Plugging In

Readying America's Cities for the Arrival of Electric Vehicles

FRONTIER GROUP

ENVIRONMENT NEW MEXICO RESEARCH & POLICY CENTER

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Executive Summary

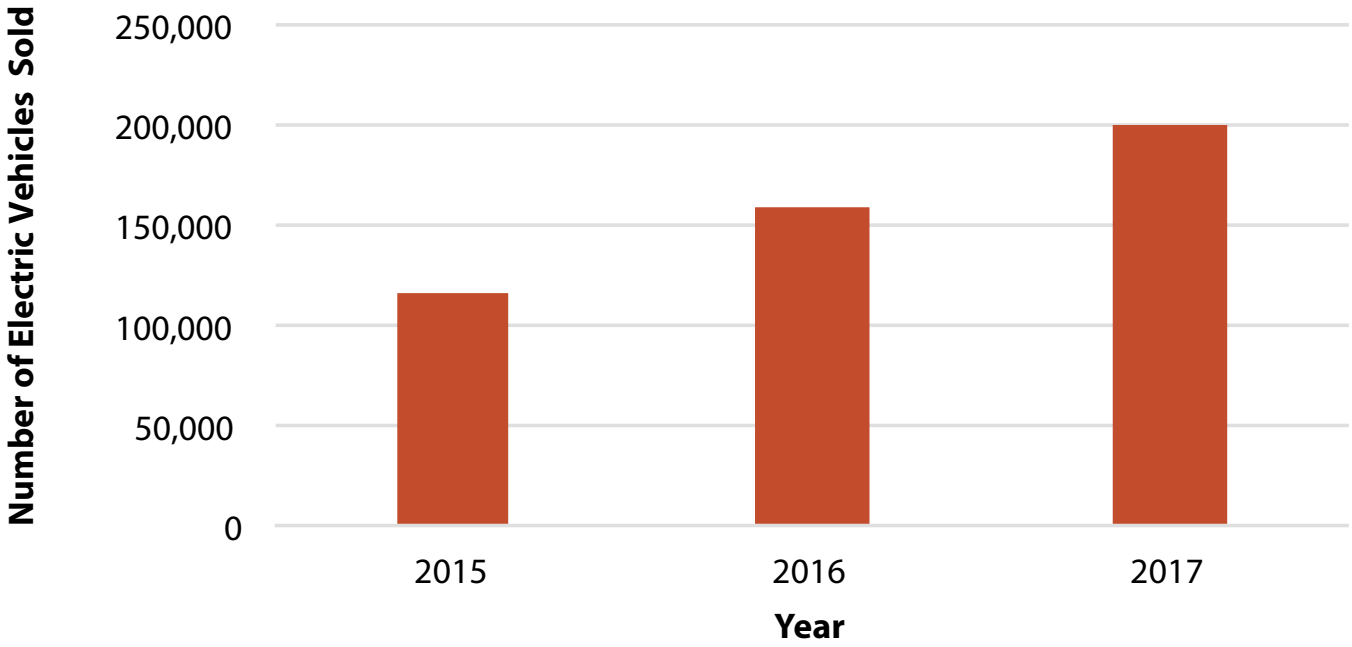
The adoption of large numbers of electric vehicles (EVs) offers many benefits for cities, including cleaner air and the opportunity to reduce greenhouse gas emissions. Electric vehicles are far cleaner than gasoline-powered cars, with lower greenhouse gas emissions and lower emissions of the pollutants that contribute to smog and particulate matter.[1]

The number of EVs on America's streets is at an all-time high. Throughout 2016, sales of plug-in electric vehicles increased nearly 38 percent.[2] In 2017, sales of electric vehicles were up again, increasing 32 percent over the year.[3] The introduction of the Chevy Bolt, Tesla's Model 3 and other affordable, long-range electric vehicles suggests that growth in EV sales is just beginning. In fact, Chevrolet's Bolt EV was named *Motor Trend*'s 2017 Car of the Year.[4]

But with more EVs on the road, and many more coming soon, cities will face the challenge of where electric vehicles will charge, particularly in city centers and neighborhoods without off-street residential parking.

The good news is that smart public policies, including those already pioneered in cities nationally and internationally, can help U.S. cities lead the electric vehicle revolution while expanding access to clean transportation options for those who live, work and play in cities.

Figure ES-1: U.S. EV Sales by Year, 2015-2017[5]



Electric vehicles are poised for explosive growth.

Technological gains that allow electric vehicles to drive farther, charge faster, and be produced more affordably are revolutionizing the vehicle market. With adequate policy and infrastructure investments, Bloomberg New Energy Finance estimates that, globally, more than half of new cars sold by 2040 will be electric vehicles.[6]

Cities need to be ready for an influx of electric vehicles.

In a few short years, tens of thousands of electric vehicles could hit city streets across America, from Portland, Maine, to Portland, Oregon. Yet, as of now, most cities are unprepared for this pending influx. These vehicles will need a place to charge, so public access to EV charging stations will be critical, especially since only about half of vehicles in the U.S. have a dedicated off-street parking space, like a driveway or garage.[7]

Major cities will require the installation of hundreds to thousands of publicly accessible electric vehicle chargers in order to serve the increased demand for electric vehicles. Studies conducted separately by the National Renewable Energy Labora-

Types of Electric Vehicle Charging Infrastructure[11]

There are three primary types, or levels, of electric vehicle chargers – Level 1, Level 2 and DCFC (often referred to as "fast charging").

- Level 1 charging is from a standard wall outlet and provides a slow charge, adding 4 to 5 miles of range per hour. Therefore, with a Level 1 charger, an empty EV battery may need to charge for 10 hours to get 50 miles of range. Level 1 chargers can work well for at-home charging, where EV owners park overnight, and in many workplaces, since the typical commute in many metro areas is less than 10 miles each way.[12] Because Level 1 charging requires only a standard three-prong outlet, it is often the most affordable way to offer charging, with minimal installation costs.
- Level 2 chargers require special installation but can charge an electric vehicle battery 2 to 6 times faster than a Level 1 charger, adding 12 to 25 miles of range per hour of charge, so 50 miles can be added in 2 to 4 hours. If people install a charger in front of their house, in their driveway, or in their garage, it is most likely a Level 2 charger. In public spaces, such as parking lots or on public streets, most chargers are Level 2, allowing EV drivers to charge their car for a few hours while at work or shopping. Level 1 and Level 2 plugs are standard in the United States so all EVs can charge at those charging stations.
- Fast chargers, known as DCFC (for direct current fast charge), can add 100 miles of range or more in an hour of charging – meaning an EV driver can add 50 miles to their battery in just half an hour. Different EV makes and models are compatible with different fast chargers and may require an adaptor to charge. Fast chargers will be especially important for long-distance travel when drivers won't be stopping for hours at a time, so DCFC chargers work well at rest stops and gas stations off highways and are important for the viability of electric shared mobility services, whose vehicles may be used for many trips – and travel many miles – in a given day. However, only pure battery electric vehicles can use DCFC charging, so it excludes plug-in hybrid EVs.

This report recognizes the value of Level 1 chargers as a low-cost option at homes, workplaces, and some public parking areas (like airports), but focuses on Level 2 and fast charging (DCFC) for public spaces, which are the chargers you would expect to find curbside, at workplaces and businesses, in parking garages and in other public areas.

tory, the Electric Power Research Institute, and Pacific Gas & Electric estimate that 1-5.2 public fast chargers are needed to support 1,000 electric vehicles.[8] The National Renewable Energy Laboratory estimates that 36 non-residential Level 2 chargers are necessary for every 1,000 electric vehicles.[9] Cities will also need to facilitate at-home charging since the majority of EV owners will need to park and charge their vehicles overnight at or near where they live.[10]

The world's leading EV cities have adopted key policies that enable urban residents to own and operate electric vehicles. In particular, these cities have been able to deliver electric vehicle infrastructure to urban drivers through innovative parking and planning policies, including:

- **Residential access to on-street EV charging:** Many residents, particularly in large cities, do not have access to an off-street parking spot where they might charge their electric vehicle overnight.[14] Cities around the world are tackling this problem with innovative solutions to install or incentivize residents to install on-street charging infrastructure at curbsides in dense areas. For example, residents in London can ask the city to install, and mostly pay for, EV charging infrastructure at streetlights on their block.[15]
- **Access to public charging stations:** By acting directly or partnering with other entities – such as private garages, public schools and community centers – cities can ensure that there are adequate

Table ES-1. Possible Number of Electric Vehicles on Selected U.S. City Streets by 2030 and Corresponding Publicly Accessible Charging Infrastructure Needs[13]

		Estimated Number of Public Plugs Needed in City Limits by 2030, by Type				Current Number of Public Plugs in City Limits (2017)
City	Number of EVs Estimated in City Limits by 2030	Level 2 Plugs in Workplaces Needed	Level 2 Plugs in Public Places Needed	Public Fast Charger Plugs (DCFC) Needed	Total L2 and DCFC Plugs Needed	Total L2 and DCFC Plugs Currently
Austin, TX	29,000	650	405	45	1,100	495
Cleveland, OH	9,000	202	126	14	342	18
Denver, CO	36,000	807	502	56	1,365	161
Hartford, CT	4,000	90	56	7	153	52
Jersey City, NJ	5,000	112	70	8	190	20
Los Angeles, CA	348,000	6,312	3,730	201	10,243	1,456
Miami, FL	14,000	314	196	22	532	50
Philadelphia, PA	34,000	869	579	44	1,492	96
San Diego, CA	139,000	2,341	1,405	141	3,887	776
Seattle, WA	47,000	744	447	75	1,266	401

parking spaces for people to charge their EVs when they aren't at home, for instance, while they are commuting, shopping or traveling.

- **Support for private investment in publicly accessible stations:** "Semi-public" stations can provide EV owners a place to charge at privately owned stations at businesses, parking garages or private driveways. By incentivizing the installation of shared charging stations, cities can optimize use of charging infrastructure.
- **Incentivized EV parking and charging:** Some cities have local government programs or agencies that offer discounted or free charging and parking for electric vehicles in public spaces.

Electric vehicle charging port on a lamppost in London. Photo: Jason Cartwright via Flickr, CC BY 2.0.

Leading cities are encouraging shared mobility options and reforming parking policies to expand access to electric vehicle travel and reduce conflicts over parking.

- Carsharing services are expanding access to EVs – and to EV charging – around the world. Fleets of shared electric cars, like BlueIndy in Indianapolis, allow people to drive electric vehicles without needing to personally own one. These services can also expand public access to EV charging by opening up their charging infrastructure for the public to use.
- Expanding shared mobility, electrified public transit, safe biking and walking and other transportation options – as well as implementing parking reforms – can reduce competition for on-street parking that might crowd out space for EV charging.

Electric vehicles are an essential tool for cities to combat global warming and air pollution, and offer consumer benefits like lower fuel costs. Technological developments mean that EVs are poised to hit the market in record numbers. However, there is a lot left to be done. If cities fail to develop comprehensive plans for EV charging now, they risk being unprepared for large numbers of EVs hitting local streets in coming years.

In order to be successful, cities will need to develop comprehensive solutions to accommodate electric vehicles, including convenient opportunities for charging. Some specific strategies include:

- Expanding access to electric vehicle charging for residents without off-street parking, by dramatically increasing the number of charging stations in residential areas.
- Partnering with businesses and public entities (like schools, community centers and municipal offices) to use their existing parking infrastructure while providing EV charging.
- Facilitating and encouraging electric shared mobility options like carsharing, ridesharing and bikesharing.
- Directing municipal utilities to install charging infrastructure and coordinating closely with investor-owned utilities to maximize opportunities.
- Considering a demand-based and shared system for parking.

Introduction

The first round of Tesla Model 3 cars ready for shipment in July 2017. Photo Steve Jurvetson via Wikimedia, CC BY 2.0.

A revolution is beginning to happen on America's roads. And our cities need to be ready.

Affordable electric vehicles are hitting the road in increasing numbers. The arrival of the 238-mile, $37,495 Chevy Bolt in early 2017, the 200-mile, $35,000 Tesla Model 3 in the fall of 2017, and the 150-mile, $30,000 Nissan Leaf in early 2018 signals the movement of electric vehicles into the mainstream.[16] Demand for these vehicles has been high: nearly half a million people reserved a Model 3 car ahead of distribution.[17] GM plans to launch 20 electric vehicle models by 2023, with two new cars hitting American streets by spring of 2019.[18] Chevrolet's Bolt was named *Motor Trend*'s 2017 Car of the Year, and a number of fully electric and plug-in hybrid electric vehicles were finalists for 2018's award.[19]

Electric vehicles have the potential to address critical public health and environmental challenges in our cities. Electric vehicles are far less polluting than gasoline-powered cars, with half the carbon footprint over their lifetime, as well as fewer emissions of the pollutants that contribute to smog and particulate matter.[20] The environmental benefits of electric vehicles will continue to improve as America switches to clean, renewable energy. In 2015, residents of 34 metropolitan areas experienced more than 100 days with elevated smog pollution, which contributes to heart and lung diseases, including asthma.[21] By putting more zero-emission electric cars on the road, cities can help improve public health, while also reducing global warming pollution.

The transition to electric vehicles will require a number of changes, including connecting charging infrastructure with the electricity grid, updating the grid, and adopting city policies to allocate space for EVs and integrate electric vehicles in the broader transportation system.

This report focuses on how cities can provide opportunities for residents to charge electric vehicles – especially those residents without access to off-street parking. Unlike traditional gasoline powered vehicles that can fuel up in a few minutes at a gas station, electric vehicles (absent the widespread availability of fast charging) need to charge over the course of several hours in locations close to where their owners live, work or spend time. In cities where on-street parking is perceived to be tight, that can be a challenge.

Cities around the world are leading the way in the electric vehicle revolution and have policies in place to ensure that EV drivers can charge their cars where and when they need to. U.S. cities must develop comprehensive solutions for electric vehicle charging now, and take action to put those plans into place, if they hope to be prepared for the larger numbers of EVs soon hitting local streets. With smart planning and policy, cities can reap the full benefits of America's electric vehicle revolution.

Electric Vehicles Are Coming to America's Cities

Pollution from cars and trucks harms the health of city residents, contributes to global warming, and makes cities less pleasant places to live. For decades, electric vehicles (EVs) have held the promise of reducing the environmental, public health and quality-of-life burdens of cars in cities.

Today, electric vehicles are on the verge of delivering on that promise. Throughout 2016, sales of plug-in electric vehicles increased nearly 38 percent.[22] In 2017, sales of electric vehicles were up again, increasing 32 percent over the year.[23]

Electric Vehicles Are Ready to Roll

Recent progress in electric vehicles stems primarily from improvements on four fronts:

- **Battery cost:** In 2016, a lithium-ion battery for an electric vehicle cost about a quarter as much to produce as it did in 2009 (see Figure 2), and delivered six times the energy for its size.[25] Batteries have long been the single most expensive part of an electric vehicle and now technology advances are letting EVs travel farther for less money. A 2017 Bloomberg New Energy Finance report estimates battery production costs will drop by more than half by 2030.[26]

Figure 1: U.S. Electric Vehicle Sales by Year, 2015-2017[24]

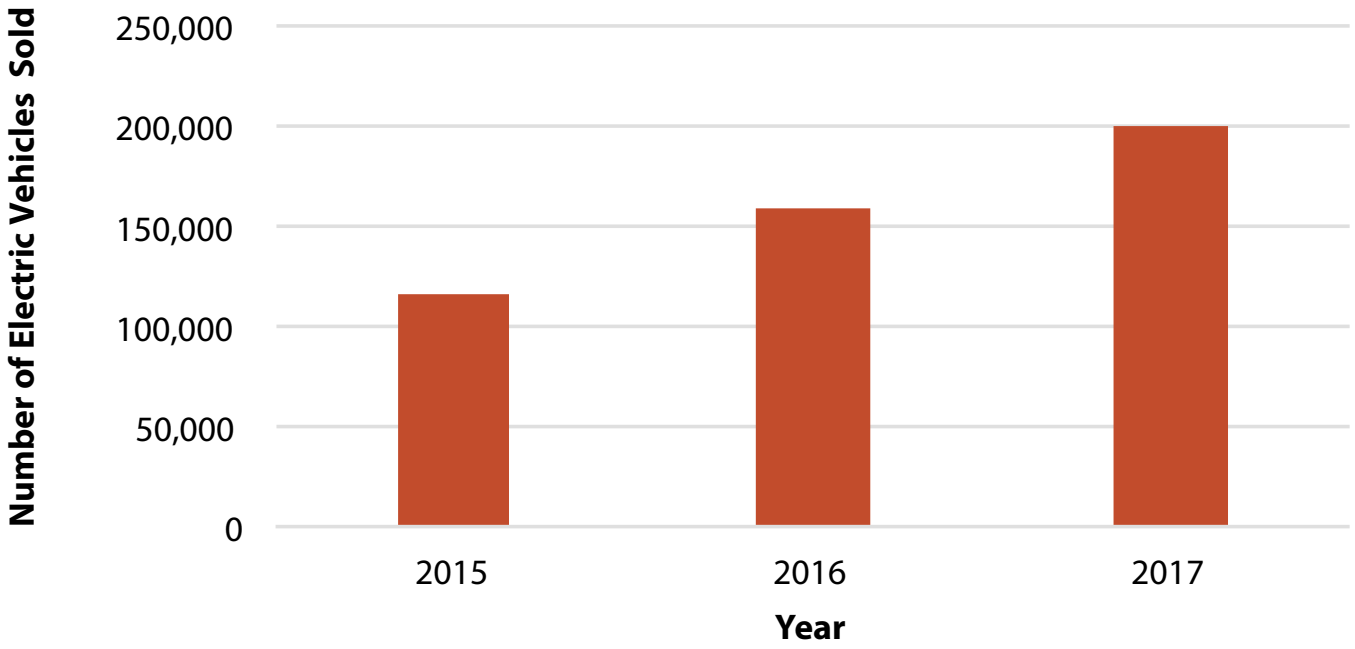
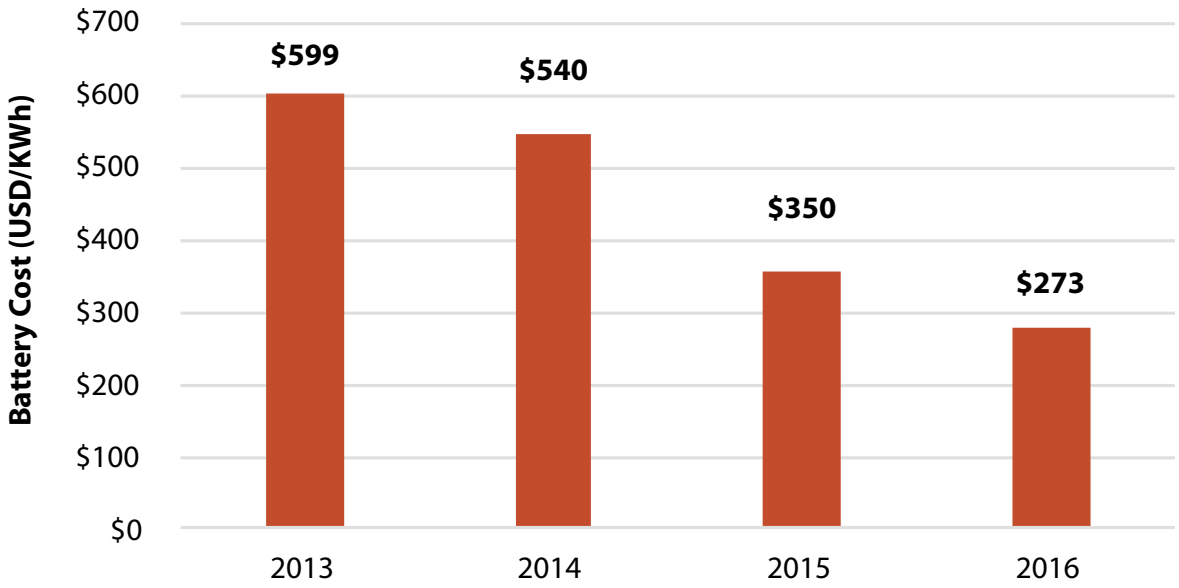


Figure 2: Cost of Lithium-Ion Batteries per Kilowatt-Hour of Energy Capacity, 2013-2016, in USD[27]



- **Travel range:** Because of battery improvements, mass-market electric vehicles like the Nissan Leaf can travel 150 miles on a single charge and Tesla's top-of-the-line Model S can travel more than 300 miles.[28] Longer-range cars are also becoming more affordable: the 2018 Nissan Leaf costs just $30,000, much less than earlier-generation electric cars. Tesla's Model 3 and the Chevy Bolt both offer over 200 miles of range for only a few thousand dollars more.[29]
- **Charging speed:** While charging some longer-range electric vehicles like the Model S from empty to its full charge on a Level 2 charger takes up to eight hours, Tesla's Supercharger stations can now fully charge a car in 75 minutes.[30] Advances in battery technology and charging equipment will allow for even faster charging in the future, comparable to filling up a gasoline tank. For instance, Toshiba's next-generation of EV batteries, expected to be deployed in 2019, can charge in just six minutes, with a range of 200 miles.[31]
- **Consumer interest:** Consumers are also growing more interested in EVs: A 2016 survey by the Consumer Federation of America found that 36 percent of those surveyed were interested in purchasing an electric vehicle, compared to 31 percent the year before.[32] Support is even stronger among young people. In the same survey, half of those aged 18-34 were interested in purchasing an EV.[33]

Shared Mobility Expands Access to EVs

Another important change in the last decade with implications for EVs is the rise of "shared mobility" services – technology-enabled services that facilitate the sharing of vehicles or rides in a city. Carsharing, bikesharing, and "ridesourcing" services like Lyft and Uber all fall within the definition of shared mobility.

Shared mobility services can be particularly amenable to the use of electric vehicles. Shared mobility services in cities can use smaller vehicles tailored for urban use and vehicles can be monitored centrally to ensure they are charged up for use.

A fast charging station at a gas station off an Oregon highway. Photo: Oregon DOT via Flickr.

A BlueIndy car recharges at a charging station. Photo: Deb Nystrom via Wikimedia, CC BY 2.0.

Globally, there are many examples of using EVs for shared fleets, with examples dating back to the early part of the decade. For example, the Autolib' carsharing program launched in Paris in 2011 and by 2016 had more than half a million subscribers. The program has 4,000 cars and nearly 5,700 docking/charging stations (half of all the electric vehicle charging stations in France).[34] Drivers can reserve cars and parking places from their phone.[35] Paris is also switching 30 percent of its shared bicycle fleet to electric bikes starting in 2018, with the hope that, by making pedaling a bit easier, more residents will replace car trips with bike trips.[36]

The company behind Autolib', Bolloré, launched its first foray into the U.S. in 2015 with electric carsharing service in Indianapolis. BlueIndy now offers 500 EVs and 1,000 charging stations across the city.[37] Bolloré is now set to bring 100 electric vehicles and 200 charging stations to Los Angeles through a new carsharing program, BlueLA, which is funded by a California program to reduce pollution.[38] The program is specifically designed for low-income residents, with stations located in low-income communities and a discounted pricing system based on income.[39]

In 2017, General Motors added 100 fully electric Chevy Bolts to Maven, its carsharing program that allows users to rent cars in hour-long increments, in Los Angeles, with plans to offer EVs in its San Francisco and San Diego programs.[40] Maven also supplies electric vehicles, including the Chevy Bolt, to Lyft's Express Drive program, which allows Lyft drivers in some cities to rent GM vehicles for ride-hailing.[41] The Bolt has become the most-requested car by Maven users who drive for Lyft and other ride-hailing services.[42] While renting a Bolt costs $40 more per week, drivers say that the EV helps them save $70 per week on gas on average, and cite fuel savings as their main reason for choosing the Bolt over GM's traditional vehicle options.[43] As part of the program in Los Angeles, users have free access to a network of EV charging at EVgo Freedom Stations.[44] Uber has announced an electric vehicle program in Portland, OR, that includes partnering with local businesses to provide electric vehicles and electric bikes for Uber's food delivery service, UberEATS.[45]

Cities Can Expect Many More Electric Vehicles Soon

Market analyses have found that EVs are poised for even more explosive growth in the near future. By 2040, about a third of the world's vehicles could be electric – almost 530 million vehicles – according to research by Bloomberg New Energy Finance.[48] Global sales in 2040 could be as many as 266 million electric vehicles, according to ExxonMobil.[49]

Estimates for the number of EVs on U.S. roads in 2025 range from 7 million (Edison Foundation), to 7.5 million (Energy Information Administration), to 11.4 million (GreenTech Media).[50] In September 2017, the National Renewable Energy Laboratory (NREL) released a new study estimating that 15 million electric vehicles will be on the road in the United States by 2030.[51]

Currently, eight U.S. states, including California – home to about half of the EVs in the U.S. – have signed on to an action plan that calls for 3.3 million EVs on their roads in 2025, and the states are taking aggressive steps to meet this goal.[52]

All scenarios point to a rapid increase in electric vehicle sales in coming years, which means we can expect many EVs to hit the roads in cities across America. Downscaling NREL's estimates for how many electric vehicles may be in states by 2030 allows for a calculation of how many EVs could be in American cities.[53] The number of EVs could reach 34,000 by 2030 in Philadelphia, 22,000 in Baltimore, 41,000 in Portland, OR, and 65,000 in Houston (with more entering the cities during daily commuting). (see Table 1. See Appendix A for a full list of the biggest cities in America's 50 largest metro areas).

Shared Electric Bicycles: A New Trend in Electric Mobility

Access to shared bicycles can help address many transportation challenges, particularly when paired with other forms of transit and shared mobility. Electric bicycles (e-bikes) make riding a bike even more accessible for the public and can enable more residents to travel without a car.

A number of shared e-bike systems are launching in cities around the United States, with more expected in coming years. In September 2017, Social Bicycles (SoBi) launched the country's first dockless electric bikesharing program in Washington, D.C., called JUMP.[46] Riders can find bikes and unlock them from an app on their phone and can drop off the bicycles anywhere people can legally park a bike. Users are incentivized to return the bikes to stations for charging through a $1 credit on their account. In January 2018, SoBi launched an 18-month pilot program in San Francisco with 250 JUMP bikes. The company is also partnering with Uber in San Francisco so people can reserve the electric bikes through Uber's app on smartphones.[47] SoBi is planning to start other dockless electric bikesharing programs in Sacramento and the city of Davis, CA, by May 2018.

Though their needs are different, electric bicycles also require charging and cities should work to identify ways to promote shared electric bikes through charging infrastructure.

Table 1. Projected Number of Electric Vehicles in Ten U.S. Cities by 2030[54]

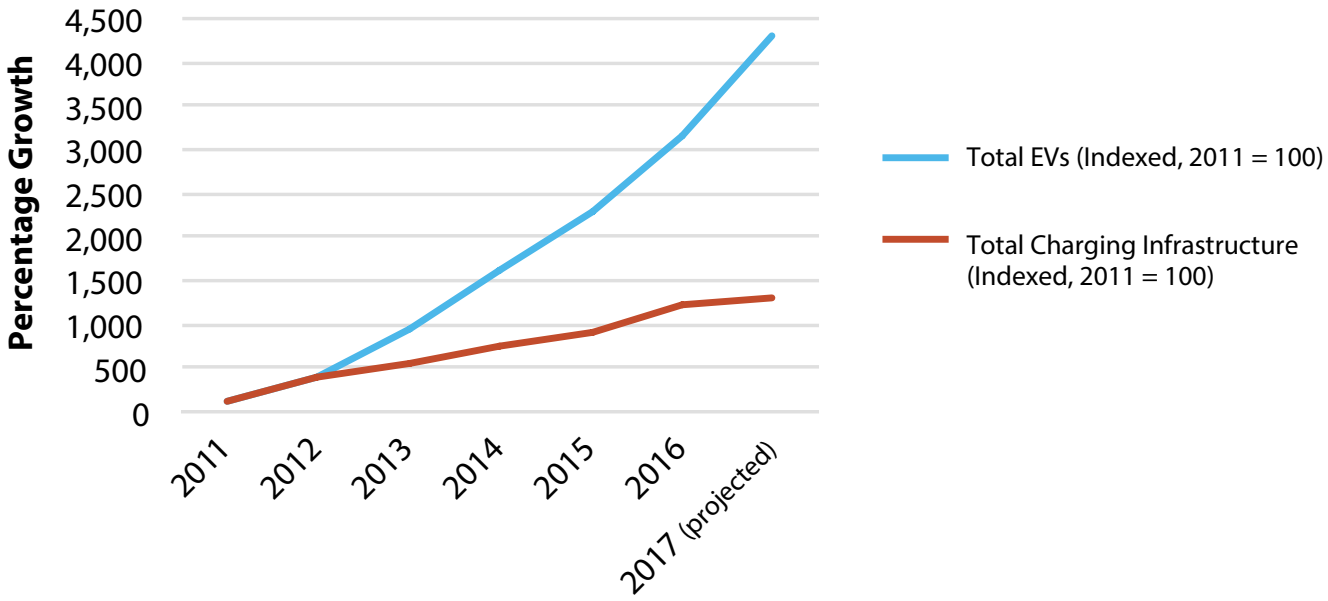
City	Number of EVs Projected in City Limits by 2030
Atlanta, GA	12,000
Baltimore, MD	22,000
Boston, MA	24,000
Chicago, IL	81,000
Cleveland, OH	9,000
Denver, CO	36,000
Houston, TX	65,000
Philadelphia, PA	34,000
Portland, OR	41,000
Seattle, WA	47,000

People Will Need a Place to Charge EVs, Including Where They Live

To support these new electric vehicles, America's energy infrastructure will need to adapt. Instead of gas stations, EVs will need charging stations. And because EV charging often takes place overnight, cities will need to ensure that people have access to charging near their homes, as well as at work and in other places where people spend time.

Recently, electric vehicle sales have been growing more quickly than the charging infrastructure needed to support them. In the past year, the number of publicly available chargers in the U.S. increased 25 percent, while EV sales increased by 37 percent.[55] Without a concerted effort to expand access to charging infrastructure, rapid increases in electric vehicle sales could continue to outstrip the availability of places to charge them. Furthermore, an insufficient supply of chargers is likely to hinder further adoption of electric vehicles.

Figure 3: Growth of Electric Vehicles and Growth of Public Charging Points in the U.S., 2011-2017 (projected growth after August 2017)[56]



Types of Electric Vehicle Charging Infrastructure[60]

There are three primary types, or levels, of electric vehicle chargers – Level 1, Level 2 and DCFC (often referred to as "fast charging").

- Level 1 charging is from a standard wall outlet and provides a slow charge, adding 4 to 5 miles of range per hour. Therefore, with a Level 1 charger, an empty EV battery may need to charge for 10 hours to get 50 miles of range. Level 1 chargers can work well for at-home charging, where EV owners park overnight, and in many workplaces, since the typical commute in many metro areas is less than 10 miles each way.[12] Because Level 1 charging requires only a standard three-prong outlet, it is often the most affordable way to offer charging, with minimal installation costs.
- Level 2 chargers require special installation but can charge an electric vehicle battery 2 to 6 times faster than a Level 1 charger, adding 12 to 25 miles of range per hour of charge, so 50 miles can be added in 2 to 4 hours. If people install a charger in front of their house, in their driveway, or in their garage, it is most likely a Level 2 charger. In public spaces, such as parking lots or on public streets, most chargers are Level 2, allowing EV drivers to charge their car for a few hours while at work or shopping. Level 1 and Level 2 plugs are standard in the United States so all EVs can charge at those charging stations.
- Fast chargers, known as DCFC (for direct current fast charge), can add 100 miles of range or more in an hour of charging – meaning an EV driver can add 50 miles to their battery in just half an hour. Different EV makes and models are compatible with different fast chargers and may require an adaptor to charge. Fast chargers will be especially important for long-distance travel when drivers won't be stopping for hours at a time, so DCFC chargers work well at rest stops and gas stations off highways and are important for the viability of electric shared mobility services, whose vehicles may be used for many trips – and travel many miles – in a given day. However, only pure battery electric vehicles can use DCFC charging, so it excludes plug-in hybrid EVs.

This report recognizes the value of Level 1 chargers as a low-cost option at homes, workplaces, and some public parking areas (like airports), but focuses on Level 2 and fast charging (DCFC) for public spaces, which are the chargers you would expect to find curbside, at workplaces and businesses, in parking garages and in other public areas.

Public access to EV charging stations, particularly in residential areas, will increasingly be critical in order to accommodate large numbers of electric vehicles. According to a 2013 study, only about half of vehicles in the U.S. have dedicated off-street parking spaces, and less than a quarter of vehicles in the U.S. have a dedicated parking space close enough to an outlet that could charge an electric vehicle overnight.[57] Furthermore, many EVs are expected to be in cities, where people may be even less likely to have dedicated parking spots where they can install chargers.[58]

Workplaces offer an opportunity for some EV owners to charge their cars, but many employers and offices have not yet installed adequate infrastructure even for their current number of EV-driving employees.[59]

In many cities around the U.S., people rely on on-street parking (like Philadelphia, above), necessitating dedicated spots where EVs can charge and charging infrastructure in public places. Photo: Tim Kiser via Wikimedia, CC BY-SA 2.5.

In order to support growing EV adoption in the U.S., the country will need a rapid expansion of charging infrastructure. Studies project that most electric vehicle charging will happen at home, so cities will need to ensure that residents have access to charging stations at or near where they live. Cities will also need publicly accessible charging infrastructure, on streets and parking lots in residential neighborhoods, in downtowns, and at destinations like shopping centers. Studies conducted separately by the National Renewable Energy Laboratory, the Electric Power Research Institute, and Pacific Gas & Electric, a utility, estimate that 1-5.2 fast chargers are needed to support 1,000 electric vehicles.[62] The National Renewable Energy Laboratory estimates that 36 non-residential Level 2 chargers are necessary for every 1,000 electric vehicles in cities (with towns and rural areas needing a higher ratio of chargers to vehicles since density is lower).[63] Cities will also need many more chargers at or near people's residences to support at-home charging.

NREL estimates that the U.S. currently has 13 percent of the public, non-residential, charging infrastructure that will be required to meet demand by 2030 (see Figure 4).[64] There are approximately 42,000 Level 2 and DC fast chargers in the United States, according to the Department of Energy, whereas NREL estimates the country will need nearly 630,000 by the year 2030 to meet demand.[65] On a city level, Philadelphia, for instance, could have as many as 34,000 electric vehicles on the roads by 2030 requiring 1,492 public charging ports, but the city has only 96 public charging ports now. San Diego could have 139,000 EVs and need up to 3,887 ports for public charging by 2030, but there are only 776 public ports currently. (See Table 2. See Appendix A for estimates of charging needs for the full list of some of America's biggest cities.)[66]

Installing public and workplace charging can help urban residents to get the most out of their electric vehicles. These estimates of charging needs, however, do not include the need for overnight charging in residential areas. Considering that these projections assume that 88 percent of EV charging happens at home, cities may need to plan for as many as thousands of additional EV charging locations in residential neighborhoods.[68]

Figure 4: Current Number of Non-Residential Electric Vehicle Charging Plugs in the U.S. Versus Projected Non-Residential Need by 2030, by Type[67]

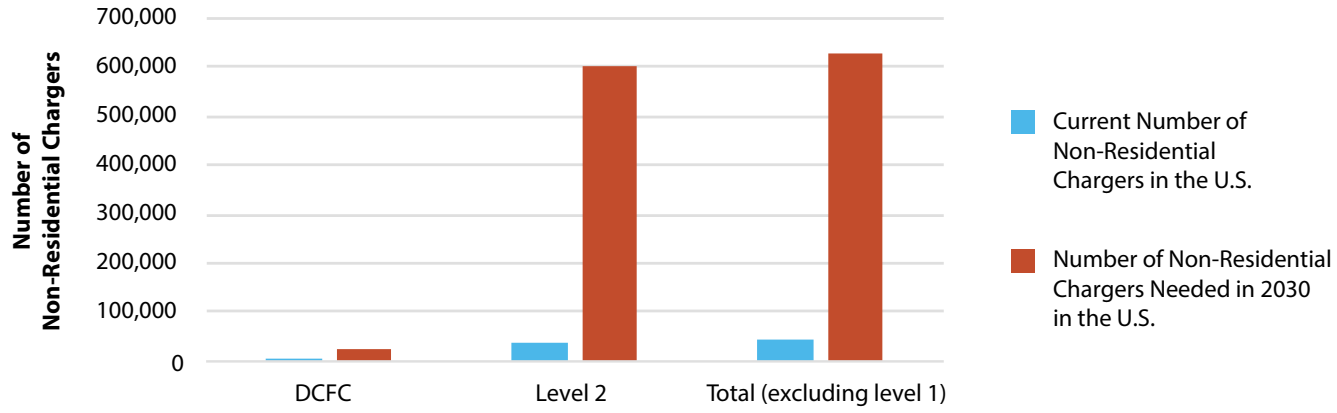


Table 2. Possible Number of Electric Vehicles on Selected U.S. City Streets by 2030 and Corresponding Charging Infrastructure Needs[69]

		Estimated Number of Public Plugs Needed in City Limits by 2030, by Type				Current Number of Public Plugs in City Limits (2017)
City	Number of EVs Estimated in City Limits by 2030	Level 2 Plugs in Workplaces Needed	Level 2 Plugs in Public Places Needed	Public Fast Charger Plugs (DCFC) Needed	Total L2 and DCFC Plugs Needed	Total L2 and DCFC Plugs Currently
Austin, TX	29,000	650	405	45	1,100	495
Cleveland, OH	9,000	202	126	14	342	18
Denver, CO	36,000	807	502	56	1,365	161
Hartford, CT	4,000	90	56	7	153	52
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Los Angeles, CA	348,000	6,312	3,730	201	10,243	1,456
Miami, FL	14,000	314	196	22	532	50
Philadelphia, PA	34,000	869	579	44	1,492	96
San Diego, CA	139,000	2,341	1,405	141	3,887	776
Seattle, WA	47,000	744	447	75	1,266	401

New Mobility Options Could Change Charging Needs

New models of mobility can result in different charging needs. Vehicles used in carsharing and ridesourcing systems, for example, may travel hundreds of miles per day, and need to have access to fast charging. If shared mobility were to reduce the number of privately owned vehicles in a city, fast charging could become relatively more important.

In Madrid, for instance, the carsharing service Car2Go launched an electric carsharing service in 2015 with 350 vehicles (up to 500 in 2018).[70] When vehicles need to be recharged, they are taken to a series of centralized fast-charging "hubs" scattered throughout the city.[71] Since then, two other electric carsharing services – the "Zity" service using Renault's Zoe electric vehicle and "Emov," which uses Citroen's C-Zero cars – have found their way onto Madrid's streets, each with an additional 500 vehicles.[72] Carsharing services are incentivized through exemptions from parking and travel bans that apply to private, gasoline-powered vehicles. Seeking to reduce the use of private vehicles to combat air pollution and congestion, the city has banned non-residents from driving in much of Madrid's urban core.[73] Electric vehicles, including shared ones, are allowed to drive in otherwise restricted areas and park in any spot for free.[74] This gives people in Madrid a strong incentive to forgo their private, fossil-fuel vehicle in favor of an emission-free, shared trip.

An emov carshare vehicle in Madrid. Staff Photo.

Smart Policies Can Help Cities Accommodate Electric Vehicles

Cities around the world are leading the electric vehicle revolution, often by adopting policies and investing public funds to expand the availability of charging infrastructure. By making it easy for EV owners and users to recharge their vehicles, these cities are positioning themselves to reap the air quality and climate benefits of growing electric vehicle use.

Of the five large metropolitan areas in the world with the greatest market share of EVs in 2015, two were in the Netherlands, two were in China, and one was in Norway. In each of these five cities – Oslo, Utrecht, Amsterdam, Shanghai and Shenzen – EVs accounted for 10 percent or more of new car sales. All of these cities have taken significant steps to facilitate EVs by investing in public charging infrastructure.[75]

Access to public charging is a key factor in the success of these cities: In a survey of Norwegians in 2012, more than 70 percent of EV owners said that having access to parking and charging were important in their decision to purchase an EV.[76] When asked about the importance of different incentives, Norwegians ranked access to public charging most important, with more than 90 percent of respondents saying it was important.[77]

The world's leading EV cities have several key policies that enable residents to own and operate electric vehicles. In particular, these cities have been able to deliver electric vehicle infrastructure to urban drivers through innovative parking and urban planning policies.

Specifically, leading cities have worked to expand access to:

1. **EV Charging Stations on Residential Streets** – A critical component of the success of electric vehicles will be residents' ability to charge their cars near their homes, even without dedicated off-street parking. These charging stations can be installed by local homeowners, private companies, utilities or by a city itself.
2. **Off-Street EV Charging Stations That Are Accessible to Residents** – Garages and lots with charging infrastructure can help alleviate residential charging demand.
3. **EV Charging at Workplaces** – While EV owners prefer to charge their vehicles at or near where they live, EV chargers at workplaces can help fill gaps and provide drivers another place to charge.
4. **Public EV Charging Infrastructure** – Adequate charging stations in public spaces allow EV owners to run errands and travel, within their city and to other cities, without worrying about if they will be able to charge their car.

EV Charging Stations on Residential Streets

One of the biggest challenges is access to charging in residential areas, because many residents, particularly in large cities, do not have access to an off-street parking spot where they might charge their EV overnight.[79] Cities around the world are tackling this problem with innovative solutions to directly install or incentivize residents to install on-street charging infrastructure in dense areas without off-street parking.

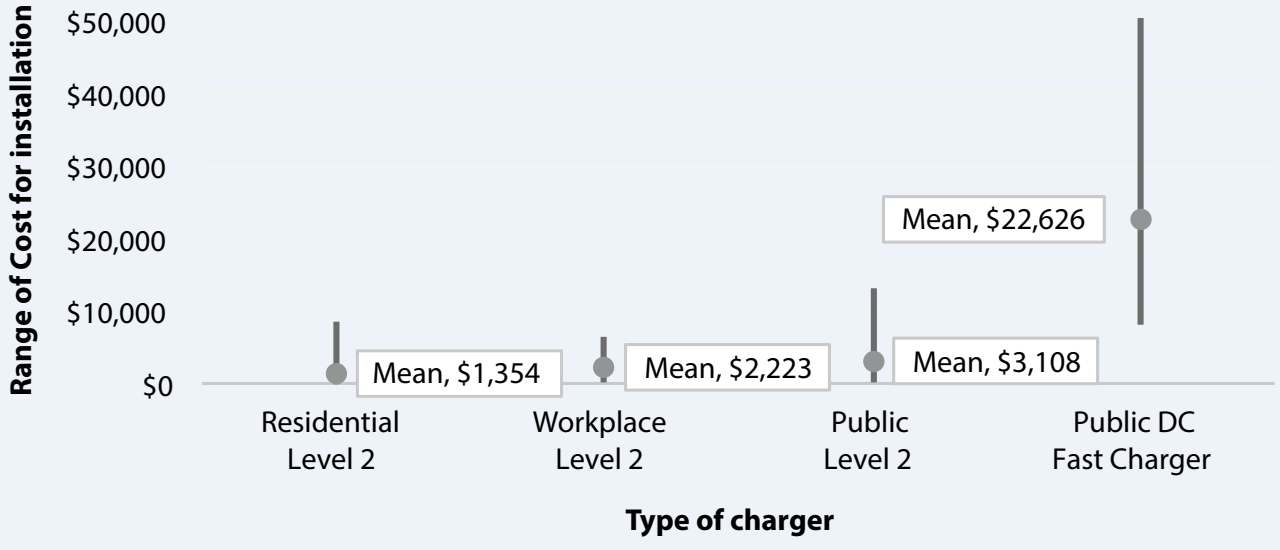
Expanding access to EV charging on residential streets reduces barriers to entry to own an EV and makes owning an electric vehicle as convenient as – or even more convenient than – owning a gasoline-fueled vehicle. Most of the studies referenced in this report indicate that EV owners prefer to charge at home and EV sales projections assume most charging will happen at people's homes.

However, in the absence of a comprehensive approach to residential parking, it may be hard for cities to overcome the perception that EVs are taking up rare parking spaces, particularly in areas where parking is harder to find. Another obstacle is that the installation of ports requires more work since the spaces are dispersed instead of concentrated in one area (like a parking lot). Finally, charging infrastructure can be expensive, with a mean cost of $1,400 for a residential Level 2 station, and $3,100 for a public Level 2 station; providing incentives for residents to install the infrastructure, or setting aside money for city-run programs, can help spur the installation of more stations.[80]

Costs of Electric Vehicle Charging Infrastructure

Many of the policies discussed in this section involve offering subsidies to residents, workplaces, developers or municipalities to install EV charging infrastructure. The cost to purchase and install a charging station varies greatly – from several hundred dollars for a residential Level 2 installation to tens of thousands of dollars for high-tech public fast chargers – depending on the type of station (see Figure 5) and the features of the site, including existing electrical capacity.

Figure 5. Costs to Install Electric Vehicle Charging Stations, by Type[78]



EV parking spaces on a residential street in Hamburg, Germany. Photo: Vitavia, via Wikimedia, CC BY 2.0.

Expanding Charging in Residential Areas

There are many examples of residential on-street charging in Europe, although implementation varies in the types of charging provided, the entities responsible for installing the chargers, and the ways in which residents make requests for stations.

Free-Standing Charging Stations: London has partnered with German startup Ubitricity to use existing streetlights to install adjacent free-standing charging stations, allowing the city to expand EV charging access cheaply and quickly.[81] Residents can apply for charging stations on their street and can list in order of preference which streetlight the installation would use. Currently any plug-in vehicle is allowed to park at any station.[82]

Low-Cost Plugs at Streetlights: Ubitricity is also experimenting with Level 1 charging points on lampposts, without a freestanding station. Where streetlights have been switched to LED lightbulbs, there is extra energy available that EVs can tap into, through a simple plug added to the lamppost, which is 10 times cheaper than a standalone station, according to Ubitricity.[83] The company is installing three plugs per customer request in London in order to see if oversupplying an area with low-cost plugs can reduce the need for dedicated parking next to charging stations.[84] Customers are sent a cord that can be used at any Ubitricity charging point and are billed monthly based on their usage, which is monitored by an electronic meter on their cord.[85] The charge from these plugs is slow, but works well for overnight parking.[86]

In 2016, the Los Angeles Department of Water and Power began a pilot program installing EV charging infrastructure on utility poles, the first of its kind in the U.S. The city has also used streetlights for charging infrastructure, noting that using existing electrical infrastructure on streets is simple and doesn't require ripping up pavement to run new lines to charging stations.[87] The city expected to install more than 80 charging points on streetlights by the end of 2017, charging between $1 and $3 for an hour of use, depending on the location of the charger. The city anticipates that the chargers will be useful for the broader public, as well as for city fleet vehicles while out in the field.[88]

Managing Residential EV Charging

Leading EV cities allow for installation of EV chargers by public or private entities, including people living in residential areas.

*Owner-installed Stations***:** Cities around the world have experimented with policies that allow electric vehicle owners to install charging stations on the curb at or near their homes.

While the city of Philadelphia recently suspended a program that allowed residents to install an EV charger in front of their house (see text box on page 26), other cities are moving forward to support electric vehicle adoption. In September 2017, the New Orleans City Council unanimously passed legislation allowing residents to apply for permits to install electric vehicle charging stations in front of their homes, on public property.[89] Residents must pay $300 for

the permit and to purchase and install the infrastructure.[90] The bill specifies that parking in front of the station is not restricted to the station's owner.[91]

Seattle started a pilot program to test EV charging and parking in the public right-of-way in July 2017.[92] The program will run for a year and allows residents to apply for permits to install EV charging infrastructure on public streets in front of multi-family dwellings. The plan notably excludes residential streets in front of single-family homes.[93]

Berkeley's curbside EV charging pilot program (which ended in December 2017 and is up for review by the city council in the spring of 2018) distributed up to 25 permits annually for three years so EV owners could install charging stations on local streets, if they lacked an off-street spot.[94] The city waived fees and permitting costs for people to install on-street chargers in residential areas and has a special permitting process to speed up installation. EV drivers had to purchase and install the stations on the curb near their home, which could cost $5,000 to $10,000, and any vehicles (including non-EVs) can use the spaces, reducing the incentive for EV owners to make the investment.[95]

Other municipalities around the world, including Amsterdam, incentivize residents to install charging stations. Amsterdam will give residents up to $1,173 USD for charger installation at homes, public parking spaces or workplaces.[96]

Company-managed Stations: In the Netherlands, Belgium and Germany, a private company, Allego, partners with municipalities to facilitate charger installation.[97] Residents submit an application to the company, which develops a proposal and submits it for municipal approval.[98] If approved, the company will install the charger in front of a person's house and all costs are borne by Allego as an investment.[99] EV drivers pay Allego a standard rate when charging at the station (to cover installation, maintenance and the electricity), though some municipalities partner with the company to offer subsidies, lowering the cost of charging.[100]

Electric vehicle charging port on a lamppost. Photo: Jason Cartwright via Flickr, CC BY 2.0.

City-installed Stations: London has allocated nearly $24 million (£18 million) to the development of a network of DC fast charging stations throughout the city, and an additional nearly $6 million (£4.5 million) for boroughs to install Level 2 or fast charging stations.[101]

The city hasn't yet determined how access to the spaces will be governed, but is considering allowing boroughs to issue parking permits and price parking and EV charging as they see fit.[102] Several boroughs have policies in place: Westminster, for example, offers EVs free residential parking permits and discounted on-street parking.[103] The city is also considering a London-wide parking policy that would override existing borough parking, allowing standardized spaces and charging access across the city.[104] By 2020, the city hopes to have charging access at one-fifth of all public parking spaces.[105]

Amsterdam also allows EV owners and businesses to suggest new public charging station locations and has expedited the construction process for installing new, on-street chargers.[106]

To help meet demand for EV charging in downtown Los Angeles, the city plans to install 84 new chargers (bringing the total to 107) at City Hall and City Hall East, which will be open to employees and the public.[107]

Utilities and Electric Vehicle Charging Infrastructure

Utilities can play an important role in the development of electric vehicle charging infrastructure. Utilities have much to gain from the widespread adoption of electric vehicles – especially at a time when overall electricity demand is stagnant.

There are several ways in which utilities can invest in charging infrastructure: they can do the electrical work and let another company or entity own and run the charging station (a "make-ready" investment); they can also provide incentives for hosts to operate the chargers; or, they can own and operate the charging infrastructure themselves.

Across the country, utilities are becoming involved in charging infrastructure development. For example:

In 2016, California's utility regulator, the California Public Utilities Commission, approved plans submitted by the state's three largest utilities (San Diego Gas & Electric, Southern California Edison, and Pacific Gas and Electric) to build electric vehicle charging infrastructure. In total, the three utilities will invest nearly $200 million in 12,500 charging stations at and near workplaces and multi-family residences, as well as in public spaces.[108]

In December 2017, the Massachusetts Department of Public Utilities approved the first major EV-utility agreement in the Northeast, allowing Eversource to install 4,000 make-ready charging stations in workplaces, apartments and other locations over the next five years.[109]

Other EV infrastructure proposals have been developed by utilities across the country, including in Oregon, Florida and Maryland.[110]

Regulating Access to Charging Spaces

Regulating access to parking spaces with EV chargers can be a contentious issue, with formerly public parking spaces being reserved for EV users.

By implementing pilot programs and testing different technologies, cities can discover which model of residential on-street charging will work best. In August 2017, the Oxford City Council in Great Britain began moving forward plans to implement a pilot program to test which kinds of on-street charging will best allow residents to charge EVs.[111] The city will install 10 each of three different kinds of chargers: some reserved for specific households, some open to the general public, and some that require membership to a subscription service. The city will collect feedback at the charging stations to determine which options best fit residents' needs and will ultimately invest more than a million dollars (£800,000) to expand the infrastructure citywide.[112]

It is likely that the type of charging infrastructure will need to vary depending on the neighborhood, but overall, cities will be best served by looking at innovative, flexible and cost-effective models. For example, using existing electrical infrastructure like streetlights speeds implementation and reduces costs.

Off-Street EV Charging Stations That Are Accessible to Residents

City neighborhoods with limited on-street parking often have off-street parking lots that are not fully used during off hours. Pay garages and lots, the parking lots of municipal facilities, and lots owned by private businesses could all be provided to residents during off-hours (overnight) to charge electric vehicles.

Many cities have an abundance of off-street parking lots that could have dedicated charging spaces for electric vehicles. For example, Philadelphia conducted a survey in 2015 of public parking lots and garages in downtown, finding that occupancy was around 74 percent on average.[113]

Making spaces in lots or garages available to nearby residents or EV owners could provide an opportunity for off-street overnight charging. This option would likely face less pushback from communities and streamline installation since the spots can be concentrated. However, it is likely less convenient and attractive for EV owners, is limited by existing distribution of lots, and would require participation from businesses and institutions that may have a variety of concerns about opening their lots to public use.

Encouraging Off-Street Charging Options

Off-hour Partnerships: In many areas, lots may be vacant at night when EV owners would most need to charge their vehicles. Programs could include partnerships with parking lots at workplaces or private lots and garages, along with public facilities like schools and community centers that are vacant in off hours. For example, the University of North Carolina at Chapel Hill, which is surrounded by residential areas, allows any electric vehicle to use charging stations on campus outside of normal university business hours.[114] Conversely, Ulster County, NY allows the public to use its EV charging stations at nine county government locations during the day, and charges its own fleet at the stations overnight.[115]

Garage-run Charging Stations: Some garages or lots may choose to install and run a charging station themselves (either Level 2 or fast chargers), potentially making profit from it. For example, the ChargePoint network, run by Coulomb Technologies, allows station hosts (like garages or lots) to set charging prices and collect money from EV drivers using the charging system.[116] This system, while a bit more work for the garage or lot owners, may provide a financial incentive for parking areas to host stations since they can attract EV drivers and make money off the stations. Furthermore, by offering EV charging stations to residents during off hours (overnight when the garage might not be full but EV owners need to charge their vehicle), garage owners can manage their parking more efficiently. Cities can help

EV charging spaces in a parking garage in Portland, OR. Photo: Oregon Convention Center, via Wikimedia, CC BY 2.0.

encourage this option by facilitating relationships between charging companies and garages or lots.

Third-party Managed Stations: Some hosts may find it easier to use a charging company that will install and maintain the infrastructure, rather than doing it themselves.[117] Cities can consider incentivizing parking areas to install charging infrastructure by offering benefits, discounts or subsidies to lots that allow stations to be installed.

Cities should also look at the system holistically and consider how the different options will work together – if a driver usually charges at a garage near their home, are they able to charge at a garage across town during a work meeting? Will a driver have to subscribe to multiple systems or can they park across systems?

The model of hosting charging infrastructure at third-party lots and garages will be successful only if EV owners can reliably charge their cars at locations that are not too far from their homes. Cities would need to evaluate existing infrastructure and opportunities to ensure that charging stations are adequately positioned for EV drivers to use them. A good first step for cities looking at this model would be to take an inventory of garages and lots in residential areas, and to identify areas of promise and areas that would still be excluded, to make sure this model would meet future demand.

EV Charging at Workplaces

While studies have shown that most EV owners would prefer to charge at home, offering electric vehicle charging at workplaces can augment and complement residential charging.

Besides charging at home, EV owners who commute by car could be able to charge at their workplaces. This option is not as convenient or as reliable as being able to charge at home, but it still provides an opportunity to offer infrastructure to employees and commuters. In order to be successful, cities need to survey how residents commute and determine whether or not this would suit current and potential EV owner needs.

EV charging garage at Google's Mountain View, CA campus. Photo: Nicolas.boullosa, from Flickr, via Wikimedia, CC BY 2.0.

Implementing Workplace Charging

Cities will need to implement policies that encourage and enable employers to install EV charging infrastructure. This can come through a combination of incentives, subsidies and partnerships, as well as long-term changes, like building codes. For instance, California's building code requires all new commercial buildings to include electric vehicle charging capacity (by at least installing appropriate electrical conduits) in a portion of the new parking spaces.[118]

Charger Management: Workplace chargers, like chargers installed in parking garages and lots, can either be on a network and run by another party, or can be run directly by the employer or the commercial property owner leasing the parking lot to employers. By using a third party to manage the chargers, employers can expect to pay a fee but have less responsibility in running the chargers.[119] If an employer or property owner owns and operates the chargers, they can offer charging for free as a benefit for employees, assess fees based on the cost of the power and/or the cost of the parking, or vary pricing for charging based on demand.[120]

*Incentivizing Installation***:** Cities can also help employers manage the cost of purchasing and installing the charging station through incentives and subsidies. Installing EV chargers at workplaces can cost between $500 and $5,000, with many chargers costing about $2,500 per unit.[121] The Department of Transportation in the UK launched a nearly $10 million program to help workplaces install EV charging stations. Businesses can apply for funding from the government, while the ChargePoint network also offers a discount to employers utilizing the service.[122]

Oslo offers subsidies for the installation of charging points on private property, including for companies, developers and apartment complex owners, making it cheaper for developers to add charging in non-public parking spaces.[123]

For cities in the U.S., funding for EV charging infrastructure may be available through the federal government's Clean Cities program and states' allocation of Volkswagen emissions-cheating settlement money.[124] Other funding, rebates or tax credits may be available for different regions, states and cities.[125] For instance:[126]

- An air pollution program in Santa Barbara County, CA, offers reimbursements up to $10,000 for public or non-profit entities to install Level 2 chargers ($20,000 for fast chargers), or $7,500 for Level 2 chargers by private entities ($15,000 for fast chargers).
- Sacramento's utility provides $1,500 for workplace or multi-family Level 2 EV charging ports, or up to $100,000 for projects that include two fast chargers and one Level 2 station.
- Colorado's Regional Air Quality Council will provide workplaces and other entities up to 80 percent of the cost of Level 2 and fast chargers.
- Delaware has a program that provides rebates up to 75 percent the cost of a Level 2 charger for workplaces (up to $5,000).
- New Jersey has a program specifically for workplaces, which provides up to $5,000 for a Level 2 charging station.

Including EV Infrastructure During New Construction: Cities can consider requiring a percentage of parking spaces at new residential and workplace developments include EV charging stations or at least be "EV-ready" (running electrical capabilities during construction). The cost of wiring a space for future EV charger installation or installing stations during construction is significantly less than retrofitting an area after a building is completed. A study by Pacific Gas & Electric on EV charging infrastructure in San Francisco found that the cost of adding one new electric vehicle charging space during construction was around $900, while adding one through retrofits later costs $2,000 to nearly $4,000.[127]

Some cities are already leading the way. San Francisco passed an ordinance requiring that, starting in 2018, all new residential, commercial and municipal construction have EV chargers installed in 10 percent of parking spaces and that an additional 10 percent of spaces be wired with the capacity to have chargers at a later date.[128] In November 2017, Atlanta passed an ordinance requiring that 20 percent of parking spaces in new commercial and multifamily residences be "EV-ready."[129] Oakland and Palo Alto have similar ordinances.[130]

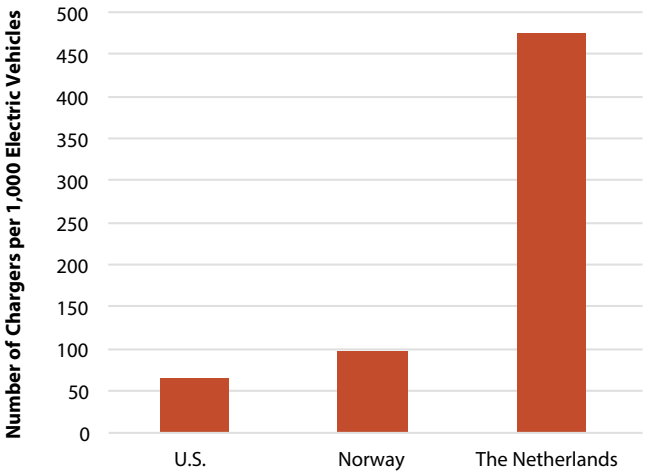
By implementing building ordinances that include electric vehicle charging, cities can ensure residents and workers in future buildings have access to charging.

Public EV Charging Infrastructure

Outside of residential and workplace charging, adequate public charging infrastructure in other locations helps fill in the gaps, allowing EV owners to complete errands and travel without worrying about not being able to charge their vehicle.

Public charging station in Hillsboro, OR. Photo: Visitor7 via Wikimedia, CC-BY-SA-3.0.

Figure 6: Ratio of Charging Infrastructure to Electric Vehicles, by Country[132]



The two countries in the world with the highest rate of EV sales – Norway and the Netherlands, which also contain three of the top five cities for EVs – have the highest number of public charging points per electric vehicle. While the U.S. has 64 charging points per 1,000 EVs, Norway has 50 percent more, at 96 per 1,000 EVs, and the Netherlands has 476 chargers per 1,000 EVs, almost eight times more than the U.S (see Figure 6).[131]

Integrating Public Charging into Cities

Comprehensive Planning and Evaluation of Charging Stations: During the first phase of charging station construction, Oslo conducted surveys and hired an agency to scout locations, with priority on placing new stations near existing electrical infrastructure to ease installation.[133] During the first phase of infrastructure buildup, most of the charging stations were installed by and at least partially paid for by the city of Oslo or Norway's government.[134] Once stations are installed, Oslo performs annual surveys of usage rates at charging stations around the city.[135]

A 2016 study by the Norwegian Electric Vehicle Association concluded that additional infrastructure would be needed to facilitate greater electric vehicle adoption.[136] In the city's last inventory in 2015, the city of Oslo had more than 2,800 public Level 2 EV charging stations (57 public chargers per 1,000 EVs), 1,100 of which are located on the street; the city was adding an additional 200 stations by the end of 2017.[137] Residents can charge electric vehicles at any of these stations for free. As of late 2016, the city also had 161 fast-charging stations – where EV owners pay to charge but discounts are offered for electric taxis and electric freight vehicles.[138] Across Norway, stations will be installed nearly every 30 miles along the country's main roads by the end of 2017.[139]

Government Coordination with Carsharing: Utrecht has nearly 1,000 public charging spots, at which parking is free while charging.[140] Many of these, as well as about a third of the Netherlands' more than 10,000 public chargers, were installed using public funds available to Foundation E-laad, a government-funded electric vehicle-promotion initiative.[141] In 2016, Utrecht partnered with carmaker Renault to construct and pilot a network of charging stations to be used by a fleet of 150 carsharing vehicles and available for use by other EV owners. The deal is planned to result in more than 1,000 solar-supplied charging stations, with costs shared between Utrecht and Renault.[142] (The program is also testing energy storage by sending energy from the car batteries back into the grid during periods of peak demand.[143]) Arrangements like this can increase public access to electric carsharing and make it easier for private EV owners to recharge their vehicles – addressing multiple challenges at once.

Singapore's electric carsharing program, which launched in December 2017, will have 2,000 charging points across the city by 2020, and 400 of them (20 percent) will be available to all EV drivers needing a charge.[144]

Facilitating the Creation of Semi-Private Charging Stations: Utrecht offers strong subsidies for "semi-public" charging stations, which are located on private property but are available for some public use.[145] Residents and entities can get up to $1,750 USD to install a charger on personal property and allow other people

to use it, either in front of homes or at businesses.[146] Shanghai has a similar program.[147] In 2015, the Netherlands expanded Utrecht's model, allowing municipalities and their regional partners to apply for part of $8.6 million (€7.5 million) in funding to reduce the price of installing new public charging points to $355 (€300).[148]

In the U.S., an app called PlugShare connects EV owners in need of a charge with private stations that other EV owners are offering to share, similar to an Airbnb model.[149] A similar application has been launched in Sweden – Elnbnb, launched by Renault Group.[150]

Oslo is looking at ways to incentivize homeowners and housing developers to add public charging stations to their properties.[151] Oslo, together with private partners, is teaming up with roadside convenience stores like Circle K and gas stations like Shell to incentivize companies to install fast chargers along roads.[152]

Enforcing EV Charging Spaces for EV-Only Use: If public charging stations are occupied by non-electric vehicles, the primary purpose is defeated and EV users still can't charge their cars, despite the infrastructure investment.

It is illegal for a non-EV to park in an EV charging space in nine states (AZ, CA, FL, HI, IL, MA, OR, RI, WA), although city-level enforcement varies.[153] Austin, Texas, has at least 200 public parking stations with EV charging points where non-electric vehicles are prohibited from parking for any amount of time.[154]

Oslo levies a fine on non-electric vehicles that occupy the spots, and allows EV owners to request towing of such vehicles.[155] Amsterdam restricts the use of almost all public parking spaces with charging infrastructure to electric vehicles, and grants free parking to EVs for the entirety of the time the vehicles spend plugged in to the charging point.[156]

A few U.S. cities also enforce time limits on the use of EV parking spaces (even for EVs). In Boulder, CO, for example, it is illegal to charge your EV or occupy an EV charging space for more than four hours, and overstaying results in a $50 fine.[157]

Some American Cities Are Paving the Way for EVs

In 2016, three large metropolitan areas in the U.S. (all in California) were among the top 15 cities in the world for the number of EVs sold, compared to all new cars sold. In the San Jose metropolitan area, 9.4 percent of cars sold were electric vehicles, in the San Francisco area it was 5.4 percent, and in the Los Angeles area, it was nearly 3 percent. Together, these three areas account for 40 percent of U.S. EV sales.[158]

San Jose: San Jose has nearly 500 public EV charging ports, 53 of which are owned directly by the city and located on streets and in garages downtown.[159] Additionally, San Jose offers free parking for qualifying EVs and hybrid vehicles throughout the city, including all parking meters, whether they have chargers or not.[160]

San Francisco: San Francisco has more than 400 publicly available L2 and fast charging plugs and has considered allowing free charging and/or parking at some of the stations.[161] Going forward, the city plans to require infrastructure investments aimed at making future parking EV-friendly, calling for the city to be "100 percent EV-ready."[162] This will involve 20 percent of all new parking spaces in residential, commercial or municipal developments being either EV-ready or "EV-flexible," meaning they will immediately be upgradable to EV spaces at no additional cost, and for the remaining 80 percent of spaces able to be converted to EV spaces at a later date. The plan would create approximately 90,000 EV charging ports by 2020.[163]

Los Angeles: LA currently has almost 1,500 public charging points.[164] A $500 rebate is available for home installation of a charging station, and the city's Department of Water and Power offers discounted electricity rates for EV charging.[165] In June 2017, LA's City Council approved more than $1.1 million in funding for new electric vehicle charging stations. Stations on public streets will be located near streetlights to utilize existing sources of power.[166]

Rethinking Parking Policy Offers Opportunities for EVs and More

The EV revolution is happening: people are buying electric vehicles in record numbers, and charging stations are springing up all over the country. However, as more and more electric vehicles hit America's streets, a central question remains: where will EVs be able to charge?

In cities where private, off-street parking spaces are often limited, providing EV charging locations can be a particular challenge. One reason is that parking is – or is perceived to be – limited, creating the potential for conflicts between EV owners, owners of conventional vehicles, and other street users (including bicyclists, delivery vehicles and carsharing services) for access to curb space.

Some leading EV cities use the scarcity of parking spaces as an incentive for residents to adopt electric vehicles. Amsterdam, for example, exempts EV owners from waiting lists for parking permits, which can otherwise be as much as 10 years long.[167] The city has stopped issuing new on-street permits for older, high-emitting vehicles, making preferential access to on-street parking an even more important incentive.[168]

But in other cities, forward-thinking approaches to reducing or managing demand for parking can help to reduce political conflict and unlock transformative opportunities, while cities that fail to adopt those strategies can find their efforts to shift from conventional to electric vehicles frustrated.

Parking Is Often More Abundant than Perceived

Everyone has felt the frustration of driving in circles looking for parking and had the thought "we really need more parking spaces." As it turns out, many cities have more parking than they need, but it is not managed effectively.

A recent analysis by Nelson/Nygaard Consulting Associates of 27 suburbs, cities, and towns in New England and California found that all 27 had an oversupply of parking – on average, 65 percent more spaces than were necessary.[169] Estimates of the number of parking spaces in the U.S. fall between 800 million and 2 billion, in a country of fewer than 300 million cars.[170]

One reason that parking can often seem scarce is that it is provided for free or at low cost in a particular area, regardless of the level demand. When people drive to a destination in a busy urban area, they expect to park as close as possible to their destination and for free or very cheap. If a free, close spot isn't available, people will cruise around the block, searching for one. Cruising is so prevalent that it might constitute as much as a third of traffic in cities.[171]

The same dynamic occurs in dense residential areas where residents might compete for on-street parking during evening hours, but pay little or nothing for the right to store vehicles on the street.

In other cases, parking spaces may actually be available nearby, but those spaces may be reserved for use by patrons of particular businesses and institutions – even after hours – and sit unused.

Rationalizing parking policy can prevent the addition of EV charging spaces to city streets from provoking conflict, as occurred in 2017 in Philadelphia. (See text box.)

Philadelphia's EV Parking Program Provides a Cautionary Tale

In 2007, Philadelphia launched a program to support EV ownership – the first of its kind in the nation – allowing residents who owned electric vehicles to get a permit to install a charging station in front of their home.[172] A permit did not include exclusive parking rights for the parking spot next to the charger, although the spots were restricted to EVs.[173] The cost of applying for and installing a charger was borne entirely by the homeowner, and could be as much as $3,000.[174] In contrast, a regular parking permit costs $35.[175]

By 2017, 67 electric vehicle spots had been permitted and completed.[176] Overall, the city of Philadelphia had approximately 43,000 permitted or metered on-street parking spaces, at least 46,000 garage or lot parking spaces in downtown, and many more free, unmetered spaces, of which there is no accurate count.[177]

Despite the permitted EV spots taking a small fraction of Philadelphia's available parking, vocal opposition blamed the program for exacerbating parking shortages. In the spring of 2017, the Philadelphia City Council approved a one-year moratorium on new parking permits under the program.[178] Additionally, parking spaces next to existing chargers (that had been paid for and installed by EV owners) were made open for two-hour parking by any vehicle during the day, from 6 a.m. until 6 p.m.[179] Previously, non-electric vehicles could be fined or towed for parking in the permitted charging spots, at any time of day.[180] This piece of the legislation is now being challenged in court by three EV owners who claim they improved public property by adding EV charging infrastructure, while the city is going back on a central part of their agreement – the exclusive right (for any EV) to use the space.[181]

The episode sparked the city to promise to create a new Electric Vehicle Task Force to address further options for promoting EV adoption.[182] In January 2018, the Task Force released a draft report recommending that the city end its EV curbside parking program, without offering concrete solutions to take its place.[183] A final version of the report and recommendations is expected in February 2018, at which point the City Council must vote to decide the final fate of the program.

The Task Force's findings are shortsighted, given the onslaught of electric vehicles expected in Philadelphia in coming years. The program made Philadelphia the first city in the U.S. to allow curbside EV chargers in residential areas (ahead of a similar program in Berkeley, CA, by seven years).[184] While the program supplied only a small number of permits, it was an essential step to facilitate more widespread electric vehicle ownership.

As the Task Force's draft report highlights, EV ownership in the city has grown only 15 percent in the last two years, half the rate of EV adoption in the Southeastern Pennsylvania region, which saw a 33 percent increase between 2015 and 2017.[185] The report also notes that most electric vehicle charging in Philadelphia occurs at home.[186] Ending the program – especially without a specific replacement strategy to get charging infrastructure on the city's streets quickly – disincentives electric vehicle purchases and puts up hurdles for Philadelphia residents to participate in America's electric vehicle revolution.

Shared Mobility Can Reduce Vehicle Ownership

One reason for competition over scarce parking is that many people – even residents of cities with transit service – may feel the need to own a car to meet their mobility needs. Since the typical car is parked and idle 95 percent of the time, dependence on privately owned vehicles creates tremendous demand for places to store vehicles.[187]

Carsharing and other forms of shared mobility can reduce the need for private car ownership by providing city residents with access to the services provided by a car without having to own one. Research has shown that many participants in carsharing programs sell their vehicles or forgo the purchase of a new vehicle. Researchers at the University of California, Berkeley's Transportation Sustainability Research Center have estimated that each vehicle in a free-floating carshare service such as Car2Go replaces between 7 and 11 private vehicles, while each vehicle in a round-trip carsharing service like Zipcar replaces between 9 and 13 private vehicles.[188]

The success of carsharing systems – especially "free-floating" systems that enable drivers to pick up a car in one location and drop it in another – depends on access to curb space in well-traveled locations, the same curb space that is often in demand for parking for privately owned vehicles. Expanding access to shared mobility services in dense urban areas has the potential to reduce overall competition for parking, creating the potential to use some on-street spaces for EV charging.

Pricing Parking Based on Demand Can Help Create Space for EVs and Other Vehicles

By reducing free parking, and by charging more in areas where there is more demand, cities can address the perceived problem of parking scarcity, ensuring that any surplus of existing spaces can be used efficiently. By creating a demand-based system for pricing parking, cities can reduce overall demand to ensure that there are always a few on-street parking spots available, including spaces dedicated for electric vehicles.[189]

Recently, San Francisco pioneered a demand-priced parking system that uses sensors on the street to measure in real-time how many on-street parking spots are available in a given area. The price for parking automatically increases in areas of high demand and decreases in areas with less demand to incentivize more effective use of the spaces.[190] The program has been very successful: average parking costs actually fell overall, while vehicle miles traveled and time spent searching for parking decreased, as any given block was more likely to have spaces available.[191] Los Angeles has implemented a similar dynamic demand pricing system in downtown LA.[192] Prices are adjusted every four to six weeks in order to ensure that blocks maintain a near ideal parking capacity.[193]

Residential areas where parking is scarce during overnight hours can consider strategies such as limiting or pricing residential parking permits in order to discourage people from occupying public curb-

SFPark smart meters in San Francisco vary the price of parking based on demand, helping manage access to curbside parking in the city. Photo: Carlos Felipe Pardo, via Flickr, CC BY 2.0.

space with vehicles, some of which may be used only infrequently.

Cities can also benefit from encouraging shared parking, in which private parking lots are used for a variety of purposes – for example, for employee parking during the day and residential parking at night. Shared parking eliminates duplicative parking spaces that are tailored for specific uses – for instance, shared parking enables shoppers and office employees to park in a given parking area during the weekday, residents to park overnight, and shoppers and residents to park during the weekend.[194] Studies have found this system can reduce parking needs by 20-40 percent.[195]

Conclusion and Recommendations

In the next 10 to 15 years, cities across the U.S. can expect tremendous growth in electric vehicles – with projections estimating that 20 percent of new cars could be electric as soon as 2030.[196] If cities wish to obtain the environmental, public health and quality of life benefits of electric vehicles – and meet the needs of their residents – they will need to plan for the dramatic expansion of electric vehicle charging infrastructure, including in residential neighborhoods where off-street parking is limited.

Cities should plan for this transition in the context of an overall mobility transition that encourages the use of public transportation, shared mobility services, bicycling and walking. A transition that reduces demand for parking from private vehicles – while creating new charging opportunities for both privately owned and shared electric vehicles – can deliver a powerful "win-win" for cities and help propel America toward a clean, efficient, zero-carbon transportation system.

New Opportunities for Expanding EV Charging

Fortunately, cities have numerous new opportunities and motivations to expand access to electric vehicle charging.

Some states are planning to use money from the settlement in the Volkswagen "Dieselgate" case – in which the carmaker was caught selling more than half a million diesel cars that polluted up to 40 times the legal limit of nitrogen oxides (NOx, a key component of smog) – to invest in EV infrastructure. U.S. states will receive nearly $3 billion to implement programs to reduce NOx. States can spend up to 15 percent of allocated money to build electric vehicle charging stations, which presents a tremendous opportunity to expand charging infrastructure.[197] The state of Colorado, for example, is planning to use the full 15 percent of its $68 million settlement ($10 million) to invest in electric vehicle charging stations; reports estimate this could add 60 fast chargers around the state.[198] States can use the remaining Volkswagen settlement money on other transportation options, including fleets of all-electric transit buses.[199]

Eight states in the US have signed a memorandum of understanding (MOU) on zero-emission vehicles, which sets ambitious goals for the number of EVs in each state. Together, the states committed to 3.3 million electric vehicles by 2025 and the MOU allows them to coordinate implementation to ensure that the programs are successful.[200] States and municipalities can consider similar approaches to foster EV adoption.

Ten states have also implemented mandates requiring that automakers sell a certain number of zero-emission vehicles compared to overall vehicle sales in the state. The goal of the mandates is to ensure that automakers are developing, marketing and selling electric vehicles.[201]

Finally, in the wake of the federal administration withdrawing the United States from the worldwide climate agreement, a growing number of states and cities have joined the United States Climate Alliance, committing to uphold the goals from the global pact to reduce greenhouse gas emissions. Fourteen U.S. states and Puerto Rico joined by October 2017, representing more than a third of the country's population.[202] Reducing emissions through transportation, including through the widespread adoption of electric vehicles and reducing vehicle miles traveled, will be key to meeting these goals.[203]

Developing Comprehensive Plans for Electric Vehicles Will Help Cities Prepare

To facilitate the adoption of electric vehicles locally, cities should develop comprehensive plans for electric vehicle charging. EV adoption will be most successful if cities develop holistic solutions that create spaces for EV charging, rationalize parking policies generally, and support shared mobility and electric fleets. A broader vision and policy framework will enable cities to take advantage of all of the opportunities presented with EVs, including the synergies that arise from considering infrastructure in tandem with parking policies and transportation planning.

Setting numeric goals will help U.S. cities ensure that they are prepared to meet demand. Cities would benefit from following the lead of top electric vehicle cities by setting a goal that 20 percent of parking spaces be "EV-ready," or capable to host EVs in the future, by 2030. Some specific strategies to get there include:

- Expanding access to electric vehicle charging for residents without off-street parking, by dramatically increasing the number of charging stations in residential areas. Leading EV cities around the world have demonstrated a variety of approaches for expanding charging access – including networks of publicly and privately-owned chargers and allowances for residents to install their own charging stations on public curbs near their homes. Cities may choose to invest public resources in a network of stations open to everyone, or take part in public-private partnerships with utilities or charging-providers to ensure thorough coverage of EV chargers in all of a city's neighborhoods. Cities that fail or refuse to create citywide networks of public EV chargers should minimally allow residents to invest their own resources to install EV chargers for their use on public curbsides.
- Partnering with businesses and public entities (like schools, community centers and municipal offices) to use their existing parking infrastructure while providing EV charging. This can include partnering with existing workplaces, businesses and destinations at which people spend time, like health care facilities, churches, gyms, shopping centers, movie theaters, etc. to ensure patrons can charge while there. It can also include partnering with locations to make charging stations available to nearby residents during off-hours and overnight.
- Facilitating and encouraging electric shared mobility options like carsharing, ridesharing and bikesharing. Providing options for people to share electric rides allows more people to utilize the benefits of EVs without having to personally own one. Fleets of shared vehicles, as well as shared electric bicycles, also reduce overall demand for parking and space needed to charge EVs.[204]
- Directing municipal utilities to install charging infrastructure and coordinating closely with investor-owned utilities to maximize opportunities.
- Ensuring public investment in electric vehicle charging results in infrastructure that is managed in the public interest. Cities should think long-term to encourage the best deal for the public and avoid missing out on future opportunities.
- Making data available on charging station locations to foster the development of apps that people can use to find available chargers and dedicated EV parking.
- Considering a demand-based and shared system for parking. By charging for parking based on where and when people need it and making access to parking shared, cities can better manage their parking resources and free up space for EVs and all vehicles.

Without thoughtful development of new policies, cities stand to not only lose out on opportunities like reduced air pollution and less congestion, but they also risk being unprepared for this impending challenge. By looking to best practices abroad and at home, cities across the U.S. can begin to develop a holistic solution that allows them to reap the full potential from America's EV revolution.

Methodology

Number of EVs in Cities by 2030

A National Renewable Energy Laboratory report from September 2017 estimates that the United States could have 15 million electric vehicles by the year 2030, and projects how those vehicles would be distributed by state.[205] We used those numbers as a baseline to estimate how many EVs might be in a number of American cities by 2030.

We estimated potential city-level EV adoption by downscaling NREL's state projections for some of America's largest cities. We calculated a ratio of the number of vehicles available in each city compared to the number of vehicles available in their respective state using American Community Survey one-year estimates for 2016 from the U.S. Census Bureau (topic B25046, "Aggregate Number of Vehicles Available by Tenure" in the American FactFinder website). We multiplied that ratio by NREL's state EV projections to estimate the number of EVs that might be in the city in 2030. This assumes the ratio of electric vehicles in any given city compared to the number in a state will be the same as the number of vehicles available overall in that city compared to the state.

Selection of cities for inclusion in the report began with the largest cities in each of America's 50 most populous metropolitan areas. For states where that resulted in fewer than two cities, we also included the two largest cities in the state with populations greater than 250,000, according to 2016 1-year estimates from the U.S. Census Bureau.

Charging Infrastructure Needs

The U.S. Department of Energy's Alternative Fuels Data Center has a list of electric vehicle charging stations in the United States.[206] To determine how many stations were in the cities included in this report, we used GIS analysis to clip all of the charging points from the Alternative Fuels Data Center by each city's geographic boundary, from U.S. Census TIGER/Line shapefiles.

To estimate future needs, we applied ratios from NREL's 2017 report to the EV projections by city, described above. NREL estimates that cities in the U.S. will need, on average, 1.5 public fast chargers and 36 public, non-residential L2 chargers per 1,000 electric vehicles. For most cities in this analysis, we applied those ratios to the number of EVs that might be in those cities by 2030. Eight metro areas were specifically addressed in the NREL report that were also included in this analysis (Atlanta, Chicago, Los Angeles, New York, San Diego, San Francisco, San Jose, Seattle). For those metro areas, we applied the estimated ratios of charging equipment needed per electric vehicle in each metro area to the principal city included in this analysis.

Unfortunately, NREL's analysis does not include the needs of residential charging and assumes 88 percent of charging happens at home. The estimates here should be seen as a lower bound estimate of the need for public charging, and account for only a small percentage of the total number of chargers needed, including those in private residences and on residential streets.

Appendix A: 2030 Projected Number of EVs by City and Infrastructure Needs[207]

Number of electric vehicles estimated to be in the largest cities in some of America's biggest metro areas by 2030, and corresponding charging infrastructure needs. See the Methodology for full details. Estimates are defined by city limits and will likely be much higher for metro areas and regions.

			Estimated Number of Public Plugs Needed in City Limits by 2030, by Type				Current Number of Public Plugs in City Limits	
City	City Population (2010 Census)	Projected Number of EVs in City Limits by 2030	L2 in Workplaces	L2 in Public Places	Total L2 Plugs Needed	Fast chargers (DCFC) in Public Places	Total L2 (No Distinction Given Between Workplaces or Public)	Fast Chargers (DCFC)
Albuquerque, NM	545,852	24,000	538	335	873	37	32	14
Anchorage, AK	291,826	8,000	180	112	292	13	2	0
Atlanta, GA	420,003	12,000	269	168	437	19	376	35
Austin, TX	790,390	29,000	650	405	1,055	45	482	13
Baltimore, MD	620,961	22,000	493	307	800	34	257	33
Birmingham, AL	212,237	4,000	90	56	146	7	13	8
Boston, MA	617,594	24,000	632	361	993	28	298	7
Buffalo, NY	261,310	8,000	180	112	292	13	16	0
Charlotte, NC	731,424	35,000	784	488	1,272	54	131	26
Chicago, IL	2,695,598	81,000	1,625	1,016	2,641	102	237	16
Cincinnati, OH	296,943	8,000	180	112	292	13	42	10
Cleveland, OH	396,815	9,000	202	126	328	14	16	2
Colorado Springs, CO	416,427	26,000	583	363	946	40	35	14
Columbus, OH	787,033	25,000	560	349	909	39	58	24

City	City Population (2010 Census)	Projected Number of EVs in City Limits by 2030	Estimated Number of Public Plugs Needed in City Limits by 2030, by Type				Current Number of Public Plugs in City Limits	
			L2 in Workplaces	L2 in Public Places	Total L2 Plugs Needed	Fast chargers (DCFC) in Public Places	Total L2 (No Distinction Given Between Workplaces or Public)	Fast Chargers (DCFC)
Dallas, TX	1,197,816	39,000	874	544	1,418	60	169	8
Denver, CO	600,158	36,000	807	502	1,309	56	146	15
Detroit, MI	713,777	11,000	247	154	401	17	109	0
Fort Wayne, IN	253,691	8,000	180	112	292	13	12	0
Hartford, CT	124,775	4,000	90	56	146	7	50	2
Henderson, NV	257,729	12,000	269	168	437	19	15	6
Honolulu, HI	337,256	22,000	493	307	800	34	210	4
Houston, Texas	2,099,451	65,000	1,456	907	2,363	100	268	29
Indianapolis, IN	820,445	24,000	538	335	873	37	60	24
Jacksonville, FL	821,784	36,000	807	502	1,309	56	73	18
Jersey City, NJ	247,597	5,000	112	70	182	8	17	3
Kansas City, MO	459,787	14,000	314	196	510	22	767	14
Las Vegas, NV	583,756	22,000	493	307	800	34	60	17
Lexington, KY	296,717	8,000	180	112	292	13	8	8
Lincoln, NE	258,379	7,000	157	98	255	11	26	8
Los Angeles, CA	3,792,621	348,000	6,312	3,730	10,042	201	1,409	47
Louisville, KY	597,337	16,000	359	224	583	25	31	8
Madison, WI	233,209	9,000	202	126	328	14	55	9
Memphis, TN	646,889	16,000	359	224	583	25	40	9
Miami, FL	399,547	14,000	314	196	510	22	49	1
Milwaukee, WI	594,833	17,000	381	237	618	27	27	4
Minneapolis, MN	382,578	13,000	292	182	474	20	109	7
Nashville, TN	601,222	19,000	426	265	691	30	179	18
New Orleans, LA	343,829	5,000	112	70	182	8	22	5
New York City, NY	8,175,133	131,000	3,080	1,659	4,739	143	526	16
Newark, NJ	277,140	5,000	112	70	182	8	11	2

			Estimated Number of Public Plugs Needed in City Limits by 2030, by Type				Current Number of Public Plugs in City Limits	
City	City Population (2010 Census)	Projected Number of EVs in City Limits by 2030	L2 in Workplaces	L2 in Public Places	Total L2 Plugs Needed	Fast chargers (DCFC) in Public Places	Total L2 (No Distinction Given Between Workplaces or Public)	Fast Chargers (DCFC)
Oklahoma City, OK	579,999	15,000	336	210	546	23	11	15
Omaha, NE	408,958	11,000	247	154	401	17	23	0
Orlando, FL	238,300	12,000	269	168	437	19	124	4
Philadelphia, PA	1,156,006	34,000	869	579	1,448	44	85	11
Phoenix, AZ	1,445,632	73,000	1,636	1,018	2,654	112	284	22
Pittsburgh, PA	305,704	9,000	202	126	328	14	120	2
Portland, OR	583,776	41,000	919	572	1,491	63	251	23
Providence, RI	178,042	5,000	112	70	182	8	40	2
Raleigh, NC	403,892	20,000	448	279	727	31	111	9
Richmond, VA	204,214	10,000	224	140	364	16	21	4
Riverside, CA	303,871	29,000	650	405	1,055	45	74	3
Sacramento, CA	466,488	47,000	1,053	656	1,709	72	305	12
Salt Lake City, UT	186,440	8,000	180	112	292	13	116	12
San Antonio, TX	1,327,407	40,000	896	558	1,454	62	176	0
San Diego, CA	1,307,402	139,000	2,341	1,405	3,746	141	730	46
San Francisco, CA	805,235	62,000	874	499	1,373	50	392	30
San Jose, CA	945,942	106,000	1,631	816	2,447	82	460	25
Seattle, WA	608,660	47,000	744	447	1,191	75	389	12
St. Louis, MO	319,294	8,000	180	112	292	13	15	2
St. Paul, MN	285,068	10,000	224	140	364	16	68	4
Tampa, FL	335,709	15,000	336	210	546	23	104	9
Tucson, AZ	520,116	24,000	538	335	873	37	57	3
Tulsa, OK	391,906	9,000	202	126	328	14	24	0
Virginia Beach, VA	427,994	26,000	583	363	946	40	22	5
Washington, DC	601,723	40,000	885	492	1,377	40	173	7
Wichita, KS	382,368	12,000	269	168	437	19	6	6

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