Joint Office of
Energy and
Transportation

Electric Vehicle Charging Solutions for Multifamily Housing

Market Scan

U.S. DOT Volpe Center

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Contents

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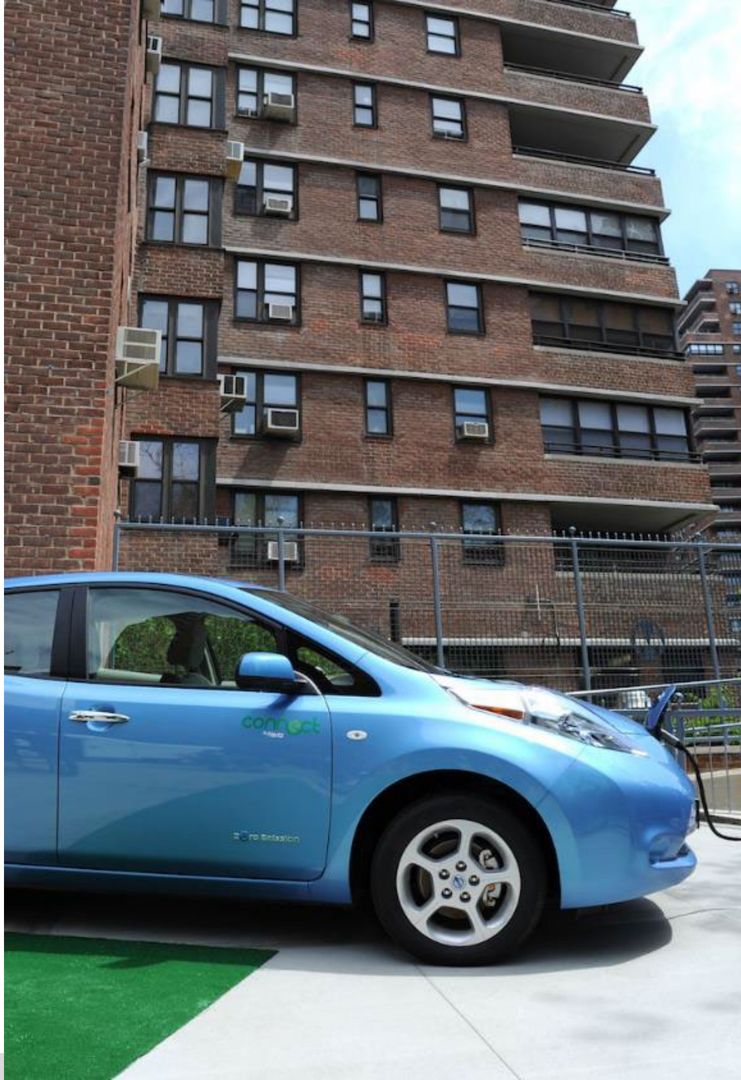


Motivating Statistics

Around 80% of electric vehicle (EV) charging takes place at home.

Yet **less than 5%** of home charging takes place in multifamily housing (MFH).

- Approximately 44 million (31%) of all households in the U.S. are MFH.
- Around 28 million (63%) of **rental households** are MFH.
- 76% of rented MFH households have 1+ vehicle

Sources: Energy Star, Forth Mobility/EVS35 (2022), National Association of Home Builders (2022), National Multifamily Housing Council (2022).

Use Case Taxonomy

Is there accessory parking?

No → **Where is public parking available?**

- *Off-street*
  - *(short-term parking)*

    1. Dedicated charging hub
  - **2. Public garage or lot**

    (longer-term parking)
- *On-street*
  - **3. Curbside**

Yes → **Are parking spaces assigned?**

- *No*
  - **4. Communal accessory parking**

    
- *Yes*
  - **5. Assigned accessory parking**

1. Dedicated Charging Hub:
General Considerations

- **Primary function** is EV charging. Strategically design and locate to maximize access and utilization:
  - Offer **flexible charging solutions** (lower power charging collocated with community destinations, DCFC ideal for time-limited parking or serving ride-hailing, etc.)
- **Sufficient grid capacity required** to support fast charging electrical demand, typically requires new electrical service.
  - Consider demand management strategies (smart charging, energy storage) to accommodate multiple fast-charging ports.
- **Networked connection required** for smart charging, demand management, ongoing O&M and payment
- Hub managers dictate **access, policies, and fees for use** for various user types (or charging levels), including passenger vehicles, fleets, ride hailing vehicles, and commercial vehicles.
- May **need staff** to supervise, control traffic, and increase throughput
- **Municipal code and zoning** may need updating to allow for charging hub and amenities (e.g., coffee shop, waiting area for drivers).
- Consider **multimodal** connections and their charging power needs (e.g., for ride-hail vehicles, car share, e-bikes)

1. Dedicated Charging Hubs: Applications and Examples

Scenario	Charging Levels and Mounting	Considerations and Challenges	Example Projects
Large Station for Fast Charging (high traffic, charge and go) High Utilization, Short Duration	**High-Power DCFC** (150 kW+) Pedestal, Wall, Canopy	▪ Larger footprint, typically a surface lot, minimal amenities ▪ Requires ample electrical capacity (Revel project @ old Pfizer facility) to support higher charging levels (150kW+) ▪ Pedestal-mounted solutions common ▪ **High charging over short duration → higher prices per kW**	• Revel 25 DCFC station in Brooklyn • Shell UK and Shell Paris • Downtown Madison DCFC Hub
Local Station w/ Amenities (moderate traffic, time for a break) High Utilization, Medium Duration	**DCFC** (20-50 kW) **Networked L2** (6 kW - 19.2 kW) Pedestal, Wall, Canopy/Ceiling	▪ Medium-large footprint, under-utilized lot or garage, wall- or ceiling-mounted solutions can maximize available space ▪ Has modest amenities (café/coffee shop, shopping, lounge area) ▪ Consider cable management and offer charging power choice (e.g.; 30kW default speeds, up to 150kW "boost" available at higher cost) ▪ Battery-enabled DCFC can reduce utility grid upgrade costs and timelines at destinations otherwise lacking sufficient power. ▪ **Charging at medium power over medium duration → modest/variable prices per kW**	• Gravity 29 DCFC + L2 in Manhattan
Destination-Oriented Charging (light-moderate traffic, time for activity) Medium Utilization, Medium Duration	**Networked L2** (6 kW - 19.2 kW) Pedestal, Wall Solar Carport(s)	▪ Small-medium footprint ▪ Leverages existing amenities/attraction ▪ Destination-oriented charging hub, paired with activity or mixed-use development ▪ Battery-enabled DCFC can provide backup power to nearby facilities or revenue through utility demand reduction programs. ▪ **Charging at lower power over long duration → lower prices per kW**	--
Pop-Up Charging Low Utilization Medium Duration	**Battery-Enabled DCFC,** **Mobile Battery DCFC, L2**	▪ Semi-permanent, portable solutions exist for grid-limited dedicated charging hubs.	• Evesco Power-Up model

2. Public Garage or Lot:
General Considerations

- **Site assessments** shed light on risks from flooding (particularly relevant to surface lots and underground parking garages) and other weather-related hazards.
- **Cost to retrofit is high**. Consider futureproofing approaches (e.g., duct banks, oversized electrical service and conduits).
- **Networked solutions** generally required for fare payment, demand management, and duration-of-stay enforcement
  - Consider **flexible payment** solutions (foreign traveler, transit fare cards, etc.)
  - **Non-networked** or complimentary charging is feasible with low levels of use. Could install non-networked behind a pay gate with additional fee for charging.
- Important to have **signage** indicating that the garage or lot offers EV charging.
- Parking facility managers can increase **visibility** of parking spaces for EVs by installing charging stations near elevators, staircases, or other points of exit and entry.
- Consider **multimodal** connections and their charging power needs (e.g., for ride-hail vehicles, car share, e-bikes)

2. Public Garage or Lot: Applications and Examples

Scenario	Charging Levels and Mounting	Considerations and Challenges	Examples
Public Surface Lot Med-High Utilization, Short-Med. Duration	**DCFC, Networked L2** Pedestal (Permanent), Containerized (Semi-Permanent)	▪ DCFC may have low rate of return due to higher electrical service costs (installation and rates) and low utilization. i. Battery-enabled DCFC can reduce costs and provide resilience and revenue benefits. ii. Off-grid solar L2 chargers are a no-trenching, re-locatable solution. ▪ Containerized solutions (chargers mounted to exterior of container with power electronics inside) can reduce installation costs.	▪ Distributed Energy via FreeWire chargers in CA ▪ Anaheim Transportation Network temporary charging hub (containerized hub with both DCFC and L2)
Public Parking Garage Med-High Utilization, Short-Med. Duration	**DCFC, Networked L2** Pedestal, Wall, Ceiling	▪ Requires an integrated design approach unique to the garage / facility ▪ Wall- or ceiling-mounted charging equipment can help reduce spatial constraints. ▪ Top-level conducive for solar canopies. Battery-enabled DCFC can provide resilience and revenue benefits. ▪ Locate charging near entrances, exits, etc. to support awareness	• Many L2 Examples
Mobile / Valet Charging	**Mobile Battery DCFC** Mobile or Valet	▪ Provides charging at public parking locations without civil construction. ▪ Requires secure storage and recharging of equipment. ▪ May require an attendant (labor). Valet services bring/drive your vehicle to available charging.	• FreeWire Mobi

3. Curbside: General Considerations

- Suitable for areas with **high traffic, visibility, and turnover** such as retail locations
- Many **competing uses for space**, e.g., loading zones, dining, bus/bike lanes. Avoid stretching charging cords over bike lanes separating parallel parking from the curb.
- **Local regulations** dictate site selection, ease of permitting, and policies affecting charger utilization
- **Data and planning guidance** vary widely by locality
- City officials should set **policies for use** (e.g., “no parking” times) to allow for street cleaning or snow plowing, or emergency access.
- Consider **multimodal** connections and their charging power needs (e.g., for ride-hail vehicles, car share, e-bikes)

3. Curbside: Applications and Examples

Accessible to 40% of large MFH buildings and 55% of small MFH buildings*

Scenario	Charging Levels and Mounting	Considerations and Challenges	Example Projects
Short-Duration, Time-Limited Metered / Hourly	**DCFC, Networked L2** Pedestal	▪ Requires adequate sidewalk width or a separating strip of land. ▪ Accessibility challenges of placement relative to curb. ▪ Battery-enabled DCFC can reduce costs and provide resilience and revenue benefits.	▪ Sacramento Southside Park Curbside DCFC ▪ NYC DOT/Con Edison Curbside Charging ▪ Los Angeles Streetlight Charging
Long-Duration, Use-Limited Residential / Overnight	**L1[a], L2** Pedestal, Pole, Streetlight	▪ Utility pole: Taps into existing power supply and is EV-charging retrofit ready. However, charging vehicles are a potential impediment and risk during pole maintenance. ▪ Streetlight: Relatively low cost and easy to permit. However, may not have sufficient power for L2 charging and may be cost-prohibitive to upgrade power at scale.	▪ Melrose, MA National Grid PMC Project ▪ Los Angeles and Kansas City Streetlight Charging (have 240V)
Mobile / Valet Charging	**Mobile Battery DCFC, L2** Mobile or Valet	▪ Risk of service mobile charging vehicle double-parking	▪ SparkCharge (12 CA cities) ▪ Freewire Mobi ▪ Evesco EVMO-S

[a] World Resources Institute (2021) found that all U.S. pole-mounted EV charging programs implement Level 2 rather than Level 1 charging.

4. Communal Accessory Parking:
General Considerations

- **User surveys** are important to determine demand (number of ports) and inform site layout.
- There is **flexibility to cluster chargers** near existing electrical source.
- It's important to specify **roles and responsibilities** for operations/maintenance and insurance.
- Set **policies for use**, e.g., dwell time restrictions, and consider conveniences like text alerts when charging is complete.
- Consider **methods of payment**: monthly fee, per session, per kWh or minute.

4. Communal Accessory Parking: Applications and Examples

Up to 55% of small MFH buildings and 90% of large MFH buildings*

Scenario	Charging Levels and Mounting	Considerations and Challenges	Example Projects
Surface Lot Shared Use, Session-Limited Duration	**DCFC, L2, L1** Pedestal, Pole, Streetlight	▪ Surveys for demand and site-assessments are first steps ▪ Networked L2 most common to facilitate shared-use and payment ▪ Non-networked L2 or L1 outlets must be independently metered or have an established payment plan (flat fee, nightly, etc.) ▪ Locate close to available power to minimize installation costs. Also, battery-enabled DCFC can reduce costs and provide resilience and revenue benefits. ▪ Develop policies and payment plans [property manager]	▪ Many L2 Examples ▪ L1 Streetlight Pole @ Holiday Inn (Lincoln, NH)
Parking Garage Medium Utilization, Flexible Duration	**DCFC, L2, L1** Pedestal, Wall, Ceiling	▪ Requires an integrated design approach unique to the garage / facility, initial installations may target one level/floor (close to power) ▪ Networked L2 most common; L1 charging possible (see above) ▪ Wall- or ceiling-mounted charging equipment can help reduce spatial constraints. ▪ Battery-enabled DCFC can reduce costs and provide resilience and revenue benefits. ▪ Develop policies and payment plans [property manager]	▪ L1-L2 Plugzio metered outlet ▪ Many L2 Examples
Mobile / Valet Charging	**Mobile Battery DCFC** Mobile or Valet	▪ Can provide charging at parking locations without civil construction ▪ Requires secure storage / recharging, may require attendant (labor) ▪ Locations without the ability to install charging may offer valet charging	▪ Freewire Mobi ▪ ZipCharge Go (and GoHubs)

5. Assigned Accessory Parking:

General Considerations

- Allows for **overnight low-level charging**
- A lottery, waiting list, increased pricing, or other method may be needed to **manage demand** for assigned EV charging spots.
- Important to **specify roles and responsibilities for O&M** and insurance. In condo buildings with dedicated, owned parking spaces, unit owners may need to pay for the purchase, installation (including wiring and possibly dedicated metering), and upkeep of their own EV charger.
- Important to **project EVSE requirements over several years**. It is less expensive to install extra panel and conduit capacity during initial construction.
- **Right-to-charge laws** may distinguish between assigned, “limited common,” and communal parking, as well as between owner and renter.

5. Assigned Accessory Parking: Solutions and Challenges

Up to 55% of small MFH buildings and 90% of large MFH buildings*

Scenario	Charging Levels and Mounting	Considerations and Challenges	Example Projects
Surface Lot Single-utilization, long- duration	**DCFC, L2, L1** Pedestal-mounted	▪ Surveys for demand and site-assessments are first steps ▪ Networked L2 most common; Non-networked L2 or L1 easier to facilitate (known users, requires payment policy) ▪ Battery-enabled DCFC can reduce costs and provide resilience and revenue benefits. ▪ May incur greater costs to electrify assigned spaces far from power	▪ Many L2 Examples ▪ L1 Streetlight Pole @ Holiday Inn (Lincoln, NH)
Parking Garage Single-utilization, long- duration	**DCFC, L2, L1** Pedestal-mounted, wall-mounted or ceiling-mounted	▪ Requires an integrated design approach unique to the garage / facility, initial installations may target one level/floor. ▪ Networked L2 most common; Non-networked L2 or L1 easier to facilitate (known user, requires payment policy). ▪ Wall- or ceiling-mounted charging equipment can help reduce spatial constraints. ▪ Battery-enabled DCFC can reduce costs and provide resilience and revenue benefits.	▪ L1-L2 Plugzio metered outlet ▪ Many L2 Examples
Mobile / Valet Charging	**Mobile Battery DCFC** Mobile or Valet	▪ Can provide charging at parking locations without civil construction. ▪ Requires secure storage / recharging, may require attendant (labor) ▪ Locations without the ability to install charging may offer valet charging	▪ ZipCharge Go (and GoHubs)

Charging solutions approximate costs and timelines

Charger Hardware	Unit Cost per Port	Install Cost Per Port [a]
L1 Residential	Low: $0 High: $0 [b]	Low: $100 High: $1,000
L2 Residential	Low: $400 High: $1,200	Low: $500 High: $1,700
L2 Commercial	Low: $2,200 High: $4,600	Low: $2,200 High: $6,000
DCFC 150 kW	Low: $66,400 High: $102,200	Low: $45,800 High: $94,000
DCFC 250 kW	Low: $91,400 High: $134,800	Low: $54,750 High: $105,950
DCFC 350+ kW	Low: $116,400 High: $167,400	Low: $63,700 High: $117,900

[a] These ranges do not span all possible situations. They are meant to be plausible low and high estimates for assessing network capital costs at scale.
[b] L1 chargers tend to be included with the purchase of a plug-in EV and thus are excluded as an infrastructure cost.

Source: Wood et al. (2023)

Rough Implementation Timeline*

Days - Weeks

Weeks - Months

Months - Years

*** These are not set ranges. Timelines vary with technology type, installation size, and existing grid capacity.**

Notable emerging business models

- **Peer-to-peer (It’s Electric)**
  - Similar to the AirBnB model for curbside pedestal charging using a 240V connection from buildings fronting the curb
  - Offers residents a passive income stream
  - If regulations permit, potentially circumvents long utility lead time.
  - Bring-your-own cable

- **Multi-use: Battery-enabled DCFC on low power + grid services + backup power (FreeWire)**
  - Incorporates battery to provide fast charging, grid services to reduce costs, and circumvents long utility upgrade lead times and demand charges
  - Provides property owners with supplemental benefits:
  - Potential passive revenue stream via utility demand management incentive programs
  - Can provide backup power to buildings in the event of a power outage

- **Mobile (SparkCharge)**
  - Battery and plug is driven across the neighborhood/city by van/trailer or wheeled across a garage/lot to the vehicle, rather than the vehicle traveling to the plug.
  - Similar to multi-use, mobile uses low power, provides backup power, and circumvents long utility lead time.

Additional Takeaways

- **"Dig once" futureproofing:** When sizing projects, consider "make-ready" steps to future-proof installations for increasing demand. For new buildings, ensuring EV capable parking yields large cost savings over future retrofits.
- **Access and Equity:** Retractable cable management solutions and implementing Access Board design recommendations can improve safety and usability. Note that different charging levels come at different costs to EV drivers.
- **Policies for Efficient Use:** Different types of EVs need different charging times and power levels, calling for dwell time management through user notification, pricing, other methods.
- **Resilience:** Conducting site assessments helps understand vulnerabilities to flooding and other natural hazards. Evaluate adaptation measures to ensure continuity in operations. Charging systems with integrated batteries can offer backup power for facilities.
- **Security:** Sites may have varying needs for additional lighting and/or security cameras to help ensure the safety of charging station users.
- **Additional Costs:** Credit card processing and charging network provider subscriptions should be factored into the operations cost.
- **Multimodal:** Consider all opportunities to maximize multimodal connections, e.g., integrate with e-bike, e-scooter, or golf cart/minicar charging.

Charging Forward

A Toolkit for Planning and Funding Urban Electric Mobility Infrastructure

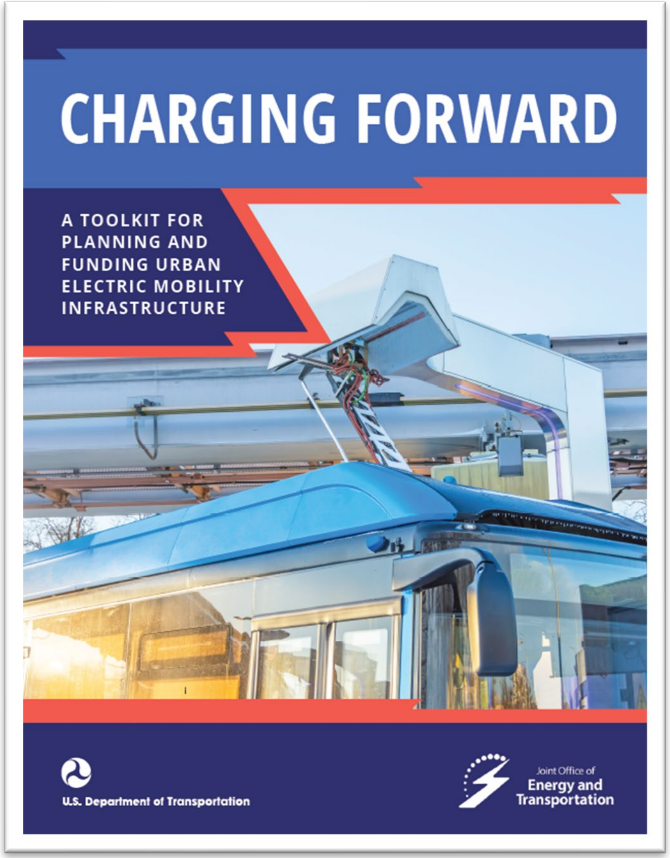
Table of Contents

- Electric Mobility Basics
- Benefits and Challenges of Urban Mobility Electrification
- Partnership Opportunities
- Infrastructure Planning
- Funding and Financing

Includes…

✓ Grant and loan opportunities
✓ Planning tools and resources
✓ Success stories

transportation.gov/urban-e-mobility-toolkit

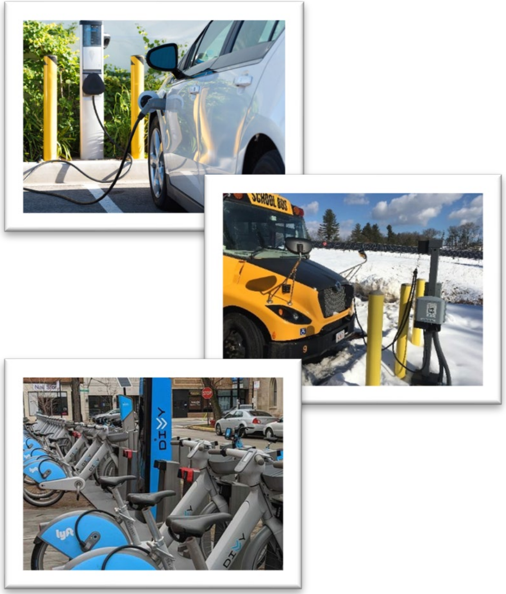


Charging Forward

A Toolkit for Planning and Funding Urban Electric Mobility Infrastructure

A one-stop resource to help urban and suburban stakeholders scope, plan, and fund electric mobility infrastructure.

- Highlights the benefits of **diverse electric mobility options.**
- Identifies **key stakeholders and partners** in project planning and implementation.
- Walks through a **project planning checklist** on project scoping and utility, installation, and operational planning.
- Compiles **tools and resources** for cost analysis, equitable planning, and other topics.
- Lists Federal **funding and financing programs** and eligibility criteria.



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Thank You

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Appendix
& Other Resources

Word Bank

Use Cases

- ❖ **Neighborhood.** Residential, mixed-use, urban, suburban
- ❖ **Parking type.** On-street, off-street lot, off-street garage
- ❖ **User type.** Renter, condo dweller, non-vehicle owner, low-income, fleet
- ❖ **Access.** Public, private (unit, building), mixed/shared
- ❖ **Mode.** Car, micromobility, multimodal
- ❖ **Availability.** Full-time, part-time (e.g., shared with loading zone)
- ❖ **Initiator.** Central planner, constituent

Project-Level Considerations

- ❖ **Site assessments.** Available power and need for upgrades, floodplain
- ❖ **Competing use of space.** Curbside, utility poles, non-EV parking
- ❖ **Roles and responsibilities.** Ownership, O&M, insurance, oversight/coordination
- ❖ **Policies for use.** Available times, no-charging dwell time
- ❖ **Payment.** Complimentary, flat fee, by time/kWh/session, app-based
- ❖ **Demand management.** Load shifting, presetting charge, data collection
- ❖ **Municipal policies.** Building codes, permitting, parking restrictions, snow removal
- ❖ **Funding.** Eligibility, project size, partners/co-applicants
- ❖ **Accessibility.** Charging station design, adaptive e-bikes
- ❖ **Stakeholders.** User, property owner, local government, general public, utility

Residence Type and Parking Option

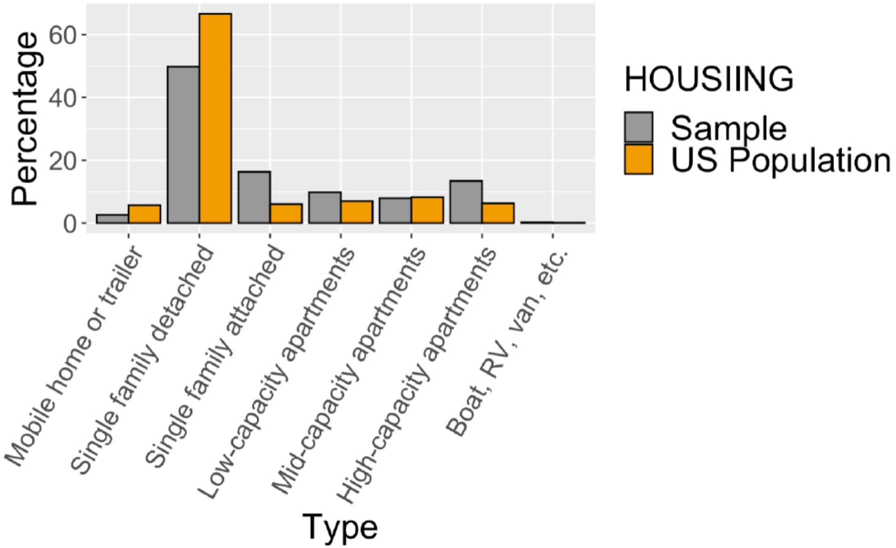


Figure 6. Housing type distribution of the sample and the U.S. population

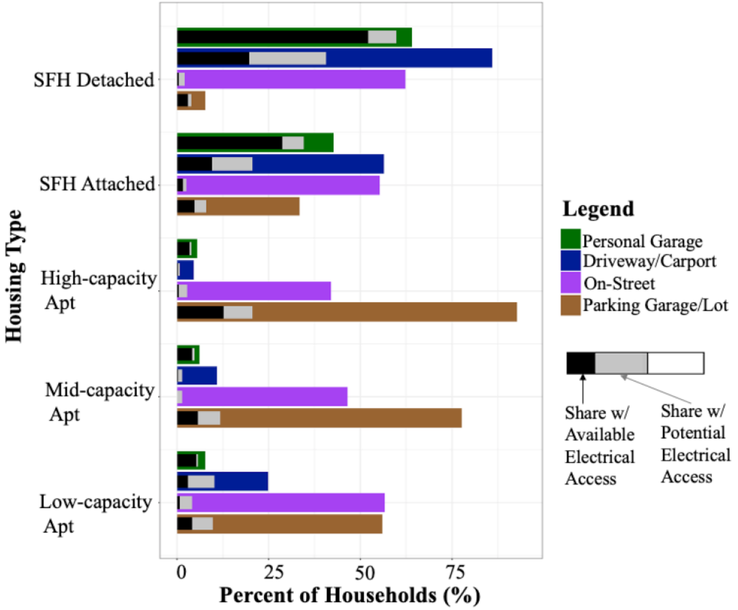


Figure 7. Existing and potential electrical access by residence type and parking option

(Note: the colored bars for the four parking types show the percentage of households that have the parking option available at home. The black and grey narrower bars convey the percentage of households that have existing or potential electrical access for each parking type, respectively. The length that is not covered by the grey and black bars indicates the percentage of households that have that parking option at home, but there is no electrical access at that parking location.)

Source: Ge, Y., Simeone, C., Duvall, A., & Wood, E. (2021) "There's No Place Like Home: Residential Parking, Electrical Access, and for the Future of Electric Vehicle Charging Infrastructure". *National Renewable Energy Laboratory.* https://www.nrel.gov/docs/fy22osti/81065.pdf

Clean Cities Website Resources:

- Curbside EV Charging
- EV Car Share
- EV Charging for MFH
- EV Mobility Hubs

Lessons learned and key considerations from 8 VTO FOA Projects:

1. American Lung Association: EV Community Partner – mix applications (multifamily housing and electric car share)
2. Center for Sustainable Energy: Vehicle Charging Innovations for Multi-Unit Dwelling
3. PacifiCorp: Western Smart Regional Electric Vehicles Adoption and Infrastructure At Scale
4. Virginia Energy: The Mid-Atlantic Electrification Partnership
5. Metropolitan Energy Center: Streetlight Charging in Kansas City Right-of-Way
6. University of North Carolina Charlotte: Curbside-Charging for Electric Vehicles for Planned Urban Growth
7. Clean Fuels Ohio: Decentralized Mobility Ecosystem: Market Solutions for 21st Century Electrified Mobility
8. Forth: The Saint Louis Vehicle Electrification Rides for Seniors (SiLVERS)

The following project summaries draw out lessons learned and key considerations that could be leveraged by others pursuing similar projects. These lessons learned include best practices for engaging stakeholders, strategies for improving the equitable distribution of project benefits, site selection factors, and permitting/policy elements that could impact the project.

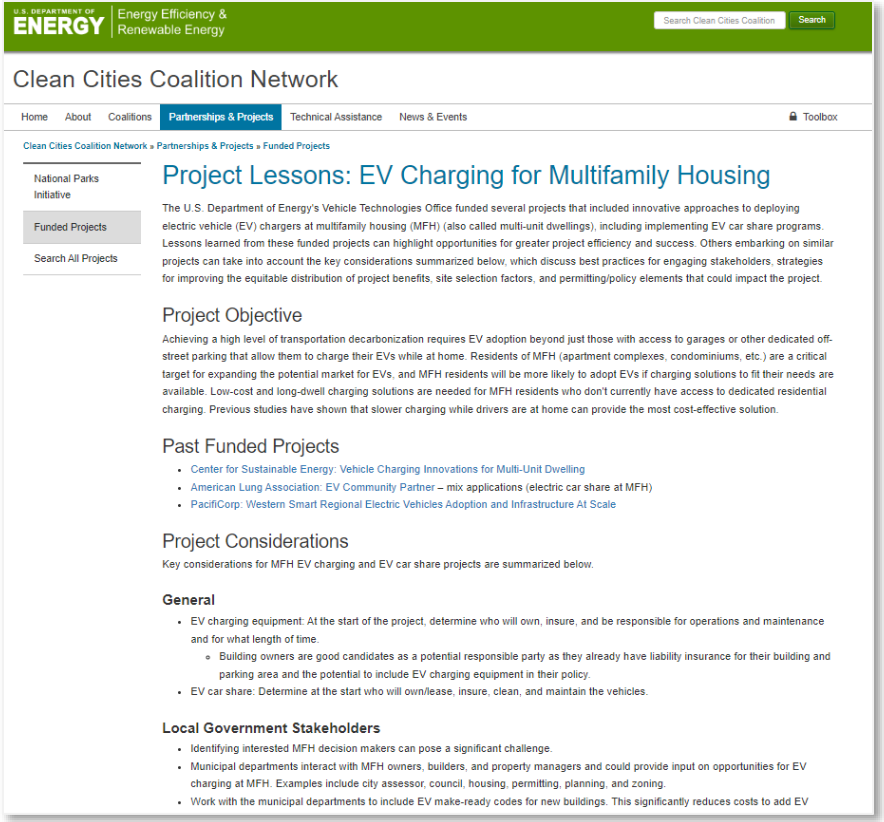
- **Curbside EV Charging:** To expand electric vehicle (EV) adoption, it is necessary to find and demonstrate solutions that enable people without home charging to charge their vehicle. Curbside charging, including chargers attached to streetlights or other poles, seeks to fill this gap by increasing the locations where consumers can charge their vehicles.
- **EV Car Share:** Car shares are short-term rentals that enable access to a vehicle for those without their own without the high cost of ownership. Establishing EV car shares reduces emissions and creates awareness of EV benefits in more communities. Car shares can also be used for gig drivers who use the EVs for ride hailing, food and meal delivery, and similar services.
- **EV Charging for Multifamily Housing:** Achieving a high level of transportation decarbonization requires EV adoption beyond just people with access to garages or other dedicated off-street parking that allow them to charge their EVs while at home. Residents of multifamily housing (apartment complexes, condominiums, etc.) are a critical target for expanding the potential market for EVs, and multifamily housing residents will be more likely to adopt EVs if charging solutions to fit their needs are available. Learn from DOE-funded projects that included innovative approaches to deploying EV chargers at multifamily housing, including implementing EV car share programs.
- **EV Mobility Hubs:** EV mobility hubs allow for charging multiple vehicles and other electrified transport modes such as electric buses or e-bikes. Funded projects developed strong local and regional partnerships to support increased use of EVs. Strong partnerships can efficiently cut through regulatory and market barriers to technology introduction.

https://cleancities.energy.gov/partnerships/projects

Clean Cities Website Resource: EV Charging for Multifamily Housing

Project Considerations:

- General
- Local Government Stakeholders
- Equity
- Identifying Potential MFH Sites
- Locating EV Chargers at MFH
- MFH EV Charging Strategies
- Car Share
- Permitting/Policy



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Project Lessons: EV Charging for Multifamily Housing

The U.S. Department of Energy's Vehicle Technologies Office funded several projects that included innovative approaches to deploying electric vehicle (EV) chargers at multifamily housing (MFH) (also called multi-unit dwellings), including implementing EV car share programs. Lessons learned from these funded projects can highlight opportunities for greater project efficiency and success. Others embarking on similar projects can take into account the key considerations summarized below, which discuss best practices for engaging stakeholders, strategies for improving the equitable distribution of project benefits, site selection factors, and permitting/policy elements that could impact the project.

Project Objective

Achieving a high level of transportation decarbonization requires EV adoption beyond just those with access to garages or other dedicated off-street parking that allow them to charge their EVs while at home. Residents of MFH (apartment complexes, condominiums, etc.) are a critical target for expanding the potential market for EVs, and MFH residents will be more likely to adopt EVs if charging solutions to fit their needs are available. Low-cost and long-dwell charging solutions are needed for MFH residents who don't currently have access to dedicated residential charging. Previous studies have shown that slower charging while drivers are at home can provide the most cost-effective solution.

Past Funded Projects

- Center for Sustainable Energy: Vehicle Charging Innovations for Multi-Unit Dwelling
- American Lung Association: EV Community Partner – mix applications (electric car share at MFH)
- PacifiCorp: Western Smart Regional Electric Vehicles Adoption and Infrastructure At Scale

Project Considerations

Key considerations for MFH EV charging and EV car share projects are summarized below.

General

- EV charging equipment: At the start of the project, determine who will own, insure, and be responsible for operations and maintenance and for what length of time.
  - Building owners are good candidates as a potential responsible party as they already have liability insurance for their building and parking area and the potential to include EV charging equipment in their policy.
- EV car share: Determine at the start who will own/lease, insure, clean, and maintain the vehicles.

Local Government Stakeholders

- Identifying interested MFH decision makers can pose a significant challenge.
- Municipal departments interact with MFH owners, builders, and property managers and could provide input on opportunities for EV charging at MFH. Examples include city assessor, council, housing, permitting, planning, and zoning.
- Work with the municipal departments to include EV make-ready codes for new buildings. This significantly reduces costs to add EV

https://cleancities.energy.gov/partnerships/projects

Infrastructure upgrade costs and timelines

Table 1 | Summary of electricity distribution system upgrades for depot charging

Component category	Upgrade	Typical cause for upgrade	Typical cost[a]	Typical timeline (month)[a]
Customer on-site	50 kW DCFC EVSE	EVSE addition	Procurement, U$20,000–36,000 per plug; installation, U$10,000–46,000 per plug[b]	3–10
	150 kW DCFC EVSE		Procurement, US$75,000–100,000 per plug; installation, US$19,000–48,000 per plug[b]	
	350 kW DCFC EVSE		Procurement, US$128,000–150,000 per plug; installation, US$26,000–66,000 per plug[b]	
	Install separate meter	Decision to separately meter	US$1,200–5,000	
Utility on-site	Install distribution transformer	200+ kW load	Procurement, US$12,000–175,000	3–8
Distribution feeder	Install/upgrade feeder circuit	5+ MW load[c]	US$2–12 million[d]	3–12[e]
Distribution substation	Add feeder breaker	5+ MW load[c]	-US$400,000	6–12[f]
	Substation upgrade	3–10+ MW load[g]	US$3–5 million	12–18
	New substation installation	3–10+ MW load[g]	US$4–35 million	24–48[h]

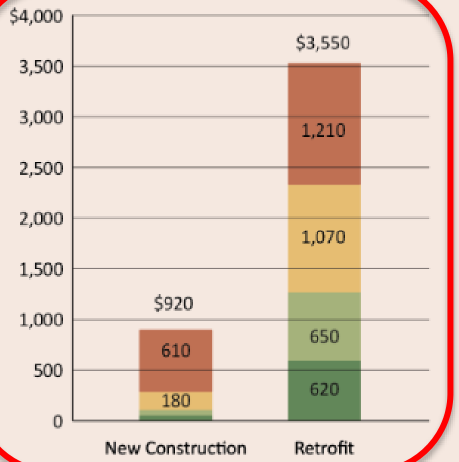
[a]Cost and timeline ranges include procurement, engineering, design, scheduling, permitting and construction and installation; estimates are project-specific and vary greatly. [b]Costs reflective of 2019 and expected to continue to fall in future years; EVSE installation includes upgrading or installing service conductors and load centres; per-unit installation costs are reduced as the number of installed units increase. [c]Feeder extensions or upgrades (including new feeder breakers) are typically required for new loads >5 MW, especially for voltages <20 kV; new loads >12 MW may require a dedicated feeder. [d]Feeder extensions or upgrades tend to be more expensive in urban areas than in rural areas. [e]Timeline for feeder extensions includes jurisdictional permitting for construction, obtaining easements and right-of-way, and procurement lead times. [f]Timeline for adding a new feeder breaker depends on substation layout and the time required to receive clearance for construction. [g]The decision to upgrade an existing substation versus to build a new one is largely dependent on the layout of the existing substation and whether there is sufficient room for expansion. [h]Additional time may be required for regulatory approval for the transmission line construction. DCFC, direct current fast charging.

Source: Borlaug, B., Muratori, M., Gilleran, M., Woody, D., Muston, W., Canada, T., Ingram, A., Greshman, H., & McQueen, C. (2021). "Heavy-duty truck electrification and the impacts of depot charging on electricity distribution systems". *Nature Energy*, **6**, 673-682. https://doi.org/10.1038/s41560-021-00855-0

L2 cost example: 4x difference between new construction and retrofit EVSE-ready outlet

Cost per EV Parking Space: New Construction vs Retrofit

Case Study prepared for the City and County of San Francisco (2016)



The case study considers a parking lot with ten total spaces and two EV parking spaces, and compares the EV infrastructure installation costs at the time of new construction versus building retrofit. "EV parking spaces" define spaces that have an EV-ready outlet, and include the electrical panel capacity, raceways, breakers, outlet boxes, and wiring to install an EV charger at any given time in the future.

- Balance of Circuit
- Raceway
- Permitting & Inspection
- Construction Management

1. EV-Capable

   Install electrical panel capacity with a dedicated branch circuit and a continuous raceway from the panel to the future EV parking spot.

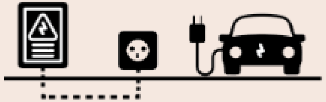
   Aspen, CO: 3% of parking is EV-Capable (IBC)

   Atlanta, GA: 20% is EV-Capable (Ordinance)

2. EVSE-Ready Outlet

   Install electrical panel capacity and raceway with conduit to terminate in a junction box or 240-volt charging outlet (typical clothing dryer outlet).

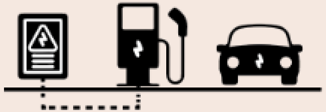
   Boulder, CO: 10% of parking is EV-Ready Outlet



3. EVSE-Installed

   Install a minimum number of Level 2 EV charging stations.

   Palo Alto, CA: 5-10% of parking is EV-Installed



Source: Southwest Energy Efficiency project (2018). "Cracking the Code on EV Ready Building Codes."