U.S. Department of Transportation, Climate Change Center
Climate Strategies that Work

ELECTRIC VEHICLE CHARGING INFRASTRUCTURE

Strategic and robust charging infrastructure deployment accelerates the transition to electric mobility, promotes equitable access to clean transportation options, and fosters economic growth through innovation and job growth.

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OVERVIEW

Best Suited for:
Short Term
Urban, Suburban, Rural & Tribal

Electric vehicle (EV) charging infrastructure plays a key role in accelerating the widespread adoption of EVs. A robust charging network provides reliable and accessible charging options for EV drivers across the transportation sector – from light-duty passenger vehicles to micromobility solutions like electric bikes and scooters, as well as transit and school buses, and medium- to heavy-duty vehicles. Strategically located along highway freight corridors, curbsides, multifamily housing units, and mobility hubs, charging stations can cater to varied travel patterns and transportation system uses.

The U.S. charging network is being developed in the context of location, charging duration, and electric energy supply. Charging levels include Level 1 (120-volt or the equivalent draw of small kitchen appliances) and Level 2 (240-volt or the equivalent of a clothes dryer) for charging in homes, workplaces and public locations; and faster Level 3/ Direct Current Fast Charging (DCFC) for 480-volt charging on road trips or for fleet vehicles. As the percentage of EVs in the fleet grows, the amount and types of chargers available are also expected to grow.

To ensure widespread adoption and encourage individuals and companies to embrace electric mobility options, the charging network must be convenient, interoperable, affordable, reliable, and equitable. Planning for charging infrastructure can occur at the corridor, community, and site levels, and can also focus on specific fleets, like transit vehicles and last-mile delivery vehicles. Thoughtful planning makes EVs a more attractive option and supports choice of lower-carbon transportation.

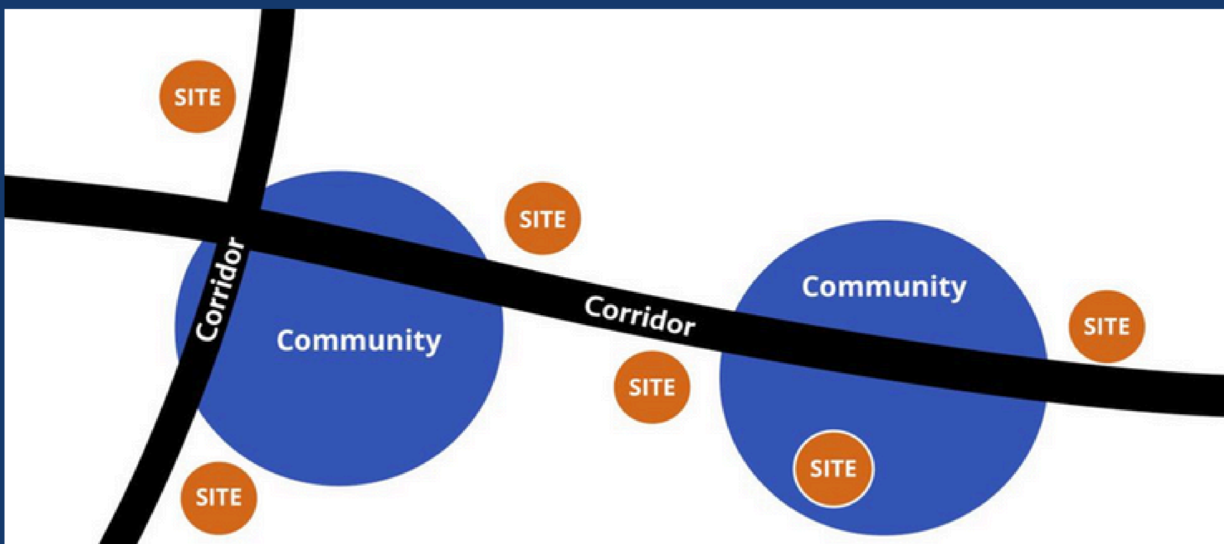
EVs have zero tailpipe emissions. Widespread adoption of EVs can greatly reduce greenhouse gas emissions and improve local air quality compared to gasoline- and diesel-powered engines. Since electricity generation can produce emissions depending on the source (natural gas, coal, wind energy, etc.), simultaneous decarbonization of the electrical grid is critical for maximizing the environmental benefits of EVs. Smart charging that accounts for peak hours and load on the grid can more effectively use renewable energy, while accounting for driver needs and electricity costs.

Charging Infrastructure Planning

As part of their E-Mobility Toolkit, USDOT provides resources for electric mobility infrastructure, including different planning approaches based on geographic scale and vehicle fleet composition. The entities best positioned to conduct each level of planning are noted in brackets.

- **Corridor-level planning** supports infrastructure along roads and highways for the needs of interregional and interstate travelers, or those "passing through" [*State DOTs, Tribal Organizations, regional planning agencies, and county governments*]
- **Community-level planning** considers infrastructure solutions to meet diverse needs within a particular region, city or neighborhood [*State, Tribal, and local governments, transportation planning agencies, transit agencies, and community organizations*]
- **Site-level planning** focuses on specific locations, including residential charging and charging infrastructure for visitors to the area [*Local leaders and stakeholders, including community- and corridor-level planners; site hosts, such as local business owners*]
- **Fleet planning** involves infrastructure planning for transit, micromobility, ride-hailing/taxi, and last-mile delivery fleets, and can occur at the corridor-, community-, or site-level [*Transit agencies, local governments, private entities, such as ride-hailing companies and delivery operators*]

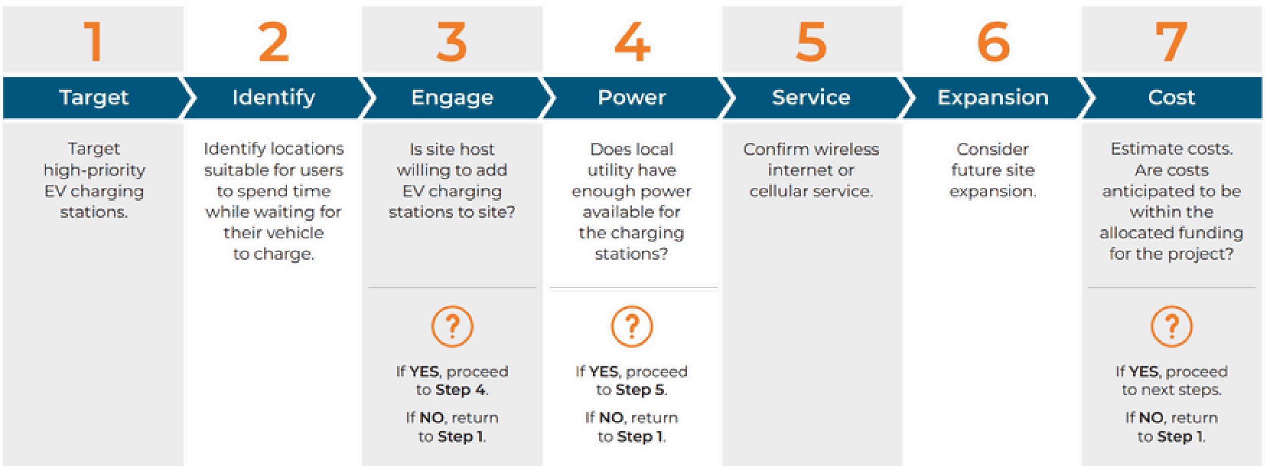
Read more here: Types of Charging Infrastructure Planning



Three levels of EV infrastructure planning: corridor, community and site (Source: Volpe Center, via USDOT, n.d.)

> On a lifecycle basis, a model year 2023 battery electric car will emit 50% the carbon dioxide equivalents over its lifetime (IEA, 2024).

Emissions from the full vehicle lifecycle are often referred to as **well-to-wheel (WTW) emissions**, covering energy and emissions associated with vehicle manufacturing, fuel production, processing, and distribution, and fuel combustion in a vehicle. In the case of an electric vehicle, WTW emissions includes emission associated with electricity production. WTW emissions can be divided into two parts: well-to-pump (WTP) and pump-to-wheel (PTW), where to pump is the gas pump with internal combustion engine vehicles (ICEV) and the charging station with electric vehicles. **On a WTW basis, EVs emit 60 g-CO_2-equivalents (eq) per mile, while ICEVs emit 35-40 g-CO_2-eq/mi** (Elgowainy et al., 2020).



There are several considerations that should be addressed when selecting a site for EV charging stations. Here are high-level steps to guide selection of publicly available charging stations (Source: Joint Office of Energy and Transportation, 2023)

GREENHOUSE GAS REDUCTION POTENTIAL

This section provides an overview of greenhouse gas (GHG) emission reductions associated with the strategy. It highlights key findings and relevant metrics from GHG modeling resources, peer-reviewed studies, and real-world applications.

LIFECYCLE EMISSIONS FROM EV CHARGING

Well-to-wheel emissions include all emissions related to fuel production, processing, distribution, and use. All-electric and plug-in hybrid electric vehicles have zero tailpipe emissions, but electricity production may generate emissions. As the grid utilizes more renewable sources, EVs produce fewer lifecycle emissions (Alternative Fuels Data Center, 2023).

A study from the National Renewable Energy Lab (NREL) examining a high-electrification scenario shows that transportation electricity use could grow from the current 0.2% to 23% of total U.S. electricity demand by 2050 due to widespread charging. Therefore, the full emissions reduction potential of EVs can be harnessed through a shift to renewable sources in the electrical grid energy mix (Mai et al., 2018).

One study found that an EV that charges only in Washington state generates around 70% fewer emissions during its lifecycle than the same EV only charging in West Virginia. The difference in lifecycle emissions is due to Washington's electrical grid being almost 90% less carbon intensive than West Virginia's (MIT Energy Initiative, 2019).

A study of trucks and buses in Europe found that lifecycle emissions are 63% lower for electric tractor trailers than diesel and can be as much as 84% lower with an electrical grid powered solely by renewable energy (O'Connell et al., 2023).

Micromobility Charging

Electric micromobility (e-MM) systems, like electric scooters and e-bikes, have the potential to decrease urban CO_2 emissions from the transportation sector by lowering car use. If urban trips taken by bicycles and e-bikes increase from 7% to 23%, global urban transport emissions could decrease by 7% or 300 mega tons of CO_2 (ITDP, 2015).

EVS LOWER CARBON EMISSIONS REGARDLESS OF GRID SOURCE

EVs emit substantially less CO_2, no matter the mix of energy sources in the local grid. According to an analysis by Yale Climate Connections, the average emissions reduction in the U.S. is 66% when comparing a gasoline-powered crossover sports utility vehicle (SUV) to a similar electric SUV (Kirk, 2023).

In States with the cleanest electricity sources, driving an EV will reduce carbon emissions by around 90% compared with gasoline-fueled vehicles. In States that rely more heavily on coal for electricity generation, EVs still reduce carbon emissions by 30% or more (Kirk, 2023).

EVs have a lower carbon footprint due to their significantly higher energy efficiency compared with gasoline vehicles. EVs use approximately 90% of the energy from their battery and regenerative braking to propel the vehicle. In contrast, conventional gasoline vehicles only convert up to 25% of their energy into propulsion work (EPA, 2024).

Calculate the GHG emissions savings from electric and plug-in hybrid vehicles where you live or work:

- Alternative Fuels Data Center EV Calculator
- FuelEconomy.Gov Beyond Tailpipe Emissions Calculator

Smart Charging

Smart charging uses grid conditions to effect charging station availability and optimize energy demand from electric vehicles. One study found that utilizing this model of charging reduced emissions from energy generation by 31% (Jenn & Brown, 2021).

CO-BENEFITS

This section outlines the multiple co-benefits associated with the strategy, including safety benefits, local air quality improvements, and improved accessibility. Each co-benefit presents examples that demonstrate how the strategy enhances regional or community well-being while addressing emissions.

COST SAVINGS

EVs require less scheduled maintenance than vehicles with gas-powered engines as maintenance and repair on elements of the engine are not necessary. While other maintenance is necessary, EVs provide cost savings in the long-run (NHTSA, n.d.).

As of February 2024, the cost of owning (buying or leasing) and operating an EV is comparable to – and sometimes less than—the cost of owning and operating an internal combustion engine vehicle (J.D. Power, 2024).

Off-peak charging at home offers cost savings due to lower energy costs during off-peak times. The cost per-kilowatt hour may be 5 to 10 times higher for public charging than home charging for consumers. Public charging often offers less flexibility for timing due to the time required away from home, so it mostly occurs during the day when energy costs are typically higher (Kampshoff et al., 2022). Greater access to charging stations, through the installation of curbside and publicly accessible chargers in residential areas, improves flexibility and reduces the burden of daytime charging (Vega-Perkins et al., 2023).

Some workplaces and businesses offer free charging as an amenity to employees or customers, offering a cost savings opportunity for EV drivers (Alternative Fuels Data Center, n.d.).

> An analysis of EV ownership in Maine, Maryland, Vermont, and Virginia found that, during the lifetime of an EV, combined savings on fuel and maintenance may range from $27,000 to $44,000 in rural areas or $22,000 to $31,000 in urban areas (Lowell et al., 2020).

AIR QUALITY AND HEALTH

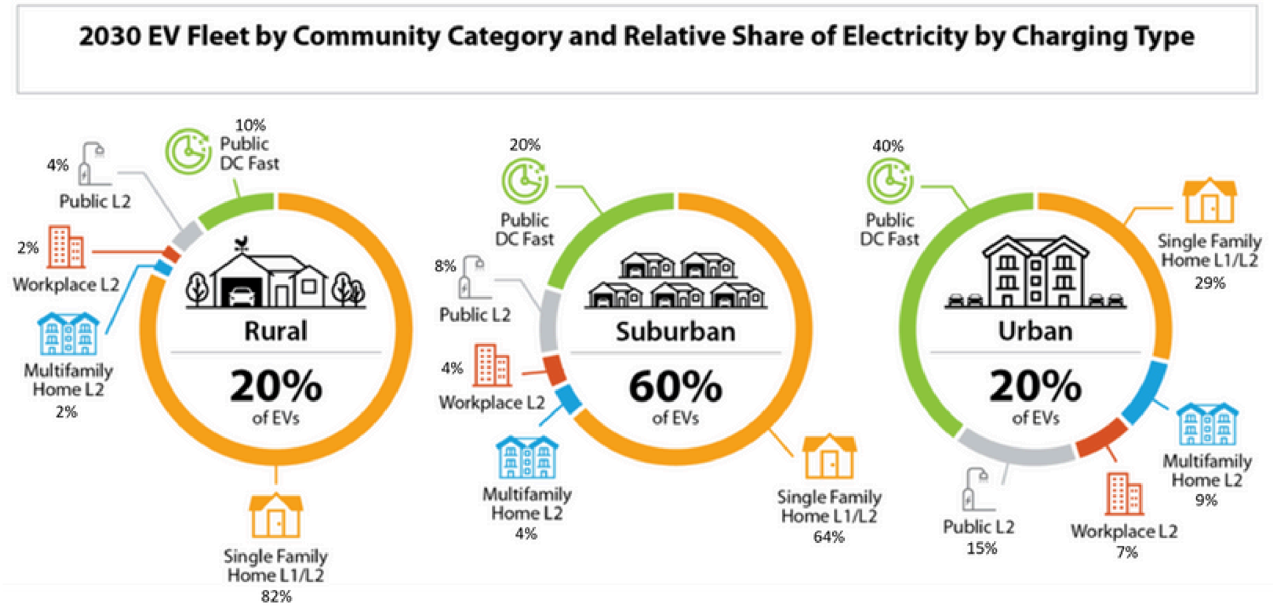
EVs produce no tailpipe emissions. Pollution from tailpipe emissions contribute to health inequities for communities, especially communities of color, which are disproportionately located near major roadways (American Lung Association, 2001).

ACCESSIBILITY AND EQUITY

Tax credits and incentives offered by federal and state governments reduce the cost of purchasing an EV (Ewing, 2023). Federal tax credits of up $7,500 on new EVs and $4,000 on used EVs are offered (Oak Ridge National Laboratory, 2023). Many states also offer rebate or tax incentive programs for EVs. For example, Massachusetts offers rebates for the purchase or lease of a new or used battery electric or fuel-cell electric vehicle, and the rebate increases for low-income residents (Massachusetts Department of Energy Resources, n.d.).

Curbside and publicly installed charging stations provide access for EV drivers without access to overnight charging at home. These individuals are more likely to be from low-income households, renters, and lack access to off-street parking.

The charging network needs for EVs are different depending on whether EV owners live in rural, suburban, or urban areas. In urban areas, there are particular gaps in charging accessibility for multifamily homes. Electricity from public DC fast chargers would be most utilized in urban areas, while in rural and suburban areas, Level 1 and Level 2 chargers in single family homes are expected to meet the majority of electricity needs (Wood et al., 2023).



Source: NREL, 2023; DOE, 2024

RURAL COMMUNITIES

Rural residents drive more and spend more on gasoline and maintenance than urban drivers. EV adoption can help rural residents save money and reduce their environmental impact, given that transportation modes other than driving are often limited (USDOT, 2023).

> Rural parts of the U.S. are home to 20% of Americans and about 70% of the country's lane miles. Expanding EV charging access can save rural residents over $2,000 per year, assuming average mileage of 15,000 (USDOT, 2023).

Two forms of planning may be implemented in rural communities. Community-level planning focuses on the needs of residents or visitors of a neighborhood, town, or region for everyday charging needs and longer stops. Corridor-level planning focuses on the needs of drivers or freight operators traveling along a regional, interregional, or interstate route for a quick charge during longer trips (USDOT, 2023).

The U.S. DOT offers resources to guide rural communities on EV adoption and charger installation. For example, the following links provide additional information on the benefits of electrification for rural individuals and communities.

- Individual Benefits of Rural Vehicle Electrification
- Community Benefits of Rural Vehicle Electrification

Deploying EV chargers can attract EV drivers as an amenity to destinations in rural communities. Drivers may pair charging time with a visit to local attractions or businesses, bringing in revenue to the local community (USDOT, 2023).

ECONOMIC GROWTH

Based on projected rates of EV adoption, it has been predicted that over 150,000 new jobs will be created, ranging from certified electricians to software developers (Bui et al., 2024).

In 2021, the energy sector employed more than 7.8 million Americans, with jobs related to net-zero emissions making up about 40% of this total. Between 2020 and 2021, jobs in carbon-reducing motor vehicles and related technologies grew by 25% collectively (DOE, 2022).

RESILIENCE AND ADAPTATION

EVs can serve as a mobile power source. Bi-directional charging allows EVs to both receive energy from and discharge it to the grid as well as deliver energy to buildings. This capability is particularly useful during natural disasters (Federal Energy Management Program, n.d.).

COST CONSIDERATIONS

COST OF IMPLEMENTATION

The cost of implementation varies based on the scale and scope of the project and the type of charger installed, as shown in the table below. These costs do not include grid upgrades which may be necessary to support charging equipment.

For a charging station with six 150 kW charging ports, fixed station costs are estimated to be $103,000 and five-year maintenance costs are estimated to be $75,000 total (Chu et al., 2023).

Charger Hardware	Unit Cost per Port	Installation Cost per Port
Level 1 residential	$0[a]	$100-$1,000
Level 2 residential	$400-$1,200	$500-$1,700
Level 2 commercial	$2,200-$4,600	$2,200-$6,000
DC 50 kW	$23,000	$12,000
DC 150 kW	$69,000	$36,000
DC 250 kW	$75,500	$60,000
DC 350 kW	$82,000	$84,000
DC 500 kW	$117,143	$120,000
DC 1,000 kW	$234,286	$240,000
DC 1,500 kW	$351,429	$360,000

[a] Level 1 chargers are often included with an EV.

Cost estimates for different charger types (Source: NREL, 2023; NREL, 2024)

COST EFFECTIVENESS

Research demonstrates that constructing an EV charging network is a cost-effective strategy to support further adoption of EVs by reducing range anxiety and other limiting factors (Li et al., 2017).

Vehicle Grid Integration (VGI) reduces the need for grid upgrades by harnessing the flexibility of EVs to improve the efficiency of EVs as a piece of the grid. Therefore, VGI aims to place downward pressure on electricity rates to lower the cost of EV ownership and improve cost effectiveness. Read more about VGI here.

Implementing smart charging at EV charging stations has the potential to reduce the cost of shifting to 100% renewable energy by $30 billion in 25 years (Jenn & Brown, 2021).

FUNDING OPPORTUNITIES

FHWA has compiled other funding and financing sources for EVs and EV charging infrastructure, including what types of activities are eligible. See this FHWA resource here.

FHWA's **Charging and Fueling Infrastructure (CFI) Discretionary Grant Program** supports publicly accessible electric vehicle charging infrastructure as well as hydrogen, propane, and natural gas fueling infrastructure along designated Alternative Fuel Corridors or in other publicly accessible locations. 50 % of CFI funding must be used for a community grant program where priority is given to projects that expand access to EV charging and alternative fueling infrastructure within rural areas, low- and moderate-income neighborhoods, and communities with a low ratio of private parking spaces.

FHWA's **National Electric Vehicle Infrastructure Formula Program (NEVI)** provides funding to States to strategically deploy electric vehicle (EV) charging infrastructure and supports establishing an interconnected network to facilitate data collection, access, and reliability. Program funds can be used for the acquisition, installation, network connection, operation, and maintenance of EV charging stations, as well as EV charging station data sharing.

FHWA's **Congestion Management and Air Quality Improvement (CMAQ) Program** provides a flexible funding source to State and local governments for transportation projects and programs to help meet the requirements of the Clean Air Act. Funding is available for transportation projects that reduce congestion and improve air quality such as EV charging infrastructure.

DOE's **State Energy Program** (SEP) provides annual formula funding and technical assistance to all 50 States, five territories, and the District of Columbia to enhance energy security, advance State-led energy initiatives, and increase energy affordability. States may choose to allocate funds for transportation projects, including planning and projects that promote access to EVs and buildout of EV charging infrastructure.

FHWA's **Carbon Reduction Program (CRP)** provides formula funding for states to develop carbon reduction strategies and for projects to reduce transportation carbon dioxide emissions, including traffic management, public transportation, pedestrian facilities, alternative fuels, and port electrification.

The Joint Office of Energy and Transportation maintains a list of EV and energy funding opportunities for tribal nations. Users can filter the list by project type, such as light-duty vehicle charging, micromobility, energy, and more. A selection of the opportunities is listed below, and the full list can be accessed here.

Rebuilding American Infrastructure with Sustainability and Equity: Provides a unique opportunity for the U.S. Department of Transportation to invest in road, rail, transit, and port projects that achieve national objectives. Starting in FY21, this program has substantially increased focus on zero emission vehicle infrastructure, including EV charging.

Federal Lands Access Program: Aims to improve transportation to and within Federal lands by improving transportation facilities that provide access to, are adjacent to, or are located within Federal lands.

Nationally Significant Federal Lands and Tribal Projects Program - Tribal High Priority Projects Program: Provides funding for the construction, reconstruction, and rehabilitation of nationally-significant projects within, adjacent to, or accessing Federal and tribal lands. This program provides an opportunity to address significant challenges across the nation for transportation facilities that serve Federal and tribal lands.

Rural Placemaking Innovation Challenge: Helps rural communities create plans to enhance capacity for broadband access; preserve cultural and historic structures; and support the development of transportation, housing, and recreational spaces.

COMPLEMENTARY STRATEGIES

Replacing heavy-duty diesel-powered vehicles, including school and transit buses, with EVs reduces emissions and improves air quality, providing health benefits, such as reduced asthma risk for children.

Efficiency improvements for zero emission vehicles, such as light weighting (using lighter materials to achieve better fuel efficiency and accommodate additional advanced emission control systems, safety devices, and electronic systems) can significantly reduce electricity demand. These improvements have the added benefit of reducing energy-related operational costs, which could incentivize their adoption.

By strategically locating charging stations at carshare hubs and incorporating electric vehicles into carshare fleets, municipalities can expand access to clean transportation alternatives for residents. This can be particularly useful for rural decarbonization as alternative transportation options, such as public transit, may be limited.

Zoning codes can significantly influence the availability and accessibility of electric vehicle charging infrastructure. Zoning codes can include provisions that require or incentivize the installation of electric vehicle charging stations in new developments, parking facilities, and public spaces. Zoning can also dictate the placement and design of electric vehicle charging infrastructure and can streamline the permitting process for installing the infrastructure.

View All Strategies

CASE STUDIES

STREETLIGHT CHARGER INSTALLATION - LOS ANGELES, CA

As of February 2024, Los Angeles has installed 735 light-pole EV chargers with an estimated potential of 3,000-4,000 more based on the current light system. The installation of these chargers required minimal changes, with the director of Los Angeles; Bureau of Street Lighting noting, “At most we’ll have to changes fuses or do structural retrofits so that we can attach it.” Los Angeles is also focused on installing these chargers in underserved neighborhoods.

LEVEL 2 CHARGING STATIONS INSTALLATION AT FRITO-LAY DISTRIBUTION CENTERS

35
Level 2 Chargers

63,000
Gallons of Fuel Reduced

1 M
Pounds of GHGs reduced

Frito-Lay installed 35 private Level 2 chargers at distribution centers in New York. These charging stations charge their 35 electric trucks overnight to allow for zero-emissions deliveries the following day. The company predicts that the electric trucks will decrease fuel use by 63,000 gallons which will reduce greenhouse gas emissions by more than 1 million pounds every year.

NEVI STATE DEPLOYMENT - HAWAII:

The National Electric Vehicle Infrastructure Program (NEVI) allocates funding to states to strategically deploy EV charging infrastructure and establish an interconnected network to facilitate data collection, access, and reliability. Under the program, states set a plan for fund use, often with a focus on disadvantaged communities and resiliency, and then provide annual progress updates. In February 2024, the first EV charging station in Hawaii funded by NEVI opened on the island of Maui. The station includes four 150-kW DC fast chargers and is located at the Kahului Park and Ride on Kuihelani Highway.

Source: Joint Office of Energy and Transportation, 2024

IMPLEMENTING ELECTRIC VEHICLE CHARGING INFRASTRUCTURE: **WHAT TO READ NEXT**

The DOE & DOT's Joint Office of Energy and Transportation provides toolkits, guidance, data, and more to support communities in deploying EV charging infrastructure.

DOT provides comprehensive guidance available on how to plan for and implement EV charging infrastructure, including the following Toolkits:

- EV Infrastructure Project Planning Checklist and Toolkit
- Charging Forward: A Toolkit for Planning and Funding Urban Electric Mobility Infrastructure

The International Energy Conservation Code recommends that infrastructure required for the installation of EV charging stations, such as sufficient energy capacity and wiring, be included in all new residential and commercial construction. Building codes that include EV-Ready provisions reduce the burden on homeowners and business owners to later install EV charging infrastructure (Thibault, 2023).

Read more about zoning for EV charging infrastructure here.

While level 2 chargers can take up to 10 hours to recharge a vehicle, Direct Current fast chargers (DCFC) reach 80% charge in 20 minutes to an hour. DCFCs are more suitable for short charges than overnight charging, suggesting they may be most useful in non-residential areas and areas with few chargers (Telang, 2021). However, DCFCs require more power, meaning that DCFC installation may be cost prohibitive in rural areas without adequate power access, including 3-phase power. Level 2 chargers are most widely used and require less power than DCFCs.

Read more about the characteristics of different chargers here.

RESOURCES

GENERAL RESOURCES

Joint Office of Energy and Transportation: The website provides access to numerous resources including a section on data and tools and provides technical assistance for states, communities, tribes, and more.

EV Charging Infrastructure Blueprint: This website includes a how-to-guide, outline of key activities, and comprehensive list of resources to help governments begin installing EV charging infrastructure.

National Electric Vehicle Infrastructure (NEVI) Program: The NEVI website includes formula program guidance, State NEVI Deployment Plans, and other EV-related resources.

Charging and Fueling Infrastructure (CFI) Discretionary Grant Program: The CFI website provides information for applicants and grant recipients.

DOE Electric Vehicle Charging Infrastructure Map: This map shows the locations of electric vehicle chargers and corridors across the United States. The results can be filtered by charger type, location, access, and fuel type.

Electric Vehicle Infrastructure Training Program (EVITP), Find A Contractor: This webpage provides a list of EVITP certified installers for each state.

Sustainable Energy Action Committee, Planning and Zoning for Electric Vehicle Deployment: This guide provides recommendations on how to navigate zoning changes for EV chargers with case text from cities across the country.

DOE Plug-In Electric Vehicle Handbook for Public Charging Station Hosts: This handbook provides guidance regarding location selection, installation, maintenance, and more for public charging station hosts.

DOE Plug-In Electric Vehicle Handbook for Fleet Managers: This handbook details how to shift a flight to electric or hybrid vehicles with specific guidance on charging infrastructure.

National Electric Vehicle Infrastructure Standards and Requirements: This final rule establishes regulations setting minimum standards and requirements for projects funded under the NEVI Formula Program and projects for the construction of publicly accessible EV chargers under certain statutory authorities, including any EV charging infrastructure project funded with Federal funds that is treated as a project on a Federal-aid highway.

Guidebook for Deploying Zero-Emission Transit Buses: This resource provides transit agencies with information on current best practices for ZE bus deployments and lessons learned from previous deployments, industry experts, and available industry resources.

Step-by-Step Guide for School Bus Electrification: This guide identifies common steps for electrifying a school bus fleet and how to center equity in that process.

State Level

California Governor's Office of Business and Economic Development, Electric Vehicle Charging Station Permitting Guidebook: While this guidebook is aimed towards California permitting, it outlines steps to meet the electrification needs that all agencies may find useful.

TOOLKITS AND MODELING APPROACHES

Joint Office of Energy and Transportation, Public Electric Vehicle Charging Infrastructure Playbook: This interactive playbook leads readers through the process of an EV charging infrastructure project.

DOT Charging Forward: A Toolkit for Planning and Funding Urban Electric Mobility Infrastructure: This toolkit outlines strategies to successfully implement projects supporting electric mobility in urban environments, including EV charging infrastructure.

DOT EV Infrastructure Project Planning Checklist and Toolkit: The checklist provides guidance on how to plan and implement an EV project.

DOE Electric Vehicle Infrastructure Projection Tool (EVI-Pro) Lite: This projection tool allows users to view the amount of charging ports needed to support the provided demand or the estimated electric load from the fleet in a given area.

FHWA and Oregon DOT, Alternative Fuel Toolkit: This toolkit provides information and additional resources to learn about, create a plan for, and implement alternative fuel strategies.

FHWA Congestion Mitigation and Air Quality Improvement (CMAQ) Emissions Calculator – Electric Vehicles and EV Charging Infrastructure: This tool estimates the emissions reduction from constructing EV charging infrastructure or purchasing an EV.

RURAL SPECIFIC

DOT Charging Forward: A Toolkit for Planning and Funding Rural Electric Mobility Infrastructure: This toolkit outlines strategies to successfully implement projects supporting electric mobility in rural environments, including EV charging infrastructure.

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