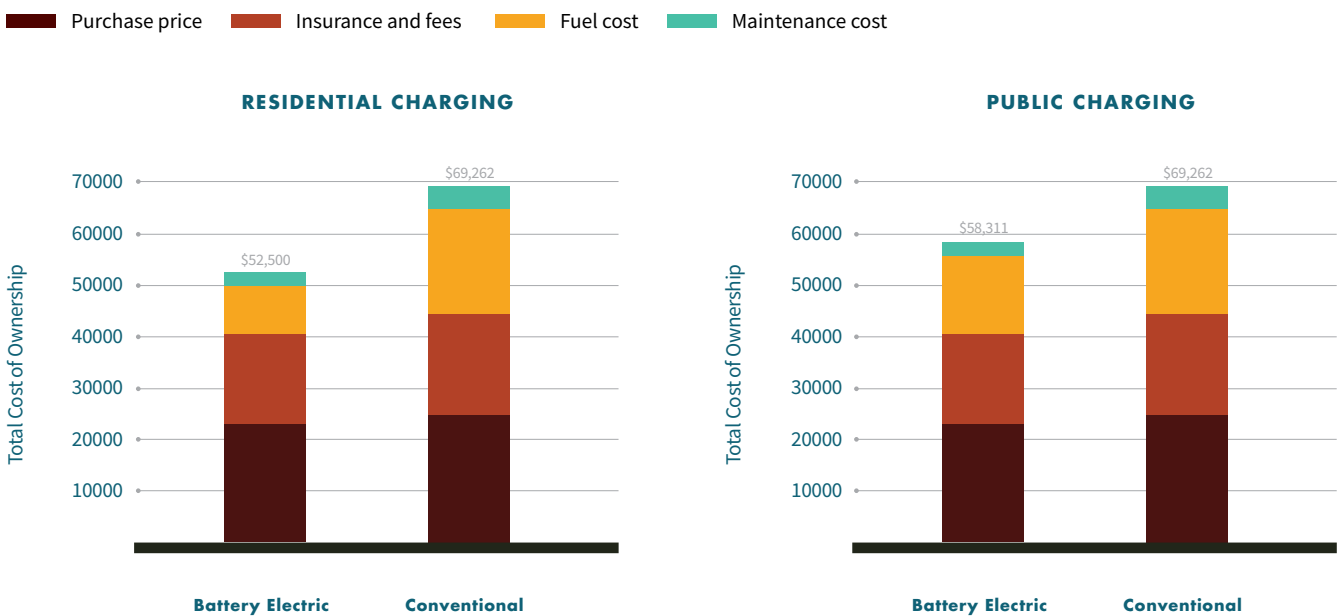
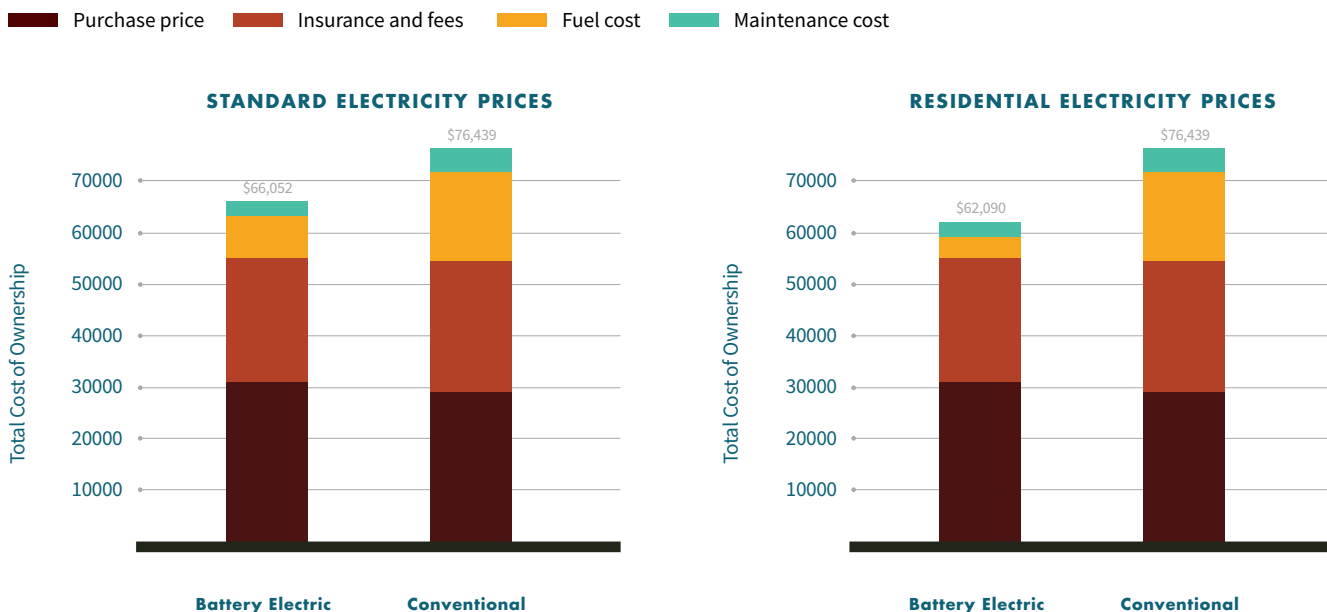


FIGURE 5. TCO FOR A MIDSIZE BEV VS CONVENTIONAL VEHICLE IN MICHIGAN ASSUMING STANDARD (L) AND TOU RESIDENTIAL (R) ELECTRICITY PRICES



TOU rates

Many utilities offer their residential customers, particularly those who own EVs, a lower rate for charging during off-peak hours. Off-peak charging helps the utility manage demand, and EVs are usually plugged in during overnight hours. While the TCO tool defaults to general residential electricity rates, users may update the electricity cost to reflect their utility’s time-of-use (TOU) rate and calculate their increased fuel cost savings.

For example, Consumers Energy offers customers an EV TOU rate of \$0.08 per kWh for all off-peak usage (between 11 pm and 7 am).²⁵ A Michigan midsize BEV driver who did not live in a utility territory that offers a TOU rate would pay \$8,200 in fuel costs during a 10-year period (as compared to \$17,200 for a conventional vehicle). If, however, the driver was eligible for the Consumers Energy TOU rate, they would pay \$4,200 in fuel costs (Figure 5).

VARIABLE VEHICLE TECHNOLOGY

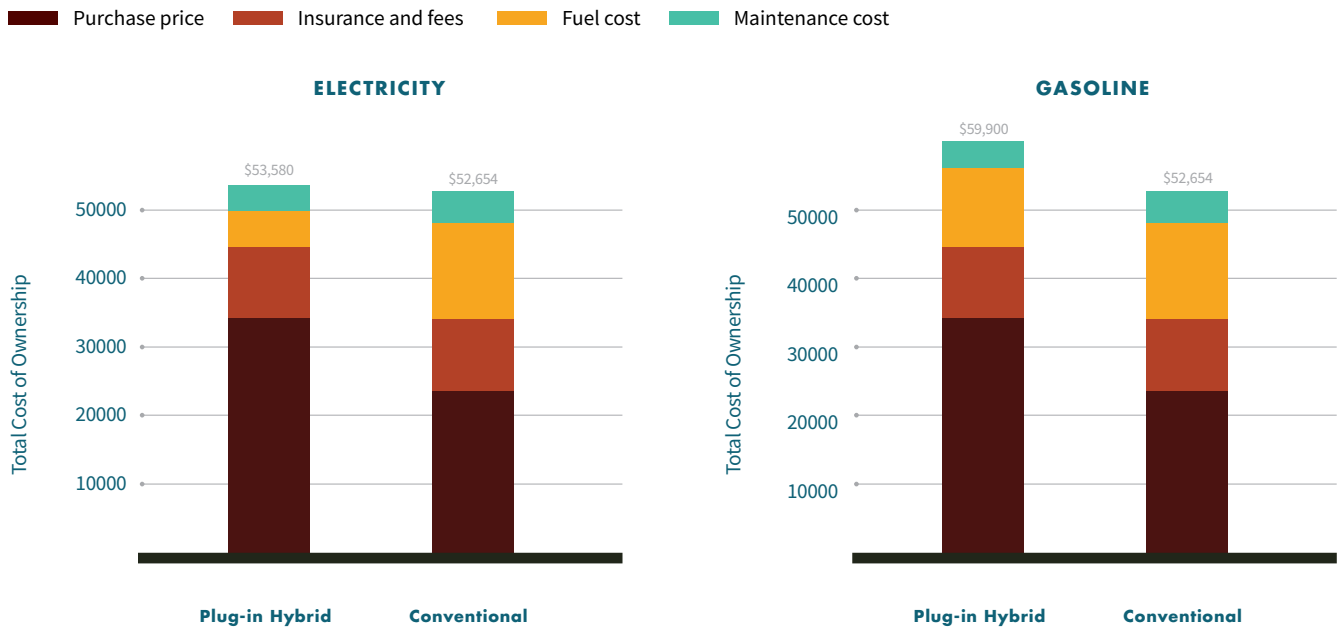
Increased electric miles in PHEVs

Because fuel costs between EVs and conventional vehicles differ significantly, the fuel use habits of PHEV drivers can have a large impact on the TCO. If drivers charge regularly and use electricity as much as possible, they will have much lower fuel costs than if they do not charge the vehicle frequently and usually drive the vehicle on gasoline.

For example, the representative compact PHEV is a Chevrolet Volt, with an all-electric range of 53 miles before switching over to its gasoline-powered engine. If a compact PHEV owner in Idaho rarely charges the vehicle and only drives it on gasoline, fuel costs would be \$11,600 over the 10-year lifetime of the vehicle and TCO would be \$59,900, significantly higher than the TCO of a comparable conventional vehicle (\$52,650). If, however, the driver charged the vehicle regularly and only used electricity, lifetime

²⁵ “Plug-in Electric Vehicle Plans,” Consumers Energy, <https://www.consumersenergy.com/residential/rates/electric-rates-and-programs/rate-plan-options/electric-vehicle-rate-options>.

FIGURE 6. TCO FOR A PHEV AND A CONVENTIONAL VEHICLE IN IDAHO WITH THE PHEV USING EXCLUSIVELY ELECTRICITY (L) OR GASOLINE (R)



fuel costs would be \$5,250, nearly a 50% reduction. Total lifetime costs for the PHEV would now be \$53,580, which is lower than the lifetime costs of the conventional vehicle, even though the purchase price of the PHEV is nearly \$8,000 higher than that of the conventional vehicle (after financial incentives) (Figure 6).

ICF’s findings are similar to those of our literature review: EVs have the potential to reduce the TCO compared to conventional vehicles. However,

myriad assumptions should be considered in the development of the analysis, and answering the question for the average consumer is difficult without a more sophisticated understanding of individual driver behaviors. Regardless, ICF maintains that it is not the TCO of a vehicle that is driving adoption for the general consumer—other factors are influencing purchasing decisions more significantly, and other aspects of EVs are moderating their current market adoption.²⁶

²⁶ The Fuels Institute understands that large DCFC systems have unique kWh costs and each installer should contact its utility provider to discern how those costs are borne upon the EVSE owner and/or consumer.



CONSUMER ACCEPTANCE

Consumer education and outreach continues to be a priority for EV supporters, as nearly every survey conducted demonstrates that consumers simply are not that familiar with EVs—the available models, available incentives, and vehicle features. The previously mentioned NAS report concluded the following with respect to consumer acceptance, which in some respects remain true six years after publication:

- **There is limited knowledge among consumers about the EV market, such as availability of models, operation, and maintenance. To help consumers familiarize with EVs, a possible federal role could be to produce public service announcements and marketing campaigns.**
- **Some consumers may perceive the driving range of EVs to be insufficient for their needs.**
- **Fewer EV model choices available for consumers and a knowledge gap among various dealerships are also major EV adoption barriers.**

Even in areas where EV awareness is higher, there is some confusion among consumers between a conventional gasoline-electric hybrid vehicle and a PHEV. Automobile manufacturers have made some progress with respect to improving the number of models available to consumers and expanding the range, such as more affordable BEVs like the Chevrolet Bolt and Tesla Model 3. The EV market is still dominated by sedans and smaller vehicles, with much more limited options in crossovers, sport utility vehicles, minivans, and light trucks, the types of vehicles that Americans are buying at higher rates today than the previous two to four years.

REPORTED INTEREST IN EVS DOES NOT ALIGN WITH CONSUMER PURCHASING PATTERNS: ABOUT 1.1% OF TOTAL SALES IN 2017 WERE EVS, INCREASING TO 2.1% IN 2018. 2019 EV SHARE OF ALL NEW CAR SALES IS ANTICIPATED TO BE BETWEEN 2.0% AND 2.6% ACCORDING TO THE EDISON ELECTRIC INSTITUTE.


Part of the discrepancy is likely attributable to consumer awareness. Since 2010, consumer surveys have continued to paint a picture of low consumer awareness of EVs with little improvement. For example:

- **A 2010 survey by Ernst & Young found that 62% of respondents had never heard of PHEV technology or heard of it but didn't know what it was. Similarly, 40% of respondents had never heard of dedicated BEV technology or had heard of it but don't know what it was.**
- **In 2013, Navigant Research reported that awareness of EVs other than the LEAF and the Volt among survey respondents was less than 25%. And even with the LEAF and Volt, the first movers in the EV market, only 31% and 44% were extremely familiar or somewhat familiar with these vehicles, respectively.**
- **A survey of 2,500 American drivers by Altman Vilandrie & Co. in 2016 concluded that 60% of drivers were “unaware of electric cars.”²⁷**
- **A February 2017 National Renewable Energy Laboratory survey of American drivers found that more than 50% of respondents were unable to name a specific EV make and model.²⁸**
- **In May 2018, AAA reported that just 20% of Americans will “likely go electric for their next vehicle purchase, albeit up from 15% in 2017.”²⁹**

27 “High Costs, Lack of Awareness Threaten to Short Out Electric Vehicle Adoption,” *Business Wire*, December 8, 2016, <https://www.businesswire.com/news/home/20161208005809/en/High-Costs-Lack-Awareness-Threaten-Short-Electric>.

28 Mark Singer, *The Barriers to Acceptance of Plug-in Electric Vehicles: 2017 Update* (National Renewable Energy Laboratory, November 2017), <https://www.nrel.gov/docs/fy18osti/70371.pdf>.

29 AAA, “1-in-5 U.S. Drivers Want an Electric Vehicle,” May 8, 2018, <https://newsroom.aaa.com/2018/05/1-in-5-us-drivers-want-electric-vehicle/>.

A man in a light-colored suit and dark tie is smiling and gesturing towards a bright green car in a dealership. The background shows other vehicles and dealership lighting.

Consumer acceptance and awareness will improve over time with concerted efforts from market participants and a strong business case for supporting transportation electrification.

- **UC Davis researchers Ken Kurani and Scott Hardman outlined their consumer survey findings from five studies conducted between 2014 and 2017, concluding that:**
[t]he excitement among policymakers, automakers and advocates as more EV models enter the market place, more charging is installed, and more EVs are sold each successive year is utterly lost on the vast majority of the car-buying public—even in California, touted as being among the global EV market leaders. The problem is the number of car-owning households that are paying attention to EVs is not growing.

Consumer awareness around critical issues, including incentives, vehicle models available, and charging infrastructure availability, continues to be a barrier to broader EV adoption.

As the California Air Resources Board (CARB) conducted a review of its own ZEV program, it outlined factors affecting EV sales in California.³⁰ There has been modest growth in EVs across California, with some specific regions experiencing rapid growth. CARB reports that EV sales are affected by various factors, including household income, access to HOV lanes, availability of rebate policies, and gas prices. These findings emphasize a broader point: The distribution of EV sales is not consistent across communities or neighborhoods. Wealthier neighborhoods and early adopters tend to continue to purchase EVs at a higher rate. Household characteristics such as higher income, higher housing values, higher rates of single-family housing, and access to residential charging opportunities positively affect EV sales. CARB makes a compelling observation: The EV market has “not yet reached typical middle-income hybrid buyers.”

30 J. R. DeShazo and Greg Pierce, “Designing Light-Duty Vehicle Incentives for Low- and Moderate-Income Households” (ARB Research Seminar presentation, Cal EPA Headquarters, Sacramento, CA, March 21, 2019). <https://ww3.arb.ca.gov/research/seminars/deshazo2/deshazo.htm>

Despite some of the awareness issues associated with EVs, the driving experience reported by early EV owners has mostly been positive. EV owners, however, continue to be somewhat hesitant to go all-in on the vehicles, as demonstrated by high lease rates for both PHEVs and BEVs. Bloomberg reports that lease rates for PHEVs and BEVs are 55% and 80%, respectively (through 2017).³¹ For reference, leasing makes up about 30% of the entire car buying market (for 2016-2018). Furthermore, Cox Automotive reports that the repurchase likelihood for EVs was 53% in 2016;³² more recently, Experian reports that 62% of EV drivers buy another EV and Tesla customers have an even higher repurchase rate of 80%—the highest level of make loyalty in the market.³³ Edmunds reported that only 27.5% of hybrid and EV trade-ins in the U.S. in early 2016 were applied to the purchase of another hybrid or EV, down from 38.5% in 2015.³⁴

There are a variety of concerted efforts to improve consumer awareness of EVs, and for EV enthusiasts there is often a scapegoat for lack of awareness. Some stakeholders have pinned blame on auto dealerships for not doing more to sell EVs; others have noted the lack of spending on advertising dollars by the major automakers, and some have called upon electric utilities to do more to push EVs. Again, ICF takes a measured view of the market: consumer acceptance and awareness will improve incrementally over time with concerted efforts from market participants that can make a strong business case for supporting transportation electrification. It is difficult to conceive of ways to compel these entities to do more without implementing expensive and potentially draconian measures that could produce tenuous results.

Many of the same surveys regarding consumer awareness have also highlighted the issues around availability of charging infrastructure. For instance, in the May 2018 AAA survey, among the respondents who were unsure or unwilling to choose an EV for their next car, 63% cited a lack of places to charge as a detractor while 58% expressed concern about running out

31 Kyle Stock, "Electric Car Drivers Are Too Smart to Own Electric Cars," Bloomberg, January 3, 2018, <https://www.bloomberg.com/news/articles/2018-01-03/why-most-electric-cars-are-leased-not-owned>

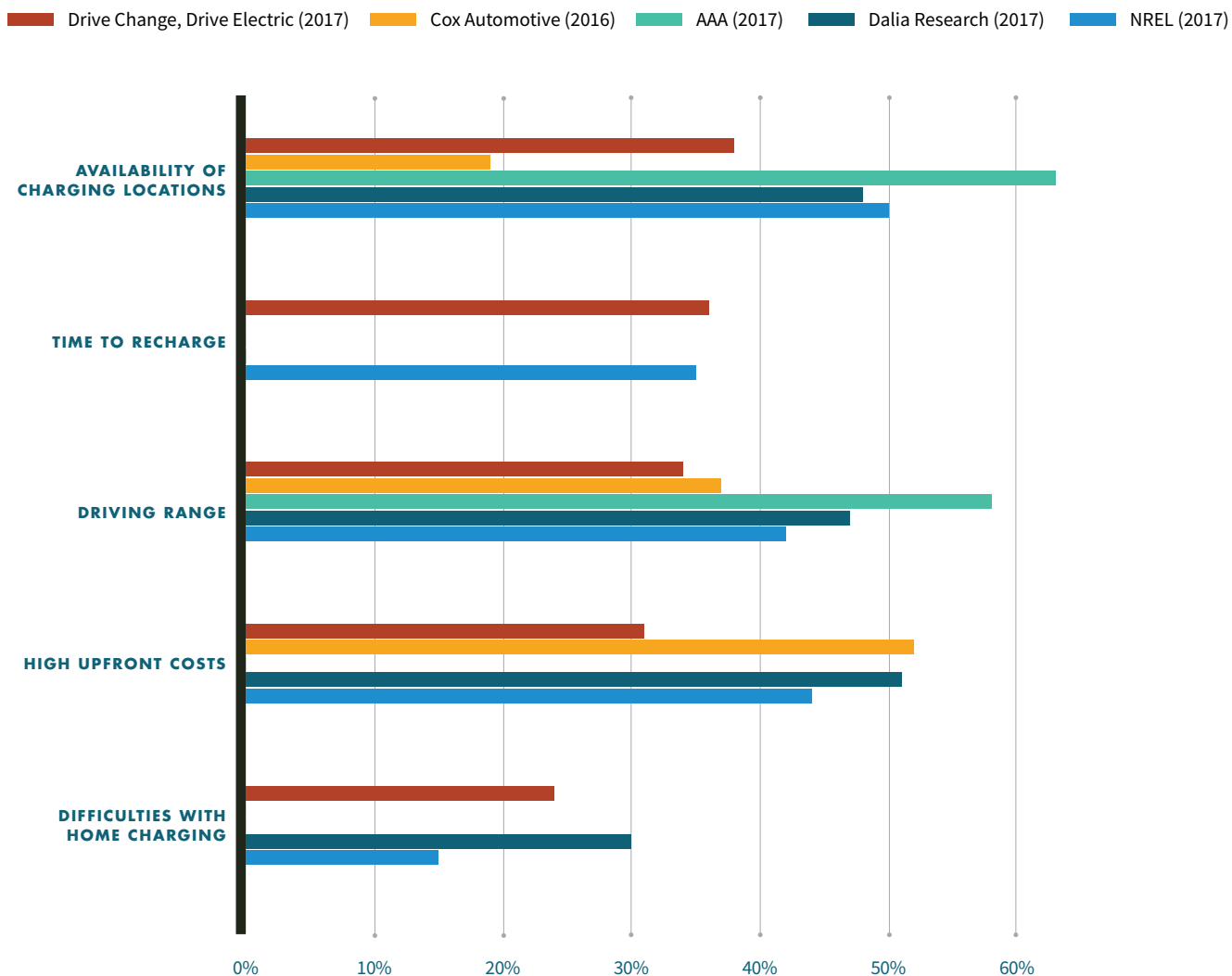
32 Rebecca Lindland, "EV Consumer Study" (PowerPoint presentation, EIA Energy Conference, Washington, DC, June 27, 2017), https://www.eia.gov/conference/2017/pdf/presentations/rebecca_lindland.pdf.

33 EVANNEX, "Experian Automotive Says Tesla's Customer Loyalty Is Unmatched," *InsideEVs*, November 15, 2018, <https://insideevs.com/experian-automotive-tesla-customer-loyalty-top/>.

34 "Edmunds.com: EV and Hybrid Loyalty Falls to All-time Low," Green Car Congress, April 21, 2016, <https://www.greencarcongress.com/2016/04/20160421-edmunds.html>.



FIGURE 7. SUMMARY SURVEY FINDINGS: CONSUMER ACCEPTANCE OF EVS



of charge while driving. AAA reports that these percentages are down 9% and 15% from the same survey in 2017, leading the group to conclude that so-called “range anxiety” may be starting to ease.³⁵

Figure 7 highlights some of the key findings from a variety of surveys mentioned already in this report, with a focus on national-level estimates over the past several years.

The findings of these surveys are consistent: Many consumers are hesitant about EVs because of the higher upfront costs of EVs, the availability of

charging (at home or in public), and uncertainty around battery technology (as indicated by driving range and to some extent the time to recharge). EV pricing and driving range are technology advancement issues related to the vehicle and batteries, which auto and battery manufacturers are working to address. Infrastructure availability, on the other hand, is more of a planning and/or investment constraint that can be addressed immediately by the stakeholder community, with a focus on utilities, charging station providers, site hosts, and even government agencies.

35 AAA, “1-in-5 U.S. Drivers Want an Electric Vehicle,” May 8, 2018, <https://newsroom.aaa.com/2018/05/1-in-5-us-drivers-want-electric-vehicle/>.

EV CHARGING INFRASTRUCTURE REQUIREMENTS

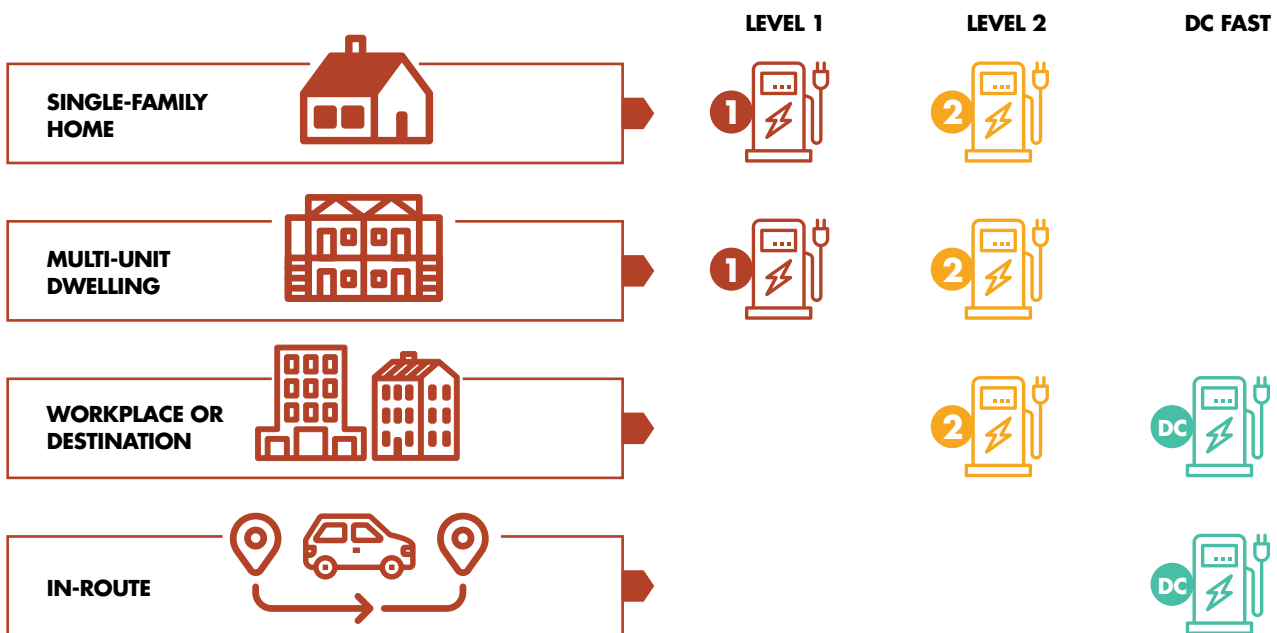
The transition to mass adoption of EVs will likely require a mix of EV charging solutions, with a focus on convenient and ubiquitous access to EV charging. The quantitative determination of convenient and ubiquitous, however, is difficult to ascertain. This subsection focuses on the drivers for EV charging infrastructure deployment to date and how these might change over time.

Figure 8 conceptualizes the types of charging that are appropriate at different locations with a focus on at-home or residential charging (including at single-family homes and MUDs), workplace or destination charging, and in-route charging options. The figure illustrates the level of charging—Level 1, Level 2, or DC fast charging—that ICF considers most appropriate for each location.

Most market analysts find that residential charging accounts for about 70%-90% of EV charging. The remaining 10%-30% of charging occurs at a combination of workplace and opportunity or destination charging locations. This report uses the following terms to review different charging considerations:

- Residential charging occurs at home where EV drivers live.** These tend to be at single-family homes, using Level 1 (110 V) or Level 2 (220 V) charging. Most anecdotal evidence suggests that most EV drivers today are charging at home using Level 1, which typically does not require additional installation costs. Level 2 charging requires the purchase of special EV supply equipment (EVSE), may require an electrician to install, and likely requires a permit.

FIGURE 8. ICF CONCEPTUALIZATION OF EV CHARGING INFRASTRUCTURE REQUIREMENTS BY CHARGING LOCATION



- Workplace charging occurs at a place of employment, where EV drivers have access to charging infrastructure.** There are a variety of employers that have opted to provide workplace charging to employees, whether as an amenity as part of a broader employee retention plan or as part of a sustainability initiative.
- Opportunity or destination charging covers a wide range of situations where an EV driver could potentially charge away from home or work.** Unlike residential and workplace charging, where vehicles are parked long enough to achieve a significant charge even with Level 1 charging, opportunity charging will take place at locations where drivers are parked for varying times. Therefore, the level of charging bears much greater consideration when siting opportunity charging. [Table 1](#) shows illustrative charging times, and charging levels at different venues.
- In-route charging refers to charging opportunities along major thoroughfares or roadways that provide access to EV charging infrastructure along various types of trips.** These types of charging locations would be considered similar to EV charging offered at fueling locations like convenience stores and gas stations.



[Table 1](#) provides some typical venues, anticipated charging times, and appropriate charging levels for non-residential EV charging.

While useful, ICF’s conceptualization and subsequent characterization of charging opportunities do not address several key questions regarding EV charging infrastructure requirements, namely, how many chargers should be installed and where the chargers should be installed. Before delving into these issues in more detail, the text below provides some basic information regarding the EV charging industry, including an overview of market participants, an overview of the costs to install EV charging infrastructure, and how these costs can be recouped through different fee structures.

TABLE 1: OPPORTUNITY OR DESTINATION CHARGING VENUES AND APPROPRIATE CHARGING LEVELS

TYPICAL VENUE	AVAILABLE CHARGING TIME	CHARGING LEVEL PRIMARY/SECONDARY
Convenience Stores/Gas Stations	<0.5 hour	DC Fast/Level 2
Highway Travel Stops	< 1 hour	DC Fast/Level 2
Shopping Centers	0.5–2 hours	Level 2/DC Fast
Street/Meters (Destination)	1–2 hours	Level 1/Level 2
Parking Garages	2–10 hours	Level 2/Level 1
Hotels/Recreation Sites	8–72 hours	Level 2/Level 1

TABLE 2: EV CHARGING INFRASTRUCTURE MARKET PARTICIPANTS

MARKET PARTICIPANT	BRIEF DESCRIPTION
Hardware Manufacturer/Equipment Retailer	Manufactures the EVSE that is installed; may be branded or unbranded. Manufacturers may also sell their equipment directly to market or to network managers/operators (i.e., retailer).
Installers/Maintenance Providers	Installs EVSE; in some cases installers also provide routine maintenance for the equipment.
Charging Station Owner/Host	Entity that owns or hosts the equipment, such as a retail outlet. May also resell electricity to EV driver.
Charging Station Network Operator	Has the ability to connect, control, and monitor charging stations on its network; generally provides metering capability. Collects payment from users (potentially on behalf of charging station owners); may also resell electricity to EV driver.
System Operator	Provides open and non-discriminatory access to the state’s wholesale transmission grid. Several publicly owned utility-based organizations provide system operations as well.
Utility Provider	Electrical utilities—including investor- and publicly owned utilities.

One of the biggest issues associated with charging infrastructure requirements remains a sustainable business model. ICF finds it important to distinguish between different actors engaged in the charging market, which include hardware and equipment manufacturers, installers and maintenance providers, charging station owners or hosts, network operators, system operators, and utility providers (Table 2).³⁶

There are a variety of business models in the market today that bundle services. While some providers may only sell the physical hardware or networking services to site hosts, others sell both services. In some cases, site hosts own and operate the infrastructure, and in some cases the installer maintains ownership. Table 2 is a reminder that the market has multiple actors, and each provides different competencies, products, and services. At times, ICF has found that the literature on charging infrastructure requirements overlooks the broader

discussion of these market participants and combines their respective roles.

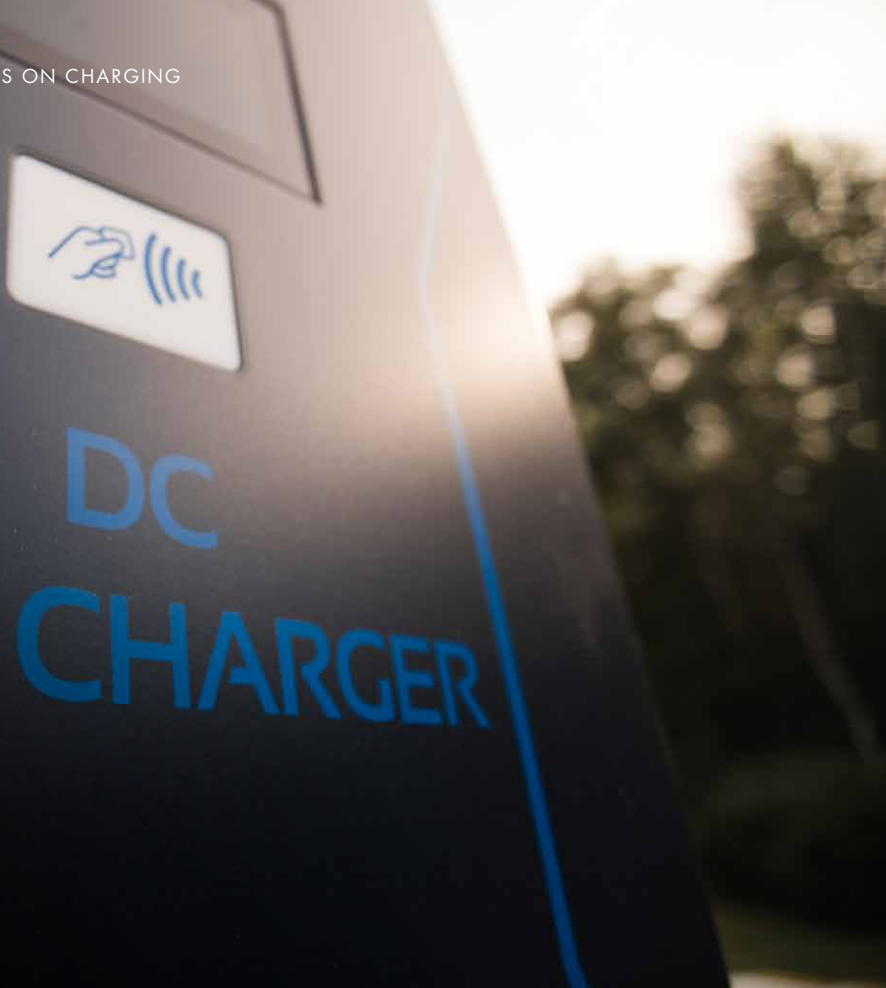
To help the reader understand the cost implications of EV charging infrastructure requirements, ICF used the estimated installation costs from Idaho National Laboratory’s (INL) various reports and updated with more recent cost estimates. The costs varied widely, with public Level 2 charging stations ranging from \$600 to \$12,660, with an average cost of \$3,108.³⁷ Based on more recent cost estimates, these figures are likely too conservative. The New York State Energy Research and Development Authority collected cost information from deployment initiatives that it supported between 2013 and 2017. The New York State Energy Research and Development Authority found that installation costs range from \$1,554 to \$25,785 with an average cost of \$7,435 per station for the nearly 700 ports that it is has data for.³⁸ ICF’s review of charging installation costs for agencies in California, including

36 ICF International and Energy+Environmental Economics, *California Transportation Electrification Assessment*, Phase 1: Final Report, August 2014, updated September 2014, https://caletc.com/wp-content/uploads/2016/08/CalETC_TEA_Phase_1-FINAL_Updated_092014.pdf.

37 Charging stations may have two or more plugs (or “ports”) to support the refueling of multiple vehicles simultaneously. Multi-port stations may cost more than comparable single-port stations in absolute terms but may have lower per-port costs.

38 Bryan Roy et al., “New York State EV Charging Station Deployment,” *World Electric Vehicle Journal* 8 (2016): WEVJ8-0877, <http://www.mdpi.com/2032-6653/8/4/877/pdf>. Presented at the EVS29 Symposium, Montréal, Canada, June 19-22, 2016.

ICF interviews with stakeholders suggests that most DC fast charging installations today are more than \$50,000 and closer to \$75,000, depending on site layout and proximity to electrical service.



for the County of Los Angeles and the Los Angeles Metropolitan Transportation Authority (LA Metro), suggests that installation costs are much closer to \$10,000 on average and can exceed \$20,000 in locations without convenient access to electrical infrastructure (thereby requiring trenching and cutting).

INL reports that DC fast charging stations range from \$8,500 to more than \$50,000, with an average cost of \$22,626. ICF interviews with stakeholders suggests that most DC fast charging installations today are more than \$50,000 and closer to \$75,000, depending on site layout and proximity to electrical service. INL reports that workplace Level 2 charging stations cost 28% less than the average public Level 2 station, largely because workplaces have more control to choose cost-effective installation sites. Most DC fast charger installations included electric panel upgrades to meet the chargers’

50-kilowatt (kW) power rating. However, with new DC fast chargers reaching capacities of 350 kW, more extensive panel upgrades may be needed to support faster refueling.³⁹ Costs also varied regionally due to permitting requirements and labor costs.

Using a simple cash flow model regarding installation costs, hardware costs, and different utilization rates for EV charging infrastructure, ICF concludes that charging stations are not currently an attractive investment for many site hosts. In short, the value proposition of EV charging infrastructure, absent subsidies, or other investments hinges upon the ability of a site host to re-sell electricity, which is already an inexpensive commodity. Some site hosts may also offer charging as an amenity and a means to increase revenue from the site host’s core business. Depending on utilization assumptions, the location of the charging infrastructure, and the fees that are assumed to be collected, payback periods

39 Eric Everts, “Electrify America Turns on First 350-kw Fast Charger in California”, *Green Car Reports*, December 10, 2018. https://www.greencarreports.com/news/1120372_electrify-america-turn-on-first-350-kw-fast-charger-in-california

for Level 2 charging stations can be in the range of 10-20 years without grants or incentives. Similarly, DC fast charging installations can have an even longer return on investment. These types of findings help explain why there are more than 35 charging incentive programs across the country to help defray the high upfront costs of EV charging infrastructure.

It is important to understand how consumers are paying for EV charging today, especially in non-residential applications. Often, site hosts contract with EV service providers or third-party operators who install, operate, and set the fees on charging equipment. However, when owners do have the ability to set fees—either explicitly or implicitly through their choice of operator—they face conflicting goals. Site hosts often need to recoup the costs of installing, maintaining, and operating chargers and may also wish to set charging fees that encourage turnover (e.g., higher fee per hour after two hours) so that chargers are available to additional customers. On the other hand, a significant motivator of EV purchases is the promise of fuel cost savings relative to gasoline. Given that electricity is a relatively inexpensive “fuel” compared to gasoline on a per-mile basis, site hosts may want to offer pricing schedules that attract current and prospective EV drivers.

When owners do have the ability to set fees—either explicitly or implicitly through their choice of operator—they face conflicting goals.

Access fees may be set on a fixed fee, a fixed rate, or a pay per energy consumed basis:

- **An access fee is associated with gaining access to the charging station irrespective of whether the vehicle is charging and/or how long it remains connected.** It is essentially a flat rate for initiating a session by connecting to the charging station.
- **A station- or time-based fee is associated with the length of time a connection is established with the station, irrespective of whether the vehicle is charging or not (typically \$1 to \$2 per hour).** If the vehicle is connected to the charging station, this fee would apply. A fixed-rate fee may be charged if high utilization and turnover of vehicles is desired. Fees may be charged per hour or other intervals for Level 2 charging and a per minute basis for DC fast charging.
- **An energy fee is associated with the amount of energy consumed by the connected vehicle.** This is based on a per kilowatt-hour flat rate and only applies when the vehicle is actively charging. This fee is typically not applied when the vehicle is not receiving power, even if the vehicle remains connected to the EV station. A multiplier on this cost may be applied to recover other operational costs. The National Conference on Weights and Measures has commercial standards for EV charging stations that measure in kWh; however, many states exempt or prevent EV station providers from reselling electricity on a per kWh basis, and reselling electricity is illegal in some states.

Some jurisdictions have implemented graduated pricing schedules to increase vehicle turnover so that there is greater availability of charging and utilization of assets. Typically, the fees are increased after a two- to four-hour period of charging at a lower rate. ICF’s interviews with stakeholders and site hosts across previous projects indicate that fees should be periodically reassessed to ensure that costs are recouped and stations are utilized.

For the long-term future, infrastructure owners should pilot innovative agreements with utilities and charging station providers to make charging cost competitive with driving a gasoline-powered vehicle. For the short-term future, however, infrastructure owners may need to establish higher fees to recoup costs and encourage turnover. In many cases, particularly in specific localities and regions, various site-host owners should consider adopting the same fee, particularly in high-demand locations, to create consistency throughout the region. With these types of fees, vehicles are less likely to remain parked once their charge is complete and other drivers are drawn to spaces that they know are likely available.

Another acute, near-term financial challenge for DC fast charging is utility demand charges. Unlike energy fees that are based on amount of energy consumed (kWh), demand charges are levied based on the highest amount of instantaneous power (kW) drawn from the grid over a given period of time. Additionally, it may not be practical or feasible for DC fast charging station operators to blunt demand charges by throttling EV charging service, which may negatively impact EV drivers' fueling experience. Utility tariffs that include demand charges can challenge the economics of DC fast charging stations, which typically have high power draw and relatively low utilization while the EV market remains nascent. Some utilities are modifying their tariffs to mitigate the impacts that demand charges may have on station operation costs in the short-term, allowing for improved economics of DC fast charging as EV

adoption grows and station utilization improves. Southern California Edison, for example, offers a commercial tariff to all qualified commercial site hosts that waive demand charges for the first five years of implementation, increase energy charges, and gradually phase demand back in for an additional five years.⁴⁰ The tariff also incorporates TOU price signals to encourage EV charging to occur during off-peak periods and support grid reliability.

CHARGING INFRASTRUCTURE MARKET TO DATE: FOCUS ON DEPLOYMENT

The charging infrastructure market has largely been focused on installing hardware in the ground. More recently the focus has shifted to strategic deployment with respect to anticipated demand. There is an advantage to scale in the nascent EV charging market, as there was less of a premium on ancillary services when the market began that might improve the value proposition of one provider over another. ICF posits that the initial phases of EV charging infrastructure deployment myopically focused on volume, with little attention to utilization or convenience. Furthermore, the initial focus was on getting Level 2 charging at both residential and non-residential locations while there was less focus on DC fast charging infrastructure deployment.

Like many nascent industries, the EV service provider market has had significant consolidation over the last several years, and the industry still faces challenges. There are many market players, but there is increasing pressure to demonstrate the

40 California Public Utilities Commission, Decision on Transportation Electrification Standard Review Projects, Decision 18-05-040, May 31, 2018, p.111.



financial sustainability of third-party providers. And at the same time, utilities are making investments in EV charging infrastructure. Regardless, there is still disagreement over the amount, location, and type of equipment that is needed to satisfy EV charging demands in different markets.

One comprehensive report to date on how EV drivers charge is by INL, although the market has changed considerably since it was published.⁴¹ Subsequent and more recent studies have confirmed many, but certainly not all, of INL’s findings. The EV Project analyzed EV driver behavior between 2011 and 2014. In these three years, INL collected data from project partners, EV drivers, and public charging stations. The data captured almost 126 million miles of driving and 6 million charging events. INL reviewed five American Recovery & Reinvestment Act–funded EV projects to determine the lessons learned of public charging infrastructure. The EV project, ChargePoint America Project, Chrysler Ram PHEV Pickup Demonstration, General Motors Chevrolet Volt Demonstration, and SCAQMD/EPRI/Via Motors PHEV Demonstration installed an aggregate 17,000 Level 2 charging stations between 2011 and 2013.

INL highlighted the varying charging demands between communities. Consistently, home charging remained the most popular, followed by Level 2 charging in areas where drivers were parked for a significant amount of time, followed by DC fast charging along transportation corridors. Distinct public charging patterns for weekdays versus weekends were found within communities, shifting from workplace charging to other public charging, particularly in retail areas. During the period of this study, however, public charging was overwhelmingly underutilized.

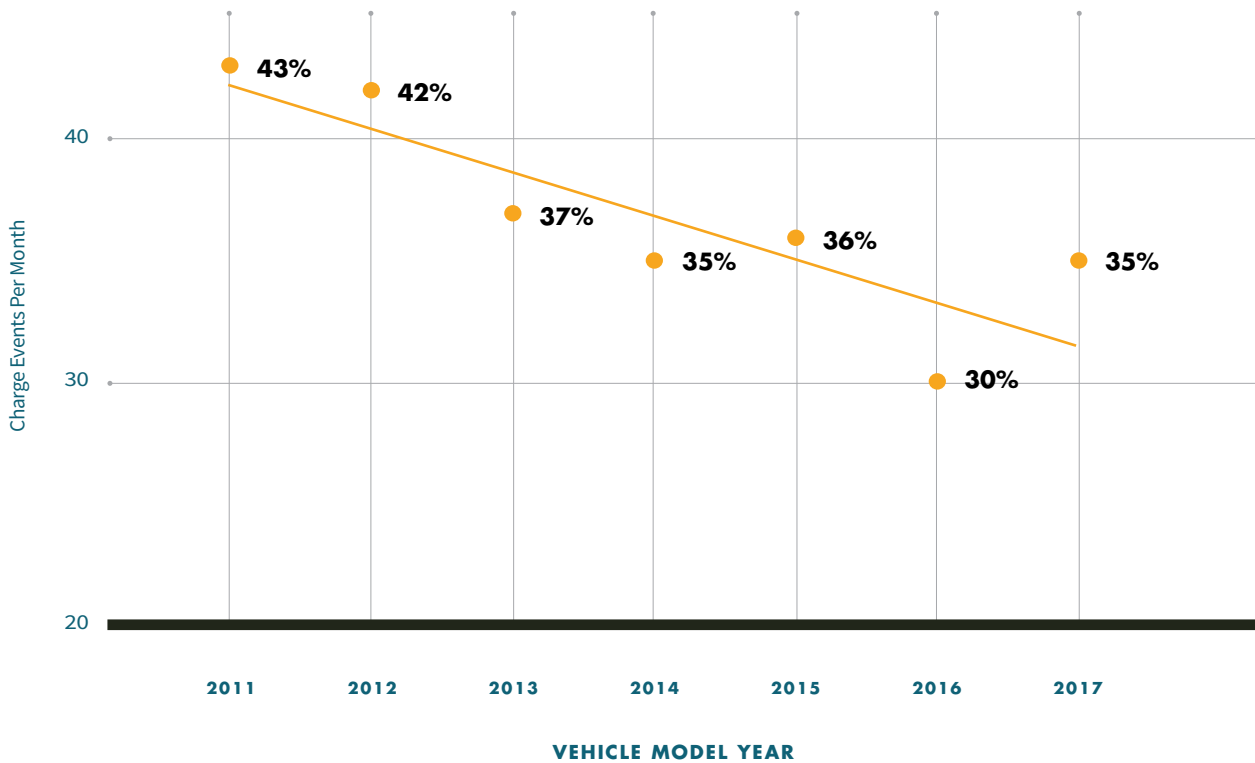
INL found that EV owners on average charged 85% of the time at home. When they were away from home, they tended to favor a select few public charging

stations with workplace stations being the most frequented. INL also found that EV drivers adjust their charging habits based on conditions like fees and rules for use. For example, drivers were less likely to plug in at work if they had to pay to charge or if they were required to move their vehicle after charging. Interestingly, INL reports that 20% of the vehicles studied accounted for a disproportionate share of non-residential charging at 75%. And lastly, INL’s results indicated that charging infrastructure should be focused at home, workplaces, and in public “hot spots” where demand for Level 2 or DC fast charging stations was high.



⁴¹ “Plugged In: How Americans Charge Their Electric Vehicles,” <https://avt.inl.gov/sites/default/files/pdf/arra/PluggedInSummaryReport.pdf>.

FIGURE 9: FLEETCARMA’S ANALYSIS OF CHARGE EVENTS PER MONTH BY EV MODEL YEAR³⁹



FleetCarma’s analysis of driving behavior confirms many of INL’s findings, noting that Level 2 at-home charging accounts for 69% of all charge events and 75% of all energy among the EV drivers for whom they have data. Interestingly, FleetCarma also found that drivers are becoming more comfortable with driving longer distances between charges and that the increased range on newer EVs has had a material impact on the amount of charging events per month. As shown in Figure 9 the number of charge events per EV model year has steadily declined since 2011.⁴²

Unfortunately, outside of the findings from INL and heavily aggregated data from market actors like FleetCarma, there is increasingly disparate data sets in the public domain for consideration and

analysis with respect to EV charging. ICF believes this is due in part to the market for EVs and EV charging infrastructure maturing and that market actors maintain that the data is proprietary to improve market position and in some cases to monetize what is perceived as valuable information. Furthermore, ICF’s recent review of more than 35 charging infrastructure incentive programs across the U.S. found that only a few programs impact data and fewer than 10 provide basic information like the amount of funds distributed and the number of charging stations installed.⁴³ The lack of charging data in the post-EV Project market for EVs requires that analysts increasingly rely on either proprietary data sets or selectively published information from EV service providers.

⁴² Based on data presented by FleetCarma, “The Key to Increasing EV Adoption is Hidden in EV Driving and Charging Data,” January 24, 2018, <https://www.fleetcarma.com/key-increasing-ev-adoption-hidden-ev-driving-charging-data/>.

⁴³ ICF International, *Draft Summary Report on Existing EV Charger Incentive Programs in the United States*, October 2018, https://www.sandag.org/uploads/projectid/projectid_560_24783.pdf.

CHARGING INFRASTRUCTURE MARKET: LOOKING FORWARD

The NAS report noted the following with respect to charging infrastructure requirements:

- Tax incentives, subsidies, adoption of building codes, and provision of dedicated parking spots could help with the high costs of residential charging and installation.
- Offering “financial incentives such as an accelerated depreciation schedule” could drive more businesses to offer workplace charging.
- Standardizing charging infrastructure and payment methods is important.
- There are concerns with regulating third-party entities or EV service providers as utilities could increase operating costs and decrease business-model flexibility. Furthermore, the role and scope allowed to utilities (as opposed to third-party entities) to provide charging equipment are unclear.

These findings, despite being developed many years ago, still hold true today.

THE EV CHARGING MARKET IS PLAGUED BY A LACK OF INTEROPERABILITY AND STANDARDIZATION, AND THIS HAS HELPED CONTRIBUTE TO AN OVERALL FAILURE TO DELIVER ON THE CONVENIENCE REQUIRED TO MAKE EV CHARGING AS CONSUMER FRIENDLY AS IS POSSIBLE.

And while local and regional readiness actions have sought to make it easier to install residential EV charging infrastructure, these initiatives have largely focused on new residential construction while providing shallow solutions for the existing housing stock. Most notably, the market continues to struggle with solutions for multi-family units, which will continue to limit EV adoption absent more aggressive investment in that space, especially in densely populated areas. And lastly, the role of utilities versus EV service providers is still contested in some jurisdictions.





There is a mismatch between the convenience of charging station locations and where EV drivers seek to charge.

INL’s EV Charging Infrastructure Roadmap (Roadmap) helps identify the charging infrastructure needed to support the objectives of the U.S. Department of Energy’s EV Everywhere Grand Challenge (EVs being as affordable and convenient as internal combustion engine vehicles by 2022). The Roadmap recognizes that different types of EVs (plug-in hybrid electric vehicles with 40 miles of electric range and all electric vehicles with a range of 100 and 300 miles) require different charging infrastructure. The Roadmap also evaluates the needs of EVs in the early, transition, and mature stages of EV adoption. The Roadmap makes recommendations for different types of charging:

- **Residential charging should be encouraged by implementing TOU rates for off-peak charging and developing building code requirements for pre-wired charging circuits in the garages of single-family homes. Residential charging could also be supported by streamlining permitting processes.**
- **Away-from-home charging can be encouraged through clarifying ADA requirements, implementing commercial building code requirements for dedicated circuits for charging stations, promoting “no charging to charge”**

programs, implementing and enforcing penalties for ICE-ing of charging stations, supporting EV industry charger location apps, streamlining permitting processes, and increasing vehicle sales. DC fast charging’s greatest challenge during this initial period of relatively low charging station utilization is electricity demand charges, which can be met by aggregating demand for billing purposes.

Generally, ICF finds that the literature indicates that the charging infrastructure market had previously lagged behind the EV market. However, more recent investments by various entities, including public agencies and utilities, have led to a rapid expansion of EV charging infrastructure in some areas. In many markets, for instance, the quantity of charging stations is likely adequate; however, there is a mismatch between the convenience of charging station locations and where EV drivers seek to charge. Market analysts have previously focused on the number of chargers required to support an evolving EV landscape, but now stakeholders are beginning to focus on two new issues: 1) DC fast charging equipment and corresponding demand charges and 2) smarter charging.

TABLE 3: DEMAND CHARGES AS A PERCENTAGE OF TOTAL MONTHLY UTILITY BILL

ELECTRICITY TARIFF STATION UTILIZATION	HOST TYPE A 15%	HOST TYPE B 8%	HOST TYPE C 8%	HOST TYPE D 4%
Southern California Edison, TOU EV 4, Actual	70%	75%	77%	81%
San Diego Gas & Electric AL-TOU Commercial, Actual	88%	91%	92%	94%
Pacific Gas and Electric A-10, Actual	67%	73%	76%	81%

DC FAST CHARGING

Electrify America, formed by Volkswagen (VW) Group to implement a major aspect of its legal settlement,⁴⁴ is undertaking the most ambitious effort to deploy DC fast charging equipment nationally. Electrify America has proposed to invest \$200 million to support the use of EVs in California. The company’s guiding principle is to build a long-term and economically sustainable network that provides services beyond the 10-year consent decree window by focusing on a charging infrastructure network that allows EV charging in the 10-20 miles per minute range.

Many stakeholders today, particularly those investing in DC fast charging equipment, have been raising concerns regarding the impact of demand charges on their ability to develop a sustainable business model. By way of background, electricity pricing at commercial locations, such as a DC fast charging station, are charged for energy on a kWh basis for actual usage as well as the demand, which is calculated as the highest power delivered during a specific time interval (e.g., a 15- to 30-minute billing period). The electrical grid is designed to ensure that electricity supply can meet maximum demand (kW), and the demand charge enables utilities to recoup the costs of ensuring the system is sufficiently built to achieve that design criteria.

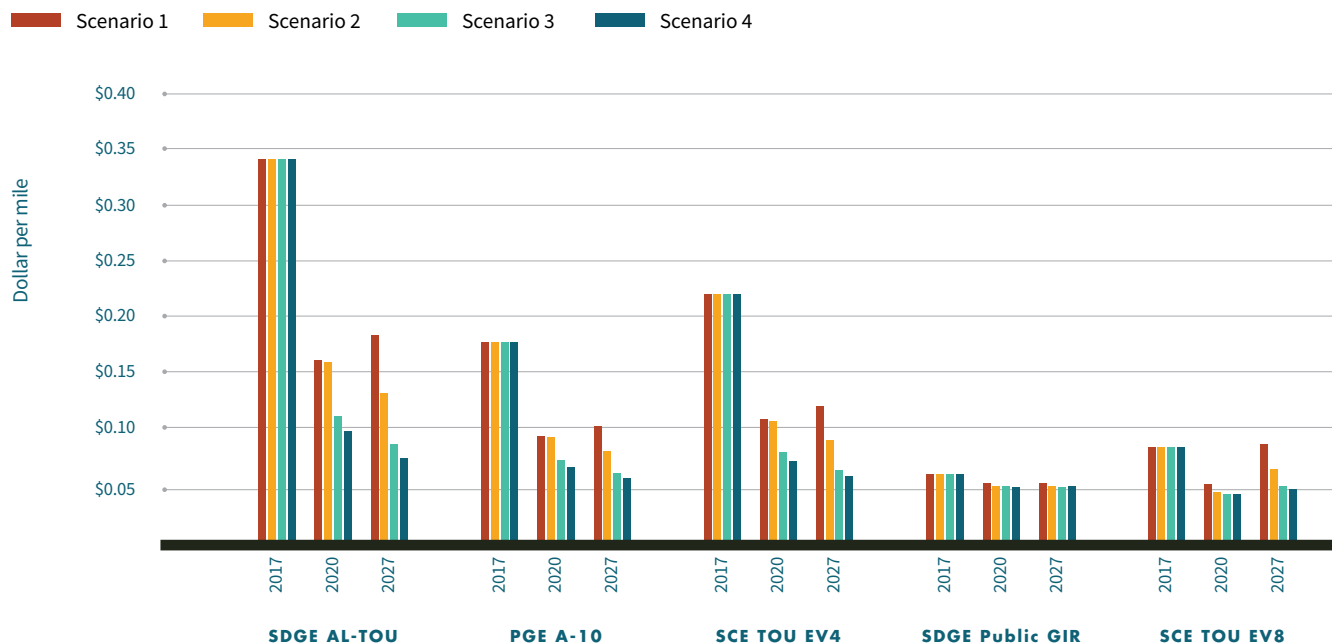
Demand charges are applied based on some peak usage, and for DC fast charging equipment, that can be quite high and many currently have insufficient throughput to recoup the cost of high-demand charges.

The Rocky Mountain Institute (RMI) studied fleets and tariffs using DC fast charging equipment on the EVGo network.⁴⁵ RMI categorized DC fast charging site hosts using the location, whether grocery, mall, dealership, retail, gas station, and government or school. These were further characterized by factors such as peak power demand (kW), average power demand (kW), average energy consumption (kWh), length of each charge (in minutes), and the number of sites. RMI develop four generic host types to illustrate the impact of demand charges on different site hosts by calculating the monthly cost of operating a station using six utility tariffs, four of which are actual tariffs and two of which are proposed (see Table 3). RMI also varied the utilization at each station. Table 3 illustrates the role of demand charges as a percentage of the total monthly utility bill for each host type under different utility rates. Figure 10 illustrates the EV cost per mile of driving under various California utility tariffs.

44 In 2016, the U.S. filed a complaint against the Volkswagen entities alleging violations of the Clean Air Act with regard to approximately 590,000 diesel vehicles sold in the U.S. The complaint alleges that Volkswagen sold vehicles containing so-called defeat devices, whereby certain computer algorithms and calibrations cause the emissions control system of those vehicles to perform differently during normal vehicle operation and use than during emissions testing. As a result, the U.S. complaint alleges that during normal vehicle operation and use, the cars emit levels of NOx significantly in excess of the EPA compliant levels. The settlement agreement includes three parts— one of which requires Volkswagen to invest \$2 billion in ZEV charging infrastructure and in the promotion of ZEVs. More information is available online at <https://www.epa.gov/enforcement/volkswagen-clean-air-act-civil-settlement>.

45 Garrett Fitzgerald and Chris Nelder, *EVgo Fleet and Tariff Analysis Phase 1: California* (Boulder, CO: Rocky Mountain Institute, March 2017), https://www.rmi.org/wp-content/uploads/2017/04/eLab_EVgo_Fleet_and_Tariff_Analysis_2017.pdf

FIGURE 10: EV COST PER MILE OF DRIVING UNDER VARIOUS CALIFORNIA UTILITY TARIFFS



Source: Rocky Mountain Institute

Table 3 demonstrates that demand charges are burdensome to publicly accessible DC fast charging, and even more so under low utilization. Figure 10 shows that the cost per mile of EV driving is initially relatively high, then gradually decreases as station utilization increases. For comparison, an EV with an efficiency of 0.25 kWh per mile (equivalent to a Chevy Bolt) charging at \$0.15 per kWh without demand charges yields a cost per mile of under four cents. Without greater station utilization or modified commercial tariffs, DC fast charging operators may experience difficulties recouping operational costs—potentially slowing investment in DC fast charging infrastructure in the near term.

As a result of the challenges that demand charges present to DC fast charging deployment, RMI posits that tariffs should have the following characteristics, including time-varying volumetric rates, such as those proposed for SCE’s TOU-EV-8 rates, low fixed charges, which primarily reflect routine costs for things like maintenance and billing; earning credits for providing grid services;

lowering costs to support DCFC infrastructure by adopting locational marginal pricing; and limited or no demand charges. These recommendations, however, are not always well received by an electric utility industry that, at times, seeks to be technology-agnostic with respect to rate design.

FOCUSING ON SMART OR MANAGED CHARGING

EV charging presents multiple unique opportunities and challenges, especially with respect to integrating them into a potentially stressed electrical grid. Many stakeholders immediately jump to the potential benefits of vehicle-to-grid (V2G) opportunities, which is characterized by bidirectional power flow between the vehicle and the grid. This is a longer-term value proposition for EVs; the current market is more focused on unidirectional power flow between the vehicle and the grid with demand response potential, more commonly referred to as managed charging or smart charging. In other words, the charging profile of the EV is influenced by price signals



communicated to the vehicle by a service provider, with the intent of encouraging charging at times when electricity is cheaper and discouraging charging at times when the grid is potentially stressed and electricity is more expensive.

Regarding smart charging, stakeholders are undertaking efforts to move EV drivers into more advantaged and smarter charging options. The Union of Concerned Scientists developed a report with key recommendations for different stakeholders, including utilities and charging providers, for the deployment of EV charging infrastructure.⁴⁶ Here are highlights from the organization's findings:

- **Smart charging is viable.** Numerous pilot projects have illustrated the real-life benefits of managed EV charging.
- **Drivers should take priority.** Drivers shouldn't find their vehicles uncharged when they need them. This concern is lessened as more EVs are deployed.
- **TOU pricing is a good near-term option.** Pricing electricity based on supply and demand can help avoid costly peak hour charging.
- **Smart charging offers ancillary services.** EVs can offer valuable storage and "flexible load" services to grid operators.
- **Utilities need a data plan.** EVs and EV chargers can collect new data for the grid, but utilities will need to know how to interpret and use the data.

⁴⁶ Pete O'Connor and Mike Jacobs, *Charging Smart: Drivers and Utilities Can Both Benefit from Well-Integrated Electric Vehicles and Clean Energy* (Union of Concerned Scientists, May 12, 2017), <https://www.ucsusa.org/resources/charging-smart>.

The prospects of managed charging require further study and collaboration among market participants. Most notably, there are three critical aspects of EV charging that need to be better understood:

- 1) When vehicles are charging
- 2) Where vehicles are charging
- 3) How much power is being delivered to the vehicle

Additional data about how customers use their vehicles and charging equipment will help stakeholders understand these trends. This information will also help define the rollout of EV charging infrastructure over the next 10 years. The key challenge centers on developing a business case around managed charging. There is no single approach to accomplishing this objective, and market actors are beginning to implement programs that incentivize managed charging that responds to grid conditions. For example, some utilities are rewarding EV charging that occurs during periods when ample spare capacity is available on the electricity grid; this is akin to a more formal TOU rate that features lower electricity rates for off-peak charging. For example, Consolidated Edison runs SmartCharge New York, an EV charging incentive program where enrolled participants can receive a \$0.10 rebate for every kWh consumed during off-peak hours and other financial rewards for managed charging.⁴⁷ Other utilities are testing and incentivizing the active-load management capabilities of EVs by implementing EV charging demand response pilots. These initiatives encourage the shift or delay of EV charging to accommodate grid conditions by calling “events” that drivers can respond to. Pacific Gas and Electric’s Electric Vehicle Smart Charging Pilot with BMW tested the demand



response capabilities of 100 BMW i3 vehicles via on-board vehicle telematics, delivering 100 kW of grid resources via delayed charging and second-life stationary EV batteries.⁴⁸ Receiving compensation for managed EV charging from independent system operators (ISOs) via wholesale markets may prove to be challenging in the near-term future. Although EV charging service provider Enel X (formerly eMotorWerks) has provided 30 megawatts of demand-response resources from residential EV charging to the California ISO,⁴⁹ evidence from the California Energy Commission’s Los Angeles Air Force Base V2G Demonstration suggests that California ISO market rules and transaction costs may pose challenges for receiving positive net revenues from EVs’ participation in demand response.⁵⁰ These initial pilots are providing more information on how managed EV charging can be compensated as a grid service, but further study and industry coordination is needed to scale its value.

47 “SmartCharge New York Program Guide,” FleetCarma, <https://www.fleetcarma.com/smartchargenewyork/setup/>

48 BMW Group and Pacific Gas and Electric Company, *BMW | ChargeForward PG&E’s Electric Vehicle Smart Charging Pilot*, October 12, 2017, <https://efiling.energy.ca.gov/GetDocument.aspx?tn=221489>.

49 Enel X, “eMotorWerks Provides CAISO with 30 MW of DR Through Smart EV Charging,” September 12, 2018, <https://evcharging.enelx.com/news/media-features/477-caiso-30mw>

50 Douglas Black et al, *Final Project Report: Los Angeles Air Force Base Vehicle-to-Grid Demonstration* (Berkeley, CA: California Energy Commission, October 2018), <https://ww2.energy.ca.gov/2018publications/CEC-500-2018-025/CEC-500-2018-025.pdf>.

EV Market Evolution

There are two main trends as part of the EV market evolution: The first is tied to the vehicle and the second to infrastructure.

FOCUS ON VEHICLES

Bullish forecasts on battery prices suggest that EV purchase prices will become competitive on an unsubsidized basis in the 2022-2023 timeframe and that EVs will reach purchase price parity in the 2025 timeframe (without subsidies). Many analysts believe that BEVs will emerge as the preferred technology over PHEVs, despite the market consistently being comprised of BEVs and PHEVs in nearly equal shares over the last six years. As part of the underlying belief that vehicles are inevitably trending to longer range (>200 miles), some stakeholders have focused on high-power charging. DC fast charging today charges around 50-150 kW, and stakeholders are considering deployment in the near-term future that would deliver electricity at a rate of 250-350 kW—a significant increase. These two issues regarding the likely architecture of EVs in the future and the levels of charging that they'll need are complicated and have an array of policy implications.

Battery technology costs continue to fall due to research and development efforts, and technologies currently in the R&D stage have better performance (lower cost and greater range) than those currently on the market. This, with the addition of increased production and associated efficiencies, indicates that EV costs will continue to decline.



The EV30@30 campaign sets an international goal for all members of the International Energy Agency's Electric Vehicles Initiative (EVI) member countries to reach 30% new vehicle sales share by 2030. Automakers, including BMW, General Motors, Daimler, Ford, Honda, Nissan, Tesla, Volkswagen, and Volvo, have publicly announced EV sales goals over the next 10 years, which fall in line with member country 2030 targets—including the U.S. However, battery manufacturing will need to significantly increase for the automaker goals to be met.

The International Council on Clean Transportation (ICCT) analyzed the connection between EV adoption and state and local policies, public and workplace charging infrastructure, consumer incentives (financial and incentives of convenience, such as parking exemptions and HOV lane access), and model availability in the 50 most populous metropolitan areas in the U.S.⁵¹ ICCT found that all

⁵¹ Peter Slowik and Nic Lutsey, *Expanding the Electric Vehicle Market in U.S. Cities* (Washington, DC: International Council on Clean Transportation, July 2017), https://theicct.org/sites/default/files/publications/US-Cities-EVs_ICCT-White-Paper_25072017_vF.pdf.

types of EV support are important in EV adoption growth.⁵² Consumer incentives remain a key factor in EV adoption, and charging infrastructure continues to be a barrier in many markets. The availability of EV model options, most notably the regional availability and stock of models, is needed for market development.

The ICCT study did not discuss causality for charging infrastructure or vehicle model availability. Further, the study did not evaluate the importance of some types of incentives over others, noting that all types of support are necessary. For example, Kansas City has the most extensive public charging infrastructure per capita, but in the absence of consumer incentives and model availability, it has a slower EV uptake than the national average. Similarly, Hartford, CT, and Providence, RI, have strong financial incentives but low model availability and also have below average EV growth. EV adoption requires the actions of many players, including but not limited to industry, state, local, and utility stakeholders.

There are pressing challenges that automakers face amid the uncertainty of the EV market: They must strike the right balance between selling enough EVs to comply with tightening regulatory standards while also preventing the incremental cost of adding battery packs from reducing corporate profits.⁵³ Further, while consumer demand may be showing signs of shifting, it is unclear to what extent these shifts will disrupt the automotive industry in the near-term future. However, the low profitability of EVs, especially in the near-term future (and despite the decreasing costs of battery technology) will require automakers to squeeze profit out of other vehicles like trucks and crossovers while also making decisions regarding downsizing, light-weighting, and mild hybridization.

The Union of Concerned Scientists reviewed automakers' efforts in the EV market and availability of different EV models to consumers in the U.S. in 2015 and identified BMW, General Motors, and Tesla as the market leaders, and Honda, Toyota, Fiat Chrysler and Hyundai/Kia Motors as the laggards.⁵⁴ In 2018, this started to change. The top 12 EV models selling in the U.S. belonged to Tesla (Model 3, Model S, and Model X), Toyota (Prius Prime), General Motors (Chevrolet Bolt and Chevrolet Volt), Honda (Clarity PHEV), Nissan (LEAF), Ford (Fusion Energi), BMW (530e and i3), and Fiat Chrysler (Pacifica Hybrid).

The EV market and the role of battery advancements is changing rapidly. Absent unexpected and disruptive interventions into the market, the prospects for transportation electrification are defined more by the timing of the transition rather than if the transition will occur. While there are many headwinds that could limit the potential for increased EV adoption, the solutions to overcome these hurdles are primarily technological.

FOCUS ON EV CHARGING INFRASTRUCTURE

The demand for EV charging infrastructure will be driven by a variety of parameters, which are subject to variation over time and between geographies. For the most part, this discussion seeks to understand how the demand for EV charging infrastructure may change over time, and this report examines this issue across different metropolitan regions, each with distinct characteristics. Ultimately, the focus is on charging infrastructure because elements such as vehicle pricing and vehicle evolution are highly uncertain and linked to technological advancements and consumer choice. But the demand for EV charging may change because of various factors that play a role in vehicle ownership and ability to charge an EV.

⁵² Conversely, local, state, or federal efforts to impose additional fees on EVs (e.g., registration fees) could negate these EV-enabling policies and incentives.

⁵³ Regulatory requirements are slightly less pressing in the proposed SAFE Vehicles Rule.

⁵⁴ Union of Concerned Scientists, *Electrifying the Vehicle Market: Evaluating Automaker Leaders and Laggards in the United States*, August 18, 2016, <https://www.ucsusa.org/resources/electrifying-vehicle-market>.

How people travel and use conventional vehicles today is largely understood, but there's very little knowledge about how people will drive EVs—including where they will charge, when they will charge, and for how long. The following subsections focus on case studies developed by ICF, with a view towards the demands for EV charging infrastructure in different geographies and different market considerations. The analysis is informed by a web-based mapping tool that ICF developed and is complemented by ICF analysis of various sources, including the NREL's [Electric Vehicle Infrastructure Projection Tool \(EVI-Pro\) Lite](#) to estimate the amount of charging infrastructure needed to support the EVs in a given metropolitan area.

Prior to transitioning into the key analytical and quantitative aspects of EV charging infrastructure deployment, it is important to highlight the rapidly evolving role of electric utilities as it relates to EV charging infrastructure deployment.

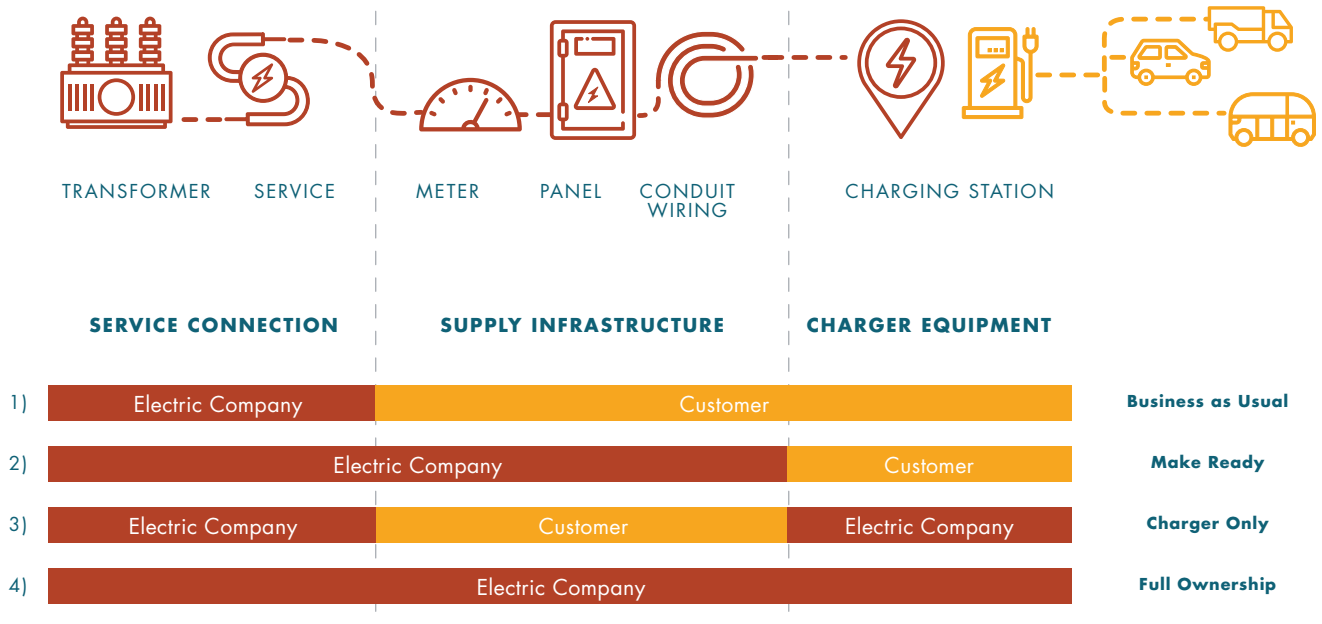
THE ROLE OF UTILITIES MOVING FORWARD

There are three types of utilities: investor-owned utilities (IOUs), publicly owned utilities (such as municipal utilities), and cooperatives. While publicly owned utilities and cooperatives often function on the local level, IOUs cover most customers in the U.S. and are regulated by public utility commissions (PUCs) at the state level. PUCs generally seek to set just and reasonable utility rates, balance the interests of customers and regulated utilities, protect the public interest, and enable the provision of safe, reliable, and environmentally sound utility services. IOUs must submit filings to PUCs and receive PUC approval for any investments or programs that recover costs through customer rates. Although utility transportation electrification filings have been rejected or delayed in several states, utility transportation electrification programs have been approved by over a dozen PUCs and have been found to align with PUC objectives. More information on these filings is found in the next section.

The long-term value proposition of EVs can be increased through consideration of V2G services.



FIGURE 11. UTILITY INVESTMENT OPPORTUNITIES IN EV CHARGING INFRASTRUCTURE



Source: Edison Electric Institute, *Accelerating Electric Vehicle Adoption*, February 2018

The Edison Electric Institute’s report *Accelerating EV Adoption* summarizes a variety of ways that utilities can engage in EV charging deployment, as shown in [Figure 11](#) and summarized here:

- **Business as usual:** The electric company funds the distribution system upgrades that may be needed to the service connection side.
- **Make ready:** The electric company funds the installation and supply infrastructure costs up to the charging equipment. The customer procures and pays for the charging equipment.
- **Charger only:** The electric company funds and/or owns the charging equipment, utilizing the existing supply infrastructure on the premises and/or offsetting any installation costs.
- **Full ownership:** The electric company funds and/or owns the full installation, up to and including the charging equipment.

Utilities are submitting filings to make investments in EVs and EV charging infrastructure. EV charging creates new electricity demand, which can increase utility revenues, and EV charging during off-peak hours can increase system load factors and create a more efficient grid, which can lower rates for all customers.⁵⁵

55 The idea that EV charging can lower rates for all customers is based on the following: If the cost to serve additional EV charging is less than the utility revenue collected from EV charging, then rates could go down. Consider for instance a recent document from Synapse Energy Economics, Inc. available online at <https://www.synapse-energy.com/sites/default/files/EV-Impacts-June-2019-18-122.pdf>. [energy.com/sites/default/files/EV-Impacts-June-2019-18-122.pdf](https://www.synapse-energy.com/sites/default/files/EV-Impacts-June-2019-18-122.pdf).

The long-term value proposition of EVs can be increased through consideration of V2G services, whereby there is bidirectional flow between the vehicle and the grid.⁵⁶ This creates an opportunity where large numbers of EVs could conceivably be aggregated as a distributed energy resource, akin to energy efficiency, demand response programs, distributed storage, or distributed generation. EVs can function as a grid asset and provide distributed storage or voltage support through distributed service provider markets. Moreover, EVs represent one of the most flexible load categories available to market actors, thereby improving the value proposition in distributed energy resource (DER) markets. DERs are small-scale units of local generation connected to the electrical grid at the distribution level (rather than the bulk transmission level). They can provide value to distribution systems and bulk power systems. Rooftop photovoltaic solar panels are the most commonly deployed DER today, where solar electricity generation is generated at homes and, in some places, two-way communications on the grid can help reward customers who generate excess electricity.

To support EV adoption, IOUs are making investments through various mechanisms:

- **Education and outreach:** Utilities invest in outreach programs to educate residents and businesses in their territories about the benefits and considerations of EVs.
- **EV incentives:** Utilities offer customers direct incentives for the purchase or lease of an EV. While these incentives are usually minor, they encourage EV drivers to notify the utility where they are residentially charging.
- **Electric vehicle supply equipment (EVSE) incentives:** Utilities support EV adoption through directly investing in EVSE.

- **Rate design:** Utilities provide customers with TOU rates for charging EVs. In addition to helping the utility identify where EVs are charging, TOU rates encourage drivers to charge during off-peak hours and help stabilize the grid.
- **Demonstration projects:** Utilities are increasingly deploying pilot projects to test the viability of relatively younger EV technologies (such as electric school buses) and business models (vehicle grid integration and participation in utility distribution grid services).

APPROVED AND PENDING FILINGS

As shown in the [Figure 12](#), 24 states (in green) have had utility filings dedicated to investment in EV charging infrastructure deployment that were approved by PUCs; 23 states (in orange) have pending filings related to EV charging infrastructure deployment; and 16 states (in red) have had utility filings either denied or withdrawn.⁵⁷

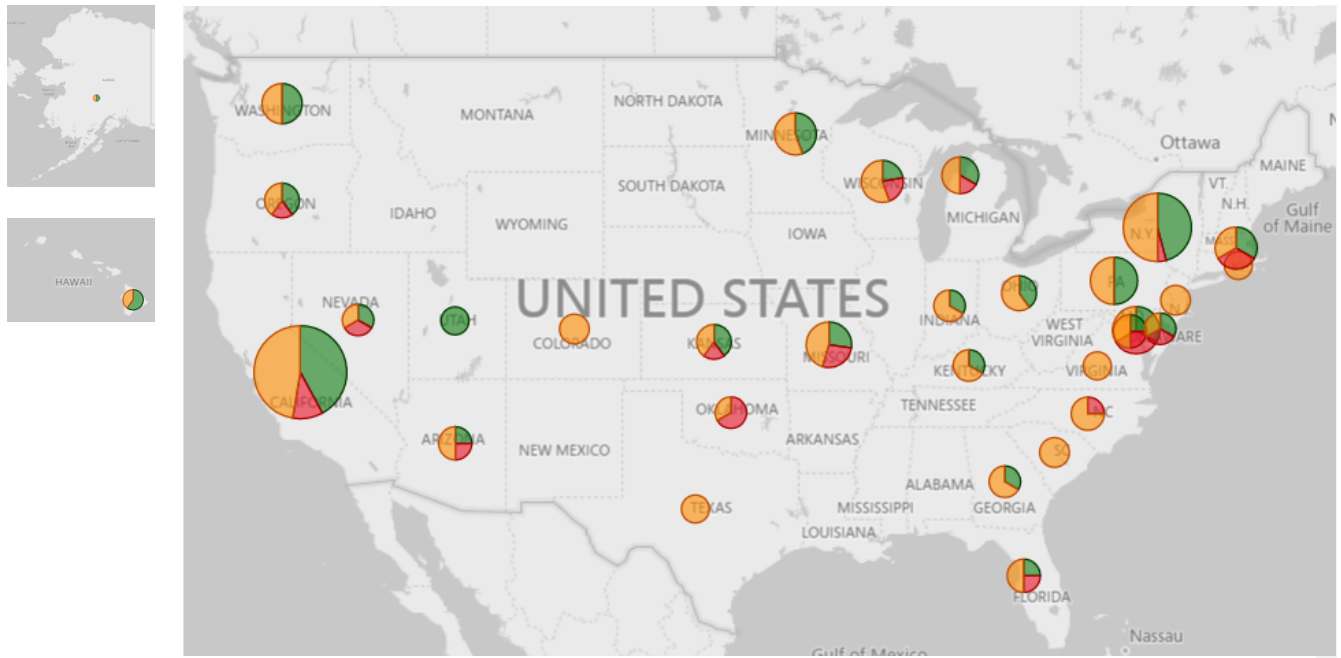
The number of proposed utility investment programs in EV charging infrastructure has increased dramatically in the past six years and become more geographically diverse ([Figure 13](#)). Although California still accounts for most of the western filings, utilities in states from all seven regions shown below submitted a filing in 2018 or 2019.

While many states have utilities that submit filings, the actual money invested is concentrated in California. Of the \$6.45 billion approved or proposed investments in the country, 73% of the utility investment from these filings dedicated to EV charging infrastructure will occur in California, and California utilities account for 79% of the approved filings.

⁵⁶ Only one light-duty auto manufacturer (Nissan) includes a warranty for V2G activities. Others void the warranty of their batteries, creating a disincentive for using EV batteries for bidirectional energy activity. V2G is not commercially available and ongoing pilots are testing technical and economic feasibility.

⁵⁷ EV Hub (website), Atlas Public Policy, accessed January 2, 2020, <https://www.atlasevhub.com/>.

FIGURE 12. SUMMARY OF UTILITY FILINGS FOR EV CHARGING INFRASTRUCTURE INVESTMENTS BY STATE



Source: EV Hub (website), Atlas Public Policy

FIGURE 13. UTILITY FILINGS FOR EV CHARGING INFRASTRUCTURE PROGRAM INVESTMENTS BY REGION

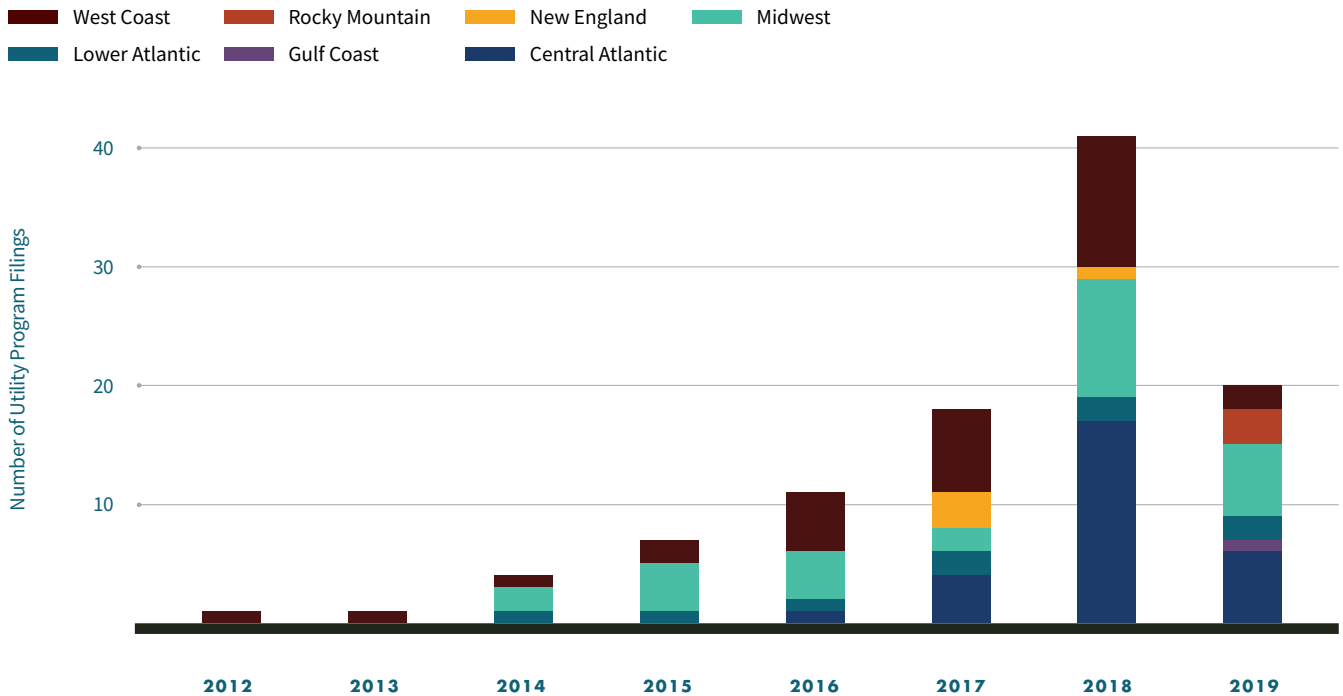
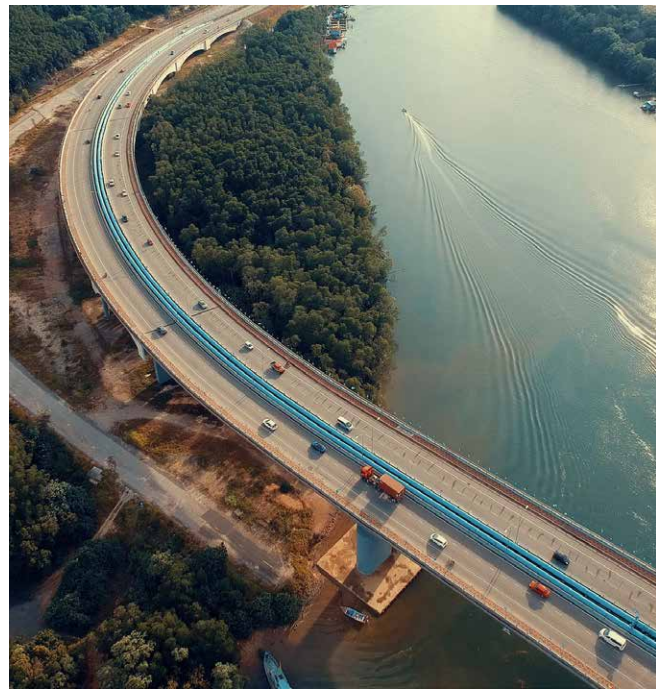
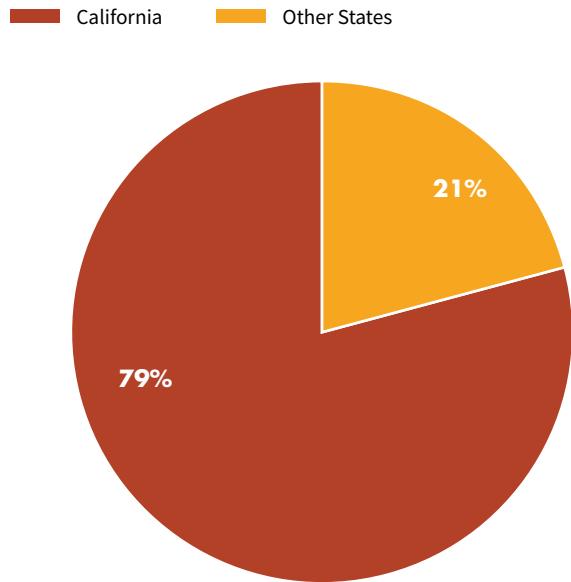


FIGURE 14: GEOGRAPHIC BREAKDOWN OF APPROVED UTILITY TRANSPORTATION ELECTRIFICATION INVESTMENTS



California’s significant investment in EV charging infrastructure is largely a result of state legislation that requires 50% of the state’s electricity must come from renewable resources by 2030 and that electric IOUs file transportation electrification programs at the California PUC in a manner that supports grid management and integrates renewable energy.⁵⁸ Additionally, a 2018 Executive Order requires state agencies to work to install 250,000 EV chargers, including 10,000 DC fast chargers, by 2030 (Figure 14).⁵⁹

TYPES OF INCENTIVES

Utilities make and propose investments in EVs through a number of mechanisms, including education and outreach, funding EVs, funding EV charging infrastructure and offering discounted rates for EV charging (Table 4).⁶⁰

Utilities have directed most filings and funding, for both approved and pending filings, to funding EVSE. EVSE funding can be provided by utilities owning and operating infrastructure, providing incentives

TABLE 4: STATUS OF FILED UTILITY EV CHARGING INFRASTRUCTURE PROGRAM ELEMENTS BY INVESTMENT TYPE

STATUS	EDUCATION ⁵⁷	EV FUNDING	EVSE FUNDING			RATE PROMOTION
			EV Funding	Make Ready	Charging Equipment	
Approved	31	4	29	19	29	33
Filed	47	12	17	9	14	46

58 Clean Energy and Pollution Reduction Act of 2015, California SB-350. (2015). https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201520160SB350.

59 Office of Governor Edmund G. Brown Jr., “Governor Brown Takes Action to Increase Zero-Emission Vehicles, Fund New Climate Investments,” January 26, 2018, <https://www.ca.gov/archive/gov39/2018/01/26/governor-brown-takes-action-to-increase-zero-emission-vehicles-fund-new-climate-investments/index.html> (includes text for California Exec. Order B-48-18).

60 For the purposes of this discussion, education and outreach includes utility investments that are not associated with another incentive. While most incentive programs have funding allocated to outreach and marketing, this education category refers to general EV education.

for the customer to purchase and own the charging equipment or providing the make-ready work for a site; *make-ready* infrastructure refers to all of the additional equipment (conduit, panel, etc.) between the customer’s utility meter and the charging station itself needed to support EV charging. Based on approved filings, utilities are split evenly between the three funding mechanisms. However, in pending filings, utilities favor a combination of incentives to own and operate stations and funding the EV charging equipment over providing make-ready work (Figure 15).

There is no significant trend in the funding mechanisms that utilities use to support EVSE installment, although make-ready incentives are increasingly less common than the utility ownership or infrastructure funding models in filed programs.

TYPES AND LOCATIONS OF CHARGING

Most of the utility investments in EV charging infrastructure are focused on Level 2 charging, with DC fast charging making up less than 5% of planned infrastructure for all filings. Utilities began including DC fast charging in their filings in earnest in 2016 and have been increasing the number of DC fast chargers that they fund; however, the number of Level 2 charging stations that have been included in approved or pending filings significantly outnumber DC fast charging station commitments in similar filings (nearly 480,000 Level 2 stations vs. about 6,600 DC fast charging stations).

Table 5 quantifies the share of utility investment programs that have targeted charging infrastructure in publicly accessible locations, at the workplace, and in residential applications, with specific mention of MUDs.

FIGURE 15. TYPES OF EV CHARGING INFRASTRUCTURE INCENTIVES INCLUDED IN UTILITY PROGRAMS FILED

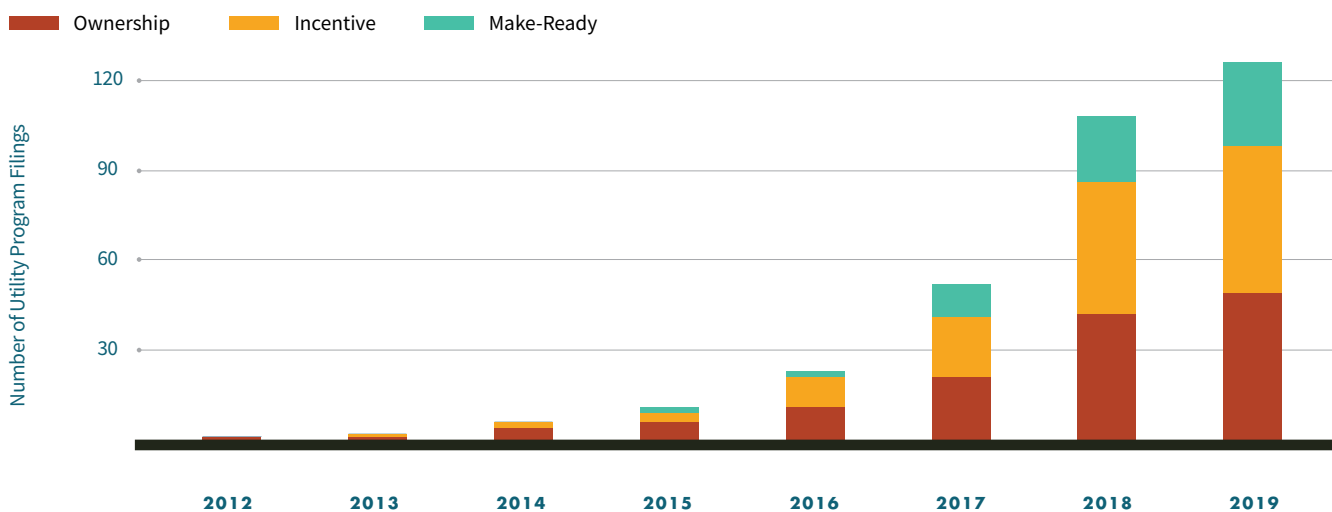
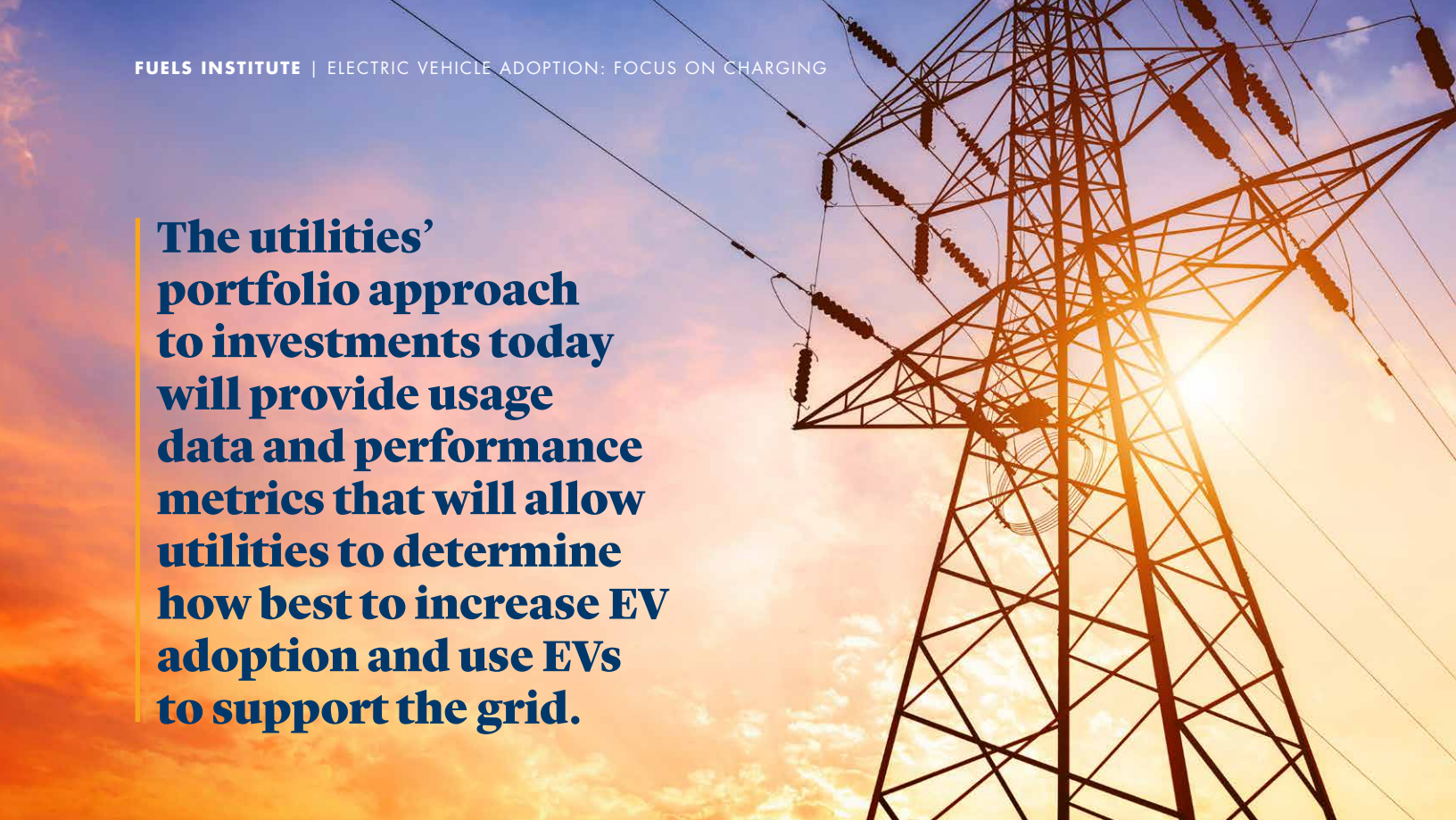


TABLE 5: PERCENT OF FILING ELEMENTS THAT INCLUDE TYPES OF CHARGING

STATUS	PUBLIC	WORKPLACES	RESIDENTIAL	MUDs	OTHER
Approved	34%	15%	13%	15%	24%
Filed	25%	16%	16%	19%	23%



The utilities' portfolio approach to investments today will provide usage data and performance metrics that will allow utilities to determine how best to increase EV adoption and use EVs to support the grid.

While approved EV charging infrastructure investment filings have focused on publicly accessible charging, pending utility filings are split more equally between the locations of charging. There is a consensus among utilities and PUCs that Level 2 charging stations are a strong investment. However, there is not a clear best practice for where the charging stations should be installed or what type of charging they should support. The relatively even split between charging types illustrates that, like the rest of the EV industry, utilities may be unsure how to best support EVs or how EVs will charge.

EQUITY

Of the approved filed programs, 36% include a program aspect that focused on disadvantaged communities (DACs) or gave those communities special preference. These figures are heavily skewed by California utilities; 57% of approved California filed programs have a DAC component. All but one of the 2018 California-filed programs include a DAC

aspect. This focus on equity aligns, and perhaps results from, state policy: Executive Order B-48 calls for the update of the 2016 ZEV Action Plan to expand investment in infrastructure in low income and disadvantaged communities.⁶¹

Utilities outside of California do not generally include DAC components in the filings. Only 11% of approved filed programs in states other than California included a DAC component, and five out of 17 of the filed programs submitted in 2018 in states other than California included a DAC requirement. These utilities are focusing on investing in charging infrastructure in areas where there will likely be high usage. In these early stages of investment, utilities are concentrating on metrics like usage rather than accessibility. Without a mandate from the state level, it seems that utilities, at least in the early stages of EV adoption, will focus on EV charging as a physical system and not as an effort to encourage equity and increase access for DACs.

⁶¹ "Governor Brown Takes Action"

SUMMARY

Outside of California, utility investments in EVs and EV charging infrastructure are comparatively modest. Lacking a state mandate to achieve specific charging and EV deployment goals, utilities are only beginning to use investments in EV charging infrastructure to drive the EV market forward. Instead, they are investing small amounts in a diverse range of programs to gain a better understanding of how and where EVs charge, what impact EVs will have on their business model, and how they can use and support EVs to benefit their operations.

Like the rest of the EV industry, utilities do not know the best model for funding charging stations. They are investing equally in different places for charging (e.g., public, workplace, MUD) as well as the mechanisms of funding (e.g., own and operate or provide incentives for infrastructure). While utilities do seem focused on funding Level 2 charging stations, this could be a result of the cost difference between Level 2 and DC fast charging projects and needing to receive approval from the PUC. As utilities start investing in EV charging infrastructure, funding many less expensive stations may be preferable to funding one or two DC fast chargers.

Fortunately for the larger industry, utilities are not allowing the lack of certainty of best practices to paralyze their actions. Instead, the utilities' portfolio approach to investments today will provide usage data and performance metrics that will allow utilities to determine how best to increase EV adoption and use EVs to support the grid.

Finally, utility investment can be considered a complement to the growth of the EV charging services market. Although initial utility investments are beginning to facilitate infrastructure deployment at a greater scale than previous initiatives, in many cases utilities are only providing a fraction of the infrastructure needed to support widespread transportation electrification. Moreover, EV charging service providers generally view utilities as partners in supporting infrastructure investment and creating opportunities for competition among EV charging service providers where it did not exist before (e.g., MUDs). Some EV charging service providers with certain business models prefer a turnkey utility ownership approach to infrastructure deployment. However, in all utility programs, utilities have relied upon the charging equipment and services of third-party vendors.

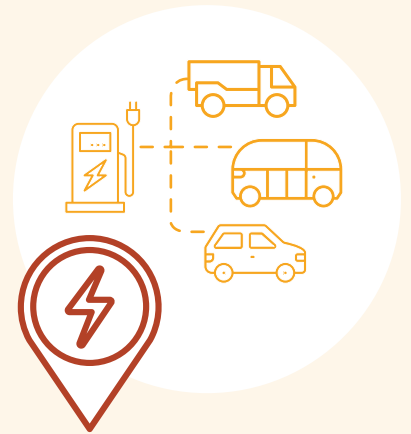
Additionally, the value proposition for deploying charging infrastructure is challenging under many scenarios today because the costs of deploying EV charging infrastructure are concentrated and the benefits (reduced GHG emissions, downward pressure on electricity rates, grid efficiencies) are spread among a broad group of stakeholders. Utilities have often premised the socialization of their transportation electrification program investments on achieving broader utility customer, electricity grid, and/or environmental benefits. These initial utility investments have been important for attracting greater private capital into the EV charging space, particularly for challenging market segments and charging technologies such as DC fast charging.



ICF ANALYSIS: SITING EV CHARGING INFRASTRUCTURE

As part of this study, ICF conducted an EV charging infrastructure demand analysis across the following metropolitan regions: Atlanta, GA; Austin, TX; Chicago, IL; Columbus, OH; Denver, CO; Des Moines, IA; Los Angeles, CA; Orlando, FL; Philadelphia, PA; and Portland, OR. The purpose of the analysis is to employ a flexible methodology that can be updated and used to understand where EV drivers will likely live, work, and visit within these metropolitan regions and understand how this might change as a result of different assumptions regarding EV ownership.

It is best to consider the results of the analysis as a useful guide to understand EV charging infrastructure demand and deployment at a high level for engaged stakeholders.



The siting analysis is a web-based tool that characterizes the demand for EV charging infrastructure at different locations based on a combination of socioeconomic indicators for EV ownership and travel patterns in and around each metropolitan area. Figure 16 summarizes the approach used to characterize demand for EV charging infrastructure, and the following sections present the methodology and data sources in more detail.

The data on income, tenure, and dwelling type were collected from the American Community Survey (ACS), an ongoing survey conducted by the U.S. Census Bureau. Hybrid ownership data were derived from motor vehicle registration information by IHS Markit. These data sets help characterize the likelihood that a particular region will adopt EVs. While all regions are expected to adopt EVs, this analysis quantifies the likelihood of EV adoption based on a current understanding of EV ownership. The likelihood of EV adoption is paired with origin-destination trip information extracted from the transportation models.

FIGURE 16. OVERVIEW OF ICF EV CHARGING INFRASTRUCTURE SITING ANALYSIS METHODOLOGY

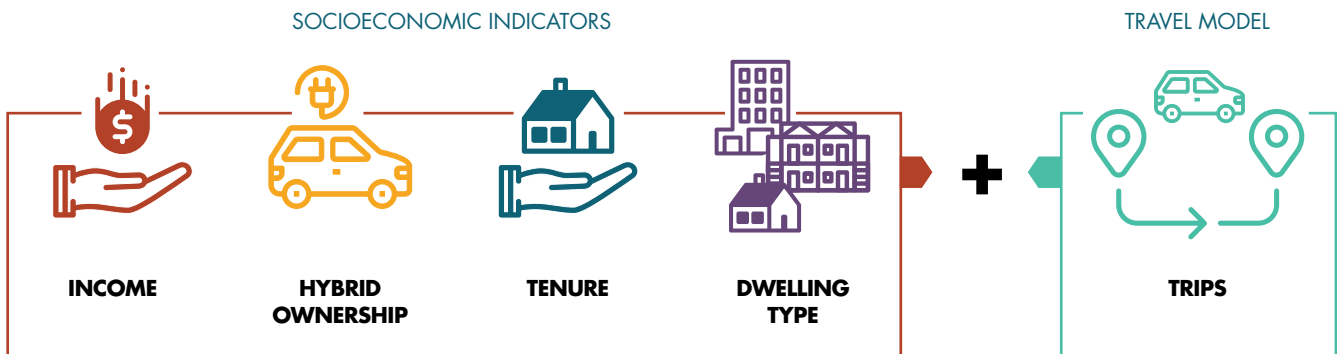
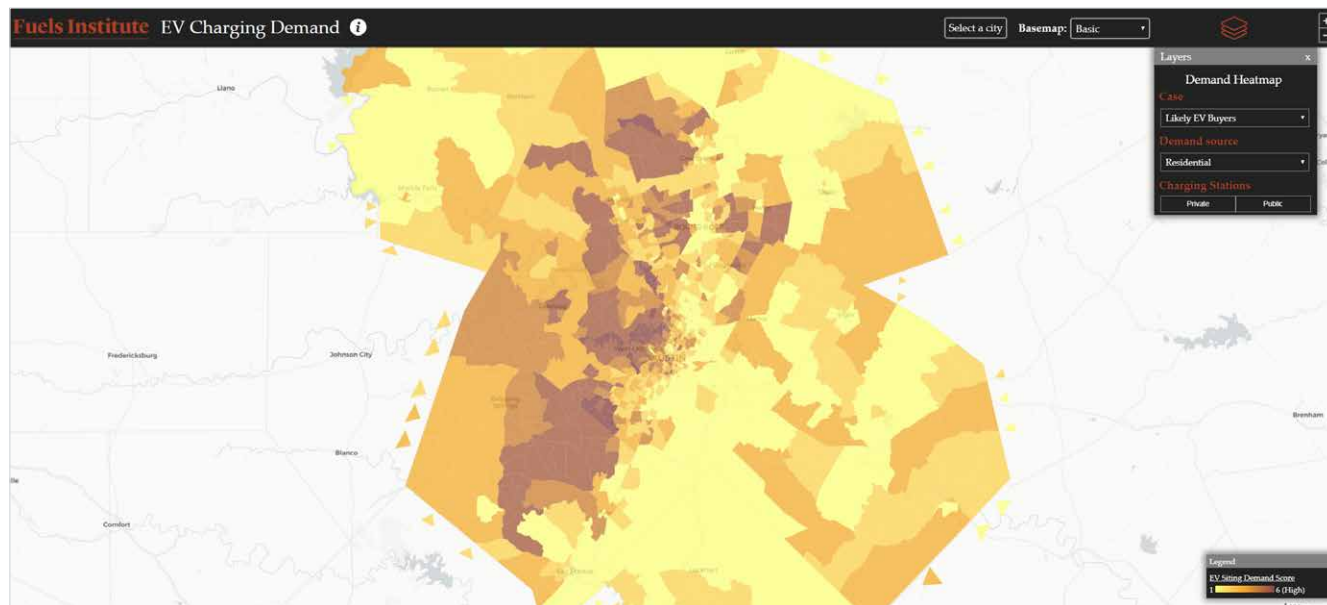


FIGURE 17. ICF EV CHARGING SITING ANALYSIS



ACCESSING AND INTERPRETING THE MAP

ICF mapped the charging infrastructure demand analysis results online: ecosystems.azurewebsites.net/fuelsinstitute/.⁶²

To change which set of data is presented, click on the demand source drop-down menu in the top right corner and select the data to view via the toggle button.

- **The user should first select the metropolitan region of interest from the drop-down menu.** After making a selection and hitting “Go,” the user will be taken to the result of the analysis for that region.
- **The first data layer shows the cases considered:** Likely EV Buyers, Expanding to Multifamily, and Mature EV Market.
- **The second data layer provides the Demand source, which is where EV charging is anticipated to occur.** These are defined as Residential, Opportunity, or Workplace.

- **Residential** highlights areas that will likely experience high demand for residential charging. Because residential charging takes place at home, these are locations in areas where likely EV adopters live.

- **Workplace** highlights areas that will likely experience high demand for workplace charging, such as where EV owners work or where vehicles are parked for several hours during the day for work related trips, including transit riders who park at ride-and-drive lots.

- **Opportunity** highlights areas that will likely experience high demand for public access charging, such as areas where likely EV owners shop, dine, and visit.

- **The third data layer allows the user to overlay existing EV charging infrastructure, characterized as either publicly or privately accessible.** Furthermore, the EV charging infrastructure is distinguished as Level 2, DC fast charging, or a co-location of the two. Existing Tesla super chargers are noted, but these are only accessible to Tesla drivers.

62 Note that the map works best in Chrome and not all features are available when viewing in Explorer.

RESIDENTIAL CHARGING ANALYSIS

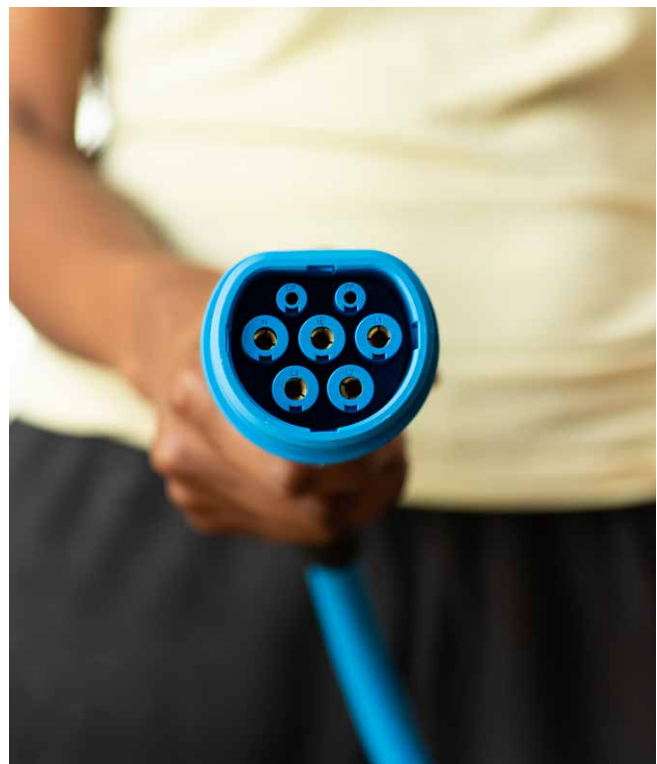
ICF initiated the analysis by identifying where EVs owners are most likely to live, which required identifying the most likely EV adopters. Based on published survey research, ICF identified key indicators for EV ownership. These key indicators were used to develop a scoring methodology that estimates the likelihood of EV adoption in a given area. The following parameters were selected for further consideration, with corresponding weighting factors highlighted below:

- **Income:** Research suggests that households with higher incomes are more likely to purchase an EV. Because EVs tend to have higher upfront costs, income can be a limiting factor. In other words, individuals with low income might not be able to afford an EV.

- **Hybrid electric vehicle (HEV) ownership:**

In addition to correlating with income, HEV ownership correlates with influencing factors such as environmental stewardship and price sensitivity to gasoline, both of which can factor into consumer interest in EVs.

- **Home ownership:** Homeowners are more likely to adopt an EV than renters. Home ownership reduces financial and non-financial barriers to charging infrastructure deployment. The influence of home ownership will likely change considerably over time as building codes change and developers begin to approach residential EV charging capability as an amenity; however, in the near future it will be a significant driver. There is already some correlation between home ownership and income, so the weighting for this parameter is designed to distinguish between Census block groups that are already likely to include EV adopters based on the income profile. ICF only considered Traffic Analysis Zones (TAZs) or Census Block Group (CBGs) that had both an income greater than median income for the region and home ownership greater than the median level of home ownership for the region.



- **Dwelling type:** Dwelling type (e.g., single-family detached, single-family attached, multi-unit) is an important parameter because drivers are expected to charge their vehicles at home. ICF assumes that consumers with a single-family detached home generally have fewer barriers to EV adoption. Only TAZs or CBGs that were above the median income and above the median percentage of single-family residences were considered for the residential analysis.

ICF obtained statistics on EV ownership indicators from ACS Census data, an ongoing statistical survey that samples a percentage of the population every year. For the purposes of this exercise, ICF determined that the most complete data sets for census block groups were the five-year estimates, using data for years 2011-2016. ICF extracted demographic data on income, home ownership, and dwelling type by census block groups from each Metropolitan Statistical Area (MSA). ICF analyzed vehicle registration data from IHS Markit from 2018 to establish hybrid vehicle ownership rates by census block group.

WORKPLACE CHARGING ANALYSIS

Workplace charging is, as the language suggests, charging infrastructure provided by an employer for employee use while at work. To identify likely areas for workplace charging, ICF used data from the regional travel demand models to identify the origin-destination pairs for home-based work trips made between various parts of each metropolitan area. Like the residential charging analysis, ICF used ACS demographics on income, home ownership, and dwelling type, as well hybrid ownership rates, to weight the trips on EV likelihood.

PUBLIC CHARGING ANALYSIS

Public charging covers a wide range of situations where an EV driver could potentially charge when away from home or work. Unlike residential and workplace charging, where vehicles are parked for long enough that they achieve a significant charge even with Level 1 charging, public access charging will take place at locations where drivers are parked for varying times; therefore, the level of charging bears much greater consideration when siting public charging.

To identify likely areas for public charging, ICF used data from the metropolitan planning organizations to identify the origin-destination pairs for non-work-related trips, such as home to shopping and home to social or recreational activity. Using the areas that have the most likely EV adopters, ICF weighted trips based on the likelihood that it would be completed with an EV.

SITING ANALYSIS SUMMARY AND TAKEAWAYS

As the siting analyses show, there are many ways to consider demand for EV charging, including site type (residential, workplace, and public) and user type (likely EV driver, multifamily dwelling residents, and mature EV market drivers). In addition to these factors, site hosts should consider their goals in installing EV charging. Charging stations can be installed to support the current EV market or built for a future EV market. Charging stations installed to meet current needs are in areas with high demand and are more likely to be immediately utilized. Charging stations that are installed with the intent of building the EV market are installed in areas that may not have high demand but where the absence

Public charging may be advantageous in areas with both high opportunity demand for likely EV drivers and high residential demand for expanding to the multifamily case.



of charging stations is a barrier to potential EV drivers. For example, residential charging installed in MUD may not see high utilization, but they make it feasible for a resident to drive an EV. Charging station goals will vary by site host type. Some municipalities or utilities install charging stations in areas that have low demand but will increase access to disadvantaged communities, which helps them achieve their equity goals. Commercial site hosts may choose to install charging stations only in areas that will have high utilization and make a strong business case.

The layers of the siting analysis are intended to allow users to sort through these different scenarios and investigate how the local demographic and travel habits of an MSA affect EV charging demand. For example, public charging may be advantageous in areas with both high opportunity demand for likely EV drivers and high residential demand for expanding to the multifamily case. Charging stations installed in these areas support the existing EV market and will have strong utilization and support the expansion of the EV market for community members without access to residential charging.

Siting analysis users should view the maps while keeping in mind what site type is within their scope (e.g., residential, workplace, or public) and their priorities for charging infrastructure (e.g., stations with high demand or stations that help expand the EV market).

Despite the geographic and economic diversity of the 10 regions identified in the siting analysis, three key takeaways emerge:

1. There is great geographic heterogeneity for charging demand across site types. This is due in part to the clustering of site types in certain areas. For example, there will not be high demand for residential charging in areas zoned for commercial property and vice versa. Given

that charging infrastructure can be deployed across an array of site types, many TAZs and CBGs see high demand from at least one demand source—be it residential, workplace, or opportunity charging.

2. There is ample opportunity for opportunity charging. Although vehicles are parked at homes and workplaces for most of the day, opportunity charging can play an important role in the development of a comprehensive regional charging network. Urban cores and closely surrounding neighborhoods, in many cases, represent key areas for opportunity charging. Ports, including airports and seaports, also experience high demand for opportunity charging. Electrification of ride-hailing and other shared mobility services may accelerate this trend. In some, but not all cases, TAZs and CBGs near major highways and roadways also exhibit high demand for opportunity charging. Proximity to commercial centers and the prevalence of home charging in nearby communities will likely influence the availability of opportunity charging sites.

3. Mapped demand is relative and static, but real-world demand is absolute and dynamic. The siting analyses rank TAZ and CBG charging demand on a relative basis. While this approach is valuable for assessing regional needs at a single point in time, it does not account for changes in demand over time. It is important to note that as EV adoption increases, absolute demand for charging infrastructure will also increase—including in areas with relatively low EV Siting Demand Scores. However, in the near-term, the siting analysis provides a clear indication of areas that are likely experiencing high demand for EV charging.



Conclusions

Transportation electrification is beginning to rapidly shape the light-duty vehicle landscape in the U.S. Technology, policy, and economic drivers are, in many cases, creating tailwinds that favor increased adoption of EVs and the deployment of supporting fueling infrastructure.

Advances in battery technology are increasing EV range and performance. Federal, state, and local policies in key markets are supportive of EV growth on the grounds of economic development, sustainability, and energy security. In some instances, EVs are already cost-competitive with comparable internal combustion engine vehicles on a TCO basis.

However, the nascent EV market also faces notable barriers that will impact the trajectory of adoption, including upfront purchase price, uncertainty surrounding EV incentives, low levels of consumer awareness, and lack of accessible charging infrastructure. Without addressing these challenges, the EV market may not mature as quickly as some analysts anticipate.

This report assesses these EV market enablers and barriers through the lens of three key areas: cost of ownership, consumer acceptance, and charging infrastructure availability. In sum:

- 1. EVs are generally cost-competitive on a TCO basis, but costs hinge on a variety of sensitive parameters.** The electric fuel and maintenance cost savings from EVs often exceed their incremental upfront price premium relative to comparable internal combustion engine vehicles. Based on ICF's TCO calculations, EVs remain competitive on a TCO basis without tax incentives, access to relatively less expensive residential EV charging, and, in the case of PHEVs, access to electricity relative to gasoline.

Expected declines in battery costs will push EVs closer to parity with internal combustion engine vehicles toward the mid-2020s. However, in the near-term, it is unlikely that consumers will internalize long-term EV fuel and maintenance cost savings at the point of vehicle purchase without concerted efforts to inform consumers of total vehicle costs. The availability of federal and state EV incentives is likely to be critical for sustained near-term EV growth while upfront vehicle cost differentials for EVs are still relatively high.⁶³

2. Consumer acceptance and awareness remains a challenge.

Key indicators of consumer awareness remain low, and consumers will generally not adopt technologies they are unfamiliar with. For consumers that are aware of EVs, concerns about driving range and charging infrastructure availability persist. However, growing levels of marketing and outreach efforts may begin to shift consumer understanding and expectations of EVs: automakers, utilities, NGOs, and other organizations are beginning to ramp up efforts to inform consumers about EVs, though the results of these efforts may not fully be understood without further study. Consumers that have purchased EVs generally note a positive experience, suggesting that once consumers “go electric,” they are likely to remain driving EVs.

3. Investment in charging infrastructure is reaching unprecedented levels, but gaps may slow broader adoption.

The confluence of EV charging service provider growth and acquisition, complementary utility investments, and settlement-mandated charging infrastructure investment (e.g., via Electrify America) is rapidly shifting the EV charging landscape. While

fueling an EV often takes longer than internal combustion engine vehicles, the versatility of charging infrastructure siting allows for fueling opportunities when vehicles sit idle for long periods of time. Moreover, higher capacity charging stations (150+ kW) deployed at publicly accessible sites more closely mimic the fueling experience of an internal combustion engine vehicle.⁶⁴ These sites may be particularly important for consumers and ride-hailing drivers that live in areas without access to residential charging. Charging station economics may prove to be challenging at current levels of EV adoption and under certain electricity rate structures. However, as demand for EV charging increases, station economics and utilization will only continue to improve. Understanding where, when, and how long consumers will charge will be critical for effectively filling market gaps and capturing new revenue opportunities.

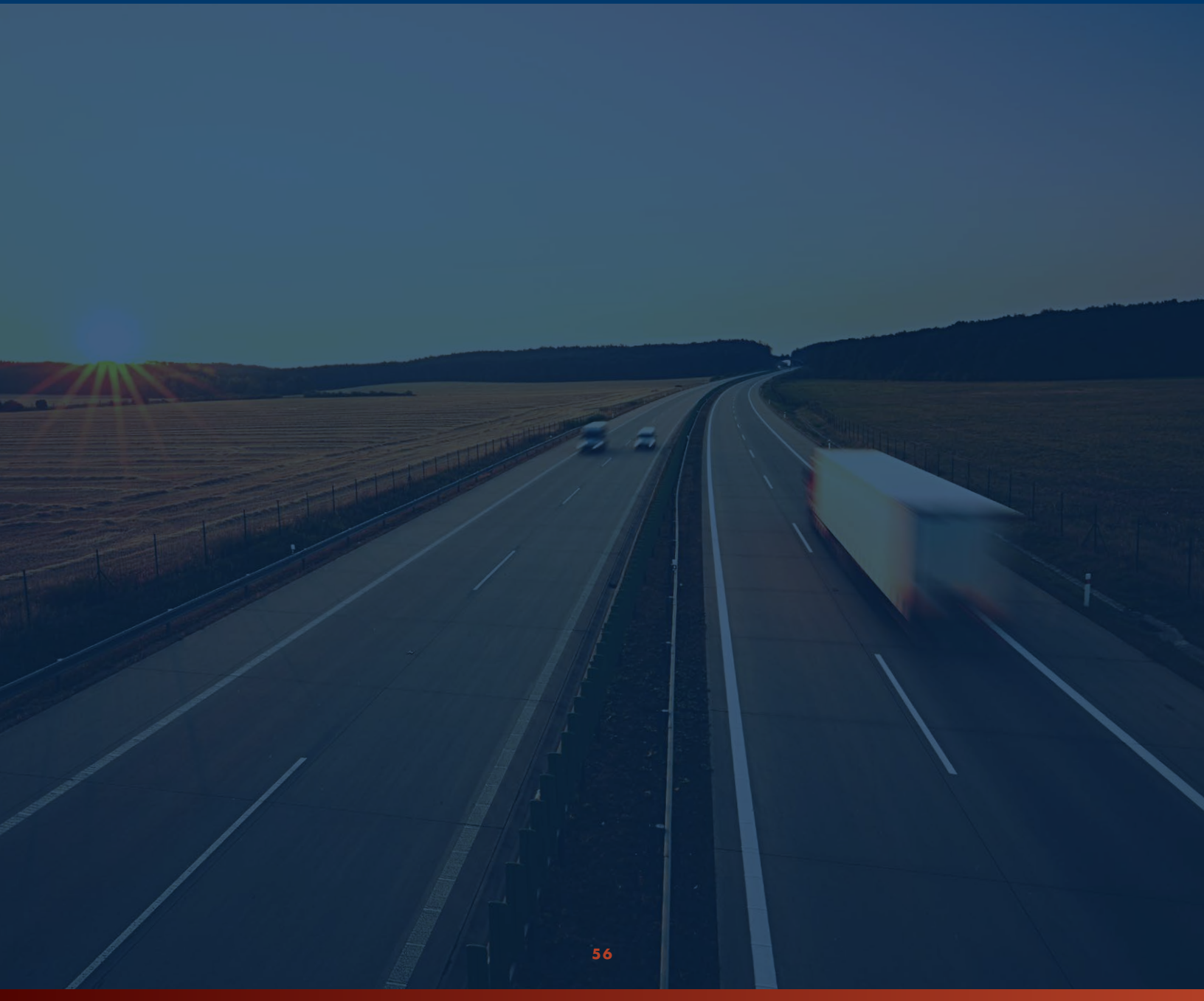
In short, the EV market is facing near-term challenges, but the industry is undergoing rapid change. Many consumers will rely on conventional petroleum-based fuels for the foreseeable future, but electricity will become an increasingly important transportation fuel that drivers will depend on for their mobility needs. Although there is ample time for the fuels community to prepare for a landscape with widespread transportation electrification, relevant stakeholders should take a proactive approach to assess how they can continue to serve future fueling needs and evaluate opportunities to incorporate electricity into an increasingly diverse suite of modern transportation fuels.

⁶³ Non-financial incentives such as HOV lane access may also be a strong driver for EV adoption in certain areas. See Alan Jenn, Katalin Springel and Anand R. Gopal, “Effectiveness of Electric Vehicle Incentives in the United States,” *Energy Policy* 119, issue C (2018): pages 349-356.

⁶⁴ It is difficult to predict how the introduction of higher powered DC fast charging will impact existing EV charging infrastructure. It is plausible that some utilization of existing stations may shift to newer stations, but these dynamics depend on a number of factors that will likely vary based on site-specific conditions, including proximity to destination, price, and queuing, among others.

APPENDIX

Case Studies on EV Charging Infrastructure Demand



APPENDIX

Introduction to the Case Studies

The demand for EV charging infrastructure will be driven by a variety of parameters, which are subject to variation over time and between geographies. For the most part, this discussion seeks to understand how the demand for EV charging infrastructure may change over time across different metropolitan regions with distinct characteristics. Rather than focus on elements of the EV market with high levels of uncertainty, such as vehicle pricing and vehicle populations, the focus is on how the demand for EV charging may change because of various factors that play a role in vehicle ownership and ability to charge.

While there is an understanding of how people travel and use conventional vehicles today, there is very little understanding about how people will drive EVs, including where they will charge, when they will charge, and for how long. These case studies provide an opportunity to explore how the deployment of EV charging infrastructure might change as a function of various parameters across different geographies. The analysis is informed by a web-based mapping tool developed by ICF and is complemented by ICF analysis of various sources, including the National Renewable Energy Laboratory's (NREL) [Electric Vehicle Infrastructure Projection Tool \(EVI-Pro\) Lite](#), to estimate the amount of charging infrastructure needed to support the EVs in a given metropolitan area.

ICF reviewed the current market for EVs in five metropolitan regions: Atlanta, GA; Austin, TX; Des Moines, IA; Los Angeles, CA; and Philadelphia, PA. These regions were selected because of their diversity, not only in terms of geography but also in terms of EV market readiness and



penetration. This mixed portfolio of metropolitan areas allows audiences to better understand how varying conditions in different markets will affect the development of EV charging infrastructure networks and EV adoption at large. The portfolio also empowers audiences to intuit and better understand underlying trends that all regions are grappling with related to EV adoption, including EV incentives, public transit expansion, and ride-hailing growth, among other factors. And through a series of assumptions about potential changes to the EV market and demand for EV charging infrastructure, the focus is on the following issues:

- The demand for charging at home.** As much as 80% of EV charging today occurs at home. This has led to a market dominated by buyers who are typically single-family homeowners with access to a garage. When combined with the potential for attractive TOU electricity rates from utilities, where it is less expensive to charge overnight, for example, charging at home is often the most cost-effective way to reduce the operating costs of owning an EV. Moving forward, however, the EV market will have to expand beyond the single-family homeowner and serve a broader socioeconomic base. ICF developed a methodology to consider this shift and how it might affect demand for EV charging infrastructure.
- Potential for decreased vehicle ownership.** Recent economic growth has spurred new vehicle sales, and vehicle miles traveled are on the rise in the U.S. However, there is increasing evidence that suggests vehicle ownership may decrease in the future as new mobility options become available to consumers, such as through car-share, ride-sharing, ride-hailing applications; expanded public transit; or improved focused on non-motorized modes like walking or biking. ICF considered the potential for decreased vehicle ownership in each region and what that might mean for demand for EV charging infrastructure.

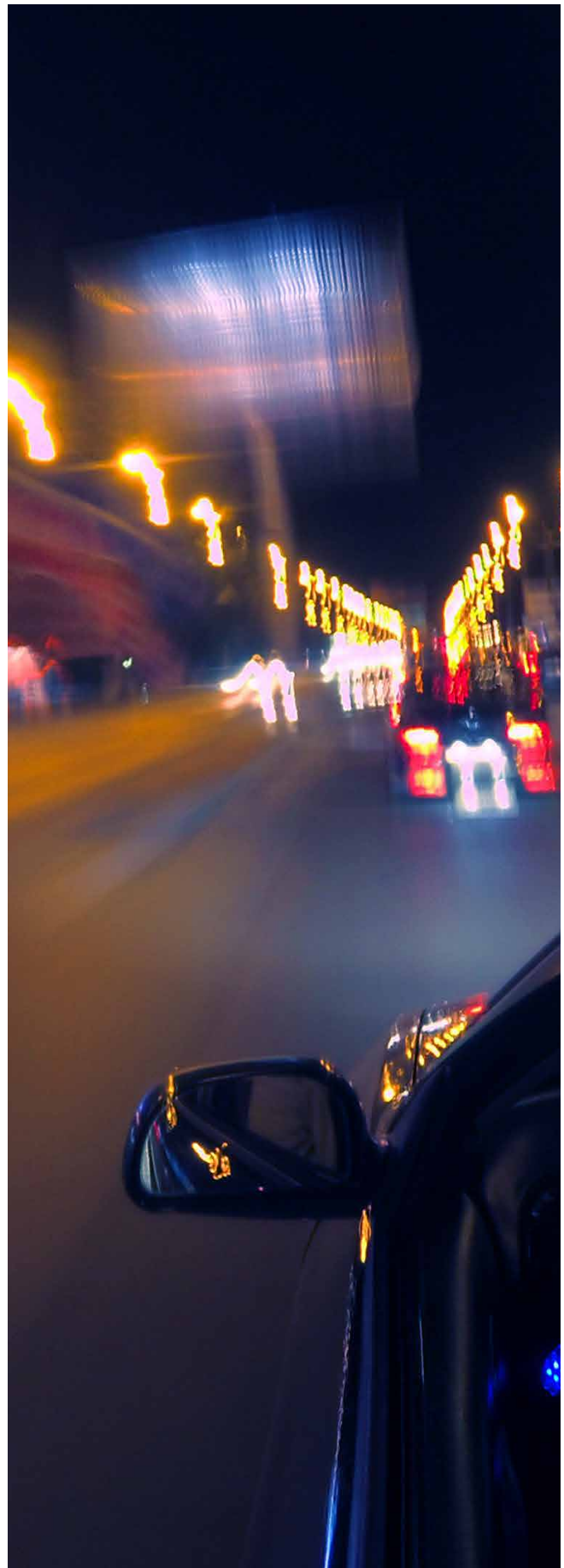


TABLE 6: MSA PROFILE DATA

METROPOLITAN AREA	VEHICLE MARKET SHARE			VEHICLE MARKET SHARE					EV INCENTIVES	
	HEVs	EVs	Total Registered Vehicles (in millions)	Median Income	Population (in millions)	Median Age	Percent Home-ownership	Percent MUD	State	Local/Utility
Atlanta	1.36%	0.36%	4.8	\$59,375	4.3	36	60%	19%	No	Yes
Austin	2.14%	0.36%	1.7	\$60,479	2.0	33.5	58%	18%	Yes	Yes
Des Moines	1.34%	0.13%	0.6	\$62,500	0.7	36	70%	15%	No	No
Los Angeles	3.70%	1.29%	9.7	\$70,000	13.0	36.9	48%	25%	Yes	Yes
Philadelphia	1.18%	0.19%	4.9	\$68,572	6.1	38.7	66%	24%	Yes	Yes

- Transitioning from early adopters to the mass market.** ICF’s base analysis for EV charging demand is focused on likely EV owners. The current understanding of EV owners is focused on high-income individuals who own a single-family home and have likely owned a hybrid vehicle. As EVs become more affordable over time, this profile will likely change as middle-income car buyers, renters, and consumers who live in MUDs give EVs a closer look. ICF considered the timing of this transition and its impact on EV charging infrastructure demand.
- Consumer preference for vehicle architecture.** Today, the market for EVs is split between PHEVs and BEVs. PHEVs are typically a combination of a smaller battery hybridized with a gasoline engine to address potential range concerns. BEVs are powered exclusively by electricity from the grid and have ranges of up to 350 miles, depending on driving conditions. The charging infrastructure solutions for these EV architectures is considerably different. Most PHEVs, for instance, are not compatible with DC fast charging equipment. BEVs have larger batteries and will likely need to be charged at more locations than the home. ICF considered the potential shifts in demand for EV charging infrastructure depending on consumer preference for PHEVs vs BEVs.
- Achieving decarbonization targets. Many states and regions have enacted policies to help achieve decarbonization.** Transportation accounts for a significant share of GHG emissions—more than 30% nationally. As such, transportation is often a key focus of metropolitan areas decarbonization efforts, and in some cases cities seek aggressive adoption of lower carbon transportation solutions, including the rapid deployment of EVs.

The analytical approach for the case studies mirrors that of the metropolitan regions modeled and mentioned previously in Section 3. Each case study includes EV market, demographic, and EV policy information, summarized in [Table 6](#).

ICF mapped the charging infrastructure demand analysis results online at: cosystems.azurewebsites.net/fuelsinstitute/.⁶⁵

⁶⁵ Note that the map works best in Chrome and not all features are available when viewing in Explorer.

APPENDIX: CASE STUDIES

Atlanta

The Atlanta MSA is in the northern portion of Georgia and includes the city of Atlanta and surrounding counties.⁶⁶

The Atlanta metro area is home to more than 4.3 million residents.

The Atlanta metro area has a median age of 36 years, slightly less than Georgia and national figures. Atlanta has a median household income of \$59,375, about equal to the U.S. but higher than Georgia.⁶⁷

Atlanta experienced rapid population growth of about 1.6% in 2015, and the Atlanta Regional Commission (ARC), the area’s metropolitan planning organization, forecasts that the area will gain another 1.5 million residents between 2015 and 2040.⁶⁸ The ARC also predicts that the population will become older as the Baby Boom generation ages and the number of residents age 65 and over triples.

The Atlanta area has a strong economy. Home to 13 Fortune 500 companies, including the Coca-Cola Company and Delta Air Lines Inc., Atlanta has a growing technology sector and a robust film and video production industry. In addition, the region has 70 higher education institutions and hosts the headquarters of many health-care research

institutions, including the U.S. Centers for Disease Control and Prevention, American Cancer Society, Arthritis Foundation, and Task Force for Global Health.⁶⁹ The ARC expects the area to add more than 1 million jobs by 2040, with the top economic areas being the health care, retail, education, and professional and scientific sectors.⁷⁰

I-75, I-85, and I-20 converge near the central business district of Atlanta, all of which have HOV and high occupancy toll (HOT) lanes. I-285 circles the city of Atlanta. There were 4,803,252 registered light-duty vehicles in the Atlanta metro area as of April 2018.⁷¹

The average Atlanta area driver spends 70 hours in traffic, ranking Atlanta fourth in the country for having the worst traffic behind Los Angeles, New York, and San Francisco.⁷²

The area is served by the [Metropolitan Atlanta Rapid Transit Authority](#) (MARTA). MARTA runs 338 rail cars to 38 stations and more than 550 buses along 101 routes, covering 1,429 miles. It provides transit to more than 500,000 riders each weekday. The [More MARTA Atlanta](#) program will invest \$2.7 billion over the next 40 years to expand and improve the MARTA system. Funded in part by an increased sales tax approved by Atlanta voters in 2016, the program will

66 For the purposes of this case study, ICF is limiting the MSA to the ten counties in the Atlanta Regional Commission territory: Cherokee, Clayton, Cobb, Dekalb, Douglas, Fayette, Fulton, Gwinnett, Henry, and Rockdale.

67 Statistical data comes from the U.S Census Bureau’s American Community Survey, available at <https://www.census.gov/programs-surveys/acs/>.

68 “About the Atlanta Region,” Atlanta Regional Commission, <https://atlantaregional.org/atlanta-region/about-the-atlanta-region>.

69 Metro Atlanta Chamber, *Profile of Metro Atlanta*, July 2017, https://www.metroatlantachamber.com/assets/executiveprofilefinalrpf_r6DnPy6.pdf.

70 [Atlanta Regional Commission](#)

71 Based on ICF analysis of IHS Markit data.

72 “INRIX 2019 Global Traffic Scorecard,” INRIX, <http://inrix.com/scorecard/>. Accessed November 15, 2018.

add 22 miles of light-rail transit, 14 miles of bus rapid transit, 26 miles of arterial rapid transit, two transit centers, additional fixed-route bus service, and upgrades to existing rail stations.⁷³

ELECTRIC VEHICLES

CURRENT STATUS

There were about 17,000 EVs in the Atlanta MSA as of April 2018, with about 30% of the market being PHEVs and 70% BEVs. Of the total light-duty market, EVs represent less than 0.5% of the entire market for the Atlanta MSA.⁷⁴ Further, the EV market share statewide was 1.2%, with BEVs making up 1.0% and PHEVs making up 0.2%. The Atlanta area makes up 59% of Georgia’s EV market. [Table CS-ATLANTA 1](#) below compares Atlanta metro area and Georgia EV statistics.

As of August 2018, there were 90 private and 1,573 public charging ports in the Atlanta MSA.⁷⁵ The breakdown by type is shown in [Table CS-ATLANTA 2](#) below.

POLICIES AND INCENTIVES

High rates of EV adoption in Atlanta can be tied to expired state tax credits. Between 2001 and 2015, Georgia offered a state income tax credit of \$5,000 per BEV. As a result, in 2014 Georgia ranked second in the country in terms of EV registrations.⁷⁶ The incentive’s focus was on BEVs rather than PHEVs, which also helps explain Georgia’s relatively high ratio of BEVs to PHEVs (84% of EVs).

Although the tax credit expired in 2015 and the legislature implemented an annual fee for EVs,⁷⁷ the state continues to offer a charging station tax credit of 10% of the cost of EVSE, up to \$2,500.⁷⁸ Additionally, Georgia allows EVs with alternative fuel license plates to use HOV lanes regardless of the number of passengers in the vehicle and use HOT lanes toll-free.

TABLE CS-ATLANTA 1: ATLANTA METRO AREA AND GEORGIA EV STATISTICS

VEHICLE TYPE	ATLANTA METRO AREA			GEORGIA		
	Vehicle Stock	LD Market Share	EV Market Share	Vehicle Stock	LD Market Share	EV Market Share
PHEV	5,094	0.11%	30%	7,588	0.09%	33%
BEV	12,125	0.25%	70%	15,272	0.17%	67%
Total EV	17,219	0.36%		22,860	0.26%	

TABLE CS-ATLANTA 2: PUBLIC CHARGING PORTS IN THE ATLANTA MSA

CHARGER TYPE	PRIVATE PORTS	PUBLIC PORTS
Level 2 (J1772)	76	1,244
DC Fast Charging (CHAdeMO or CCS Plug Standard)	4	139
Level 2 (Tesla)	10	76
DC Fast Charging (Tesla)	0	14

73 More MARTA Atlanta,” MARTA, <https://www.itsmarta.com/moremarta.aspx>

74 Based on ICF analysis of IHS Markit data.

75 “Alternative Fueling Station Locator,” U.S. Department of Energy Alternative Fuels Data Center, <https://afdc.energy.gov/stations>. Accessed August 27, 2018.

76 Union of Concerned Scientists, *Electric Vehicles and Georgia: The Many Benefits of Driving on Electricity*, January 20, 2015, <https://www.ucsusa.org/sites/default/files/attach/2015/02/EVs%20and%20Georgia.pdf>.

77 “Plug-In Electric Vehicle (PEV) Annual Fee,” U.S. Department of Energy Alternative Fuels Data Center, <https://afdc.energy.gov/laws/11602>

78 “Electric Vehicle Supply Equipment (EVSE) Tax Credit,” U.S. Department of Energy Alternative Fuels Data Center, <https://afdc.energy.gov/laws/5182>

At the local level, the Atlanta area has several policies that support EV adoption. Through its *EV Readiness Workbook*,⁷⁹ updated in January 2018, the city provides EV charger installation information, signage guidance, and steps on how to obtain permits for charging stations. In 2017, the Atlanta City Council passed an ordinance that requires that 20% of spaces in new public and multi-family parking facilities and all new single-family homes must be EV ready.⁸⁰

Georgia Power, a subsidiary of Southern Company, is the utility that serves the Atlanta area. The utility owns a network of charging stations and provides incentives for EV use.⁸¹ Georgia Power offers customers a TOU rate for EVs,⁸² as well as rebates of up to \$250 for residential customers, \$500 for businesses, and \$250 for builders who install Level 2 charging stations.⁸³

Georgia will receive \$64 million in Volkswagen (VW) Clean Air Act settlement funding. According to the Beneficiary Mitigation Plan,⁸⁴ finalized in January 2018, the state has allocated 100% of the funds to replacing buses, including purchasing new diesel and all-electric transit buses for the State Road and Tollway Authority’s Xpress system and purchasing all-electric buses for the Hartsfield-Jackson Atlanta International Airport.

ANALYSIS

Just as EV adoption projections vary based on multiple factors, how EVs will charge is dependent on vehicle and community characteristics. Access to home charging affects both how many and where chargers should be located, and as the EV market

moves beyond the early adopter phase, where EV drivers live and travel will change as well. Changes to how people travel, such as increased use of transit and ride-hail services, will impact the number of chargers needed to support the community as well as how the stations are used. Different vehicle technologies (e.g., PHEVs vs. BEVs) charge differently and in different patterns, based on port compatibility and vehicle range. Lastly, if an area has motivation for increasing EV deployment, such as to fulfill public climate goals, the region may see increased incentives and actions to support EVs.

EVS AND HOUSING TYPE

About 19% of Atlanta metro area residents live in MUDs with 10 or more units and 60% of residents own their homes. Because MUD residents do not usually have control over their access to home charging, driving (and charging) an EV is typically less convenient for them than for residents who live in single-family houses. However, a 2017 Atlanta ordinance requires new MUDs to have 20% of parking spots be EV-ready and wired for charging stations. The analysis highlights areas where likely EV adopters live in MUDs. With the new regulations, these areas could be new areas for increased EV ownership and would be good areas to focus education and outreach about EVs.

The EVI-Pro Lite tool allows users to change what percentage of drivers have access to home charging.⁸⁵ Assuming current MUD residents do not have access to charging, about 20% of Atlanta area drivers do not have home charging. However, as newly constructed buildings comply with the

79 Atlanta Office of Resilience, *City of Atlanta EV Readiness Workbook*, updated January, 2018. Available at: <https://www.atlantaga.gov/home/showdocument?id=34401>

80 City of Atlanta Georgia Ordinance 17-O-1654 (passed November 20, 2017). http://atlantacityga.ig2.com/Citizens/Detail_Legifile.aspx?MeetingID=2068&ID=13626

81 “Georgia Power Network Card,” Georgia Power, <https://www.georgiapower.com/residential/save-money-and-energy/products-programs/electric-vehicles/ev-ga-power-network-card.html>

82 “Plug-In Electric Vehicle: Rate Overview,” Georgia Power, <https://www.georgiapower.com/residential/billing-and-rate-plans/pricing-and-rate-plans/plug-in-ev.html>

83 “Electric Vehicles: Georgia Power Is Committed to Growing the Electric Vehicle Market,” Georgia Power, https://www.georgiapower.com/residential/save-money-and-energy/products-programs/electric-vehicles.html?nav=footer_ee_plugin&hp=em_ci_electric_vehicles

84 Governor’s Office of Planning and Budget, *Beneficiary Mitigation Plan for the State of Georgia Pursuant to the Environmental Mitigation Trust Agreement for State Beneficiaries*, January 30, 2018, available at: https://opb.georgia.gov/sites/opb.georgia.gov/files/related_files/site_page/Georgia%20Mitigation%20Plan%20%28Final%29.pdf

85 EVI-Pro Lite default assumptions for vehicle mix: 15% PHEV with 20-mile electric range, 35% PHEV with 50-mile electric range, 15% BEV with 100-mile range, 35% BEV with 250-mile range. The default assumption for PHEV charging is that about 50% of PHEVs will use gasoline and not need to charge in a typical day.

FIGURE 18. RESIDENTIAL EV CHARGING DEMAND FOR LIKELY EV BUYERS AND A MATURE EV MARKET IN ATLANTA

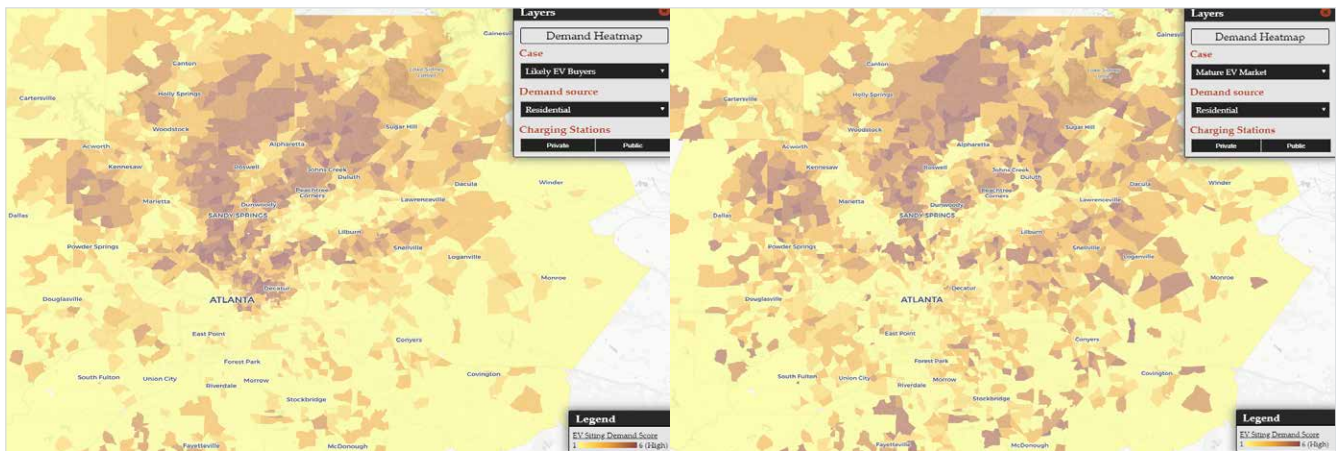


TABLE CS-ATLANTA 3: HOW THE INFRASTRUCTURE NEEDS CHANGE TO SUPPORT 445,909 EVS

TYPE/LOCATION, CHARGING LEVEL	CHARGING PORTS BY PERCENT DRIVERS WITH ACCESS TO HOME CHARGING	
	80%	100%
Workplace Level 2	16,818	9,115
Public Level 2	10,664	5,780
Public DC Fast Charging	1,781	682

EV-ready requirements, a significant portion of MUD residents could eventually have access to home charging. See [Table CS-ATLANTA 3](#) for how the infrastructure needs change to support 445,909 EVs, 10% of the 2016 light-duty vehicle market, based on different home charging assumptions.

TRANSITION TO THE MASS MARKET: MOVING BEYOND EARLY ADOPTERS

By offering a \$5,000 tax credit until 2015, Georgia significantly reduced the cost of EVs and attracted buyers that were motivated by cost savings rather than early technology adoption or sustainability benefits. In the absence of the tax credit, the Atlanta area EV market has cooled. However, as battery cost and vehicle purchase prices decrease, EVs may be

able to move past the early adopter buyer profile and reach the mass market. Due to low electricity costs, fuel costs for EVs in Georgia are lower than those nationally (\$1.12 per eGallon compared to \$1.19) and much lower than gasoline costs (\$2.69 per gallon).⁸⁶ This, combined with lower maintenance expenses, could appeal to cost-conscious consumers looking at TCO.

In this scenario of a mature EV market, the driver profile does not factor in whether the driver is a likely HEV owner. By not including HEV ownership as a profile factor, the model does not favor drivers that are technology enthusiasts or motivated for environmental reasons. Instead, this scenario places weight on income, home ownership, and dwelling type. As shown in [Figure 18](#), the residential EV

86 “eGallon,” U.S. Department of Energy, <https://www.energy.gov/maps/egallon>. Accessed November 16, 2018.

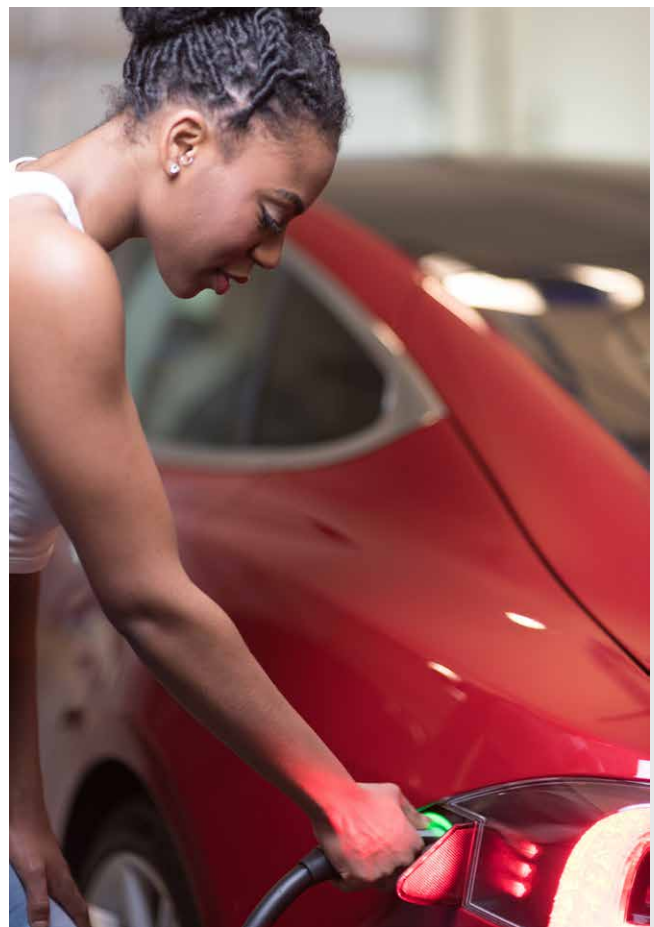
charging demand maps for likely EV buyers and EV buyers in a mature EV market are very similar, which indicates that utilities can focus on meeting demand and expanding capacity within areas currently seeing high levels of residential EV charging.

THE POTENTIAL FOR DECREASING VEHICLE OWNERSHIP

As an area with severe traffic issues, Atlanta is committed to reducing congestion and decreasing the number of single occupancy rides in the metro area. In the 2040 Regional Transportation Plan,⁸⁷ the ARC identified congestion as a threat to the economic competitiveness of the region. The City of Atlanta is currently updating its Regional Transportation Plan, and published drafts include information about multi-modal urban growth, new mobility and technology, and public transportation.

As mentioned previously, the More MARTA Atlanta program will invest \$2.7 billion over the next 40 years to expand and improve the current transit system. According to the ARC, the current premium transit services provide access to less than half of existing major activity centers. In addition to generally expanding the MARTA service area, the More MARTA project aims to improve equity and is projected to provide 61% greater access to transit for communities with large minority or low-income populations.⁸⁸

With support from city and regional transportation plans, the public transit expansion will provide increased access to modes of transportation to more people. If public transportation becomes a cost-effective option for more residents, vehicle ownership may decrease. If residents can meet most of their transportation needs with public transit, they may rely more heavily on ride-hailing or



car-share options to make occasional trips to areas not served by the MARTA system. As these systems become electrified, charging infrastructure will be needed to support them. For example, Georgia Power partnered with Lyft to create the Charge Up Atlanta program.⁸⁹ The program provides Lyft drivers with a \$500 bonus for driving a BEV, with the goals of increasing the number of EVs in the ride-hailing system’s fleet and increasing awareness and education among riders. For a limited time, Lyft also reimburses drivers for their charging costs when they use Georgia Power–owned charging stations. If more ride-hailing and car-sharing vehicles are electric, centrally-located DC fast charging stations will be necessary to support the duty cycle of the vehicles.

87 Atlanta Regional Commission, “The Atlanta Region’s Plan,” updated 2017, available at: <http://documents.atlantaregional.com/The-Atlanta-Region-s-Plan/rtp/rtp-complete-document.pdf>

88 “More MARTA Atlanta Fact Sheet,” More MARTA Atlanta, October 3, 2018, https://www.itsmarta.com/uploadedFiles/MARTA_101/Why_MARTA/City%20of%20Atlanta%20More%20MARTA_Print_v9.pdf.

89 Georgia Power, “Georgia Power Promotes Electric Transportation to Meet Customers’ Changing Needs,” October 19, 2018, <https://www.georgiapower.com/company/news-center/2018-articles/georgia-power-promotes-electric-transportation-to-meet-customer-needs.html>

TABLE CS-ATLANTA 4: HOW CHANGES IN THE EV POPULATION CAN IMPACT THE AMOUNT AND TYPE OF CHARGING INFRASTRUCTURE NEEDED

TYPE/LOCATION, CHARGING LEVEL	CHARGING PORTS BY SCENARIO		
	SCENARIO 1	SCENARIO 2	SCENARIO 3
Workplace, Level 2	3,061	5,008	6,955
Public, Level 2	2,029	3,187	4,345
Public, DC Fast	284	221	140

VEHICLE ARCHITECTURE: PHEV VS. BEV

The current EV population in the Atlanta metro area is about 70% BEVs and 30% PHEVs. The majority of EVs on the road have ranges that can complete most trips, including daily commutes, without needing to charge. These vehicles have the range to serve as the primary vehicle for a household and can use DC fast charging stations.

NREL’s EVI-Pro Lite tool can demonstrate how changes in the EV population can impact the amount and type of charging infrastructure needed. [Table CS-ATLANTA 4](#) shows three scenarios, with all assuming 10% of the light-duty population (445,909 vehicles) will be EVs and favoring longer range batteries/vehicles:

- 1. Maintain the current split of 70% BEVs and 30% PHEVs**
- 2. Move to an even (50%) split between PHEV and BEV**
- 3. Flip to 30% BEV and 70% PHEV**

Understanding the types of charging needed to support the different types of vehicles is important for municipalities, regional government, and utilities. If the area continues to have a higher percentage of BEVs, investments and support of public DC fast charging will be important. If PHEVs become more popular, particularly in the absence of the state BEV

tax credit, workplace charging infrastructure will be key in supporting adoption and DC fast charging stations will be less necessary, as PHEVs cannot use DC fast charging stations.

ACHIEVING DECARBONIZATION TARGETS

The City of Atlanta has set a goal of a reduction of GHG emissions by 20% below 2009 levels by 2020 and 40% below 2009 levels by 2030. As part of this goal, the 2015 Atlanta Climate Action Plan outlines strategies to reduce GHG emissions produced by transportation, which account for 31% of community emissions,⁹⁰ 20% by 2020 and 40% by 2030. Actions recommended by the plan include promoting the purchase of EVs through initiating conversations with state legislators about reinstalling EV purchase incentives and support the installation of charging infrastructure.

In 2017, the Atlanta City Council voted to shift city operations to 100% clean energy by 2025 and the community to 100% clean energy by 2035.⁹¹ The timeline for city operations to achieve 100% renewable energy is currently under review and may shift to 2035. However, any move to cleaner energy will help EV adoption make an even greater GHG impact in the area.

⁹⁰ City of Atlanta Mayor’s Office of Sustainability, *City of Atlanta Climate Action Plan: Local Actions and Policies for Reducing City of Atlanta’s Greenhouse Gas Emissions*, July 23, <https://atlantaclimateactionplan.files.wordpress.com/2016/02/atlanta-climate-action-plan-07-23-2015.pdf>

⁹¹ “Clean Energy Atlanta: A Vision for a 100% Clean Energy Future” (website), <http://100atl.com/>.

APPENDIX: CASE STUDIES

Austin

The Austin MSA is in central Texas and includes Austin, Bastrop, Caldwell, Hays, Travis, and Williamson counties. The MSA is centered on the state capital of Austin and is home to approximately 2 million residents.

The Austin metro area has a median age of 33.5 years, four years younger than the national median (37.5 years), 32.8% of the population is between the ages of 25 and 44 (compared to 26.4% nationwide), and 10.2% is older than age 65 (compared to 15.2% nationally).⁹² The Austin MSA median household income is \$60,479, higher than Texas and the U.S.⁹³

The Austin MSA saw nearly 20% growth from 2010 to 2016, and in 2015 Austin was ranked first out of the 50 largest MSAs based on net migration as a fraction of total population. As of 2015, 6.4% of Austin residents had lived elsewhere the prior year.⁹⁴

The Austin MSA is home to multiple major employers and has one of the fastest growing economies by employment in the nation, with a 3.9% increase in jobs from September 2017 to September 2018.⁹⁵ The University of Texas Austin, the flagship campus of the University of Texas system, is located in Austin and is home to over 50,000 students and

24,000 faculty and staff.⁹⁶ The Austin MSA is also a technology hub, hosting Dell’s headquarters and major campuses for Apple and IBM.

The Austin MSA is bisected by I-35, running north-south through the center of the area, and I-10, running east-west to its south. The area is also served by U.S. 79, U.S. 90, U.S. 183, and U.S. 290. There were 1,655,067 light-duty vehicles in the Austin MSA as of April 2018.⁹⁷

Due to rapid population growth, Austin’s transportation corridors have become congested. According to the Austin Transportation Department, the average weekday peak travel time in 2017 was 48% longer than free-flowing traffic in the mornings and 64% longer in the evenings. About 77% of the annual commuters in the Austin-Round Rock Metro Area drove alone with an average travel time of about 27 minutes.⁹⁸ The City of Austin is actively working to reduce single occupancy vehicle commutes.

The Capital Metropolitan Transportation Authority operates 2,500 bus stops and 17 park-and-ride facilities in Central Texas as well as a commuter rail line, which runs between Leander and downtown Austin. The Capital Area Rural Transportation System connects the rural areas of the Austin MSA area with

92 “Greater Austin Profile,” Austin Chamber, <https://www.austinchamber.com/economic-development/austin-profile/population#Population%20Growth> =

93 U.S Census Bureau

94 Austin Chamber

95 Austin Chamber

96 The University of Texas at Austin, <https://www.utexas.edu/about>

97 Based on ICF analysis of IHS Markit data.

98 BestPlaces, “Commuting in Austin-Round Rock Metro Areas, Texas,” https://www.bestplaces.net/transportation/metro/texas/austin-round_rock

the City of Austin and coordinates with the Capital Metropolitan Transportation Authority to ensure that regional transportation services are cohesive and complementary.

ELECTRIC VEHICLES

CURRENT STATUS

There were 6,037 EVs in the Austin MSA as of April 2018; about 42% PHEVs and 58% were BEVs. EVs represented 0.36% of the MSA’s light-duty market share.⁹⁹ In April 2018, the EV market share statewide was 0.3%, with BEVs making up 0.2% and PHEVs making up 0.1%.¹⁰⁰ The Austin area makes up about 21% of the EV market of Texas, despite accounting for only about 7% of the population of Texas.¹⁰¹

Table Table CS-AUSTIN 1 compares Austin metro area and Texas EV statistics.



As of August 2018, there were 21 private and 753 public charging ports in the Austin MSA area.¹⁰² The breakdown by type is shown in Table Table CS-AUSTIN 2.

Most charging stations provide ports that can be used by all vehicles; of the 774 ports available, about 9% are accessible by Tesla vehicles only. Most private stations in the area are either located at Nissan dealerships or are reserved for employee use at the Google campus.

TABLE CS-AUSTIN 1: AUSTIN METRO AREA AND TEXAS EV STATISTICS

VEHICLE TYPE	AUSTIN METRO AREA			TEXAS		
	Vehicle Stock	LD Market Share	EV Market Share	Vehicle Stock	LD Market Share	EV Market Share
PHEV	2,553	0.15%	42%	12,382	0.13%	43%
BEV	3,484	0.21%	58%	16,414	0.19%	57%
Total EV	6,037	0.36%	100%	28,796	0.32%	100%

TABLE CS-AUSTIN 2: PUBLIC CHARGING PORTS IN THE AUSTIN MSA AREA

CHARGER TYPE	PRIVATE PORTS	PUBLIC PORTS
Level 2 (J1772)	17	658
DC Fast Charging (CHAdeMO or CCS Plug Standard)	4	23
Level 2 (Tesla)	0	67
DC Fast Charging (Tesla)	0	5

99 Based on ICF analysis of IHS Markit data.

100 “Advanced Technology Vehicle Sales Dashboard,” Alliance of Automobile Manufacturers, updated August 20, 2019, <https://autoalliance.org/energy-environment/advanced-technology-vehicle-sales-dashboard/>.

101 U.S Census Bureau

102 “Alternative Fueling Station Locator”

POLICIES AND INCENTIVES

There are a number of state rebates and grants in Texas for the purchase of EVs. The Texas Commission on Environmental Quality (TCEQ) administers the Light-Duty Motor Vehicle Purchase or Lease Incentive Program, which provides a rebate of \$2,500 for the purchase of electric drive vehicles.¹⁰³ TCEQ also ran the AirCheckTexas Drive a Clean Machine program, which provides vouchers of up to \$3,500 for the purchase of a battery electric vehicle to qualified low-income individuals with old vehicles that no longer pass emissions inspections.¹⁰⁴ Fleets in the Austin MSA area are eligible to apply to TCEQ for funding from the Texas Clean Fleet Program to replace diesel vehicles with alternative fuel vehicles, including EVs.¹⁰⁵

In addition to state incentives, the Austin area has committed to reducing emissions and recognized EVs as a promising mechanism for GHG emission reduction. The Austin Community Climate Plan calls for the city to support programs and efforts that expand EV infrastructure and consider offering incentives for the purchase of EVs by individuals and fleet owners.¹⁰⁶ The plan requires that the city pursue code options to increase charger-ready parking and conduct a coordinated effort to prioritize strategic development of smart grid/intelligent energy management systems to further enable intermittent resources and the use of EVs for storage and demand shift. The plan also suggests that the city explore emerging technologies, including inductive charging systems inside city streets for the fast charging of EVs.

The plan considers three scenarios for BEV adoption by 2050:

- **Low case with 300,000 EVs comprising 20% of vehicle stock**
- **Medium case with 600,000 EVs and 40% of stock**
- **High case with 1.2 million EVs and 80% of stock**

Austin will have access to various funding sources for EVs and charging infrastructure. For instance, Texas will receive \$209 million in VW Clean Air Act settlement funding. The TCEQ is the lead agency designated to manage VW settlement funds for the state. Although TCEQ is currently developing the final plan, the draft plan indicates that TCEQ intends to allocate up to 15% of funds (approximately \$31.4 million) for light-duty zero emission vehicle supply equipment projects.¹⁰⁷

UTILITY ENGAGEMENT

Austin Energy, which is a municipal utility that serves the Austin metro area, provides incentives for EVs and EV charging. EV owners in the Austin Energy service area are eligible for a TOU charging rate as well as a rebate of 50% of the cost to purchase and install a qualified residential Level 2 charging station, up to \$1,500. Austin Energy also provides local employers with rebates of 50% of the cost to install Level 1 or Level 2 workplace charging stations, up to \$4,000, and rebates of up to \$10,000 for installing DC fast charging stations. Austin Energy operates the Plug-In Everywhere network, where users pay a monthly flat fee (via their utility bill) to use the over 170 Austin Energy public charging stations.

¹⁰³ "Light-Duty Motor Vehicle Purchase or Lease Incentive Program," Texas Commission on Environmental Quality, updated April 14, 2020, <https://autoalliance.org/energy-environment/advanced-technology-vehicle-sales-dashboard/>.

¹⁰⁴ <https://www.tceq.texas.gov/airquality/mobilesource/vim/driveclean.html>

¹⁰⁵ "Texas Clean Fleet Program (TCFP)," Texas Commission on Environmental Quality, updated March 30, 2020, <https://www.tceq.texas.gov/airquality/terp/tcf.html>.

¹⁰⁶ City of Austin Office of Sustainability, *Austin Community Climate Plan 2015*, http://austintexas.gov/sites/default/files/files/Sustainability/FINAL_-_OOS_AustinClimatePlan_061015.pdf.

¹⁰⁷ Texas Commission on Environmental Quality Air Quality Division, *Volkswagen Environmental Mitigation Trust: Draft Beneficiary Mitigation Plan for Texas* (TCEQ Publication RG-537, August 8, 2018), <https://www.tceq.texas.gov/assets/public/implementation/air/terp/VW/RG-537-Draft-for-Public-Review-180801.pdf>.

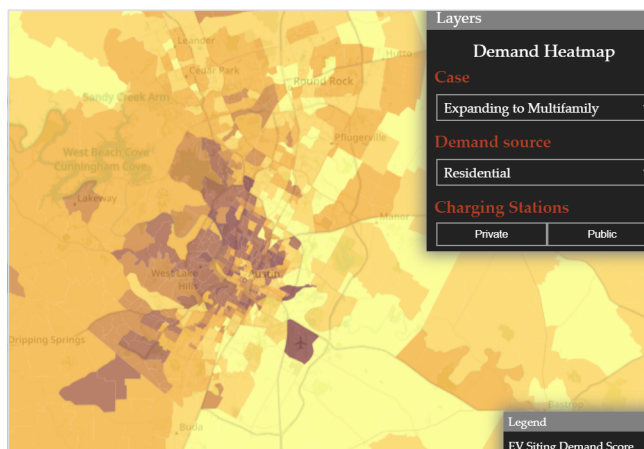
In addition to existing incentives, Austin Energy is incorporating EVs into their planning. The 2017 Austin Energy Resource Plan includes the goal to commit to accelerate EV-based demand response capabilities, including modifying the EV residential charging station rebate program to encourage the deployment of equipment that enables peak shaving for EVs.¹⁰⁸ The resource plan calls for the deployment of at least 300 new charging stations by 2020 and at least eight to 10 utility-owned DC fast charging stations by the end of 2018. Austin Energy will support the growth of public and private charging stations through offering rebates, operational support, outreach, and special public charging rates to include support for low-income populations. Austin Energy's Austin SHINES project assesses the value and business case for integrating stationary distributed energy storage and determines applicability to EV batteries.

ANALYSIS

Just as EV adoption projections vary based on multiple factors, how EVs will charge is dependent on vehicle and community characteristics. Access to home charging affects both how many and where chargers should be located, and as the EV market moves beyond the early adopter phase, where EV drivers live and travel will change as well. Changes to how people travel, such as increased use of transit and ride-hail services, will impact the number of chargers needed to support the community as well as how the stations are used. Different vehicle technologies (e.g., PHEVs vs. BEVs) charge differently and in different patterns, based on port compatibility and vehicle range. Lastly, if an area is motivated for increasing EV deployment, such as to fulfill public climate goals, the region may see increased incentives and actions to support EVs.



FIGURE 19. RESIDENTIAL EV CHARGING DEMAND FOR MULTI-FAMILY RESIDENTS IN AUSTIN



EVS AND HOUSING TYPE

Approximately 58% of Austin MSA residents own their homes and 18% of households are in MUDs with 10 or more units. Because residents of MUDs do not usually have control over their access to home charging, outreach and education for building owners about the benefits of offering residential charging or rewiring new construction is especially important. The analysis highlights areas where likely EV adopters live in MUDs. Figure 19 shows where residents of MUDs who are likely to drive EVs live.

¹⁰⁸ Austin Energy, *Austin Energy Resource, Generation and Climate Protection Plan to 2027*, October 2, 2017. Available at: <https://austinenergy.com/wcm/connect/6dd1c1c7-77e4-43e4-8789-838eb9f0790d/2027+Austin+Energy+Resource+Plan+20171002.pdf?MOD=AJPERES&CVID=IXv4zHS>. Peak shaving refers to when a vehicle reduces power draw or provides power back to the grid or a building when power demand is high.

TABLE CS-AUSTIN 3: HOW THE INFRASTRUCTURE NEEDS CHANGE TO SUPPORT 135,859 EVS

TYPE/LOCATION, CHARGING LEVEL	CHARGING PORTS BY PERCENT DRIVERS WITH ACCESS TO HOME CHARGING	
	80%	100%
Workplace Level 2	4,819	2,612
Public Level 2	3,047	1,651
Public DC Fast Charging	503	193

One of the modifiable parameters of the EVI-Pro Lite tool is access to home charging; if all drivers have access to EV charging, there will be less of a need for public stations. If, however, 20% of EV drivers do not have access to residential charging, the mix of chargers needed to support the EV community changes. Table CS-AUSTIN 3 illustrates how the infrastructure needs change to support 135,859 EVs, 10% of the 2016 LDV market,¹⁰⁹ based on different residential charging assumptions.¹¹⁰

Ensuring that all EV drivers have access to home charging drastically reduces the need for workplace and public charging. As public charging installations are typically more expensive than residential installations (including MUD installations), increasing MUD residential charging is a way to reduce the cost to a region to support EVs. Municipalities can increase MUD charging by offering financial incentives, mandating prewiring or charging installations in new construction, or simply by providing education and outreach to building owners.

TRANSITION TO THE MASS MARKET: MOVING BEYOND EARLY ADOPTERS

With a high average income, available state incentives, and decreasing vehicle purchase prices, the upfront cost of EVs is not a major barrier for the Austin area. Instead, as EVs become as convenient

as conventional vehicles, with longer ranges and more available charging infrastructure, the profile of the EV driver will move beyond the “early adopter” and shift to drivers that are willing to pay slightly higher purchase prices to save on cost over the lifetime of the vehicle. In Texas, the cost to fuel an EV is less than half that of a gasoline vehicle (\$1.02 per gasoline gallon equivalent and \$2.56 per gasoline gallon).¹¹¹ Combined with lower maintenance costs, the economics of EVs can help persuade drivers that are not typically considered early adopters to drive electric.

EVs will also move to the mass market as more vehicle models become available. In Texas, many drivers prefer pickup trucks; in 2016, pickup trucks made up nearly 30% of passenger vehicles in the state.¹¹² Although electric passenger trucks are not currently available, the expansion of the EV market into larger vehicle classes will make them an option to more drivers.

The standard analysis shows where EV drivers are likely to live, work, and travel. However, in this scenario of market penetration, the driver profile does not factor in whether the driver is a likely HEV owner. By not including HEV ownership as a profile factor, the model does not favor drivers that are technology enthusiasts or motivated for

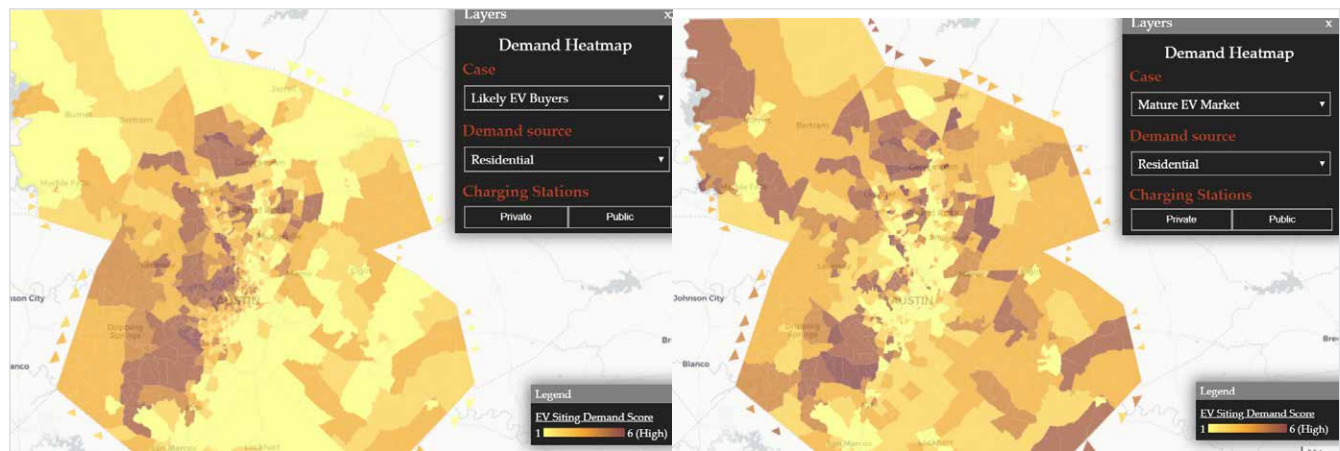
109 EVI-Pro Lite allows calculations up to, but not including, 10% of the 2016 light-duty market. For the purposes of this case study, ICF used 10% of the 2016 market and subtract one vehicle to get a close estimate for 10%.

110 EVI-Pro Lite default assumptions for vehicle mix: 15% PHEV with 20-mile electric range, 35% PHEV with 50-mile electric range, 15% BEV with 100-mile range, 35% BEV with 250-mile range. Assuming PHEVs will use electricity 50% of the time.

111 “eGallon”

112 “Registration Data,” Texas Department of Motor Vehicles, https://www.txdmv.gov/txdmv-forms/cat_view/13-publications/25-reports-data/65-vehicle-titlesregistration/229-number-of-vehicles-registered.

FIGURE 20. RESIDENTIAL EV CHARGING DEMAND FOR LIKELY EV BUYERS AND A MATURE EV MARKET IN AUSTIN



environmental reasons. Instead, this scenario places weight on income, as the driver is still assumed to be able to afford purchasing a new vehicle, and home ownership and dwelling type, as these factors can affect the convenience of charging EVs.

Workplace and opportunity charging sites do not vary significantly between the likely EV buyers and mature EV market scenarios. This indicates that charging stations installed in current areas of demand will serve a mature EV market as well as the current and future market of EV enthusiasts. As shown in Figure 20, residential demand does shift in the mature EV market scenario, as the siting analysis highlights more suburban areas with single family home ownership and the income to afford EVs but that aren't necessarily early EV adopters. In this mature EV market scenario, areas surrounding the City of Austin will have higher EV adoption. This change is of interest to utilities, as they will want to plan to meet residential charging demand.

THE POTENTIAL FOR DECREASING VEHICLE OWNERSHIP

As a tech-heavy, rapidly growing area, the Austin MSA is actively seeking ways to meet travel demand. Austin is currently developing the [Austin Strategic Mobility Plan](#), which addresses how residents will move in Austin and guides transportation policies and investments. According to draft Austin Strategic Mobility Plan documents, strategies include:

- **Promote transit-supportive densities along the Transit Priority Network**
- **Encourage employment to locate near public transportation**
- **Minimize the impact of development on the roadway system by prioritizing multimodal solutions**
- **Right-size future parking supply to encourage sustainable trip options**
- **Implement community-wide strategies to reduce drive-alone trips**
- **Emphasize and incentivize shared mobility solutions**

TABLE CS-AUSTIN 4: HOW CHANGES IN THE EV POPULATION CAN IMPACT THE AMOUNT AND TYPE OF CHARGING INFRASTRUCTURE NEEDED

TYPE/LOCATION, CHARGING LEVEL	CHARGING PORTS BY SCENARIO		
	SCENARIO 1	SCENARIO 2	SCENARIO 3
Workplace, Level 2	1,156	1,435	1,714
Public, Level 2	745	911	1,076
Public, DC Fast	73	62	51

By encouraging density, transit, and shared mobility, the Austin area is supporting a future with fewer personal vehicles. While a decrease in the number of vehicles and, relatedly, a decrease in the number of personal EVs would reduce the need for extensive public charging infrastructure, a shift in how people move could change how charging needs to be provided. For example, if the ride-hailing market grows and uses EVs, drivers will need access to DC fast charging hubs in central locations. If public transit is strongly utilized, then Level 2 charging will be useful in park-and-ride facilities to reduce first-mile emissions.

VEHICLE ARCHITECTURE: PHEV VS. BEV

The current EV population in the Austin metro area is about 60% BEVs and 40% PHEVs. The majority of EVs on the road have ranges of over 100 miles and can use DC fast charging stations. This vehicle mix plays a significant role in what types of infrastructure is required to support EV drivers; if EV drivers continue to choose BEVs as vehicle costs decrease and available ranges increase, they will require less workplace charging (as most commutes can easily be met with current EV ranges) and more public DC fast charging stations.

NREL’s EVI-Pro Lite can also be used to demonstrate how changes in the make-up of the EV population (i.e., BEV vs. PHEV) may impact the amount of charging infrastructure needed. [Table CS-AUSTIN 4](#) presents the results of three different scenarios, with all assuming 10% of the 2016 light-duty population (135,859 vehicles) will be EVs and all favoring longer range batteries/vehicles:

1. **Maintain the current split of 60% BEV and 40% PHEV**
2. **Move to an even (50%) split between PHEV and BEV**
3. **Flip to 60% PHEV and 40% BEV**

Understanding how the vehicle mix affects demand for different types of charging infrastructure helps municipalities plan for how to prioritize support for stations. In its Community Climate Plan, Austin considers emissions reductions through the frame of BEVs; if the city needs increased BEV adoption to meet its climate goals, it should continue to incentive infrastructure that will meet BEV charging patterns.

ACHIEVING DECARBONIZATION TARGETS

The City of Austin adopted a goal of carbon neutrality for city operations by 2020. In 2014, they expanded that goal to include having net-zero community-wide GHG emissions by 2050. As part of the 2015 Austin Community Climate Plan, the city lists driving electric as an “advanced action” for community members to take to support these goals.

According to the Austin Community Climate Plan, 36% of community emissions are the result of transportation. As previously mentioned, the plan lists scenarios for BEV adoption by 2050, with the low adoption scenario being 20% of vehicle stock and the high adoption scenario being 80% of vehicle stock. The city recognizes that EVs will play a major role in emissions reductions and has developed strategies to increase EV adoption.

APPENDIX: CASE STUDIES

Des Moines

The Des Moines-West Des Moines MSA is in central Iowa and surrounds the state’s capital city of Des Moines. The MSA includes Dallas, Guthrie, Jasper, Madison, Polk, and Warren counties. Based on the 2016 American Community Survey, the Des Moines metro area is home to nearly 650,000 residents.¹¹³ Census data show the area is growing rapidly, with Des Moines positioned as one of the fastest growing cities in the Midwest.

The Des Moines metro area has a median age of 36 years, slightly lower than both the Iowa and national figures.¹¹⁴ The area’s primary industries include insurance, financial services, data centers, and advanced manufacturing, in addition to state government.¹¹⁵

According to IHS Markit, there were 594,545 light-duty vehicles in the Des Moines-West Des Moines MSA as of April 2018.¹¹⁶ Iowa’s major highway corridors, I-80 and I-35, pass through the MSA.

The Des Moines Area Regional Transit Authority (DART) serves the metro area and is the largest public transit agency in Iowa. DART’s annual ridership for Fiscal Year 2017 was 4.6 million people served by 150 buses and 112 vans.¹¹⁷ DART plans to add battery electric buses to the fleet in 2019 and received a Federal Transit Agency grant to assist with this transition.¹¹⁸

ELECTRIC VEHICLES

CURRENT STATUS

According to IHS Markit, there were 745 EVs in the Des Moines-West Des Moines MSA as of April 2018. Nearly 70% (519) of those vehicles were PHEVs and 30% (226) are BEVs.¹¹⁹ In total, EVs represent 0.13% of the metro area’s light-duty vehicle market share.

The Des Moines area EV population is approximately one-third of all 2,300 EVs on the road in Iowa. At the state level, according to the Auto Alliance,¹²⁰ PHEVs dominate the EV market with 0.20% of light-duty market share while BEVs currently have 0.08%. Iowa ranks in the bottom half of states in terms of both EV sales and market share. [Table CS-Des Moines 1](#) compares Des Moines metro area and Iowa EV statistics.

113 U.S Census Bureau

114 “Des Moines-West Des Moines, IA Metro Area,” Census Reporter, <https://censusreporter.org/profiles/31000US19780-des-moines-west-des-moines-ia-metro-area/>.

115 The website for the Greater Des Moines Partnership, <https://www.dsmpartnership.com/>.

116 Based on ICF analysis of IHS Markit data.

117 Des Moines Area Regional Transit Authority, *Transit Impact Report*, September 2017, <https://www.ridedart.com/sites/default/files/DART%20White%20Paper.pdf>.

118 DART. September 2017. <https://www.ridedart.com/news-archive/dart-receives-grant-fund-purchase-electric-buses>.

119 Based on ICF analysis of IHS Markit data.

120 “Advanced Technology Vehicle Sales Dashboard,” accessed November 9, 2018.

TABLE CS-DES MOINES 1: DES MOINES METRO AREA AND IOWA EV STATISTICS

VEHICLE TYPE	DES MOINES METRO AREA			IOWA		
	Vehicle Stock	LD Market Share	EV Market Share	Vehicle Stock	LD Market Share	EV Market Share
PHEV	519	0.09%	70%	1,707	0.20%	73%
BEV	226	0.04%	30%	639	0.08%	27%
Total EV	745	0.13%	100%	2,346	0.28%	100%

TABLE CS-DES MOINES 2: PUBLIC CHARGING PORTS IN THE AUSTIN MSA AREA

CHARGER TYPE	PRIVATE PORTS	PUBLIC PORTS
Level 2 (J1772)	1	45
DC Fast Charging (CHAdeMO or CCS Plug Standard)	0	0
Level 2 (Tesla)	0	5
DC Fast Charging (Tesla)	0	8

As of August 2018, there was one private and 58 public charging ports in the Des Moines MSA.¹²¹ The breakdown by type is shown in [Table CS-Des Moines 2](#).

Most public stations in Iowa are currently Level 2. Nearly all private access charging stations in the Alternative Fuels Data Center database are located at car dealerships. Except for two ports, all of the DC fast chargers in Iowa are Tesla Superchargers, including one located at the Hy-Vee in Des Moines. The Des Moines metro area has the largest concentration of EV chargers compared to other parts of the state.

Electrify America, the company responsible for implementing the ZEV Investment Plan resulting from the VW settlement, lists Waukee, Iowa, as the location of a future DC fast charger on its highway network.¹²²

POLICIES AND INCENTIVES

There are currently no state tax credits or other financial incentives to increase EV adoption in Iowa. Recent policy activity, however, suggests a growing interest in planning for market growth. For instance, legislation enacted in 2018 directs the Iowa Economic Development Authority (IEDA),¹²³ in collaboration with the Iowa Department of Transportation (DOT) and the utility industry, to conduct a study of EV charging infrastructure for both commercial and non-commercial vehicles. The study will evaluate costs and benefits associated with different options for EV infrastructure support. IEDA will submit the study report to the Iowa General Assembly by June 30, 2019.

IEDA, particularly through the Iowa Clean Cities Coalition, has taken a lead role in EV advocacy and

121 "Alternative Fueling Station Locator"

122 "Locate a charger," Electrify America, <https://www.electrifyamerica.com/locate-charger>.

123 Iowa Senate File 2311 (2018).

coordination efforts, working with the Iowa DOT and other public and private stakeholders. IEDA was a partner to the Des Moines Area Metropolitan Planning Organization to develop an EV readiness plan in 2014.¹²⁴ The report summarizes the steps Des Moines metro area municipalities can take to support leadership in public charging station installation, increased workplace and multi-family charging, and the integration of EV charging infrastructure into comprehensive planning. IEDA published *Advancing Iowa's Electric Vehicle Market* in July 2016, the result of a study assessing Iowa's EV market—current and future—and evaluating programs and policies that could support a growing market.¹²⁵

Other funding sources are available for EVs and charging infrastructure. Iowa will receive more than \$21 million in VW Clean Air Act settlement funding. The Iowa DOT is the lead agency designated to manage VW settlement funds for the state and intends to award up to \$3.15 million over the next 10 years for light-duty zero emission vehicle charging projects.¹²⁶

UTILITY ENGAGEMENT

The Iowa Utilities Board opened a rulemaking proceeding on EVs in August 2018.¹²⁷ Through public comments and a workshop, stakeholders will provide the Iowa Utilities Board with information related to the regulation of EV charging infrastructure in Iowa.

MidAmerican Energy Company, which serves the Des Moines metro area, provides basic EV education online and is partnering with DART to incorporate battery electric buses into the public transit fleet.¹²⁸ While the Alliant Energy service territory does

not overlap with the MSA, the utility has an active electrification program. In addition to customer education, Alliant Energy provides rebates for qualified EVs, residential EV charging stations, and commercial (workplace, public) EV charging stations.

ANALYSIS

Just as EV adoption projections vary based on multiple factors, how EVs will charge is dependent on vehicle and community characteristics. Access to home charging affects both how many and where chargers should be located, and as the EV market moves beyond the early adopter phase, where EV drivers live and travel will change as well. Changes to how people travel, such as increased use of transit and ride-hail services, will impact the number of chargers needed to support the community as well as how the stations are used. Different vehicle technologies (e.g., PHEVs vs. BEVs) charge differently and in different patterns, based on port compatibility and vehicle range. Lastly, if an area is motivated for increasing EV deployment, such as to fulfill public climate goals, the region may see increased incentives and actions to support EVs.

EVS AND HOUSING TYPE

Approximately 70% of Des Moines metropolitan area residents own their homes. Single-family homes dominate the market, with only about 15% of households located in MUDs with 10 or more units. MUD residents will be a source of EV charging demand, with opportunities to accommodate future demand by pre-wiring new developments for charging infrastructure. Widespread market acceptance, however, will not depend on a build-out of multi-family charging.

124 Des Moines Area Metropolitan Planning Organization and Iowa Economic Development, *Electric Vehicle Readiness: Energy Efficiency through Regional Planning*, August 2014, <https://dmampodemo.files.wordpress.com/2014/12/electric-vehicle-report1.pdf>.

125 Iowa Clean Cities Coalition and Iowa Economic Development, *Advancing Iowa's Electric Vehicle Market*, July 2016, <https://www.iowaeconomicdevelopment.com/userdocs/documents/ieda/AdvancingIowasElectricVehicleMarketReport.pdf>.

126 Iowa Department of Transportation, *Iowa's Volkswagen Settlement Beneficiary Mitigation Plan: Iowa's Plan for Using Funds from the National Volkswagen Settlement*, July 2018, https://www.iowadot.gov/vwsettlement/docs/iowas_FINAL_BMP.pdf.

127 Iowa Utilities Board, *Docket Summary for Docket RMU-2018-0100*, <https://efs.iowa.gov/efs/ShowDocketSummary.do?docketNumber=RMU-2018-0100>.

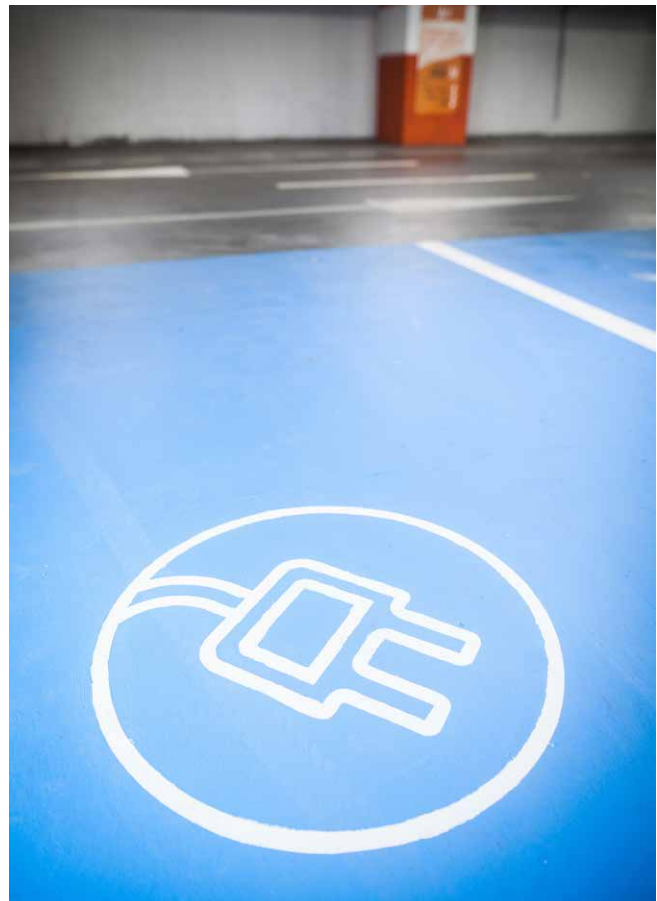
128 "DART Receives Grant to Fund Purchase of Electric Buses"

TRANSITION TO THE MASS MARKET: MOVING BEYOND EARLY ADOPTERS

The median household income in the Des Moines metro area is approximately \$62,500. Given the current MSRP of EVs and the lack of state incentives to supplement the federal tax credit that may eventually phase out, the transition to widespread EV adoption will require a significant decrease in upfront purchase price, robust incentives to reduce the cost at the point of sale, or increased availability of used EVs.

MidAmerican Energy Company, the electric utility serving the Des Moines metro area, provides electricity at a rate of \$0.10/kWh for residential and \$0.08/kWh for commercial.¹²⁹ These rates are lower than national averages, making EV charging relatively inexpensive. The cost to fuel an EV in Iowa is \$1.32 per e-gallon compared to \$2.69 per gallon for a similar gasoline vehicle.¹³⁰ Messaging focused on monetary savings in the total cost of vehicle ownership will help educate a broader audience on the benefits of EVs.

Sustained EV adoption in the Des Moines metro area may be limited by vehicle availability. Because Iowa is not among the states that require a certain number of ZEVs (i.e., EVs, fuel cell vehicles) to be available for sale, not all EV makes and models will be available in Des Moines area dealerships. The lack of plug-in electric light truck options—including pick-ups, SUVs, and vans—is also a major factor. Iowa ranked eighth in the nation with light trucks making up nearly 75% of total light-duty vehicle sales in 2016.¹³¹ Without suitable EV options to replace these vehicles, a significant portion of the vehicle stock will remain powered by gasoline and diesel.



THE POTENTIAL FOR DECREASING VEHICLE OWNERSHIP

The likelihood that vehicle ownership will decrease in the Des Moines MSA is low, as it would require a significant cultural shift. The average number of vehicles per Des Moines metro area household is already slightly higher than the national average. Further, more than 80% of Iowa commuters drive alone to work. Even Des Moines' most recent mobility plan, Connect Downtown, does not mention reducing the number of vehicles on the road and focuses mostly on improving the safety and accessibility of traveling by foot, bike, or transit.¹³²

¹²⁹ "State & Local Energy Data," U.S. Department of Energy Integrated Deployment Office, <https://www.eere.energy.gov/sled/#/>, accessed November 9, 2018.

¹³⁰ "eGallon"

¹³¹ "What Consumers Drive ... Drives the Auto Industry," Alliance of Automobile Manufacturers, <https://autoalliance.org/economy/consumer-choice/>, accessed November 15, 2018.

¹³² City of Des Moines, Urban Land Institute Iowa, and Greater Des Moines Partnership, *Connect Downtown*, November 2017, http://connectdowntowndesmoines.com/wp-content/uploads/2018/01/DM_Connect-Downtown_FINAL-web.pdf.

FIGURE 21. OPPORTUNITY EV CHARGING DEMAND AND WORKPLACE EV CHARGING DEMAND FOR LIKELY EV BUYERS IN DES MOINES

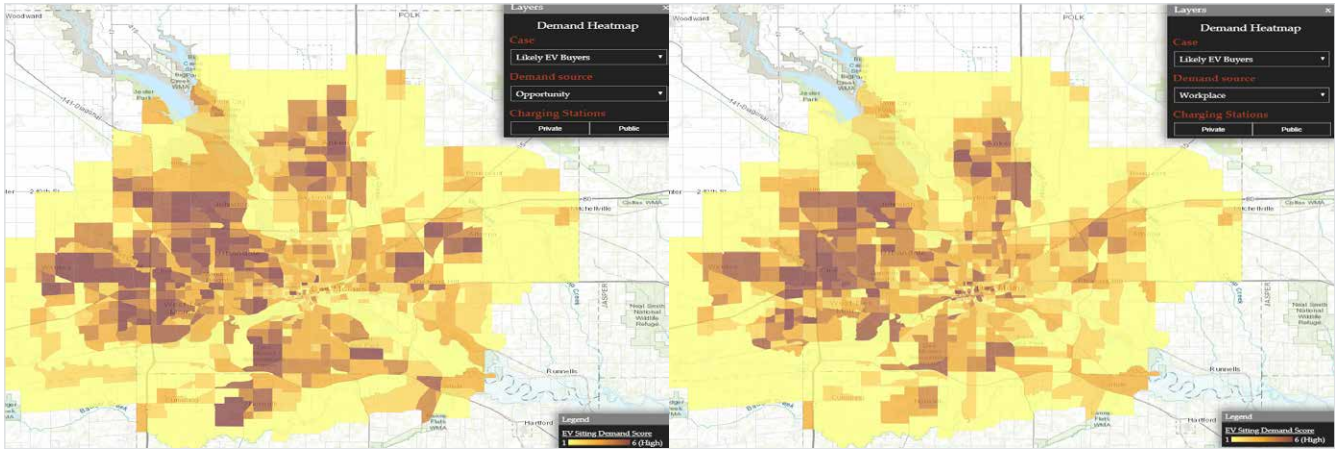


TABLE CS-DES MOINES 4: HOW CHANGES IN THE EV POPULATION CAN IMPACT THE AMOUNT AND TYPE OF CHARGING INFRASTRUCTURE NEEDED

TYPE/LOCATION, CHARGING LEVEL	CHARGING PORTS BY SCENARIO		
	SCENARIO 1	SCENARIO 2	SCENARIO 3
Workplace, Level 2	1,706	1,340	974
Public, Level 2	1,056	826	598
Public, DC Fast	90	100	130

VEHICLE ARCHITECTURE: PHEV VS. BEV

The current EV population in the Des Moines metro area is 70% PHEVs and 30% BEVs. This means most of the EVs on the road have all-electric ranges of 50 miles or less. Residential charging and public Level 2 charging is likely enough to meet today’s charging demand, but this may change as more BEVs are purchased in the area and as EV battery ranges increase.

As PHEVs have a shorter all-electric range than BEVs, workplace charging can significantly increase PHEV electric miles travelled. In an area where most EVs are PHEVs, like Des Moines, workplace charging is important to increase the electric range of vehicles and reduce driver range anxiety.

As shown in [Figure 21](#), the workplace and public charging demand for likely EV buyers is very similar in Des Moines.

Since workplace charging stations are only used by employees during the workday, opening them for public charging after hours and during the weekend can increase the station utilization and maximize site host investment.

The EVI-Pro Lite tool can also be used to demonstrate how changes in the make-up of the EV population (i.e., BEV vs. PHEV) may impact the amount of charging infrastructure needed. [Table CS-Des Moines 3](#) presents the results of three different scenarios, with all assuming 10% of the

light-duty population will be EVs and all favoring longer range batteries/vehicles:

1. **Maintain the current split of 70% PHEV and 30% BEV**
2. **Move to an even (50%) split between PHEV and BEV, which is equivalent to the EVI-Pro Lite default assumptions¹³³**
3. **Flip to 70% BEV and 30% PHEV**

Understanding the types of charging needed to support the different types of vehicles is important for municipalities, regional government, and utilities. Considering the current inventory of less than 300 charging ports across the entire state, recognizing

that some private workplace charging may not be included in that total, infrastructure in the Des Moines area will need to expand significantly to meet projected EV demand.

ACHIEVING DECARBONIZATION TARGETS

To date, there has been little activity on record at the state and MSA level regarding the link between EVs and decarbonization. The Great Plains Institute has published several reports and white papers resulting from Midcontinent coordination, including *Electric Utility Roles in the Electric Vehicle (EV) Market: Consensus Principles for Utilities EV Program Design*.¹³⁴

133 EVI-Pro Lite default assumptions for vehicle mix: 15% PHEV with 20-mile electric range, 35% PHEV with 50-mile electric range, 15% BEV with 100-mile range, 35% BEV with 250-mile range. The default assumption for PHEV charging is that about 50% of PHEVs will use gasoline and not need to charge in a typical day.

134 Read the report at: https://www.betterenergy.org/wp-content/uploads/2018/04/MTEC_White_Paper_April_2018-1-1.pdf.



APPENDIX: CASE STUDIES

Los Angeles

The Los Angeles MSA, consisting of Los Angeles and Orange counties, is the second largest metro area in the U.S. It is home to more than 13 million people and covers close to 5,000 square miles. Los Angeles is a diverse region, both socioeconomically and racially. In terms of overall GDP, it is the third leading city in the world, with an economy of over \$1 trillion.

As of January 2018, there were over 9.7 million light-duty vehicles within the Los Angeles MSA.¹³⁵ The average commute is 30.8 minutes, with 75% of residents driving alone, 10% carpooling, and 5% using public transportation.¹³⁶ The region is served by the Los Angeles County Metropolitan and the Orange County Transportation Authorities, which provide both rail and bus services.

ELECTRIC VEHICLES

CURRENT STATUS

There were 129,895 EVs in the Los Angeles MSA as of January 2018.¹³⁷ Of those EVs, there is a 49%/51% split between PHEVs and BEVs, respectively. In total, EVs represent 1.29% of the Los Angeles MSA's light-duty vehicle stock. In 2017, Los Angeles was the largest single market of EVs within California with more than 38,000 new EVs purchased, which is more than one-fifth of the all the new EVs sold in the U.S. during that same time.¹³⁸

The Los Angeles MSA EV population constitutes 25% of all EVs in California. At the state level, according to the Auto Alliance,¹³⁹ the PHEV/BEV split favors BEVs slightly more than in the Los Angeles MSA. [Table CS-Los Angeles 1](#) compares Los Angeles MSA and California EV statistics.

As of August 2018, there were 1,104 private and 6,427 public charging ports located throughout the Los Angeles MSA, for a total of 7,531 ports.¹⁴⁰ The breakdown by type is shown in [Table CS-Los Angeles 2](#).

¹³⁵ Based on ICF analysis of IHS Markit data.

¹³⁶ "Los Angeles-Long Beach-Anaheim, CA Metro Area," Census Reporter, <https://censusreporter.org/profiles/31000US31080-los-angeles-long-beach-anaheim-ca-metro-area/>.

¹³⁷ Based on ICF analysis of IHS Markit and EMFAC data.

¹³⁸ International Council on Clean Transportation, *California's Continued Electric Vehicle Market Development*, <https://www.theicct.org/sites/default/files/publications/CA-cityEV-Briefing-20180507.pdf>.

¹³⁹ "Advanced Technology Vehicle Sales Dashboard," accessed November 9, 2018.

¹⁴⁰ "Alternative Fueling Station Locator," accessed August 27, 2018.

TABLE CS-LOS ANGELES 1: LOS ANGELES MSA AND CALIFORNIA EV STATISTICS

VEHICLE TYPE	LOS ANGELES MSA			CALIFORNIA		
	Vehicle Stock	LD Market Share	EV Market Share	Vehicle Stock	LD Market Share	EV Market Share
PHEV	67,922	0.67%	52%	210,213	0.83%	48%
BEV	61,973	0.61%	48%	231,466	0.91%	52%
Total EV	129,895	1.29%	100%	441,679	1.73%	100%

TABLE CS-LOS ANGELES 2: PUBLIC CHARGING PORTS IN THE LOS ANGELES MSA AREA

CHARGER TYPE	PRIVATE PORTS	PUBLIC PORTS
Level 2 (J1772)	1,097	5,470
DC Fast Charging (CHAdeMO or CCS Plug Standard)	7	476
Level 2 (Tesla)	0	350
DC Fast Charging (Tesla)	0	131

POLICIES AND INCENTIVES

California is distinguished by strong regulatory policies for EVs coupled with ambitious goals, funding, and incentive commitments from state-level leaders. A key policy driver of EVs in California is the ZEV Program, which was first adopted in 1990 and has since been modified numerous times with more stringent regulations, with the last major policy update occurring in 2012. This program requires that a certain percentage of light-duty vehicles sold in California are ZEVs, which includes BEVs, fuel cell, and transitional ZEVs like PHEVs.¹⁴¹ An Executive Order signed by the governor in January 2018 set a target for California to have 1.5 million ZEVs on the roadways by 2025.¹⁴²

Through Executive Order B-48-18, signed in January 2018, Gov. Jerry Brown called for a target of 5 million ZEVs in California by 2030.¹⁴³ To support these ZEVs,

he also set the goal of deploying 250,000 EV charging stations, including 10,000 DC fast chargers, by 2025. The administration has proposed a \$2.5 billion, eight-year initiative to continue clean vehicle rebates and fund more infrastructure investments.

Clean Vehicle Rebate Program

California’s state-wide Clean Vehicle Rebate Program (CVRP) provides rebates for the purchase or lease of a new qualified EV to moderate and low-income residents. The incentive amount varies by vehicle type and income level, ranging from \$1,500 to \$5,000. Households with incomes less than or equal to 300% of the federal poverty level are eligible for an increased rebate of \$2,000 per vehicle. CVRP has been providing vehicle rebates for many years, with various levels of incentives and income eligibility requirements. Since 2010, CVRP has provided more than 200,000 rebates to California residents.

141 State of California Governor’s Office of Planning and Research, “Zero-Emission Vehicles” <https://ww2.arb.ca.gov/our-work/programs/zero-emission-vehicle-program>

142 ARB. Advanced Clean Cars Summary. <http://opr.ca.gov/planning/transportation/zev.html>.

143 “Governor Brown Takes Action”

California Electric Vehicle Infrastructure Project

The California Electric Vehicle Infrastructure Project (CALeVIP) is a California Energy Commission funded program for regional EV infrastructure programs that aims to support the state's goals to improve air quality, fight climate change, and reduce petroleum use. In August 2018, CALeVIP launched their Southern California Incentive Program that aims to promote access to EV charging infrastructure in Los Angeles, Orange, Riverside, and San Bernardino counties.¹⁴⁴ The program has a total of \$29 million and uses the funds to cover 75% of the cost of installing public access DC fast charging, up to \$70,000 per charging at new sites and up to \$40,000 per charger at replacement and make-ready sites. Installations in disadvantaged communities are eligible for 80% of project costs, up to \$80,000.

CALGREEN BUILDING CODE

In 2017, California began to implement mandatory requirements for the pre-wiring of EV charging stations within the state's building code. Pre-wiring is when builders run electrical conduit that can power charging equipment to locations where vehicles will be parked. Since no chargers are installed, pre-wiring in and of itself does not create new charging opportunities, but it dramatically reduces the costs of installing chargers in the future. CALGreen's mandatory requirements specify that new single-family homes and townhomes with attached garages must pre-wire locations where vehicles will be parked, and that MUD developments with 17 or more units must pre-wire at least 3% of total parking spaces.¹⁴⁵ At non-residential developments, pre-wiring is required for a portion of total parking spaces, ranging from 4-10%.

Los Angeles Zero Emissions 2028 Roadmap

The Los Angeles Cleantech Incubator formed the Transportation Electrification Partnership in May 2018 to accelerate progress toward transportation electrification and zero emissions good movement in the Greater Los Angeles region before the 2028 Olympic and Paralympic Games. The Partnership Leadership Group is composed of CARB, the City of Los Angeles, County of Los Angeles, the LA Metro, the Los Angeles Department of Water and Power, and Southern California Edison (SCE). The Partnership developed the Zero Emissions 2028 Roadmap with the goal of an additional 25% reduction in GHG emissions and air pollution through accelerating transportation electrification.¹⁴⁶ The Roadmap set targets for 20-45% of all light-duty private vehicles on the road to be electric and 60,000 to 130,000 public chargers installed throughout the region by 2028.

UTILITY ENGAGEMENT

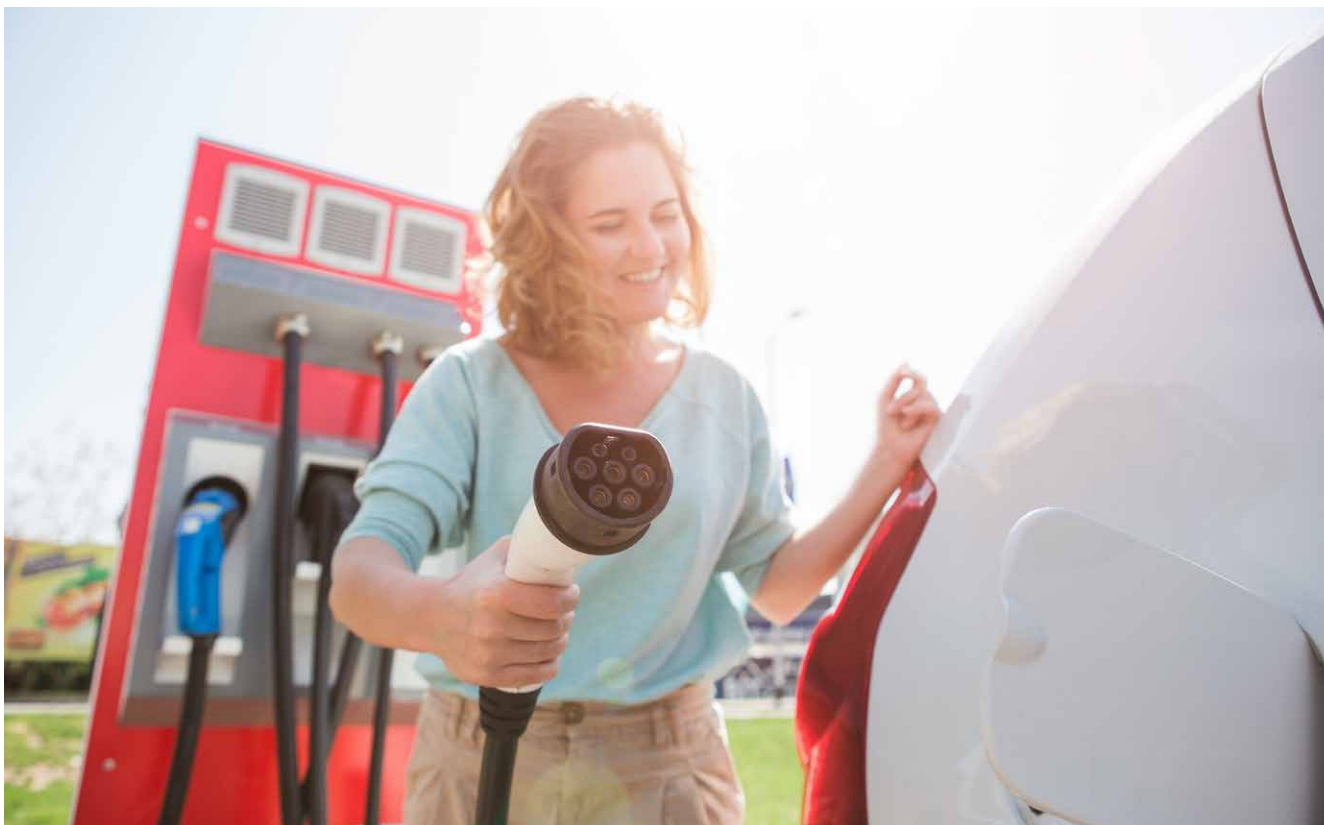
There are several utilities engaged in the EV space within Los Angeles, both investor and municipally owned. SCE, the large investor-owned utility serving the region, is making significant investments in transportation electrification. SCE launched the Charge Ready program in 2016 to support its clean energy vision of 7 million EVs on state highways by 2030.¹⁴⁷ Charge Ready increases the availability of charging for passenger EVs by installing and maintaining EV charging infrastructure as well as providing rebates to participants who choose to own, operate, and maintain charging stations. Funded charging infrastructure is located at workplaces, fleet sites, MUDs, and destination centers, such as hotels or sports venues. After the success of the pilot program, SCE has filed a plan with the California Public Utilities Commission to expand the program

¹⁴⁴ "Building EV Infrastructure," Center for Sustainable Energy and California Energy Commission, <https://calevip.org>.

¹⁴⁵ California Air Resources Board, *Electric Vehicle (EV) Charging Infrastructure: Multifamily Building Standards*, April 13, 2018, <https://ww3.arb.ca.gov/cc/greenbuildings/pdf/tcac2018.pdf>.

¹⁴⁶ "Zero Emissions 2028 Roadmap," Los Angeles Cleantech Incubator, <https://lincubator.org/roadmap/>.

¹⁴⁷ "Charge Ready: A Plan for California," Edison International, <https://www.edison.com/home/innovation/electric-transportation/charge-ready-a-plan-for-california.html>.



to support 48,000 charging ports over four years, with a proposed budget of \$760 million.¹⁴⁸ As part of the second phase, the Charge Ready program will focus more on multi-family charging. It has also set the goal of installing 30% of charging stations in communities that are disproportionately affected by pollution and economic hardship.

LADWP’s Charge Up LA program provides rebates for EV charging infrastructure to its customers on a first-come, first-served basis.¹⁴⁹ Rebates range from \$500 for a residential L2 charger to \$5,000 for a public, multi-family unit or workplace charger with a dedicated meter. Various other small municipally owned utilities, such as Burbank, Glendale, and Pasadena, also offer rebates for charging infrastructure or the purchase of an EV. These typically range from \$500-\$6,000 per charger, depending on the end-user and type of equipment.

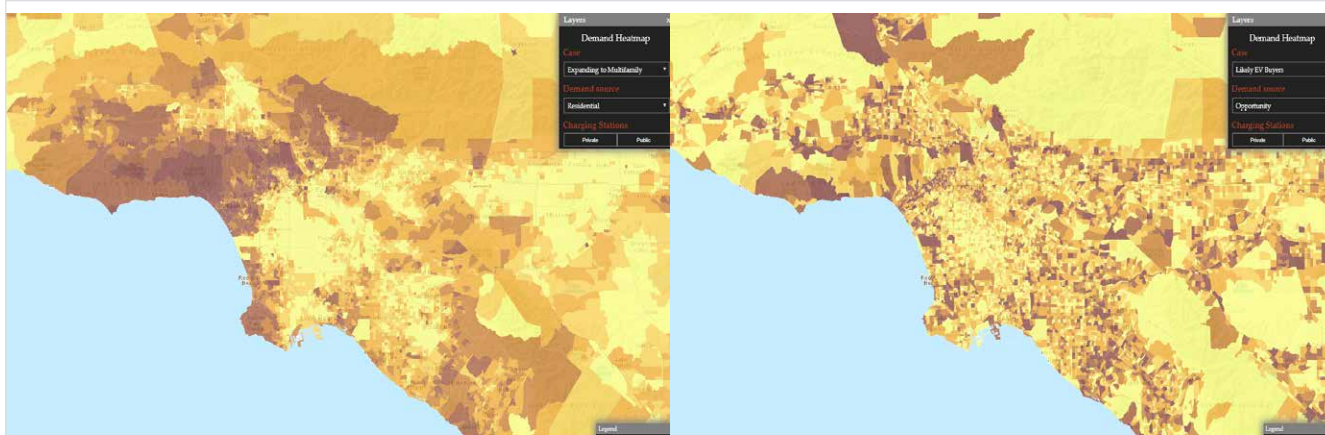
ANALYSIS

Just as EV adoption projections vary based on multiple factors, how EVs will charge is dependent on vehicle and community characteristics. Access to home charging affects both how many and where chargers should be located, and as the EV market moves beyond the early adopter phase, where EV drivers live and travel will change as well. Changes to how people travel, such as increased use of transit and ride-hail services, will impact the number of chargers needed to support the community, as well as how the stations are used. Different vehicle technologies (e.g., PHEVs vs. BEVs) charge differently and in different patterns, based on port compatibility and vehicle range. Lastly, if an area has motivation for increasing EV deployment, such as to fulfill public climate goals, the region may see increased incentives and actions to support EVs.

148 SCE. Charge Ready 2 Proposal. <https://www.greentechmedia.com/articles/read/socal-edison-seeks-760m-to-build-48000-new-ev-charging-stations>.

149 “Electric Vehicles (EVs),” Los Angeles Department of Water and Power, <https://www.ladwp.com/ladwp/faces/ladwp/residential/r-gogreen/r-gg-driveelectric>.

FIGURE 22. RESIDENTIAL EV CHARGING DEMAND FOR MULTI-FAMILY RESIDENTS AND OPPORTUNITY EV CHARGING DEMAND FOR LIKELY EV BUYERS IN LOS ANGELES



EVS AND HOUSING TYPE

According to census data for the Los Angeles MSA, slightly more than half (52%) of residents rent their homes and the remaining 48% own their homes.¹⁵⁰ Single-family units comprise 57% of the total residential housing stock. Housing structures with two to nine units represent 16% of the building stock while those with 10 or more units are 21%.¹⁵¹ As the Los Angeles EV market strives to expand beyond early adopters and achieve the 2028 goals set out by LACI, demand for charging will increasingly come from uses supporting those who do not live in single-family houses, such as MUDs, workplaces, and convenient public access charging locations. [Figure 22](#) includes two maps: 1) areas in Los Angeles where multi-family building residents who are likely to drive an EV live; and 2) areas with high demand for public EV charging.

While the two maps do not perfectly match, installing charging stations in the areas that have both high public charging demand and are located in areas with MUDs increases charging station access to more members of the community while still prioritizing high station utilization.

TRANSITION TO THE MASS MARKET: MOVING BEYOND EARLY ADOPTERS

The median household income in the Los Angeles metro area is just under \$70,000. A significant portion of households (37%) have annual incomes of under \$50,000.¹⁵² With the federal EV tax credit reaching its limits for many vehicle manufacturers and state level incentives representing only a small portion of an EV’s purchase price (approximately 6-9%), EVs are often not an affordable option for many families in the region. Profiles of early EV adopters show that they are typically higher income, more likely to live in single-family homes that they own where they can have easy access to charging, and are more likely to have owned a hybrid vehicle in the past. As the market moves past the early adopters and more EVs are bought and sold in the region, there is a significant opportunity for lower income households to own EVs through the used car market.

The City of Los Angeles also recently started the BlueLA Electric Car Sharing Program that will provide 100 EVs and 200 charging stations to select neighborhoods within the City of Los Angeles, giving

¹⁵⁰ “Los Angeles-Long Beach-Anaheim, CA Metro Area”

¹⁵¹ U.S., Census Bureau. 2016 American Community Survey 5-Year Estimates. <https://censusreporter.org/profiles/31000US31080-los-angeles-long-beach-anaheim-ca-metro-area/>

¹⁵² “Los Angeles-Long Beach-Anaheim, CA Metro Area”

TABLE CS-LOS ANGELES 4: HOW CHANGES IN THE EV POPULATION CAN IMPACT THE AMOUNT AND TYPE OF CHARGING INFRASTRUCTURE NEEDED

TYPE/LOCATION, CHARGING LEVEL	EXISTING PORTS	PORTS NEEDED TO SUPPORT LA MSA EV MARKET	
		CURRENT EV POPULATION	INCREASED (10%) EV MARKET SHARE
Workplace, Level 2	6,917	1,938	15,982
Public, Level 2		1,172	9,050
Public, DC Fast	614	149	644

a discounted rate to low-income individuals. The program is a public-private partnership being funded by a \$1.7 million grant through California Climate Investments, a statewide program aimed at reducing GHG emissions and improving public health in disadvantaged communities.

THE POTENTIAL FOR DECREASING VEHICLE OWNERSHIP

Los Angeles is infamously a car-dominant region. While access to transit has grown significantly with the expansion of rail and bus lines, so has urban sprawl. There is a renewed focus on developing transit-oriented housing and creating denser, more urban housing in the region. The City of Los Angeles recently established a Transit Oriented Communities Affordable Housing Incentives Program, which provides new incentives to developers to build mixed-income and affordable housing within a half-mile of a major transit stop. One of the key goals of transit-oriented communities is to reduce vehicle ownership.

VEHICLE ARCHITECTURE: PHEV VS. BEV

The current EV population in the Los Angeles MSA is about 50% PHEVs and 50% BEVs. As batteries increase in size, EV owners will need to transition to Level 2 charging at home to meet their overnight charging needs. As EV owners diversify away from a home-dominant charging profile, they will become

increasingly reliant on workplace and public charging stations. Sustaining the larger share of BEVs in Los Angeles will also rely on the availability of DC fast charging to make longer trips outside of the region.

Table CS-Los Angeles 3 presents data on the existing EV chargers within the Los Angeles MSA, the number of chargers the EVI-Pro Lite model suggests is needed to support the current EV population, as well as EVI-Pro Lite’s estimates on the number of chargers needed to support a future with a 10% EV market share (970,825 EVs on the road). Note that the tool’s default assumptions for vehicle mix are similar to the existing vehicle mix currently within the MSA, and is kept constant for the future scenario.¹⁵³

Currently, the EVI-Pro Lite tool suggests that there is a sufficient number of charging ports in the Los Angeles MSA; however, it is unclear if the geographic distribution of chargers is sufficient to satisfy the region’s EV charging demands.

ACHIEVING DECARBONIZATION TARGETS

As noted earlier, the Los Angeles region views EVs, for both passenger and goods movement applications, as a key strategy in meeting GHG emission reduction goals. The Los Angeles Zero Emissions 2028 Roadmap includes a goal of an additional 25% reduction in GHGs and air pollution through accelerating transportation electrification.

153 EVI-Pro Lite default assumptions for vehicle mix: 15% PHEV with 20-mile electric range, 35% PHEV with 50-mile electric range, 15% BEV with 100-mile range, 35% BEV with 250-mile range. The default assumption for PHEV charging is that about 50% of PHEVs will use gasoline and not need to charge in a typical day.

APPENDIX: CASE STUDIES

Philadelphia

The Philadelphia-Camden-Wilmington MSA is in the Delaware Valley region covering large portions of southeastern Pennsylvania, southern New Jersey, northern Delaware, and northeastern Maryland. The MSA is anchored by Philadelphia and is home to approximately 6.1 million residents; it has a median age of 38.7 years—marginally higher than the national median of 37.5 years.¹⁵⁴ Median household income in the MSA is \$68,572, which surpasses median income levels across Pennsylvania and the U.S.¹⁵⁵

The Philadelphia-Camden-Wilmington MSA grew approximately 2.2% from 2010 to 2018.¹⁵⁶ The region is more diverse than the rest of the country, with nearly 40% of the population identifying with a minority group.

The regional economy supported nearly 3 million jobs in 2017 and experienced a one-year growth rate of 0.614%.¹⁵⁷ Health services, retail, and education comprise the three largest economic sectors in the region.¹⁵⁸ The University of Pennsylvania, Temple University, and Drexel University are three of the largest universities in the regions by number of degrees awarded and are all located in Philadelphia.¹⁵⁹

The Philadelphia-Camden-Wilmington MSA sits in one of the most densely populated corridors in the country and serves as an important transportation hub linking other regions in the Northeast. Systems like the Southeastern Pennsylvania Transit Authority (SEPTA) and New Jersey Transit provide the backbone for commuter rail and bus services that link urban, suburban, and rural areas in the region; SEPTA alone provided over 300 million trips in fiscal year 2018.¹⁶⁰ Philadelphia is also a central node on some of Amtrak’s busiest rail routes, including the Northeast Regional and Acela Express services, which support over 17 million trips annually.¹⁶¹

154 “Philadelphia-Camden-Wilmington, PA-NJ-DE-MD Metro Area,” Census Reporter, <https://censusreporter.org/profiles/31000US37980-philadelphia-camden-wilmington-pa-nj-de-md-metro-area/>.

155 “Philadelphia-Camden-Wilmington, PA-NJ-DE-MD Metro Area”

156 U.S. Census Bureau

157 “Philadelphia-Camden-Wilmington, PA-NJ-DE-MD Metro Area”

158 “Philadelphia-Camden-Wilmington, PA-NJ-DE-MD Metro Area”

159 “Philadelphia-Camden-Wilmington, PA-NJ-DE-MD Metro Area”

160 SEPTA, SEPTA Operating Facts: Fiscal Year 2018, <http://septa.org/strategic-plan/reports/2018-opfacts.pdf>.

161 “About the NEC [Northeast Corridor],” Amtrak National Railroad Passenger Corporation, <https://nec.amtrak.com/about-the-nec/>.

TABLE CS-PHILADELPHIA 1: PHILADELPHIA-CAMDEN-WILMINGTON MSA AND PENNSYLVANIA EV STATISTICS

VEHICLE TYPE	PHILADELPHIA			PENNSYLVANIA		
	Vehicle Stock	LD Market Share	EV Market Share	Vehicle Stock	LD Market Share	EV Market Share
PHEV	4,585	0.09%	51%	10,280	0.07%	65%
BEV	4,463	0.09%	49%	7,997	0.04%	35%
Total EV	9,048	0.19%	100%	18,277	0.11%	100%

TABLE CS-LOS PHILADELPHIA 2: PUBLIC CHARGING PORTS IN THE PHILADELPHIA MSA AREA

CHARGER TYPE	PRIVATE PORTS	PUBLIC PORTS
Level 2 (J1772)	28	281
DC Fast Charging (CHAdeMO or CCS plug standard)	0	39
Level 2 (Tesla)	0	21
DC Fast Charging (Tesla)	0	6

The MSA is home to about 4.9 million vehicles that rely on a dense network of critical road infrastructure: I-95, and I-295 all pass through the Philadelphia area and link to other major cities on the East Coast as well as western Pennsylvania. Given Philadelphia’s position near the center of a particularly dense, interconnected region of the country, the city is vulnerable to significant traffic congestion. Inrix ranks the city ninth worst in terms of congestion in the country and estimates that drivers spend 112 hours in congestion annually.¹⁶² The city is taking steps to address these issues, but despite Philadelphia’s increasingly diverse mobility options, the City of Philadelphia found that more than half of the residents commute to work by car alone.¹⁶³

ELECTRIC VEHICLES

CURRENT STATUS

There were about EVs in the Philadelphia-Camden-Wilmington MSA as of December 2018; about 50% PHEVs and 50% were BEVs. EVs represented 0.19% of the MSA’s light-duty market share. By December 2018, the EV market share statewide in Pennsylvania was approximately 0.16%, or about 18,000 vehicles, a 37% increase over 2017 deployment.¹⁶⁴

Table CS-Philadelphia 1 compares Philadelphia (not the entire MSA) and Pennsylvania EV statistics.

As of August 2018, there were 28 private and 347 public charging ports. The breakdown by type is shown in Table CS-Philadelphia 2.

162 “INRIX 2019 Global Traffic Scorecard”

163 City of Philadelphia, Connect: Philadelphia’s Strategic Transportation Plan, October 2018, http://www.phillyotis.com/wp-content/uploads/2018/11/Connect_9.8_11-09-18_sm.pdf

164 “Advanced Technology Vehicle Sales Dashboard,” accessed May 2, 2019.

Most charging stations provide ports that can be used to charge all EVs: J1772 for Level 2 charging and a combination of CHAdeMO and CCS for fast charging applications. Seven percent of ports are accessible only to Tesla vehicles.

POLICIES AND INCENTIVES

Pennsylvania has a modest suite of incentives in place to encourage the purchase of EVs and EV charging infrastructure in the Philadelphia area. The Alternative Fuel Vehicle Program, administered by the Department of Environmental Protection (DEP), provides rebates to Pennsylvania residents to defray the upfront cost of purchasing an EV, hydrogen fuel cell electric vehicle, or natural gas vehicle.¹⁶⁵ The size of the rebate is dependent on EV battery capacity and ranges from \$750 to \$2,000 for vehicles under \$60,000. The program issued \$1.3 million in rebates in 2017.¹⁶⁶ DEP also administers the Alternative Fuels Incentive Grant program for public, non-profit, and commercial entities to purchase, retrofit, provide fueling infrastructure for, or support research and development for qualified alternative fuel vehicles. The program awards approximately \$5 million in grants annually and is open to light-, medium-, and heavy-duty fleets.¹⁶⁷ DEP is also responsible for implementing the state's \$118 million VW Settlement Beneficiary Mitigation Plan.¹⁶⁸ The plan allocates the maximum 15% of funds permitted by the settlement (\$17.7 million) to the deployment of EV charging infrastructure.¹⁶⁹ The remainder of the funding will be used to replace medium- and heavy-duty diesel

vehicles primarily with alternative fueled vehicles—including EVs. Gov. Tom Wolf also established a policy signal on transportation electrification in his recent executive order on climate change, which requires state agencies to achieve 25% EV adoption in their passenger fleets by 2025.¹⁷⁰ Finally, in the City of Philadelphia's recent report, *Connect: Philadelphia's Strategic Transportation Plan*, the city expresses interest in transportation electrification as a means to achieve city health and climate goals and plans to further electrify local transit fleets: SEPTA is expecting to introduce 25 new battery electric buses to its fleet in the near future.¹⁷¹

UTILITY ENGAGEMENT

PECO, the investor owned utility that serves greater Philadelphia, is the largest utility in Pennsylvania serving 1.6 million electric customers across six counties in southeastern Pennsylvania. PECO has been actively engaged on EVs and has modest incentives in place for EVs, including a \$50 credit for residents that register their EVs with the utility and a pilot incentive to reduce demand charges associated with operating DC fast charging stations in its service territory.¹⁷² The utility has also partnered with Nissan to offer a rebate on the 2019 Nissan LEAF for up to \$3,500.¹⁷³ Finally, PECO hosted the MidAtlantic Transportation Electrification Forum in September 2018.¹⁷⁴ The event assembled industry, academic, and policy experts to discuss electrification trends in the region.

165 "Alternative Fuel Vehicle (AFV) Rebate," U.S. Department of Energy Alternative Fuels Data Center, <https://afdc.energy.gov/laws/5812>. The authors are unaware of any commercially available light-duty fuel cell electric vehicles or natural gas vehicles that are available for purchase in Pennsylvania at the time this report was written.

166 Pennsylvania Department of Environmental Protection, *Pennsylvania Electric Vehicle Roadmap*, February 2019, <http://files.dep.state.pa.us/Energy/OfficeofPollutionPrevention/StateEnergyProgram/PAEVRoadmap.pdf>.

167 *Pennsylvania Electric Vehicle Roadmap*

168 "Driving PA Forward," Pennsylvania Department of Environmental Protection, <http://www.depgis.state.pa.us/DrivingPAForward/>.

169 "Driving PA Forward"

170 Pennsylvania Exec. Order: 2019-01 (January 08, 2019), <https://www.governor.pa.gov/newsroom/executive-order-2019-01-commonwealth-leadership-in-addressing-climate-change-and-promoting-energy-conservation-and-sustainable-governance/>.

171 *Connect: Philadelphia's Strategic Transportation Plan; Pennsylvania Electric Vehicle Roadmap*

172 *Pennsylvania Electric Vehicle Roadmap; PECO Energy Company, "Electric Service Tariff," Supplement No. 4 to Electric PA. P.U.C. No. 6, issued February 22, 2019, effective March 29, 2019, https://www.peco.com/SiteCollectionDocuments/ThirdPartyEV.pdf*.

173 PECO Energy Company and Nissan, "2019 Nissan LEAF® You don't need sky to soar" (print advertisement), ending date March 31, 2020, <https://www.peco.com/SiteCollectionDocuments/NISSAN3500.pdf>.

174 PECO Energy Company, "PECO Announces New Incentive for Electric Vehicle Charging Stations," October 4, 2018, <https://www.peco.com/News/Pages/Press%20Releases/PECOAnnouncesNewIncentiveforElectricVehicleChargingStations100418.aspx>.

TABLE CS-PHILADELPHIA 3: HOW THE INFRASTRUCTURE NEEDS CHANGE TO SUPPORT 135,859 EVS

TYPE/LOCATION, CHARGING LEVEL	CHARGING PORTS BY PERCENT DRIVERS WITH ACCESS TO HOME CHARGING	
	80%	100%
Workplace Level 2	18,377	9,961
Public Level 2	10,808	5,858
Public DC Fast Charging	1,759	674

ANALYSIS

Just as EV adoption projections vary based on multiple factors, how EVs will charge is dependent on vehicle and community characteristics. Access to home charging affects both how many and where chargers should be located, and as the EV market moves beyond the early adopter phase, where EV drivers live and travel will change as well. Changes to how people travel, such as increased use of transit and ride-hail services, will impact the number of chargers needed to support the community, as well as how the stations are used. Different vehicle technologies (e.g., PHEVs vs. BEVs) charge differently and in different patterns, based on port compatibility and vehicle range. Lastly, if an area is motivated for increasing EV deployment, such as to fulfill public climate or health goals, the region may see increased incentives and actions to support EVs.

EVS AND HOUSING TYPE

According to census data for the Philadelphia-Camden-Wilmington MSA, approximately 66% of residents own their homes while 34% are renters; single-family units comprise 74% of the housing stock while MUDs make up 24%.¹⁷⁵ In order to move beyond EV adopters in single-family homes, renters need to be confident that they have a place to refuel EVs where they live, work, or visit. The analysis

highlights areas where likely EV adopters live in MUDs. One particularly sensitive parameter within the EVI-Pro Lite tool is access to home charging; the number of drivers that have access to home charging is inversely correlated to the amount of public charging infrastructure, particularly DC fast charging infrastructure, needed to support a given number of EVs in the tool. [Table CS-Philadelphia 3](#) illustrates how the infrastructure needs change to support 489,640 EVs, or 10% of the light-duty vehicle market in the region in 2016.

In a scenario where all EV drivers have access to home charging, the need for public charging is somewhat diminished—though substantial investments will still need to be made to support higher penetrations of EVs relative to the status quo. However, the 80% home access scenario is likely more reflective of current home charging access conditions, which means that more significant investments in public charging will be needed to support the EV market.¹⁷⁶ Increasing MUD charging access through financial incentives, EV-ready building codes, or education and outreach to building owners could potentially reduce the amount of public charging infrastructure needed to support the regional EV fleet. Again, however, significant investment in all types of charging will likely be required to support a growing EV market.

175 Mobile homes make up the remaining 1% of the region’s housing stock. See “Philadelphia-Camden-Wilmington, PA-NJ-DE-MD Metro Area”

176 An analysis recently found that only about half of vehicles in the U.S. have access to dedicated, off-street parking, which may be necessary in some residential charging applications. Elizabeth Traut et al., “U.S. Residential Charging Potential for Electric Vehicles,” *Transportation Research*, 25(D): 139-145, doi: 10.1016, December 2013.

TRANSITION TO THE MASS MARKET: MOVING BEYOND EARLY ADOPTERS

The Philadelphia-Camden-Wilmington MSA has higher than average income levels and some available state and local incentives, yet there are still barriers to EV adoption in the region. The city of Philadelphia lags neighbors like Baltimore, Boston, New York, and Washington, D.C., in terms of EVs as a percentage of new vehicle sales, and the ICCT finds that despite the number of actions the city has taken to increase EV uptake, lack of charging infrastructure remains a critical barrier to adoption.¹⁷⁷

If regional charging infrastructure gaps are addressed, Pennsylvania residents within the MSA have a particularly compelling reason to switch to EVs: As of 2018, Pennsylvania had the highest state gas tax in the country (58.7¢/gallon).¹⁷⁸ This means that drivers can realize significant fuel cost savings by switching to EVs, which improves the overall TCO. According to the Department of Energy, fueling an EV on a gallon-equivalent basis costs only \$1.23 compared to \$2.86 per gallon of gasoline. Moreover, if PECO offered appropriate TOU electricity rates that lower the cost of fueling an EV during periods when the grid is not constrained (e.g., overnight when vehicles are plugged in at home), this could further improve the economics of EVs and make them even more competitive against internal combustion engine vehicles in an earlier time frame.

The standard analysis shows where EV drivers are likely to live, work, and travel. However, in this scenario of market penetration, the driver profile does not factor in whether the driver is a likely HEV owner. By not including HEV ownership as a profile factor, the model does not favor drivers that are technology enthusiasts or motivated for environmental reasons. Instead, this scenario places

weight on income, as the driver is still assumed to be able to afford purchasing a new vehicle, and home ownership and dwelling type, as these factors can affect the convenience of charging EVs. This market penetration scenario shows the travel behavior of drivers that may purchase an EV for economic reasons, such as lower fuel costs, rather than environmental reasons.

THE POTENTIAL FOR DECREASING VEHICLE OWNERSHIP

In October 2018, the City of Philadelphia released strategic transportation plan outlining the city’s vision for a safe, accessible, sustainable, and healthy transportation system over the next seven years.¹⁷⁹ While the plan does not explicitly call for a reduction in car ownership, it emphasizes the need to make investments in alternative transportation modes to equitably serve all Philadelphians, particularly those who do not have access to personal vehicles. High-level strategies include:

- **Developing a City Transit Plan to improve and modernize transit bus service**
- **Expanding Indego Bike Share program**
- **Developing a high-quality bicycle network**
- **Ensuring a walkable city**
- **Managing the curbside and parking**

Like many other cities with traffic congestion issues, Philadelphia is taking steps to improve access to and quality of transit, walking, and biking networks to encourage alternative transportation and improve mobility in the city. However, car ownership in the city is only increasing: over the last eight years, 68,000 registered vehicles were added in Philadelphia and contribute to the total 754,253 vehicles that are registered in the city.¹⁸⁰ In the

¹⁷⁷ Peter Slowik and Nic Lutsey, *The Continued Transition to Electric Vehicles in U.S. Cities* (Washington, DC: International Council on Clean Transportation, July 2018), https://theicct.org/sites/default/files/publications/Transition_EV_US_Cities_20180724.pdf.

¹⁷⁸ Katherine Loughead, “State Gasoline Tax Rates as of July 2018,” *Tax Foundation*, August 8, 2018, <https://taxfoundation.org/state-gas-tax-rates-july-2018/>.

¹⁷⁹ *Connect: Philadelphia’s Strategic Transportation Plan*

¹⁸⁰ *Connect: Philadelphia’s Strategic Transportation Plan*

TABLE CS-PHILADELPHIA 4: HOW CHANGES IN THE EV POPULATION CAN IMPACT THE AMOUNT AND TYPE OF CHARGING INFRASTRUCTURE NEEDED

TYPE/LOCATION, CHARGING LEVEL	CHARGING PORTS BY SCENARIO		
	SCENARIO 1	SCENARIO 2	SCENARIO 3
Workplace, Level 2	10,870	7,650	4,440
Public, Level 2	6,310	4,510	2,700
Public, DC Fast	220	250	280

short term, it seems unlikely that vehicle ownership will decline dramatically and the current lack of EV charging provide substantial headroom for EV charging infrastructure deployment to support a growing EV market. Moreover, the decline in vehicle ownership may not necessarily mean that less EV charging infrastructure is needed but instead that different types of charging infrastructure may be necessary. Car-sharing and ride-hailing fleets may rely much more heavily on publicly accessible DC fast charging in urban centers and corridors than vehicles that have dedicated access to home charging. Additionally, electrification of transit bus fleets will require additional investments in DC fast charging in depot and on-route configurations. Greater emphasis on transit rail service may allow for additional Level 2 charging opportunities that provide refueling for first- and last-mile trips to transit hubs.

VEHICLE ARCHITECTURE: PHEV VS. BEV

The current EV population in the Philadelphia-Camden-Wilmington MSA is about 50% BEVs and 50% PHEVs. The majority of new BEVs on the road have ranges of over 100 miles and can use DC fast charging stations whereas PHEVs generally cannot. This vehicle mix plays a significant role in what types of infrastructure is required to support EV drivers; if EV drivers continue to choose BEVs as vehicle costs decrease and available ranges increase, they will require less workplace charging (as most commutes

can easily be met with current EV ranges) and more public DC fast charging stations.

NREL’s EVI-Pro Lite can also be used to demonstrate how changes in the make-up of the EV population (i.e., BEV vs. PHEV) may impact the amount of charging infrastructure needed. [Table CS-Philadelphia 4](#) presents the results of three different scenarios, with all assuming 10% of the 2016 light-duty population (489,640 vehicles) will be EVs and all favoring longer range batteries/vehicles:

- 1. Maintain the current split of 50% BEV and 50% PHEV**
- 2. Continuing the trend towards higher BEV population, with a split of 65% BEV and 35% PHEV**
- 3. Accelerating the trend towards higher BEV population, with a split of 80% BEV and 20% PHEV**

It is important to understand how the distribution of EV architectures may influence charging needs in the greater Philadelphia region. Although the dynamics of the auto industry continue to shift, general trends appear to indicate a future with greater numbers of BEVs as battery technology continues to mature and consumers become more comfortable with all-electric vehicles.

ACHIEVING DECARBONIZATION TARGETS

The City of Philadelphia has committed to achieving the GHG emissions reduction targets set forth in the Paris Climate Accord and set a goal for reducing citywide greenhouse gas emissions 25% by 2025 from 2006 levels and 80% by 2050 from 2006 levels.¹⁸¹ Transportation is currently the second-largest source of emissions in the city, comprising 17% of total emissions.¹⁸² However, the share of transportation emissions is likely to be greater in areas outside of the city where residents are more dependent on passenger vehicle travel for transportation. In both cases, EVs can play a critical role in lowering emissions in a manner consistent with climate goals.

Governor Wolf also established a recent executive order that calls on the state to reduce greenhouse gas emissions 26% by 2025 from 2006 levels and 80% by 2050 from 2006 levels.¹⁸³ Given that the greater Philadelphia region generates a notable share of statewide emissions, the MSA will need to make meaningful progress on decarbonization to support the state goal. Philadelphia is also part of the Bloomberg American Cities Climate Challenge, an initiative to support cities’ plans to decarbonize their economies through expanding energy efficiency, renewable energy, and clean transportation options.¹⁸⁴

181 City of Philadelphia Office of Sustainability, *Powering Our Future: A Clean Energy Vision for Philadelphia* (no date), <https://www.phila.gov/media/20180821150658/Powering-Our-Future-Full-Report.pdf>.

182 *Connect: Philadelphia’s Strategic Transportation Plan*

183 Pennsylvania Exec. Order: 2019-01

184 Bloomberg Philanthropies, “Mike Bloomberg Names Pittsburgh, Philadelphia, Boston and Washington, DC as Winners in Bloomberg American Cities Climate Challenge,” October 21, 2018, <https://www.bloomberg.org/press/releases/mike-bloomberg-names-pittsburgh-philadelphia-boston-washington-dc-winners-bloomberg-american-cities-climate-challenge/>.



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The Fuels Institute, founded by NACS in 2013, is a 501(c)(4) non-profit research-oriented think tank dedicated to evaluating the market issues related to vehicles and the fuels that power them. By bringing together diverse stakeholders of the transportation and fuels markets, the Institute helps to identify opportunities and challenges associated with new technologies and to facilitate industry coordination to help ensure that consumers derive the greatest benefit.

The Fuels Institute commissions and publishes comprehensive, fact-based research projects that address the interests of the affected stakeholders. Such publications will help to inform both business owners considering long-term investment decisions and policymakers considering legislation and regulations affecting the market. Research is independent and unbiased, designed to answer questions, not advocate a specific outcome. Participants in the Fuels Institute are dedicated to promoting facts and providing decision makers with the most credible information possible so that the market can deliver the best in vehicle and fueling options to the consumer.

For more about the Fuels Institute, visit fuelsinstitute.org

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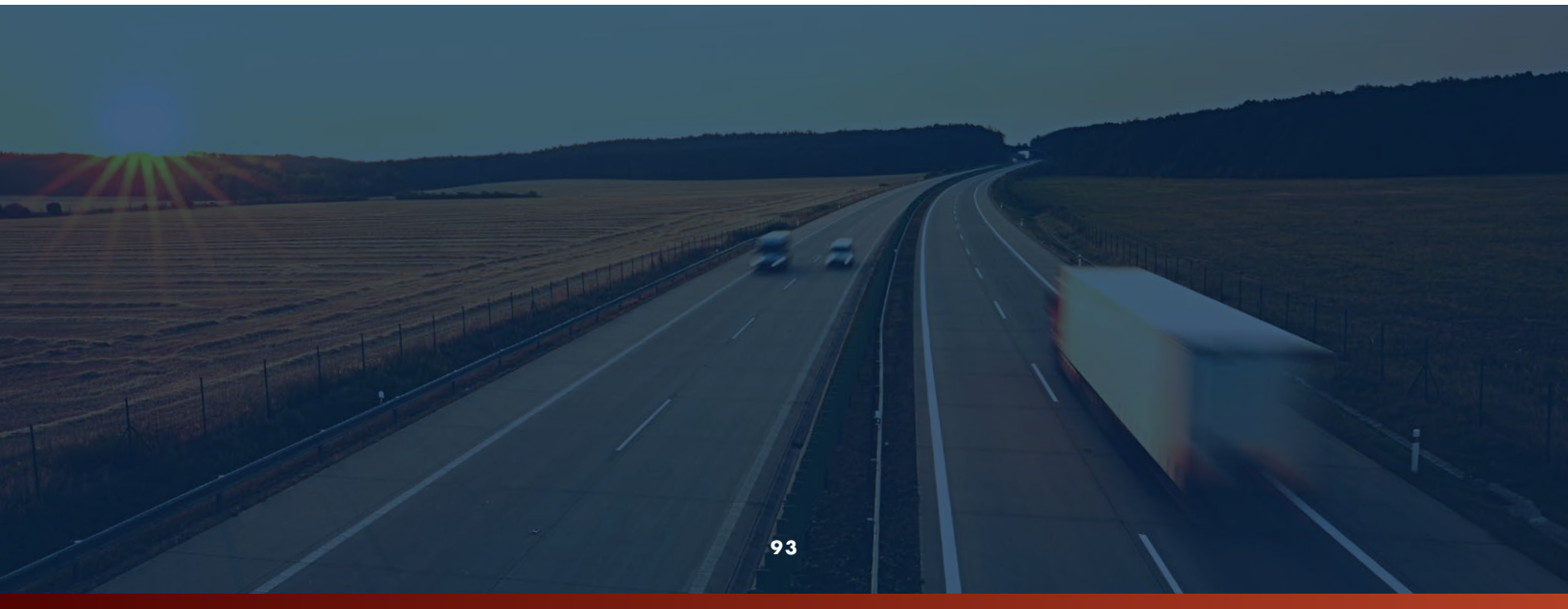
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