Community Charging: Emerging Multifamily, Curbside, and Multimodal Practices

February 2024


DOE/EE-2806 2024

Acknowledgments

This work was funded by the Joint Office of Energy and Transportation and was authored by staff from the U.S. Department of Transportation Volpe Center: Alexander K. Epstein, Kirby Ledvina, Scott Lian, Juwon Drake, Stephen Costa, and Kim Washington.

Special thanks to reviewers from the Joint Office of Energy and Transportation (Debs Schrimmer, Alex Schroeder, and Kerry Skemp); the U.S. Department of Energy Vehicle Technologies Office (Alycia Gilde and Mike Laughlin); the National Renewable Energy Laboratory (Wendy Dafoe); and the Department of Housing and Urban Development (Michael Freedberg). Additional thanks to subject matter experts who provided input: Rene Wetzel, Mickael Garreau, and Salil Upadhyay (Ubitricity); Clinton Tsurui (City of Los Angeles); Mark Simon and Susan McSherry (New York City); Michael Salisbury (City and County of Denver) and Peter Krahenbuhl (Colorado CarShare); Richard Chamberlain and Tim Evans (3ti); Ted Bohn (Argonne National Laboratory); Rodney McGee and Willett Kempton (University of Delaware); Shannon Dulaney, Tiya Gordon, and Nathan King (itselectric); Cory Bullis (FLO); Haley Robinson and Tobias Lescht (Revel); and Mohammad Akhlaghi and Madison Shah (Plugzio).

DOE/EE-2806 2024

Letter from the Executive Director

The transportation sector creates nearly one-third of all greenhouse gas emissions in the United States. To respond to the climate crisis and create a more equitable and prosperous future, the Biden-Harris administration is making bold investments to decarbonize the transportation sector and transition to net-zero emissions economywide by 2050.

Completely transforming our transportation network and economy is an ambitious vision that can't be accomplished by any single entity. Here at the Joint Office of Energy and Transportation, it's our role to bring everyone together to deliver a convenient, efficient, and clean transportation network for all Americans.

Since the start of the Biden-Harris administration, electric vehicle (EV) sales have quadrupled to more than 1.4 million in 2023, private investment in transportation electrification has expanded, and the number of publicly available charging ports has grown by 70%. There are now more than 170,000 public EV chargers nationwide, putting the United States ahead of schedule to reach the administration's goal of a national network of 500,000 public EV charging ports by 2030. Other forms of electrified mobility, including lightweight, affordable devices such as e-bikes, also continue to grow in popularity.

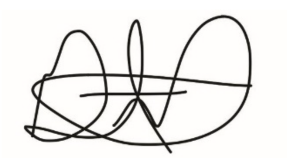
But when it comes to charging, the saying "there's no place like home" holds true, with an estimated 80% of EV charging happening at home. As the Joint Office continues to advance the nation's transition to clean transportation, we are committed to addressing major barriers and ensuring equitable access to charging. Our goal is to make it possible for everyone to ride and drive electric, whether you live in an older single-family home, a rental property, or a multiunit dwelling like an apartment complex or condominium. While early waves of EV drivers have often had access to charging at home in a garage, the National Renewable Energy Laboratory estimates that as many as 25% of EV drivers won't be able to charge at home in the future.

Achieving this vision will require amendments and updates to local building codes and parking regulations. At the same time, to fully address the gap in home charging, we need to install more public charging facilities. As a former transportation commissioner of two major cities, I have firsthand experience with creating new transportation options and infrastructure in the public right-of-way. When my teams introduced the Capital Bikeshare program in Washington, D.C., and the Divvy bike-share system in Chicago, we took a neighborhood-level approach that sought to seamlessly fit these stations into the urban fabric. The networks were designed to meaningfully improve people's lives and help them get from A to B. I strongly believe these lessons can be extended to deploying community e-mobility charging. The task at hand will also require thinking creatively about how we can move quickly, decrease installation costs, respond to grid demands, and support not just privately owned cars but a broader range of electrified mobility options and services as well.

Every community has its own needs and local considerations, so this white paper does not propose a one-size-fits-all approach. Rather, it aims to document the emerging charging solutions—primarily in the public right-of-way—and the technical and policy considerations that can make it easier for individuals who can't charge at home to choose electric mobility. We also draw on best practices from cities across Europe that have many more years of experience in scaling electric mobility.

The United States is rapidly catching up. I continue to be impressed by the private sector's proliferation of new charging technologies and operational models, and by the public sector's ability to pilot these ideas, learn quickly, and adjust policies for scalability. When we work together, we can harness this innovation to make our communities more sustainable and to more equitably extend the benefits of zero-emission mobility.

Ride on,



Gabriel Klein
Executive Director, Joint Office of Energy and Transportation

Table of Acronyms

Acronym	Term
AC	alternating current
BYOC	bring your own cord (or cable)
CaaS	charging as a service
CARES	Coronavirus Aid, Relief, and Economic Security
CASR	Denver Office of Climate Action, Sustainability, and Resiliency
DCFC	direct current fast charging
DHA	Denver Housing Authority
DOTI	Denver Department of Transportation and Infrastructure
EV	electric vehicle
EVSE	electric vehicle supply equipment
kW	kilowatt
LA	Los Angeles
LABSL	Los Angeles Bureau of Street Lighting
NACS	North American Charging Standard
NYC DOT	New York City Department of Transportation
O&M	operations and maintenance
QR	quick response
RFID	radio-frequency identification
UK	United Kingdom
V	volt
W	watt

Executive Summary

Approximately 44 million households—31% of the United States total—are in multifamily housing. This encompasses both rented and owned homes in apartment buildings, condominiums, townhouses, and mixed-use developments. Regardless of where they live, nearly one-third of Americans do not drive. As U.S. transportation is electrified, it will be imperative to support car-free or car-light households, as well as residents living in multifamily and rental housing, with tailored solutions.

This white paper coalesces emerging practices and technologies that can bring the benefits of electric mobility infrastructure to residents in multifamily housing, residents dependent on curbside or on-street parking, and those without access to privately owned electric vehicles (EVs).

Multifamily residents who own an EV face unique charging barriers due to their lack of private off-street parking and their wide range of parking arrangements. This paper identifies the role of policy and technical solutions in alleviating common charging barriers for multifamily residents, including barriers posed by limited payment options, insufficient grid infrastructure, high capital costs, and long installation timelines.

Emerging technical solutions to these challenges include contactless and other innovative payment methods, smart outlets and panels, battery-enabled fast charging, and mobile and containerized charging options. For curbside charging, pole-mounted chargers as well as developments in “peer-to-peer” and “bring-your-own-cord” charging can decrease capital, operations, and maintenance costs by tapping into existing electrical infrastructure and enabling simpler charger designs. Finally, mobility hubs that co-locate transit services, bike sharing, car sharing, ride-hailing, private parking, or other mobility services can reduce construction and installation costs while providing residents greater flexibility to access the right mode of transportation for each trip.

Selected case studies developed for this paper illustrate curbside and multimodal solutions that serve multifamily residents, residents without private parking, and residents who do not own cars:

- In Colorado, the City and County of Denver partnered with a nonprofit car-sharing organization and the local housing authority to bring electric carshare vehicles to low- and medium-income multifamily public housing properties.

- In California, the Los Angeles Bureau of Street Lighting transitioned its streetlights to more efficient light bulbs, freeing up excess power for lamppost-based EV charging stations at approximately 600 locations as of fall 2023.

- In New York, the City of New York launched a curbside charging pilot program with 100 charging ports at 35 locations, collectively providing nearly 50,000 charging sessions across 7,200 unique users by the end of 2022.

- Looking beyond the United States, several pilots and large-scale charger deployments across European cities offer potential models for car and micromobility public charging.

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1 Overview

This white paper coalesces emerging practices and technologies that can bring the benefits of electric mobility infrastructure to residents in multifamily housing, residents dependent on curbside or on-street parking, and those without access to privately owned electric vehicles (EVs). Intended as a resource for public officials, policymakers, multifamily property owner-operators, vehicle owners, transit and micromobility operators, and utilities, this document includes information on installing private on-site EV chargers, as well as expanding publicly accessible charging facilities. Selected case studies illustrate common EV charging challenges and electrification opportunities for public charging networks in urban contexts.

Inclusion in this white paper or the referenced case studies does not constitute endorsement or recommendation by the U.S. government, Department of Energy, or Department of Transportation of the linked resources or their content. The Joint Office of Energy and Transportation does not exercise any control over the content on these sites. Potential funding sources for charging have different requirements, and this document is not intended to define eligibility under any one program. Those considering applying for a funding source should contact the applicable funder for requirements.

1.1 What Is Electric Mobility?

Electric mobility (or e-mobility) includes light-, medium-, and heavy-duty EVs, micromobility devices such as e-bikes and scooters, and electric transit vehicles. The electric light-duty vehicle market is evolving rapidly, with models available in a range of vehicle types, from motorcycles, compact cars, and sedans to SUVs and pickup trucks. Some EVs operate solely on batteries, while others are plug-in hybrid models with both an electric motor and an internal combustion engine.

Electric mobility offers numerous benefits to individual EV owners and businesses, including lower operating and maintenance costs, increasing ability to charge vehicles in a variety of locations, and the ability to provide a backup power source for home or personal use during power outages. Declining prices, tax credits, and expanding selection are also creating more options for EV buyers.

A subset of electric mobility is micromobility, defined by the Federal Highway Administration as any small, low-speed, electric-powered transportation device, including electric-assisted bicycles (e-bikes) and electric scooters (e-scooters).[1] The lower cost of e-bikes and e-scooters compared to EVs and internal combustion vehicles. With e-bike sales outpacing EV sales in the United States in 2021 and 2022,[2]

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[1] https://www.fhwa.dot.gov/livability/fact_sheets/mm_fact_sheet.cfm
[2] https://www.forbes.com/sites/rinatorchinsky/2023/10/04/welcome-to-the-year-of-the-e-bike/?sh=5a7584df53fe

e-micromobility is providing increased and more equitable access to jobs and services. Electric micromobility can also mitigate traffic congestion, crowded transit, and limited parking space. At scale, it can yield a host of other benefits, especially for underserved communities where dependency on personal automobiles may be especially burdensome. Globally, 280 million electric mopeds, scooters, motorcycles, and three-wheelers are already reducing oil demand by 1%.[3]

1.2 Why Addressing Multifamily and Rental Housing Matters

Approximately 31% of all U.S. households (44 million households) are rented and owned multifamily housing, including apartment buildings, condominiums, townhouses, and mixed-use developments.[4] Additionally, 63% of all rental households in the United States (about 28 million households) are multifamily.[5] Even though the median rental household income in 2020 was 45% lower than the income of an average owning household, 76% of multifamily renters still have at least one privately owned vehicle.[6,7] Policies and programs designed to provide charging opportunities for renters and residents of multifamily housing must consider ways to do so that are financially equitable when compared to charging opportunities available to those who own their homes or are residents of single-family homes with charging.

Compared to those in single-family housing, multifamily housing residents face unique challenges in realizing the benefits of driving electric vehicles. While approximately 80% of EV charging in the United States takes place at home, less than 5% of this home charging occurs in multifamily buildings.[8] Just as space limitations in multifamily housing can limit on-site charging options for EVs, building accessibility can limit on-site charging for e-bikes and scooters.[9] Even when there is a building elevator or other accessible path to a resident's home, building policies[10] stemming from battery fire safety concerns[11] can still prevent e-bike and scooter owners from safely and securely storing and charging on-site, an urgent issue that calls for additional study and best practices. As American transportation is electrified, it will be imperative to support the populations that live in multifamily and rental housing by tailoring solutions to the

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[3] https://www.nytimes.com/2023/12/09/business/energy-environment/two-three-wheel-electric-vehicles.html; https://bnef.turtl.co/story/evo-2022/page/2/1
[4] https://www.nahb.org/other/consumer-resources/types-of-home-construction/Multifamily
[5] https://www.nmhc.org/research-insight/quick-facts-figures/quick-facts-resident-demographics/household-characteristics/
[6] https://www.nmhc.org/research-insight/quick-facts-figures/quick-facts-resident-demographics/household-incomes/
[7] https://www.nmhc.org/research-insight/quick-facts-figures/quick-facts-resident-demographics/household-characteristics/
[8] https://forthmobility.org/storage/app/media/Reports/MUD%20EVS%20Paper.pdf
[9] Stairs are a particular challenge for e-bike access, intersecting with users who may also be less able to lift heavy weights: https://youtu.be/TAxgu83k_yo?si=QxWItd6WMIJCiTuJ&t=349, https://www.reddit.com/r/RadPowerBikes/comments/o53cpp/the_stair_problem/, https://www.bikeforums.net/fifty-plus-50/1111502-carrying-e-bike-up-stairs.html, and https://www.berkeleyparentsnetwork.org/questions/how-can-i-get-electric-bike-flight-stairs
[10] For example: https://www.curbed.com/2023/08/e-bikes-reddit-tips-building-bans.html and https://electrek.co/2023/08/27/why-college-campuses-are-starting-to-ban-electric-bikes/
[11] In 2022 in New York City, there were more than 200 fires caused by lithium-ion batteries, killing six people and injuring nearly 150. https://www.nyc.gov/office-of-the-mayor/news/195-23/mayor-adams-plan-combat-lithium-ion-battery-fires-promote-safe-electric-micromobility#/0

individual neighborhood or building. Electric public transit, electric ride-hailing and car-sharing services, and shared micromobility can provide universal e-mobility benefits, regardless of wealth and housing type. Key examples are highlighted throughout this paper.

1.3 Defining the Challenges

Primary barriers facing multifamily residents with EVs include the location and availability of chargers, especially when dedicated on-site parking is not available. Such “charging deserts” are often found in underserved, lower-income, or otherwise disadvantaged areas associated with lower EV ownership rates and with renting as the predominant housing arrangement.[12] Permitting or parking policies administered by local governments can further present barriers to curbside charging. Parking policies may eliminate curbside sites from consideration (for example, due to short time limits), and so could regulatory uncertainty over future curb use, which may discourage investment.

At the building level, the responsibility for providing charging to multifamily residents falls on a willing property owner or manager to help procure or otherwise facilitate charging. Alternatively, the local jurisdiction may have purview over an adjacent public right-of-way and can elect to locate publicly accessible charging nearby. Both avenues require investment, time, and available nearby electrical capacity, and will likely depend on residents’ initiative.

Other barriers include payment logistics. Low-income EV owners or carshare members may not have access to a personal credit card, which is typically required to facilitate payments for EV charging or carshare use.

1.4 How Parking Arrangements Affect Charging Solutions

In contrast to residents of detached, single-family housing, who often have private off-street parking, a wide range of parking situations apply to multifamily residents who own an EV. These arrangements may be determined by the multifamily property owner, the homeowner association, local zoning, the local transportation agency or fire department, and other stakeholders. While electrifying parking spaces is a decarbonization strategy, so is eliminating minimum parking requirements. The latter measure can support walkable communities and housing affordability and advance the convenience strategy of the National Blueprint for Transportation Decarbonization.[13] It is important that local planners consider future charging needs in this broader context.

Both the location and duration of multifamily residents’ parking become important factors for successfully bringing electrification benefits to those residents. It can therefore be helpful to segment the universe of multifamily parking arrangement possibilities into five basic types, as depicted in Figure 1. Discussed further in the next

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[12] https://www.washingtonpost.com/business/2021/12/09/charging-deserts-evs/
[13] https://www.energy.gov/sites/default/files/2023-01/the-us-national-blueprint-for-transportation-decarbonization.pdf

section, each parking arrangement calls for a distinct set of considerations in installing, operating, and accessing charging infrastructure. In this schema, “curbside charging” refers to long-dwell residential charging on a public right of way, typically providing between 4 kilowatts (kW) and 19 kW for EV charging or up to 1 kW for e-micromobility.

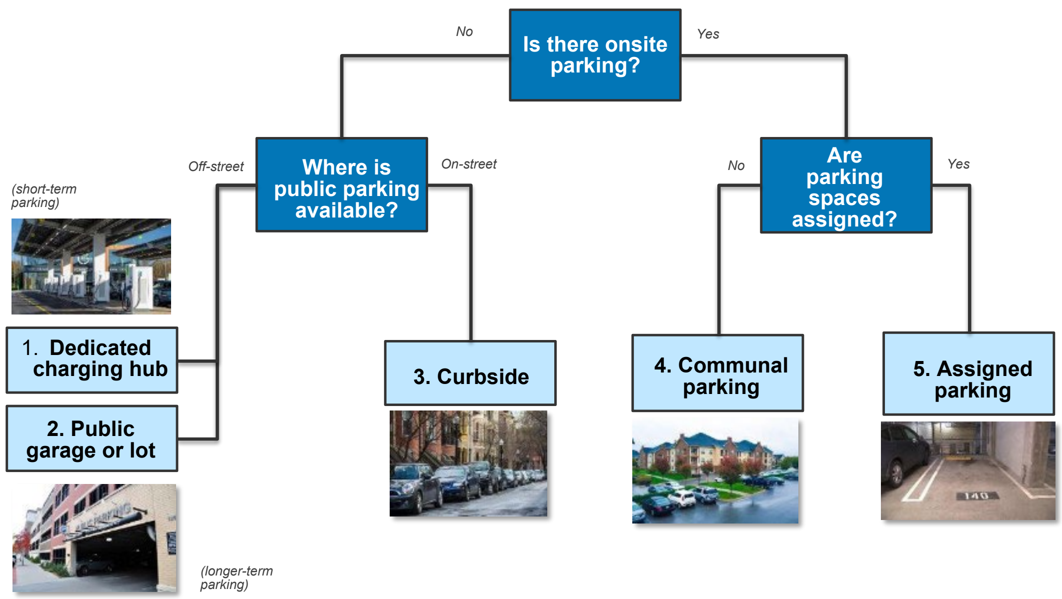

Figure 1. Types of parking available to multifamily residents. Source: U.S. DOT Volpe Center

2 Market Scan of Solutions by Parking Arrangement

The type of parking available, and how that parking is used, are important factors in identifying the EV charging solutions that can serve a particular set of multifamily residents. This section first introduces select considerations for most EV charging projects and then describes approaches to implementation for each of the five parking arrangements previously introduced. The parking arrangements comprise off-site options (dedicated charging hubs, public garage or lot, and curbside) and on-site options (communal and assigned parking). Appendix B includes summary tables with relevant technologies, considerations, and examples.

2.1 General Considerations

Several considerations apply to all charging projects that serve residents who park overnight. Initial planning efforts should ensure early and frequent outreach to the community, including building residents, along with the local utility provider. Early outreach to the local electric utility is also critical to ensure the timely completion of a project.

2.1.1 Site Assessments

Site assessments of potential charging station locations should include:

- Estimating the number of vehicles that will be charged simultaneously to determine overall power requirements
- Determining available power capacity or identifying required utility upgrades
- Ensuring charging infrastructure is not installed in a floodplain and including resilience in the design if flooding is possible
- Assessing intended locations of chargers and their distance to electrical service panels
- Testing cellular or wireless signal strength to support networked EV supply equipment (EVSE)
- Considering multimodal connections and other power needs, such as charging for e-bikes and ride-hailing or car-sharing services.

Local conditions and requirements may also impact charging management options; the ability to "future-proof" installations to accommodate projected demand; "make ready" requirements for infrastructure; the potential for integration with on-site energy generation such as solar panels or on-site battery storage; and accessibility requirements and design options.[14]

When identifying required utility upgrades, it is important to consider all possible power needs at a location. "Digging once" to build sufficient grid connection points for all current and future installations can save costs for projects involving trenching or grid upgrades.[15] For example, each installation presents an opportunity to co-locate current and future EV charging stations, as well as other transportation and public uses, as seen in the City of Vancouver's Public Realm Electrification Program (see callout box). Colocation of charging for multiple modes can provide residents with meaningful mobility connections to complete trips while EVs charge or to make trips outside of private vehicles altogether.

For shared e-bike or scooter systems, not all docks or hubs necessarily need to be electrified. While the percentage may vary, a major operator recently reported that electrifying 20% to 30% of locations in a shared e-bike or scooter system could adequately serve charging needs.[16]

[14] The U.S. Access Board notes potential accessibility considerations for various EVSE deployments: https://www.access-board.gov/ta/tad/ev/#on-street-ev-charging-stations-design
[15] A new "Dig Once" initiative for broadband, transportation, and electrification projects is referenced in the Biden-Harris administration's "Action Plan for Accelerating Infrastructure." https://www.whitehouse.gov/wp-content/uploads/2022/10/Action-Plan-for-Accelerating-Infrastructure-October-2022.pdf
[16] https://www.lyft.com/rev/posts/electrifying-just-20-of-bike-share-stations-could-drastically-reduce

Vancouver “Digs Once” for E-Bike Share, EV Charging, Food Trucks

Shared e-bike or scooter charging only requires 120-volt (V) connections, with individual plugs typically drawing 100–250 watts (W). At its new Rainbow Park, Vancouver, Canada, recently installed an electrified bike-share station in coordination with direct current fast charging (DCFC) and extended-dwell EV charging stations. Part of the city’s Public Realm Electrification Program,[17] the installation coincided with a complete streets project that constructed an all-ages-and-abilities protected bikeway.[18] The program strategy includes “digging once” to build a network of conduit and power connections for use by the film industry, food trucks, special events, and e-bike and EV charging stations.

Source: Google Maps Street View

Source: City of Vancouver

[17] https://vancouver.ca/green-vancouver/public-realm-electrification-program.aspx
[18] https://www.youtube.com/watch?v=VDVbuN0TTrU

2.1.2 Operations and Maintenance

Operational considerations include physical security (e.g., fences, access gates), policies for use, and payment methods, as well as roles, responsibilities, and potential insurance requirements. It is important to start a multifamily charging project by determining who will own, insure, and be responsible for operations and maintenance (O&M) of the charging equipment and for how long. To help support O&M cost considerations in charging projects, ongoing study may be needed, including on the following two aspects.

2.1.2.1 Methods of Payment

Most installations will require a method of payment, which can include quick-response (QR) code-enabled, pay-as-you-go solutions, or built-in credit card or radio-frequency identification (RFID) readers along with user-information displays and screens. Pending updates to industry standards are expected to provide for SecureID and may open the possibility of "Plug & Charge" payment systems,[19] potentially eliminating the need for integrated payment processing systems at each charger.

2.1.2.2 Technical Support

Charging site owners should also prepare policies or procedures for requesting maintenance or technical support. Typically, a network provider will offer limited-duration warranties as well as remote monitoring and data access solutions. Since network connectivity and internal charger issues (hardware- or software-related) are leading causes of downtime, site owners need to have access to technical and service support.

QR code scanning for pay-as-you-go EV charging. Source: Ubitricity

[19] https://electrek.co/2023/07/12/sae-wants-to-certify-nacs-by-end-of-year-and-fix-plug-charge-too/

Networked and Non-Networked Chargers

Options for payment and maintenance vary depending on whether a charging station is "networked." Networked charging stations can be remotely accessed and are part of an infrastructure system of connected chargers. Non-networked charging stations are stand-alone units that are not accessible remotely and do not support payment for charging. They can be used free of charge, or the vehicle owner is billed for associated electric consumption if the circuit is metered or managed at the panel.

2.2 Dedicated Charging Hubs

Dedicated charging hubs can serve multifamily residents by providing a reliable location for DCFC away from home. In addition, dedicated hubs can support electric rideshare vehicles, which can in turn serve multifamily residents. The dedicated hub approach is comparable to how gas stations provide quick refueling for conventional vehicles. Multimodal charging hubs also integrate other transportation modes and services in publicly accessible locations.[20]

Dedicated charging hubs can be implemented in multiple ways. A fast-charging hub provides quick charging in a short duration, with potentially high hub utilization and throughput. Alternatively, a hub could provide fast charging or Level 2 charging while providing on-site services such as restrooms and a convenience store to accommodate drivers charging over a medium duration. Similarly, a destination-oriented charging hub is a lower-powered, dedicated charging area strategically located near existing attractions such as a shopping district or community center. Finally, a pop-up charging hub with battery integration can provide a semipermanent or portable fast-charging solution for special events or in grid-limited locations.

With a dedicated charging hub, site owners or managers determine policies and fees for use, which could vary by charging level and user type. Hub managers may set different fees for drivers charging rideshare or commercial vehicles versus personal vehicles, electric bikes, or scooters. Hubs could also provide drivers a choice of charging power (e.g., lower-power default speeds with a faster, higher-powered "boost" available at a premium).

[20] https://driveelectric.gov/ride

Schematic of a mobility hub. Source: [Metropolitan Transportation Commission]

Multimodal hubs combine EV charging with a hierarchy of other mobility options to help people access the right mobility tool for the right trip. Anchor services like frequent transit service (e.g., a subway or bus rapid transit station), personal and shared e-bikes or scooters, and other private feeder services serve as the most proximate options at mobility hubs. Recent mobility hub examples include electric bike-share stations in Chicago and Vancouver that are located at public transit stations along with EV chargers; electric scooter and bike-share charging co-located with EV chargers, carshare vehicles, and transit in Pittsburgh (see Section 3.2.6); and a growing list of other sites. Most are hardwired, though a recent bike-share station design has used solar panels to support the modest power demands of charging shared e-bikes.[21]

2.3 Public Garage or Lot

EV chargers at a public parking garage or lot can serve both the public and nearby multifamily residents without on-site parking. Public surface lots and parking garages present distinct design considerations. For example, a parking garage may be conducive to wall- or ceiling-mounted charging equipment as well as top-level, exposed solar canopies with battery integration to partially support charging with a renewable energy source. Mobile or valet services can also bring charging equipment to a parked vehicle or efficiently relocate a vehicle to a separate EV charging area.

Exterior signage indicating that the garage or lot offers EV charging and prominently located EV parking spaces—e.g., near the entrance to the garage or lot, or near the staircase or elevators—can increase visibility and use of the charging service. Signage should clearly label parking spaces reserved for EVs only.

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[21] https://www.we-cycle.org/news/worlds-first-network-of-solar-powered-e-bike-charging-stations/

2.4 Curbside (On-Street Parking)

Curbside, or on-street, parking also serves multifamily residents without access to dedicated off-street parking. Lower-power overnight curbside charging may be a viable approach for medium- to high-density residential neighborhoods where residents park on-street. In this scenario, pole-mounted chargers can be a relatively low-cost and quick-to-deploy solution that taps into existing curbside power sources, such as utility poles and streetlights, to provide low-power charging. In areas with higher traffic, visibility, and turnover such as commercial centers, communities can install metered or hourly curbside charging that can charge a vehicle at higher power over a shorter duration. Mobile or valet charging services can provide charging at public, curbside locations without civil construction or even dedicated parking spots for charging.

A unique challenge and point of contention for curbside charging is that there are many competing uses for curb space, such as loading zones, outdoor dining, and bus and bike lanes.[22] Because installing permanent EV chargers can lock in curb use, city and town leaders should carefully consider how different uses for the curb interact in the present and in the desired future. For example, if a bike lane is added between a parking lane for vehicles and a curb with chargers, drivers will extend charging cords across the bike lane to reach their vehicle, creating a safety hazard. In addition, Americans with Disabilities Act concerns must be addressed, because as with any other street furniture design and placement, ensuring accessibility to curbside chargers is a critical part of planning.[23] Beyond curb allocation and accessibility, local regulations dictate site selection, ease of permitting, and policies affecting charger utilization. To ensure public works and emergency personnel have access to the curb, city officials may wish to set or update parking policies to account for charger use. Policies may include "no parking" times to allow for street cleaning, snow plowing, utility pole maintenance, or emergency access.

2.5 Communal Parking

A multifamily building with communal parking can provide off-street charging stations shared by building residents. Communal parking allows flexibility to cluster chargers near an existing electrical source, and a few chargers can serve multiple residents. Resident surveys are important to determine an estimated number of charging ports to install and to inform site layout.

In addition, an entity such as the property manager or condominium board must specify the payment plans and policies for use. For example, residents could pay a subscription-based fee for access, pay a per-kilowatt-hour cost at the time of use, or receive EV charging as a building amenity, like a pool or exercise room. Clearly stated dwell-time restrictions on cars that have finished charging and services such as text

[22] https://www.ite.org/technical-resources/topics/complete-streets/curbside-management-resources/
[23] For example, U.S. Access Board design recommendations: https://www.access-board.gov/tad/ev/#ev-charging-stations-in-the-public-right-of-way

alerts notifying drivers when charging is complete can help ensure sufficient access to chargers for all EV-driving residents.

As with public parking, design and technology options can vary with surface lots and parking garages. In both cases, clear signage is important for distinguishing EV charging locations, especially any parking spaces reserved for EVs only. Mobile or valet charging can also serve EV drivers in a multifamily building with on-site parking but little or no on-site charging infrastructure. It is important to determine whether the EVSE in the communal parking areas will be dedicated solely to residents or also available to visitors (and potentially the general public), as this will have implications for EVSE availability for residents.

2.6 Assigned Parking

With assigned parking, individual rental or condominium units have parking spaces reserved for their vehicle(s) only. Access to a private charger without charging or dwell-time restrictions allows for slower, low-level charging, including overnight.

The specific roles and responsibilities for installing and operating EV chargers at assigned parking spots can vary greatly across multifamily buildings. At a condo building, residents own their individual housing unit and may also have assigned, deeded parking. In this case, each owner may be able to pay for the purchase, installation (including wiring and possibly metering), and upkeep of their own EV charger. Still, condo owners may need to seek approval from their condo board. Renters may have less flexibility and less incentive to install a personal charger.

Alternatively, the multifamily property manager, condo board, or property owner may wish to install EV chargers at multiple parking spaces and offer those private spots to residents via a lottery, waiting list, or for purchase at a premium. In this case, it is important to clearly specify roles for O&M and insurance.

Beyond the unique considerations above, use cases are similar for assigned and communal on-site parking, with options for surface lots, parking garages, and for charging solutions that do not require civil construction: mobile or valet charging.

3 Evolving Solutions

Solutions to help multifamily housing residents benefit from e-mobility include a range of established policy levers, as well as emerging technical strategies. This document focuses principally on the identification of charging barriers and technical solutions that can help extend e-mobility benefits to both owners and users.

3.1 State and Local Policies and Codes

Split incentives between rental property owners and renters, as well as shared responsibility in owned multifamily housing, can pose barriers to establishing on-site EV charging. Many states and local governments have added EV provisions to their building codes, local ordinances, and zoning requirements, which can help residents in new construction to access charging. The EV Charging for Residential and Commercial Energy Codes Technical Brief published by Pacific Northwest National Laboratory offers examples.[24] Implementers of multifamily housing charging can take advantage of opportunities to work with municipal departments on including such codes for new buildings. For residents of existing multifamily housing stock, policies such as right-to-charge laws, which allow EV owners to install charging stations in their homes, often expand general access.[25]

State and Local Resources

- **Electric Vehicle Charging Access for Renters: A Guide to Questions, Strategies, and Possible Next Steps,** *Urban Sustainability Directors Network,* https://s3.amazonaws.com/somervillema-live/s3fs-public/USDN_EVChargingAccess_UpdatedReport_Final11.18.20.pdf

- **Electric Vehicle Readiness Policy for New Developments,** *City of Boston,* https://www.boston.gov/sites/default/files/file/2020/03/EV%20Readiness%20Policy%20For%20New%20Developments%20%287%29.pdf

- **EV Building Codes Toolkit,** *Plug In America,* https://pluginamerica.org/policy/ev-charging-for-all/ev-building-codes-toolkit/

- **Policies to Promote Electric Vehicle Deployment***, International Energy Agency,* https://www.iea.org/reports/global-ev-outlook-2021/policies-to-promote-electric-vehicle-deployment

3.2 Emerging Technical Solutions

3.2.1 Payment Methods

Contactless payment methods used at EV chargers include QR scan app-enabled payments and RFID, or “tap-to-pay.” The latter is a preferred payment method for newer, public-facing EVSE, with some charging stations further equipped with credit card readers and information screens. Regardless of the approach, all payment systems in federally funded EVSE must meet accessibility requirements, including providing an automated toll-free phone number or a short message system option.[26]

However, nearly all current payment systems require the customer to have access to a credit card. Lower-income users are less likely to have a credit card and may not be able to equitably access such public EVSE. Recent efforts in California have helped to deploy one potential solution, a universal Zero-Emission Vehicle (equity charging card that is a “preloaded and reloadable contactless debit card designed to make it easier for

[24] https://www.energycodes.gov/sites/default/files/2021-07/TechBrief_EV_Charging_July2021.pdf
[25] https://www.nescaum.org/documents/ev-right-to-charge.pdf
[26] https://www.ecfr.gov/current/title-23/chapter-I/subchapter-G/part-680

priority communities to access and use mobility subsidies."[27] The project has demonstrated successes and challenges that may offer lessons learned for similar programs elsewhere. Simultaneously addressing language accessibility in charger payment systems would further advance equity.

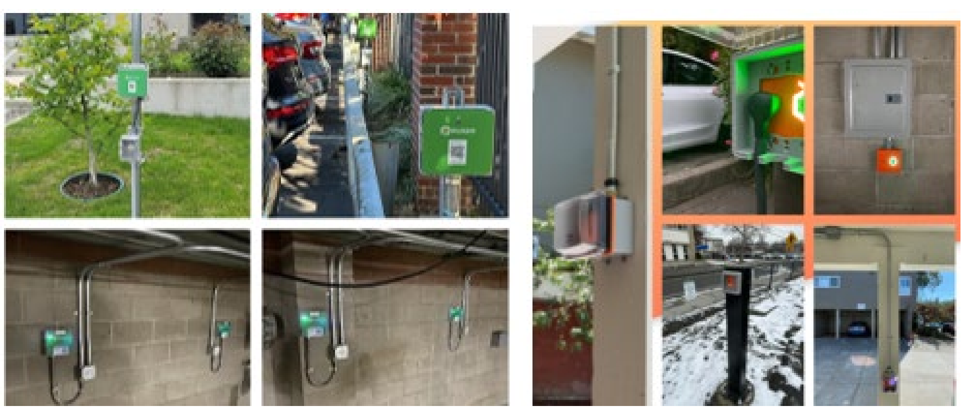
Pending updates to SAE standards aim to incorporate SecureID protocols, enabling another potential solution: "Plug & Charge" payment services where no payment processor or phone application is needed to facilitate payments.[28]

Another payment option for multifamily housing developments is billing a flat fee to residents for charging. This is often considered in conjunction with adoption of lower-cost, non-networked EVSE to reduce costs to residents. This may address some issues with the need for credit cards to access networked EVSE. A downside is the limited ability of these systems to manage charging and provide information to users on charge status and charge faults.

3.2.2 Smart Outlets and Panels

Smart outlets can enable metering of 120-V or 240-V outlets for consumption and payments while allowing use of the car's included charging cable, in essence turning any existing household outlet into a metered charging port. Smart outlets cost less than Level 2 chargers, enabling a property to deploy nearly twice as many outlets compared to traditional Level 2 EVSE for the same level of investment.

Smart outlets work best in parking garages or underground parking areas where the outlets themselves are likely to remain clean and protected from the elements. Outdoor installations may feature housing around the outlet. Smart outlets can be deployed alongside traditional Level 2 EVSE and can also supply power for charging e-bikes or other resident needs.



Example smart outlet implementations. Source: Plugzio, Orange Outlet.

Smart panels monitor and meter the electricity use of a particular circuit using hardware located at the panel rather than at the charge port or outlet. Smart panels can also

[27] https://www.calitp.org/assets/Cal-ITP.Universal.Equity.Zero.Emission.Vehicle.Charging.Card.Report.pdf
[28] https://electrek.co/2023/07/12/sae-wants-to-certify-nacs-by-end-of-year-and-fix-plug-charge-too/

integrate with heating, ventilation, and air conditioning or laundry systems to manage overall electrical demand at a multifamily property.

3.2.3 Battery-Enabled Fast Charging

Battery-enabled fast chargers incorporate integrated energy storage to provide fast charging while minimizing demand spikes, reducing infrastructure cost requirements, and reducing or eliminating long utility lead times. Some battery-enabled fast-charging solutions have integrated management services to reduce costs (either by reducing peak demand or providing grid services) and can provide property owners backup power in the event of a power outage.

3.2.4 Mobile and Containerized Solutions

Mobile and containerized solutions include batteries, switchgear, power electronics, fans, and other elements mounted to a shared platform that can be moved natively when mounted in a vehicle or hauled by truck. Solutions may incorporate energy generation via solar panels, lighting, and security cameras for user safety, and they may provide for a selection of Level 2 or DCFC ports based on user needs. The primary benefit of mobile or containerized solutions is their ability to bring charging services to the user at a pre-existing parking lot and be operational within a short time by minimizing trenching and other civil construction costs. Some solutions may not require a power connection at all.

Figure 6. Mobile and containerized charging solutions: Beam Arc (left) and Papilio3 in the UK (right). Source: Beam, 3ti.

Mobile charging solutions use battery energy storage and are charged before they can provide service to an EV. Mobile units can be mounted inside a vehicle (van or truck and trailer) that can be driven to a garage or lot to be charged,[29] or they can take the form of smaller charger units on wheels[30] that can be brought from a central location in a parking garage or underground parking area to a user's car. Many mobile or containerized technology providers offer their solutions under a "Charging-as-a-Service" (CaaS) model where the charging network provider is responsible for the capital

[29] https://www.prnewswire.com/news-releases/sparkcharges-mobile-dc-fast-charging-service-joins-courials-charging-valet-service-to-deliver-on-demand-electric-vehicle-charging-for-customers-in-california-301901990.html
[30] https://www.heliox-energy.com/us-products/mobile-dc-50-kw

expenditures and deployment.[31] Under a CaaS model, the charging rate paid by the user includes a fee paid to the network provider. Mobile charging solutions potentially create a need for a building or garage attendant to take responsibility for moving the unit as needed. The time to recharge the mobile unit also needs to be addressed, as this time can be considerable.

3.2.5 Innovations in Curbside Charging

Figure 7. Utility-mounted curbside charger in Newcastle, Australia. Source: Ausgrid

3.2.5.1 Streetlights and Utility Poles

Powering EV chargers—usually at curbside sites—from existing, powered infrastructure such as streetlights or utility poles can significantly reduce or eliminate civil construction costs and lead times. Where available power permits, this approach, as profiled in the Los Angeles (LA) and Ubitricity case studies later in the report, provides a typically lower-power connection for extended-dwell charging. The image here shows the first installation in a broader program that aims to deliver up to 30,000 pole-mounted EV chargers in Australia by 2029.[32]

3.2.5.2 Bring Your Own Cord

In the bring-your-own-cord (BYOC) or socket charging approach, the vehicle owner provides their own charging cord (also known as a carry-along cord, detachable cord, or consumer cord) to connect the EV to a powered outlet. The cord is supplied by the charging network provider, the vehicle manufacturer, or a third-party retailer.

Charging stations following a BYOC approach can be 15 to 50 times cheaper per port to install,[33] depending on location. The approach may similarly decrease O&M costs through simpler charger designs and by eliminating wear-, theft-, or vandalism-prone

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31 https://www.sparkcharge.io/pages/roadie-portable
32 https://www.ausgrid.com.au/About-Us/News/Pole-mounted-EV-charger
33 From industry interviews: approximately $2,500 to $5,000 for Ubitricity curbside BYOC and $8,000 to $9,000 for Its Electric curbside BYOC in New York City, as compared to $130K for tethered curbside chargers in New York City.

components, including the cord and connector. Some automakers already supply cords.[34] The cost of one to the consumer can range from $90 to $120.[35]

BYOC is commonly deployed internationally but has not been deployed widely in the United States, where tethered charging stations secured an early foothold. Tethered stations provide potentially more convenient charging and have been the default domestic deployment approach.

Under pending updates to SAE Standard J3068, the commonly deployed universal EV power supply socket (see item B in Figure 2) will be brought into North American standards (see box), enabling access to a standardized, universal EV power supply form factor that may simplify the deployment of BYOC charging in the United States.

SAE J3400 North American Charging Standard and SAE J3068 Updates

SAE's J3400 North American Charging Standard (NACS) goes beyond standardizing the vehicle connector. It revises alternating current (AC) charging, aligning voltage levels with the North American 480-V, three-phase, commercial grid power (of which 277 V is one phase). NACS supports up to 277 V, whereas Level 2 charging operates between 208 V and 240 V, often requiring transformers in commercial locations to "step down" grid voltage levels for charging use.[36]

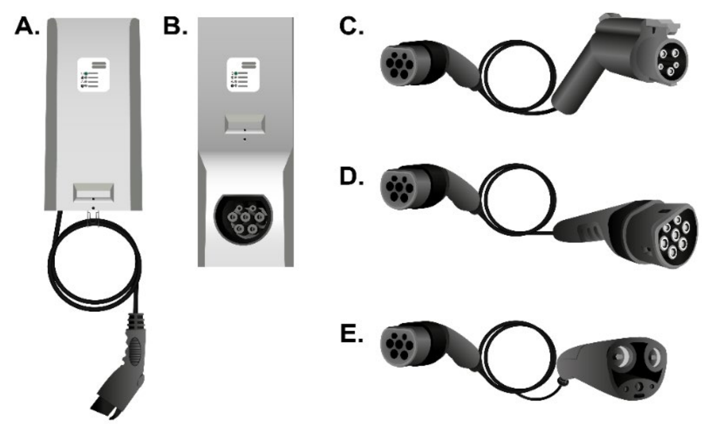


Figure 2. Examples of charging stations and cables.

A. *Example U.S. charging station with the cable and connector permanently attached. B. Charging station with the universal EV outlet. Images C, D, and E illustrate portable charging cables that all plug into the universal EV outlet and have connectors for different U.S. EVs. Source: Willett Kempton, University of Delaware*

By eliminating transformer requirements, which can represent up to 30% of typical parking lot Level 2 installation cost, and by increasing power transfer efficiency by about 1% (since 277-V installations allow for 33% more power transfer through the cable, compared to common 208-V installations) the new standard could reduce costs and increase efficiency for on-site (at larger buildings) and off-site AC charging stations.

SAE is also making updates to J3068. As discussed briefly in Section 3.2.5.2 , the update includes a new for North America standardized, universal EV power supply outlet, or "universal EV outlet," the same outlet that is used in Africa, the European Union, and China. The update

[34] https://electrek.co/2019/10/02/review-rating-oems-ev-charging-cords-tesla-audi-get-as-gm-jaguar-fail/
[35] Interview with It's Electric, July 6, 2023.
[36] Per Volpe interviews with Rodney McGee (SAE) and Willett Kempton (University of Delaware).

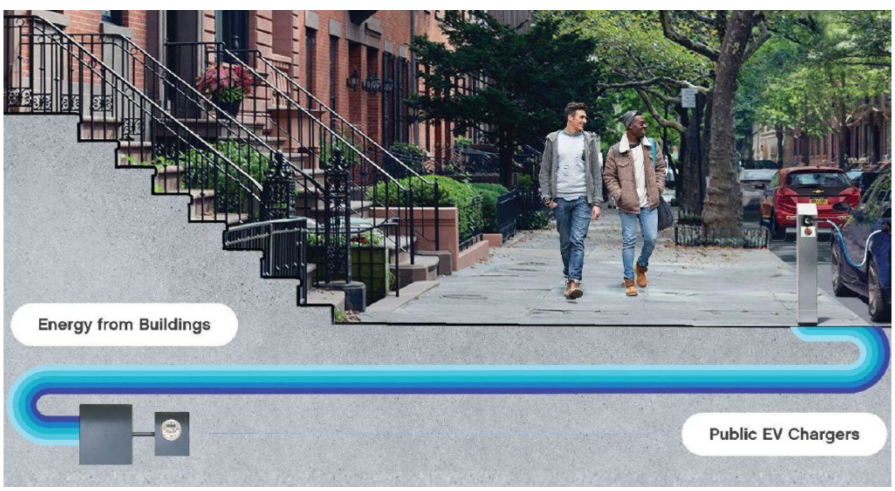
also includes new communication protocols to enable SecureID, which in turn enables payment processing or Plug & Charge functionality, removing barriers to payments and supporting potential future vehicle-to-grid applications.

The combination of J3400 and J3068 could enable both secure identification of the vehicle and varying charge levels suitable for different vehicle types. A universal EV outlet would be capable of supporting light-duty vehicles, as well as medium- and heavy-duty vehicles, using identical AC EVSE hardware. Single-phase power could supply 6.2 to 19.2 kW for light-duty vehicle charging, while three-phase power could supply up to 52 kW for medium- and heavy-duty vehicle charging from the universal EV outlet combined with vehicle-specific cords. Up to 100 kW could be provided with an integrated cable, providing AC charging power levels suitable for larger vehicles and commercial fleets.

The universal EV outlet could eliminate the need for cable management systems and vehicle-specific adapters for various vehicle connectors in the market, as well as reduce failure points and damages from theft or vandalism—all while facilitating universal maintenance (parts and diagnostics) across disparate charging networks, offering more seamless V2G functionality and enabling more transparent metering.

3.2.5.3 Peer-to-Peer

An emerging business model for extended-dwell residential charging is a peer-to-peer arrangement. Like the Airbnb business model for short-term lodging, peer-to-peer charging powers a curbside EV charging station using a 240-V connection from a building fronting the curb. The arrangement can offer building owners or residents a passive income stream and, if regulations permit, can potentially circumvent long utility permitting lead times by taking advantage of existing excess capacity behind building meters. This approach is compatible with BYOC, as it eliminates the need to decide on the vehicle connector offered.



Peer-to-peer charging can take advantage of excess electrical capacity behind building meters to bypass utility approval lead times and costs. Source: itselectric

3.2.6 Innovations in Multimodal Mobility

3.2.6.1 Mobility Hubs

Mobility hubs co-locate mobility services and multimodal options, providing efficient access to the right mobility tool for the right trip. Frequent transit service often serves as the hub anchor, while personal and shared electric micromobility serve as the most proximate options, followed by car sharing, ride-hailing, and finally private EV charging parking (see hierarchy in Figure 3).[37]

Schenley Plaza mobility hub in Pittsburgh, Pennsylvania, leveraging no-trench connections to city-owned lampposts for electric bike-share and scooter stations, according to email correspondence with the Pittsburgh Department of Mobility and Infrastructure. Source: Google Maps Street View

[37] https://mtc.ca.gov/sites/default/files/MTC%20Mobility%20Hub%20Implementation%20Playbook_4-30-21.pdf

Given the high cost of trenching, mobility hubs are a way to maximize the benefit of digging once, supplying power for a range of uses and users. This approach can be seen in the City of Pittsburgh, where the Department of Mobility and Infrastructure has worked to co-locate scooter stations, bike-share stations, and carshare locations. At Schenley Plaza, the city has installed an electric bike-share station on one side of the intersection and an electric scooter station on the other, each powered by an adjacent lamppost. The stations are coordinated with a Zipcar carshare space on the same block and a high-frequency bus transit stop.

The City of Pittsburgh has found that it can quickly permit connections to poles owned by the city, whereas connections to utility-owned poles must go through a lengthier and more expensive utility review process. Currently, the mobility hubs are connected above ground to city-owned poles, which has reduced installation costs but may introduce long-term maintenance or accessibility issues.

There appears to be an opportunity and need to evaluate the potential trade-offs of different power connection solutions to best scale mobility hubs across cities in the United States.

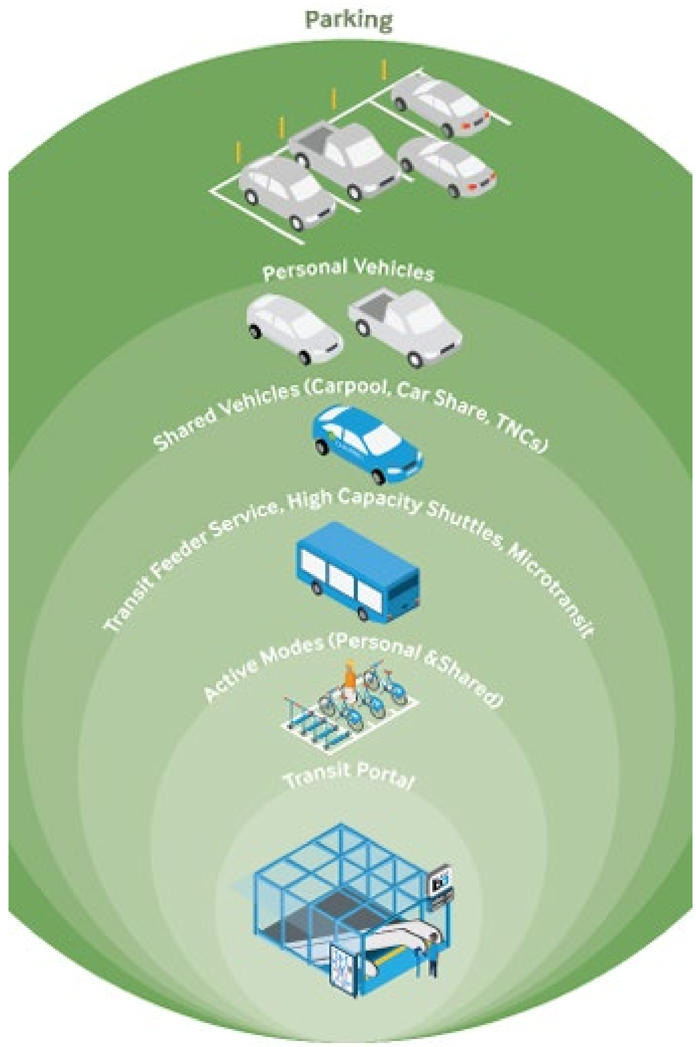


Figure 3. Hierarchy of mobility hub services
Source: Metropolitan Transportation Commission

3.3 Matching Technical Solutions to Challenges

The following table summarizes the solutions in Section 3.2 and maps them to the principal challenges they can address. Some of the solutions can be combined; for example, a battery-enabled fast charger or a peer-to-peer charger may be combined with BYOC, and universal payment cards may be combined with most of the other solutions.

Solution Type	Description and Siting	Barriers Addressed
Unbanked/Universal Payment Methods	Introduces a universal EV charging equity card, a preloaded and reloadable card to facilitate payments at public charging networks ✓ On- or off-site	Low-income EV owners or carshare members who lack personal credit cards Foreign travelers without domestic credit cards
Smart Outlets and Panels	Enables metering of 120-V or 240-V outlets for user payment, turning existing household outlets into shared charging ports for EVs or e-micromobility ✓ On- or off-site	Decreases capital and O&M costs Enables metering of individual parking spaces Circumvents long utility lead time
Battery-Enabled Fast Charging	Integrates energy storage to provide fast charging while minimizing grid power needs ✓ On- or off-site	Possible in grid-limited areas Circumvents long utility lead time
Mobile and Containerized Solutions	Packages the charger and onboard energy storage or generation into a portable system that can either connect to the grid or operate off-grid ✓ On- or off-site	Possible in grid-limited areas Decreases installation costs and timeline
Streetlight & Utility Pole Charging	Mounting and powering EVSE from existing, powered infrastructure such as streetlights or utility poles ✓ Typically off-site	Reduces civil construction requirements Provides a power source connection to a building-agnostic power source
Bring Your Own Cord	Presents a socket into which the EV user plugs in their own charging cable, similar to plugging in a phone or other device ✓ On- or off-site	Decreases capital and O&M costs Decreases installation costs and timeline

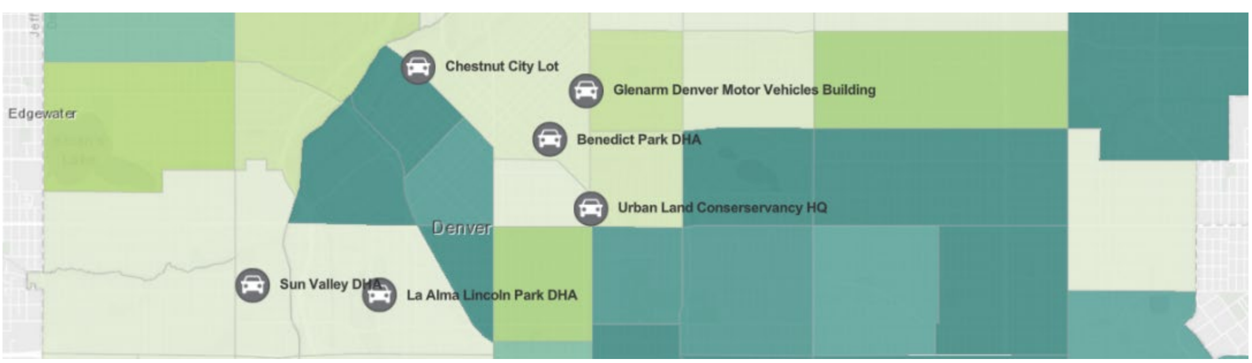
Solution Type	Description and Siting	Barriers Addressed
Peer-to-Peer	Leverages excess capacity behind the meter of a building fronting a street to power an EV charger ✓ Typically off-site	Circumvents long utility lead time
Mobility Hub	Co-locates mobility services for efficiency and multimodal options, providing the right e-mobility tool for the right trip ✓ Typically off-site	Reduces trenching, installation, and permitting by digging once; supports non-EV-owning users with a wider range of mobility options such as e-bikes, e-scooters, and transit

4 Case Studies: Multifamily, Curbside, and Multimodal Solutions

The following case studies serve to illustrate novel approaches to expand e-mobility charging and access in Denver, New York City, Los Angeles, and three European countries.

4.1 Multifamily and Multimodal: Colorado CarShare

Since 2019, the City and County of Denver has partnered with state nonprofit Colorado CarShare to operate a local EV car-sharing program. Currently, the program includes seven charging stations and electric carshare vehicles located at six distinct sites, including three low- and medium-income multifamily public housing properties, where car ownership is lower than in the general population.



Map of Denver EV car-sharing locations. Source: City and County of Denver

Most of the chargers are dual port, with one port reserved for Colorado CarShare vehicles and the second port available to the public free of charge. Denver offers subsidized carshare memberships to help low-income Denver residents access the car-sharing program.

4.1.1 Project Partners

Colorado CarShare

This nonprofit organization owns the vehicle and operates the car-sharing program. Currently active in Denver and Boulder with 60 carshare vehicles.

Denver Office of Climate Action, Sustainability, and Resiliency (CASR)

CASR is an office with the City and County of Denver that acquired funding for vehicles and chargers, led site identification, led community outreach, and provided subsidized CarShare memberships. The City and County of Denver also owns most of the project's EV chargers.

Denver Housing Authority (DHA)

DHA provides affordable housing to Denver residents. EV chargers are located on or next to three DHA multifamily sites.

Denver Department of Transportation and Infrastructure (DOTI)

DOTI, an office with the City and County of Denver, supported permitting for the EV chargers.

Other Site Hosts

Site hosts beyond DHA include the Urban Land Conservancy and other city locations.

4.1.2 Implementation

Dual-port Colorado CarShare charger located off-street in Sun Valley DHA accessory parking lot. Source: CASR [StoryMap]

Denver's car-sharing program began with a single city-funded pilot charging station in 2019. With federal funding through the Coronavirus Aid, Relief, and Economic Security (CARES) Act, the program expanded to seven stations located at six sites. Denver was able to streamline its internal processes to rapidly install chargers and maximize use of the available funding. CASR, with the City and County of Denver, applied for and received CARES Act funding in Summer 2020 and by the end of 2020 had installed the chargers and set up the contract with Colorado CarShare.

CASR-based charger siting is based in part on DOTI's Equity Index, which is a data-based measure communicating where Denver residents are most burdened by transportation inequities.[38] Both Denver and Colorado CarShare desired new shared EVs to be located near affordable housing, so they leveraged existing relationships with DHA, in one instance installing chargers during construction of a new DHA building to expedite the installation process and decrease installation costs. In total, three of the six sites are proximate to multifamily buildings within DHA's public housing portfolio. To use a carshare vehicle, Colorado CarShare members pay for the car rental and use, which has per-mile and per-hour components. Rates are currently the same for conventional and electric vehicles. Denver offers subsidized Colorado CarShare memberships to help low-income residents access the program.

All chargers are Level 2 (6.48 kW) and networked through ChargePoint with a mix of curbside and off-street locations. Most of the charging stations are dual-port chargers with one port dedicated to a Colorado CarShare vehicle and the second port available for free to the public. The City and County of Denver owns most of the chargers, but for the off-street locations, Denver provided funding to the site host to buy and install the chargers. The curbside installations cost around $12,000 to $15,000 per station. Costs were lower to install in off-street parking lots than on-street. CASR is working to deploy four more vehicles in 2023 but estimates that costs will be two to three times higher than in 2020 based on equipment cost increases. CASR is using financial incentives from the local utility to offset some of the costs.

4.1.3 Successes and Challenges

The table below summarizes the successes and challenges in implementing the carshare program, as communicated by interviewees at CASR and Colorado CarShare.

[38] https://denvermoveseveryone.com/wp-content/uploads/2023/04/2023_0426_DenverMovesEveryone2050_StrategicTransportationPlan_Opt2.pdf

Special thanks to Michael Salisbury (City and County of Denver) and Peter Krahenbuhl (Colorado CarShare) for sharing their time and expertise during the development of this case study.

Successes	• **Car-sharing impact.** The Colorado CarShare program improves mobility and displaces the need for private vehicles. Carshare members are more strategic in route planning, which enables collective emissions reductions as more individuals join car-sharing organizations.[39] • **Quick implementation.** The City and County of Denver fast-tracked its internal permitting and contracting processes to meet grant spending deadlines. • **Public ports.** Public ports have high utilization compared to private ports, as they can serve multiple vehicles per day. • **"Car Captains" program.** In exchange for car-sharing credit, on-site liaisons and member ambassadors help DHA residents reserve carshare vehicles, move and wash cars as needed, and generally demonstrate program buy-in.
Challenges	• **Varying utilization.** Utilization of the shared EVs ranged from 1.4% to 19% across sites in the first half of 2022. Factors contributing to higher utilization include the presence of community liaisons, property owner support, siting within a mixed-use neighborhood, and access by a mix of membership types. A "lesson learned" was to pre-engage communities for siting and familiarization. • **Trade-off between ease of installation and visibility.** CASR reported they may have chosen to install more stations in visible, on-street locations if time and money were less constrained. CASR and Colorado CarShare make up for low visibility with additional education and outreach. • **Technology barrier.** EVs are higher tech and less approachable for users than conventional vehicles. • **Maintenance.** (i) There is more vandalism and accidental damage to curbside chargers than to off-street chargers. (ii) Supply chain and labor constraints have posed a challenge in station upkeep. (iii) As the fleet but not the charging operator, Colorado CarShare needs to work through the City and County of Denver to resolve hardware and software issues with city-owned chargers.

4.2 Curbside: Los Angeles Streetlight Charging

Starting in 2009, the Los Angeles Bureau of Street Lighting (LABSL) transitioned streetlights to more efficient light bulbs, resulting in excess available power in the 223,000 streetlights LABSL owns and operates. In support of the mayor's "Sustainable

[39] Martin, E. and Shaheen, S. (2012). "Greenhouse Gas Emission Impacts of Carsharing in North America." *IEEE Transactions on Intelligent Transportation Systems* 12(4): 1074–1086, DOI:10.1109/TITS.2011.2158539

pLAn"[40] to increase EV adoption by 25% and add 100,000 new electric vehicles in the city by 2025, LABSL has used the excess available power to install lamppost-based EV charging infrastructure at approximately 600 locations (as of fall 2023).[41]

4.2.1 Project Partners

Los Angeles Bureau of Street Lighting

The LABSL, an agency housed in the Department of Public Works, designs, constructs, and maintains approximately 223,000 streetlights across the City of Los Angeles.

FLO, ChargePoint, and Shell Recharge

Hardware and software vendors FLO, ChargePoint, and Shell Recharge have supplied and operated the EV chargers mounted on LABSL-owned streetlights.

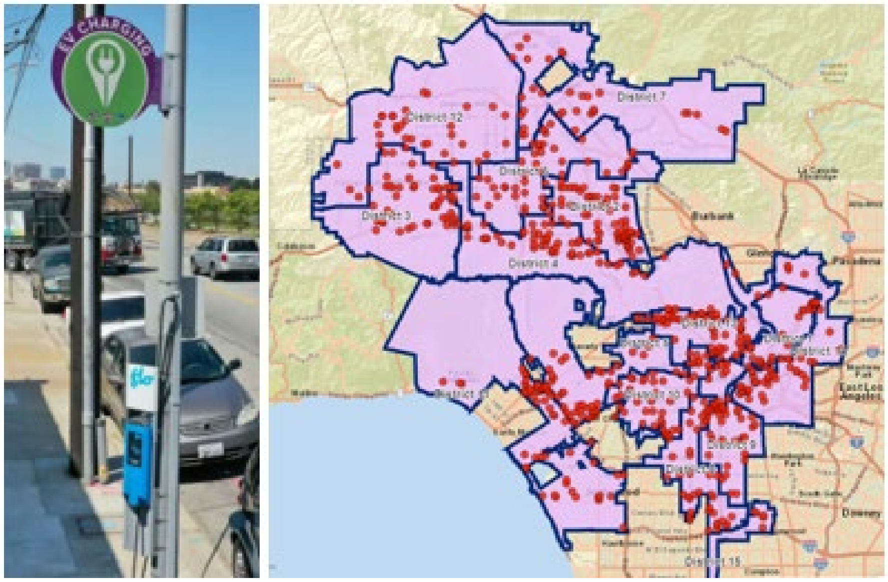
PlugShare

The program promotes the PlugShare app as an easy way for users to locate and reserve nearby EV charging sites.

4.2.2 Implementation

The rollout of EV chargers on LA streetlights has followed other applications of the street lighting infrastructure as a versatile electrified platform, such as pedestrian sensors, video cameras, and environmental sensors. No modifications to the streetlight architecture or power levels have been required for EV charging. The fact that the city owns the electric utility (whereas in many cities, streetlights are owned by a private electric utility) has streamlined the charger installations. Each streetlight carries 120 V on the pole but—unusually for North American cities—has 240 V underground, close to the service point where the chargers have been mounted. LABSL has used three software vendors (FLO, ChargePoint, and Shell Recharge), which charge customers by duration, ranging from $2 to $4 per hour.

[40] https://plan.lamayor.org/
[41] https://lalights.lacity.org/connected-infrastructure/ev_stations.html; phone interview with Clinton Tsurui (City of Los Angeles)



Curbside, streetlight-mounted Level 2 charger in LA (left). Map of charger locations (right). Source: [LA Bureau of Street Lighting]

Seventy-five chargers were first installed in 2020, and since then the rollout has continued at about 150 installations per year and increased to 180 installations beginning in 2023. The city can install about two per day with one crew.[42] Each installation costs between $5,000 and $8,000, and LABSL has an aspirational goal of reaching 500 to 1,000 annual installations to cover a large geographic area while servicing the largest percentage of the EV-driving community possible. Many of the charging sites are intentionally located near multifamily housing.

4.2.3 Successes and Challenges

The table below summarizes successes and challenges in implementing the streetlight EV charging program.

Successes	• **Widespread implementation.** The program has rolled out about 600 sites as of fall 2023. • **Quick to deploy and install.** Excess capacity on 240-V electrical service at each streetlight eliminates the need for trenching. • **Multiple vendors and station types.** The streetlight as an electrified platform is agnostic to the hardware and software installed on it.
Challenges	• **Vandalism.** Cord cutting, power theft, and screen smashing have been frequent issues. • **Competition with cell towers.** The transition to 5G cell towers, which consume significantly more power than 4G predecessors,

[42] https://www.route-fifty.com/infrastructure/2022/10/how-cities-are-deciding-where-electric-vehicle-chargers-should-go/378339/

has created competition for the excess electrical capacity in the streetlights and a need for additional coordination and planning.

- **Pricing structure.** Use of hourly instead of energy pricing has not been well received by plug-in hybrid owners, whose vehicles draw less power than battery electric vehicles.
- **Parking enforcement.** Ensuring that non-EV drivers do not park in designated EV charging spots is an ongoing challenge and requires interagency collaboration.

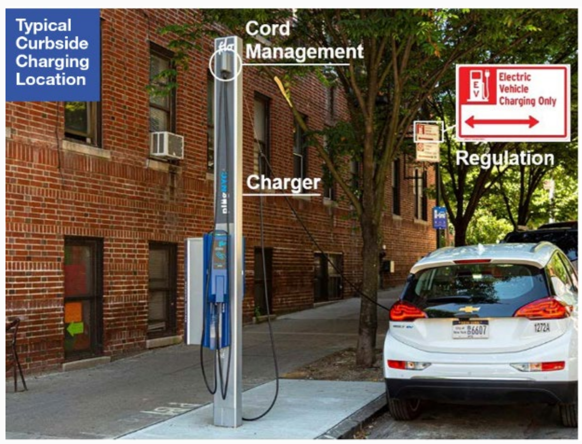
Examples of charger vandalism challenges. Power is redirected to a washing machine (left). A cut charging cable (right). Source: City of Los Angeles

Curbside Charging Pilot in New York City

In June 2021, the New York City Department of Transportation (NYC DOT) partnered with the local utility, Con Edison, to launch the city's first curbside charging pilot program. The program rolled out 100 Level 2 EV charging ports at 35 locations across all five boroughs. In operating the pilot, NYC DOT was responsible for siting guidelines, community outreach, curb regulation, and program evaluation. Con Edison led site engineering and construction; provided project funding; and selected the EV charging company FLO to provide the charging hardware, manage payment, and maintain the chargers.

By the end of 2022, the installed chargers had collectively provided nearly 50,000 charging sessions across 7,200 unique users, with a median charging session length of about 3 hours. The chargers had a resulting overall utilization rate (percent of time a charger was plugged into an EV) of 34%, with varying levels of utilization across sites. In addition, the stations had an uptime of 99.9%, as there were limited instances of vandalism during the pilot.

However, NYC DOT noted that a primary challenge in the first 18 months of the program included non-EVs blocking access to the curbside chargers, reducing access for users. NYC DOT and Con Edison have partnered with the New York City Police Department to educate the public and support the issuance of parking tickets to noncompliant vehicles.[43]



Typical curbside charging in New York. Source: NYC DOT Pilot Evaluation Report

[43] https://www.nyc.gov/html/dot/downloads/pdf/curbside-level-2-charging-pilot-evaluation-report.pdf

4.3 Multimodal and Curbside: Ubitricity Lamppost and Bollard Charging

Since 2008, Berlin-based Ubitricity has built and operated charging networks by retrofitting existing electrical street furniture in three countries, including:

- **United Kingdom (UK):** About 7,000 ports, the largest public charging network in the UK
- **Germany:** About 1,000 ports
- **France:** About 750 ports.

Ubitricity's chargers allow users to charge their EVs at designated charging points in public spaces, such as on-street parking spaces or in parking lots. A distinguishing feature of the chargers is their compact size, fitting either inside or on the side of a lamppost or bollard. The chargers also provide covered sockets for the charging cable, which the user supplies. This approach has reduced the need for costly and delay-prone infrastructure upgrades and made it faster and less expensive to deploy EV charging infrastructure in those urban areas.

Ubitricity bollard charging station in the UK. Source: Ubitricity

4.3.1 Project Partners

ubitricity
A Member of the Shell Group

Ubitricity

Ubitricity deployed lamppost charging point retrofit in three countries.

ebee SMART TECHNOLOGIES

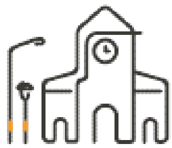
eBee Smart Technologies

eBee developed hardware for the German market.

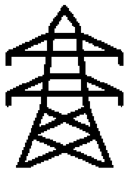
SIEMENS

Siemens

Siemens was the technology partner in the London market entry and rollout.



Towns/Councils
Municipalities manage on-street parking allocation and EV space assignment.



Utilities
Partnering utilities such as EDF Energy and ScottishPower supply renewable energy.

4.3.2 Implementation

In Europe, Ubitricity currently operates the largest lamppost-mounted public charging network. The company has produced a different version of the lamppost retrofit hardware for each country to comply with local standards. The UK and French versions integrate into the lamppost or bollard, tapping into existing 220-V electrical service, while the German version mounts on the outside of the lamppost. The version in France, Simple Socket Etoile, includes a second socket to allow users to charge not only EVs but also motorized two- and three-wheelers, e-bikes, or other micromobility devices.

Localized versions of the lamppost chargers. Source: Ubitricity

Each charge point presents a low-profile, covered power outlet, and the user supplies their own charging cable. Between 3.7 and 5.5 kW of power, ideal for overnight or other extended-dwell charging, flows from the power outlet into the plug, through the user-supplied cable, and into the vehicle inlet.[44] According to Ubitricity, the average EV dwell time for lamppost chargers has been 9.5 hours, and the average charging time has

[44] The supplied power varies by country based on the electrical service present in street lighting or bollards. Also, note that SAE J3068 includes a universal EV outlet, as used by Ubitricity, which is expected to be brought into standards in the United States.

been 5.5 hours, representing mostly overnight charging. Users pay either by scanning a QR code for pay-as-you-go charging or using a smartphone app for frequent charging.[45]

The company has worked with local authorities in each country (e.g., Transport for London and borough councils in the UK) to deploy EV charging infrastructure in public spaces, principally on-street parking spaces. Station locations have been selected by the local officials according to EV demand levels.

According to Ubitricity, the cost of retrofitting an existing streetlight with the EV charging retrofit can range from £2,000 to £4,000 (about $2,500 to $5,000), depending on the location and other factors, and it takes from 30 minutes to a few hours to complete, assuming all the necessary cabling is in place. UK hardware costs help keep retrofitting costs on the low end of the range there, whereas German conformity and calibration laws have been associated with the high end of the range. By comparison, stand-alone public chargers requiring civil construction or disruption to infrastructure can cost several-fold more.

4.3.3 Successes and Challenges

The table below summarizes successes and challenges in implementing the lamppost charger network. Special thanks to Rene Wetzel, Mickael Garreau, and Salil Upadhyay (Ubitricity) for sharing their time and expertise during the development of this case study.

Successes	• **Large-scale rapid deployment.** Ramped up deployment in 2018; achieved top market share of UK public charging (~16%).
	• **Utility partnerships.** Partnered with energy suppliers such as EDF Energy and Scottish Power to use electricity from renewable sources.
	• **Township partnerships.** Long-term collaboration model reduced the total cost of ownership.
	• **Reliability and uptime**. About 98% average uptime as of 2023.
	• **Minimal issues with damage and vandalism.** Vandalism has affected less than 2% of installations, mostly graffiti or damage to socket covers. The product was designed to be damage-resistant:
	  ○ An agreement with the customer reimburses for vandalism.
	  ○ Accidental damage affects ~2% of installations and is not a major issue on residential streets.

Challenges	• **Street parking management.** Berlin lacks EV parking rights, so EVs have competed with non-EVs. In some London boroughs, there are three EV-specific street spaces assigned per user to reduce competition, which can be insufficient; some boroughs use

[45] A third payment option, a proprietary cable with integrated power meter, was phased out in 2022 to support open charging networks.

apps to allow residents to request future EV charge points at specific locations, which aids planning.

- **Expanding to the North American market.** Most U.S. streetlights are 120 V, supplying half the power of European streetlights that operate on 240 V. In 2018, Ubitricity piloted but did not move forward on a streetlight charger in New York City.

Additional Examples from Europe

London, United Kingdom

Beyond expanding streetlight charging, London is prioritizing the development of other charging methods, including on-street pop-up charge points and both public and taxi dedicated rapid chargers.[46] Pop-up charging stations are embedded into the pavement and remain underground until activated by the user and can charge at 2 to 22 kW.[47]

Source: Urban Electric

Source: L-Charge

Amsterdam, Netherlands

In partnership with a UK-based company, Amsterdam has launched a mobile, on-demand, and off-grid charging service that can charge an EV from 0% to 80% state-of-charge in 15 to 25 minutes. The charging unit is transported by van and delivers electricity produced from liquefied natural gas, hydrogen, or a mixture of both.[48]

46 https://lruc.content.tfl.gov.uk/tfl-london-electric-vehicle-infrastructure-delivery-plan.pdf
47 https://www.greencarreports.com/news/1129498_electric-car-chargers-pop-up-from-the-sidewalk-to-be-tested-in-the-uk
48 https://theevreport.com/l-charge-launches-worlds-first-mobile-ultra-fast-off-grid-ev-charging-service-in-amsterdam

Oslo, Norway

Oslo currently has more than 2,300 public charging ports and plans to expand the number of ports by 200 per year until 2031. The Norwegian Environmental Agency considers several criteria in selecting future charging locations, including formal requests from residents for a charging station and the presence of multifamily buildings without off-street parking. With EVs currently making up more than a third of cars in Oslo, the city aims to be the world's first emission-free city by 2030.[49,50]

Source: Agency for Urban Environment, City of Oslo

Source: Rheinmetall

Cologne, Germany

The City of Cologne has launched a pilot project to install curb stone chargers as an alternative to curbside charging posts. The chargers will be flush with the pavement. EV owners can lift up a section of the charger to plug in their charging cable. The curb stone chargers can provide up to 22 kW to support medium-term and overnight charging.[51]

Stuttgart and Hamburg, Germany

At more than 250 stations in Stuttgart's RegioRad shared e-bike system, around 700 e-bikes and 35 cargo e-bikes are available for public use.[52] The cargo e-bikes hold up to 45 kg (132 lb) of cargo, or up to two children.[53] Between trips, riders dock at stations using a cable that both locks the e-bike and charges it through an integrated plug. Hamburg and other cities across Germany feature similar shared e-micromobility systems operated as a partnership between the municipalities and the German Railway Company Deutsche Bahn.[54]

Source: RegioRadStuttgart

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[49] https://www.oslo.kommune.no/slik-bygger-vi-oslo/lad-i-oslo-utbygging-av-ladeplasser-for-elbil/#gref
[50] https://www.electrive.com/2023/06/08/oslo-opts-for-new-charge-point-manager-in-czech-chargeup/
[51] https://www.autoweek.com/news/green-cars/a43942025/rheinmetall-curb-stone-electric-vehicle-charger/
[52] https://www.regioradstuttgart.de/de/start
[53] https://www.regioradstuttgart.de/de/regio-rad-typen/#pedelec
[54] https://www.nyserda.ny.gov/-/media/Project/Nyserda/Files/Publications/Research/Transportation/Electric-Bicycle-Share-Feasibility-Study.pdf

4.4 Multifamily, Multimodal, and Curbside: Vehicle Technologies Office Projects

The Department of Energy's Vehicle Technologies Office has funded numerous projects[55] that bring the benefits of electric mobility infrastructure to residents in multifamily housing, residents dependent on curbside or on-street parking, and those without access to privately owned electric vehicles.

4.4.1 Vehicle Charging Innovations for Multi-Unit Dwellings

Led by the Center for Sustainable Energy, the Vehicle Charging Innovations for Multi-Unit Dwellings project[56] developed a Multi-Unit Dwelling EV Charging Toolkit that includes necessary information on technical considerations and the development of the business case for installing and operating EV charging at multifamily housing developments. It also includes sample agreements and policies. The project evaluated and implemented innovative, cost-effective, and flexibly expandable charging technology and software solutions that will enhance the residential multifamily housing and curbside EV charging systems market. The project's results and the toolkit have been broadly disseminated in collaboration with Clean Cities coalitions across the nation to facilitate increased multifamily housing property and curbside charging infrastructure deployment.

4.4.2 Streetlight Charging in the Kansas City Right-of-Way

Led by the Metropolitan Energy Center, the Streetlight Charging in the Kansas City Right-of-Way project[57] expands the availability of EV charging at low cost in urban settings. The project used existing electrical infrastructure—streetlights—to provide on-street EV charging, as well as charging for multifamily residences, in Kansas City, Missouri. By using grid-tied systems already in place, this approach can substantially cut installation costs and create a replicable approach for flexible, affordable charging systems that are feasible anywhere cities operate streetlights. This project tested charging and data technologies, tracked use of charging networks for on street and residential applications at over 20 new EV charging locations, and generated a process for siting EV charging stations while balancing concerns related to demand and equitable access.

4.4.3 Solutions for Curbside-Charging Electric Vehicles for Planned Urban Growth

Led by the University of North Carolina (UNC), the Solutions for Curbside-Charging Electric Vehicles for Planned Urban Growth project[58] developed a retrofit charging solution that could be installed into existing streetlight infrastructure. The primary enabling technology is a cloud-connected electrical circuit breaker with built-in Level 2

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[55] https://cleancities.energy.gov/project-lessons
[56] https://vci-mud.org/
[57] https://metroenergy.org/current-projects/streetlight-ev-charging/
[58] https://www.energy.gov/eere/vehicles/articles/solutions-curbside-charging-electric-vehicles-planned-urban-growth

charging capability. This device, the Electric Vehicle Energy Management Circuit Breaker (EV-EMCB) from Eaton Corporation, can be remotely actuated from commands given by a smart phone or web-based application. The team at UNC Charlotte developed a prototype charging station and performed the industrial design work needed to encapsulate the charger into an enclosure that can be easily and safely installed on a streetlight. The final product will allow a user with a smart phone to enable and disable EV charging.

5 Conclusion

Nearly a third of Americans live in multifamily housing. Many depend on curbside parking or do not drive at all. As the nation transitions to cleaner mobility options, it needs charging solutions tailored to the needs of these groups. Multifamily residents who own an EV or micromobility device have a wide range of parking situations, depending on their building and neighborhood. Where multifamily residents can park—and for how long— are important factors in whether they can fully experience the benefits of electrified transport.

As the emerging solutions and case studies in this paper illustrate, there are as many opportunities as there are challenges in supporting electrification in urban communities, for both EV owners and nonowners. For EV owners, leveraging existing excess electrical capacity, whether in street furniture or buildings, and innovating the charger design represent two broad areas of opportunity to bring down installation cost and lead time—in other words, to scale faster.

Emerging AC charging standards may make the international case studies in this paper and the BYOC model significantly more relevant to the U.S. context, as well as significantly cheaper to deploy where EVs are parked overnight. A standardized, universal EV outlet could reduce cost and deployment time, simplify cable management, address vandalism and theft challenges, yield efficiency benefits, and provide flexible charging for a wide range of vehicles, with delivered charging power levels ranging from 6 kW to 52 kW (versus 6 kW to 19.2 kW under existing Level 2 solutions).

Where capacity or long utility lead times present barriers to EV charging, peer-to-peer or battery-integrated curbside solutions may provide effective workarounds. In parking lots or small charging hubs, containerized charging that bypasses civil construction can reduce lead times and capital costs, and it is implementable in a CaaS model.

A solution that can serve drivers, as well as the 3 out of 10 Americans who do not drive, is mobility hubs. Mobility hubs co-locate clean transportation choices like transit, electric micromobility, and electric car sharing, providing the right mobility tool for the right trip, and they can help support seamless multimodal connections. Given the high cost of trenching for EV charging, mobility hubs can be combined with other technology solutions to maximize the return on investment of "digging once," supplying electricity for a wide range of not only e-mobility but also stationary uses, such as food trucks, sidewalk dining, and outdoor event venues—a complete spectrum of movement and place.

Appendix A. Resources

A.1 Technical

- **Breakdown of Electric Vehicle Supply Equipment Installation Costs,** *Stephen Schey, Kang-Ching Chu, and John Smart*, *Idaho National Laboratory (2022), https://inldigitallibrary.inl.gov/sites/sti/sti/Sort_63124.pdf*

- **Charging Forward: A Toolkit for Planning and Funding Urban Electric Mobility Infrastructure,** *Joint Office of Energy and Transportation (2023),* https://www.transportation.gov/urban-e-mobility-toolkit

- **Curb Enthusiasm: Deployment Guide for On-Street Electric Vehicle Charging,** *WXY Architecture + Urban Design and Barretto Bay Strategies (2018),* https://www.wxystudio.com/uploads/2400024/1550074865953/Final_Curb_Report_Nov2018_web.pdf

- **Denver Car Share Program 2019 Program Summary,** *Apex Design for Denver Public Works (2020),* https://denvergov.org/files/assets/public/v/1/parking/documents/2019-car-share-program-summary.pdf

- **Design Recommendations for Accessible Electric Vehicle Charging Stations***, U.S. Access Board (2022),* https://www.access-board.gov/ta/tad/ev/

- **Drive Electric Chicago,** *City of Chicago,* https://www.chicago.gov/city/en/progs/env/drive_electric_chicago.html

- **Electric Vehicle Charging for Residential and Commercial Energy Codes Technical Brief,** *Pacific Northwest National Laboratory (2021),* https://www.energycodes.gov/sites/default/files/2021-07/TechBrief_EV_Charging_July2021.pdf

- **Electric Vehicle Charging Station Program,** *District Department of Transportation,* https://ddot.dc.gov/page/electric-vehicle-charging-station-program

- **NYC DOT Curbside Level 2 EV Charging Pilot: Evaluation Report,** *New York City Department of Transportation (2023),* https://www.nyc.gov/html/dot/downloads/pdf/curbside-level-2-charging-pilot-evaluation-report.pdf

- **Pole-Mounted Electric Vehicle Charging: Preliminary Guidance for a Low-Cost and More Accessible Public Charging Solution for U.S. Cities,** Emmett.

Werthmann and Vishant Kothari, World Resources Institute (2021), https://doi.org/10.46830/wriwp.21.00023

- **Project Lessons: EV Charging for Multifamily Housing**, *U.S. Department of Energy Vehicle Technologies Office*, https://cleancities.energy.gov/project-lessons-multifamily-housing/

- **Project Lessons: EV Mobility Hubs,** *U.S. Department of Energy Vehicle Technologies Office,* https://cleancities.energy.gov/project-lessons-mobility-hubs/

- **Readying New York City for Electric Vehicle Use at Scale,** *Newlab and New York City Department of Transportation (2023),* https://www.newlab.com/casestudies/readying-new-york-city-for-electric-vehicle-use-at-scale

- **There's No Place Like Home: Residential Parking, Electrical Access, and Implications for the Future of Electric Vehicle Charging Infrastructure,** Yanbo *Ge, Christina Simeone, Andrew Duvall, and Eric Wood, National Renewable Energy Laboratory (2021),* https://www.nrel.gov/docs/fy22osti/81065.pdf

- **Webinar: Community Charging Models,** *Joint Office of Energy and Transportation (2023),* https://driveelectric.gov/webinars/community-charging

A.2 Incentives and Public Funding Opportunities

- **Alternative Fuel Vehicle Refueling Property Credit,** *U.S. Internal Revenue Service,* https://www.irs.gov/credits-deductions/alternative-fuel-vehicle-refueling-property-credit

- **Carbon Reduction Program**, *U.S. Federal Highway Administration*, https://www.fhwa.dot.gov/environment/sustainability/energy/policy/crp_guidance.pdf

- **Charging and Fueling Infrastructure Discretionary Grant Program,** *U.S. Federal Highway Administration,* https://www.fhwa.dot.gov/environment/cfi/

- **Community Development Block Grants.** *U.S. Department of Housing and Urban Development,* https://www.hud.gov/program_offices/comm_planning/cdbg (localities may use Community Development Block Grant funds for EV charging provided the project meets national objectives)

- **Database of State Incentives for Renewables and Efficiency,** *North Carolina Clean Energy Technology Center,* https://nccleantech.ncsu.edu/renewable-energy-resources/dsire/

- **Federal and State Incentives,** *U.S. Department of Energy Alternative Fuels Data Center,* https://afdc.energy.gov/laws/search#/

- **Funding Opportunity Announcements,** *U.S. Department of Energy Vehicle Technologies Office,* https://www.energy.gov/eere/vehicles/funding-opportunities

- **Green and Resilient Retrofit Program,** *U.S. Department of Housing and Urban Development,* https://www.hud.gov/GRRP (funding can include on-site EV charging stations)

- **National Electric Vehicle Infrastructure Formula Program,** *Federal Highway Administration,* https://www.fhwa.dot.gov/environment/nevi/

- **Rural EV Infrastructure Funding Table,** *U.S. Department of Transportation,* https://www.transportation.gov/rural/ev/toolkit/ev-infrastructure-funding-and-financing/funding-matrix

- **Transportation Alternatives Program,** *Federal Highway Administration,* https://www.fhwa.dot.gov/environment/transportation_alternatives/

- **Urban Electric Mobility Infrastructure Funding Table,** *Joint Office of Energy and Transportation,* https://www.transportation.gov/urban-e-mobility-toolkit/e-mobility-infrastructure-funding-and-financing/funding-table-dataset

Appendix B. Parking Arrangements and Scenarios

B.1 General Cost Estimates

Costs for EV charging installations are highly variable and depend on local site conditions, including available power capacity and required utility upgrades (if applicable), the number of planned stations and their respective power requirements, facility-side or energy management considerations, and distances required to bring power to parking areas, among other factors. Generalized cost estimates below are provided to aid in high-level comparison of the technologies in different parking arrangements and scenarios. The legend below assigns a general price range to various generic charging equipment, with AC equipment shown for Level 1 (120 V) and Level 2 (240 V) installations and DCFC solutions grouped by “Low-Power” (~50 kW–150 kW) solutions and “High-Power” (150 kW–400 kW+) solutions. AC Level 2 installations can feature lower-power chargers on 40-A circuits, or higher-power chargers on 80-A (or higher) circuits, with the latter generally costing more to procure and install.

Note that charging system designs may combine multiple charging power levels or use chargers that can serve multiple ports, and the following is provided only as a rough cost guide for technologies in different settings.

Generally, the maximum total power (of either all stations at full operating power or the anticipated maximum charging need with a managed system) will dictate capacity requirements for the utility infrastructure that supplies power to the installation. The higher the power needs, the higher the cost.

The general cost ranges below are represented on a unit basis for both purchase and installation. Estimates are intended to include all costs except potential rebates or other incentives. Some states or utility programs may have incentives to help cover certain portions of EVSE installations that can dramatically affect the ultimate direct cost of any given project.

Solution Type	**Cost Assessment**	**Unit Cost**	**Install Cost**
AC Level 1	$	$500–$1.5K	$500–$2.5K
AC Level 2	$$–$$$	$1.5K–$7K	$2.5K–$10K
Low-Power DCFC	$$$$	$50K–$100K	$15K–$20K
High-Power DCFC	$$$$$	> $100K (highly variable)	> $20K

B.2 Dedicated Charging Hubs

Scenario	Charging Levels and Relative Costs	Considerations
Fast-Charging Hub	**High-Power DCFC** – *$$$$$*	• High utilization, short duration • Larger footprint, typically a surface lot, minimal amenities • Requires ample electrical capacity to support higher charging levels • May be ideal for electric rideshare vehicles • *Example: 25 Revel 75 kW[59] DCFCs at a hub station in Brooklyn*
Charging Hub with Amenities	**DCFC** – *$$$$* **AC Level 2** – *$$$*	• High utilization, medium duration • Medium-large footprint, underutilized lot or garage, wall- or ceiling-mounted solutions can maximize available space • On-site amenities such as a convenience store and restroom to serve visitors while they wait • *Example: Shell UK (vary, 150 kW+[60]) and Shell Paris (50 kW pictured in press release[61])*
Destination-Oriented Charging Hub	**Mix of High-Power DCFC and Networked Level 2** *$$$$* – higher power *$$$* – lower power	• Medium utilization, medium duration • Small-medium footprint • Hub located near commercial or community center • Destination-oriented charging hub paired with activity or mixed-use development • *Examples: Downtown Madison, Wisconsin, DCFC Hub (350 kW[62]), Gravity 29 DCFC + Level 2 in Manhattan (Up to 180 kW or 90 kW for each of two ports[63])*
Pop-Up Charging Hub	**Battery High-Power DCFC** – $$$$ **Battery Low-Power DCFC** – $$$ AC Level 2 – $$	• Low utilization, medium duration • Semipermanent or portable solution to meet temporary charging needs, such as at special events • Option for grid-limited locations (lower installation costs) • *Example: Evesco Power-Up model (Semipermanent)*

[59] https://www.marketscreener.com/quote/stock/TRITIUM-DCFC-LIMITED-120780718/news/Revel-Opens-Largest-Universal-Fast-Charging-Depot-in-the-Americas-With-Launch-of-Brooklyn-Superhub-35748030/
[60] https://www.shell.co.uk/electric-vehicle-charging.html
[61] https://www.shell.com/energy-and-innovation/new-energies/new-energies-media-releases/shell-launches-its-first-european-ev-mobility-hub-in-paris.html
[62] https://www.mge.com/our-environment/electric-vehicles/charging/charging-stations
[63] https://techcrunch.com/2021/09/15/gravity-is-launching-an-indoor-charging-hub-in-nyc-with-plans-to-scale/

B.3 Public Parking

Scenario	Charging Levels and Relative Costs	Considerations
Public Surface Lot	**Low-Power DCFC** – $$$$ **AC Level 2** – $$$	• For medium-to-high utilization and short-to-medium charging duration • DCFC may have low rate of return due to higher electrical service costs (installation and rates) and low utilization • May incur greater costs to electrify assigned spaces far from power
Public Parking Garage	**Low-Power DCFC** – $$$$ **AC Level 2** – $$$	• For medium-to-high utilization and short-to-medium charging duration • Requires an integrated design approach unique to the garage/facility; initial installations may target one level/floor • Wall- or ceiling-mounted charging equipment can help reduce spatial constraints • Top-level conducive for solar canopies integrated with an energy storage system for resilience and revenue benefits • Locate charging near elevators, staircases, and entrances and exits to support awareness
Nonpermanent Charging	**Battery Low-Power DCFC** – $$$$ **Battery Level 2** – $$$	• Provides charging at public parking locations without civil construction • Does not require dedicated EV charging spot • Requires secure storage and recharging of equipment • May require an attendant (labor); valet services bring/drive your vehicle to available charging • *Examples: Distributed Energy via FreeWire chargers in California, Anaheim Transportation Network temporary charging hub (containerized hub with DCFC and Level 2), FreeWire Mobi*

B.4 Curbside (On-Street) Parking

Scenario	Charging Levels	Considerations
Residential/ Overnight Charging	**AC Level 1** – $ **AC Level 2** – $$	• Lower power for a longer duration • Lower power levels can tap into existing power supply in utility poles and streetlights • Utility poles: Provides existing power supply; however, charging vehicles pose a potential impediment and risk during pole maintenance • Streetlight: Relatively low cost and easy to permit; however, may not have sufficient power for Level 2 charging and may be cost-prohibitive to upgrade power at scale • *Examples: NYC DOT/Con Edison Curbside Charging, Los Angeles Streetlight Charging; Melrose, Massachusetts National Grid PMC Project; Los Angeles and Kansas City Streetlight Charging (have 240 V)*
Metered/Hourly Charging	**Low-Power DCFC** – $$$$ **AC Level 2** – $$$	• Higher power for a short duration • Requires adequate sidewalk width or a separating strip of land • Accessibility challenges of placement relative to curb • *Example: Sacramento, California, Southside Park Curbside DCFC*
Nonpermanent Charging	**Battery Low-Power DCFC** – $$$$ **AC Level 2** – $$	• Provides charging at public parking locations without civil construction • Does not require dedicated EV charging spot • Risk that the service vehicle providing the mobile charging may need to double park • *Examples: Freewire Mobi; Evesco EVMO-S; SparkCharge (12 California cities)*

B.5 Communal On-Site Parking

Scenario	Charging Levels	Considerations
Surface Lot	**High-Power DCFC** – $$$$$ **Low-Power DCFC** – $$$$ **AC Level 2** – $$$ **AC Level 1** – $	• Shared-use, session-based, limited duration • Surveys for demand and site assessments are the first steps • May incur greater costs to electrify assigned spaces far from power
Parking Garage	**High-Power DCFC** – $$$$$ **Low-Power DCFC** – $$$$ **AC Level 2** – $$$ **AC Level 1** – $	• Shared-use, session-based, limited duration • Requires an integrated design approach unique to the garage/facility; initial installations may target one level/floor • Wall- or ceiling-mounted charging equipment can help reduce spatial constraints • Top-level conducive for solar canopies integrated with an energy storage system for resilience and revenue benefits
Nonpermanent Charging	**Battery Low-Power DCFC** – $$$$ **AC Level 2** – $$	• Provides charging at public parking locations without civil construction • Does not require dedicated EV charging spot • Requires secure storage/recharging; may require attendant (labor) • *Examples: Plugzio metered outlet, Freewire Mobi, SparkCharge*

B.6 Assigned On-Site Parking

Scenario	Charging Levels	Description
Surface Lot	**Low-Power DCFC** – $$$$ **AC Level 2** – $$$ **AC Level 1** – $	• Single household utilization, long-duration • For condos/owner-occupied units, the unit owner may also be the EVSE owner • May incur greater costs to electrify assigned spaces far from power
Parking Garage	**Low-Power DCFC** – $$$$ **AC Level 2** – $$$ **AC Level 1** – $	• Single household utilization, long-duration • For condos/owner-occupied units, the unit owner may also be the EVSE owner • Requires an integrated design approach unique to the garage/facility, initial installations may target one level/floor • Wall- or ceiling-mounted charging equipment can help reduce spatial constraints
Nonpermanent Charging	**Battery Low-Power DCFC** – $$$$ **AC Level 2** – $$$ **AC Level 1** – $	• Provides charging at public parking locations without civil construction • Does not require dedicated EV charging spot • Requires secure storage/recharging, may require attendant (labor) • *Examples: Plugzio metered outlet, Freewire Mobi, SparkCharge*