AGENDA
LACEY PLANNING COMMISSION MEETING
Tuesday, September 7, 2021 – 5:00 p.m.
MEETING WILL BE CONDUCTED REMOTELY, NOT IN-PERSON
Please click the link below to join the webinar:

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Webinar ID: 872 6016 2384

Call to Order: 5:00 p.m.

Approval of Agenda & Consent Items: 5:01 p.m.
A. Approval of Agenda
B. Approval of July 20, August 3, and August 17 Minutes

Public Comments: 5:02 p.m.

Commission Members' Reports: 5:04 p.m.

Director's Report: 5:05 p.m.

Old Business: 5:10 p.m.
Electric Vehicle Parking: Ryan Andrews, Planning Manager. Staff will brief the Planning Commission and present options on adding standards within the Lacey Municipal Code for electric vehicle parking.

Communications and Announcements: 5:55 p.m.

Next Meeting: September 21, 2021.

Adjournment: 6:00 p.m.

CITY OF LACEY PLANNING COMMISSION **WORK SCHEDULE**	
Planning Commission Meeting **September 7, 2021** **Packets due: September 2, 2021**	1. **Work Session:** Parking Code (EV Amendments)
Planning Commission Meeting **September 21, 2021** **Packets due: September 16, 2021**	1. **Work Session:** Martin Way Corridor Update 2. **Work Session:** Parking Code (multi-family follow-up)
Planning Commission Meeting **October 5, 2021** **Packets due: September 30, 2021**	1. **Public Hearing:** Parking Code

MINUTES
Lacey Planning Commission Meeting
Tuesday, July 20, 2021 – 5:00 p.m.
Conducted remotely via videoconference

Meeting was called to order at 5:00 p.m. by Dave Wasson.

Planning Commission members present: Dave Wasson, Gail Madden, Peg Evans-Brown, Daphne Retzlaff, Kyrian MacMichael, Mark Mininger, Eduardo Maldonado, Eddie Bishop, and Robin Vasquez. Staff present: Rick Walk, Ryan Andrews, and Jessica Brandt.

Dave noted a quorum present.

Eddie Bishop made a motion, seconded by Mark Mininger, to approve the agenda for tonight's meeting and the June 15 meeting minutes. All were in favor, the motion carried.

1. **Public Comments:** None.

2. **Commission Members Reports:**
   - Daphne noted that she completed the Martin Way Corridor survey.
   - Kyrian reported on her attendance at the City's 4th of July celebration and noted that she completed the Martin Way Corridor survey.
   - Gail asked for an update on the Hicks Lake development. Rick said he will arrange for one of the planners to give an update at the next Planning Commission meeting, and pointed out that there is a community forum webinar recording available and he'll send the link for the recording.
   - Mark commented on the street upgrades along Mullen Road from College Street to Timberline High School.
   - Robin commented on a conversation she had with some residents of the Clearbrook area and was surprised to learn that they are still on septic systems. Rick discussed the septic to sewer conversion process.
   - Peg commented on the Martin Way Corridor survey and the Hicks Lake development project.
   - Dave asked new Planning Commissioner Eduardo to introduce himself.

3. **Director's Report:**
   - Rick reported on the action taken at the last Council meeting, which included establishing a mobile outreach team to engage with the homeless community.
   - Rick gave an update on the Community Workgroup on Homelessness.
   - Rick noted that this Thursday's Council worksession will include a discussion regarding returning to in-person meetings. Planning Commission will follow what Council decides and meetings may be held as in-person hybrid beginning in September.
   - Rick asked Planning Commissioners to introduce themselves to Eduardo.

4. **New Business:**
   LMC 16.72 Parking Amendments: Ryan Andrews, Planning Manager.
   - Ryan gave some background information and shared a YouTube video on parking history.
   - A brief discussion followed.
   - Multi-family and electric vehicle parking was discussed.

5. **Old Business:**
   Debrief on Council Work Sessions for 2021 Comp Plan Amendments: Ryan Andrews, Planning Manager; Jessica Brandt, Associate Planner.
   - Jessica updated Planning Commission on Council worksessions regarding Climate Mitigation and Urban Forest Management plans.
   - Ryan discussed the Housing Action Plan.

6. **Communications and Announcements:**
   - It was noted that entertainment in the park has resumed in Huntamer Park.
   - There was a discussion regarding whether or not the August 3 Planning Commission will be cancelled. Staff said most likely the meeting will be cancelled.

7. **Next Meeting:** August 3, 2021 (tentative).

8. **Adjournment:** 6:35 p.m.

MINUTES
Lacey Planning Commission Meeting
Tuesday, August 3, 2021 – 5:00 p.m.
Conducted remotely via videoconference

Meeting was called to order at 5:00 p.m. by Dave Wasson.

Planning Commission members present: Dave Wasson, Gail Madden, Peg Evans-Brown, Daphne Retzlaff, Kyrian MacMichael, Mark Mininger, Eduardo Maldonado, Eddie Bishop, and Robin Vasquez. Staff present: Rick Walk, Scott Egger, Peter Brooks, and Samra Seymour.

Dave noted a quorum present.

Eddie Bishop made a motion, seconded by Kyrian MacMichael, to approve the agenda for tonight's meeting. All were in favor, the motion carried.

1. **Public Comments:** None.

2. **Commission Members Reports:**
   - Robin commented on the Parks Outreach Committee meeting.
   - Kyrian noted that she watched the webinar regarding the Hicks Lake multi-family development and reported on her attendance at the Washington State Legislative Redistricting Commission.
   - Dave noted that the items on tonight's agenda are merely for informational/educational purposes and no action will be required of Planning Commission.

3. **Director's Report:**
   - Rick introduced Scott Egger, Peter Brooks, and Samra Seymour.

4. **New Business:**
   Septic to Sewer Conversion Program: Scott Egger, Public Works Director.
   - Scott and Peter briefed Planning Commission on the septic to sewer conversion program including when connection to sewer is required and tools available to facilitate conversion from septic to sewer.
   - Discussions followed and Scott and Peter answered questions.

   Hicks Lake Multi-family Projects: Samra Seymour, Senior Planner.
   - Rick gave some background information and noted that there are two separate projects on two parcels along Hicks Lake that are in review. Rick went over the levels of the review process.
   - Samra gave a presentation that included an overview of the land use permitting process.
   - Discussions followed and Staff answered questions.

5. **Communications and Announcements:**
   - Kyrian asked that Staff provide a presentation regarding differing costs of parking and the effect on development. Rick noted that will be included in the next discussion of the parking amendments.

6. **Next Meeting:** August 17, 2021.

7. **Adjournment:** 6:35 p.m.

MINUTES
Lacey Planning Commission Meeting
Tuesday, August 17, 2021 – 5:00 p.m.
Conducted remotely via videoconference

Meeting was called to order at 5:00 p.m. by Dave Wasson.

Planning Commission members present: Dave Wasson, Gail Madden, Peg Evans-Brown, Daphne Retzlaff, Kyrian MacMichael, Mark Mininger, Eduardo Maldonado, and Robin Vasquez. Staff present: Rick Walk, Ryan Andrews, Jessica Brandt.

Dave noted a quorum present.

Peg Evans-Brown made a motion, seconded by Mark Mininger, to approve the agenda for tonight's meeting. All were in favor, the motion carried.

1. **Public Comments:** None.

2. **Commission Members Reports:**
   - Peg reported on her viewing of the last Council meeting.
   - Robin reported on her attendance at the last Parks Outreach Meeting.

3. **Director's Report:**
   - Rick reported on the August 5 Council meeting. In light of recent increasing Covid cases, Council decided that meetings will continue to be held via Zoom.
   - Rick gave an update on selection process for the candidate for the new assistant director position in Community & Economic Development.

4. **New Business:**
   Capital Facilities Plan Update: Jessica Brandt, Associate Planner.
   - Jessica gave some background information and shared a presentation on the Capital Facilities Plan Update.
   - Discussions followed and staff answered questions.

5. **Old Business:**
   Multi-family Parking Standards: Ryan Andrews, Planning Manager.
   - Ryan went over current parking standards, discussed the need for amending the standards, and costs associated with developments.
   - Discussions followed and staff answered questions.
   - Ryan noted that electric vehicle parking will be discussed at the next Planning Commission. Staff will provide draft amendments and demographics for further discussion before moving forward to public hearing.

6. **Communications and Announcements:** None.

7. **Next Meeting:** September 7, 2021.

8. **Adjournment:** 6:20 p.m.

CITY OF LACEY
Shaping our community together

PLANNING COMMISSION STAFF REPORT
September 7, 2021

SUBJECT: **LMC 16.73, Parking Standards for Electric Vehicle Charging**

RECOMMENDATION: Hear a briefing from staff and consider options to amend parking standards in LMC 16.73 to include electric vehicle charging. No recommendation at this time.

TO: Lacey Planning Commission

STAFF CONTACTS: Rick Walk, Director of Community and Economic Development
Ryan Andrews, Planning Manager RA

ATTACHMENT(S):
1. Lacey Municipal Code 16.73: Electric Vehicle Infrastructure
2. Example Electric Vehicle Charging Station Requirements:
   a. Covington
   b. Mountlake Terrace
   c. Port Orchard
3. *Electric Vehicles Are On the Rise,* Planning article
4. *Estimating electric vehicle charging infrastructure costs across major U.S. metropolitan areas,* ICCT article.

PRIOR COUNCIL/ COMMISSION/ COMMITTEE REVIEW: July 20, 2021 Planning Commission Meeting

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BACKGROUND:

At the July 20th work session, the Planning Commission began reviewing parking standards in LMC 16.73 to address electric vehicle parking. The purpose of this briefing is to consider options for standards related electric vehicle parking and charging stations.

Electric Vehicle Parking/Charging

A priority implementation item within the Thurston Climate Mitigation Plan is to establish code requirements for electric vehicle parking. Currently, Lacey does have municipal code standards for electric vehicle infrastructure (see attachment 1), however, the code does not require electric vehicle parking.

Staff has researched other development codes for similar-sized cities around the Puget Sound area which require electric vehicle parking and have attached them for review. Most of the codes establish thresholds for when electric vehicle parking is required associated with new development or remodels/expansion. The regulations also require a number of stalls based on the underlying use of the building and the size of the parking lot. Most ratios are between 1% and 10% of the total number of stalls being dedicated to electric vehicles. The higher ratios are for multi-family residential uses where demand will be higher than lower demand areas like commercial and industrial uses.

Type of Charger Required

Level 2 or 3 is a typical requirement in the context of commercial, office, and multi-family residential. Single family homes already have Level 1 charging with a standard 120V wall outlet.

Charging level	Voltage	Typical power	Electric vehicle miles of range per charging hour	Location
Level 1	120 V AC	1.2-1.4 kW AC	3-4 miles	Primarily home and some workplace
Level 2	208 V-240 V AC	3.3-6.6 kW AC	10-20 miles	Home, workplace, and public
DC fast	400 V-1,000 V DC	50 kW or more	150-1,000 miles	Public, frequently intercity

Note: AC = alternating current; DC = direct current; kW = kilowatt; V = volt

Cost of Installation

Costs can vary depending on scale. Level 1 charging for residential is a simple wall outlet, which could be upgraded to a Level 2 for a few hundred dollars if there is space on the electrical panel. If a single family home panel needs upgrading the costs can get up to a few thousand dollars, mostly due to hiring a licensed electrician.

For installing standalone pedestal chargers, the cost goes up due to labor and materials.

Level	Type	Chargers per pedestal	Per-charger cost
Level 1	Non-networked	One	$813
Level 1	Non-networked	Two	$596
Level 2	Non-networked	One	$1,182
Level 2	Non-networked	Two	$938
Level 2	Networked	One	$3,127
Level 2	Networked	Two	$2,793
DC fast	Networked 50 kW	One	$28,401
DC fast	Networked 150 kW	One	$75,000
DC fast	Networked 350 kW	One	$140,000

Ratio of EV stalls to standard stalls

- Covington – Mixed residential and multi-family residential, a minimum of one Level 2 or Level 3 charger for every 30 parking stalls (3%). Neighborhood commercial and community commercial a minimum of one Level 2 or Level 3 for every 50 parking stalls (2%). Regional Commercial Mixed use one Level 2 or Level 3 for every 100 parking stalls (1%).
- Mountlake Terrace – Multifamily has highest required at 10% of spaces. Lodging, Office, Medical, Institutional, Municipal, and Other require 3%. Retail, Eating,

Drinking establishments, Industrial, and Recreational/entertainment/cultural require 1%.
- Port Orchard - Multifamily has highest required at 10% of spaces. Convenience store with fuel pumps require 5%, minimum of two spaces. Lodging, Office, Medical, Institutional, Civic, and Other require 3%. Retail, Eating, Drinking establishments, Industrial, and Recreational/entertainment/cultural require 1%.

<u>Design Standards</u>
Port Orchard and Mountlake Terrace have similar standards.
- Posted signage
- Location, design, maintenance
- Time limits
- Accessible EV stations ratios (1 per 5-50 EV stalls, 2 per 50-100, etc.)

<u>What Triggers New EV stalls?</u>
The jurisdictions that require EV stalls require them with new development. Some also require them when substantial alterations or remodels are completed. Listed below are the triggers that require the installation of EV stalls within the various jursidictions:
- Covington
    - New development in commercial, office, multi-family development zone
    - New public park or public building

- Mountlake Terrace
    - A new building or new off-street parking is developed
    - An addition or implement that meets a certain threshold pursuant to MTMC 19.120.250
    - The parking capacity of an existing building, site, or parking facility is increased by more than 50 percent

- Port Orchard
    - A new development of 10,000 gross square feet or more
    - A new multifamily residential development with 10 or more units
    - Addition or improvement to existing that brings total development to 10,000 or more
    - Parking capacity of exiting parking garage or lot is increased by more than 50 percent

<u>Which Location and Types of Uses Should Have Charging?</u>

When considering standards for EV parking, there are some land uses that would be more appropriate than others when it comes to longer term parking that would benefit from the time needed to charge a vehicle. Those land uses are listed below that would be the most appropriate for EV charging stations:
- Medical Campus
- Higher Education
- Public Sector
- Neighborhood Center – retail/commercial
- Leisure Destination
- Multi-Family Apartment

At the work session, staff will provide an overview of the development codes from other jurisdictions to the Planning Commission. Based on the discussion and direction by the Planning Commission, staff will develop draft amendments for electric vehicle parking requirements for further consideration by the Planning Commission. Other jurisdictions in Thurston County have not yet adopted electric vehicle charging requirements. By Lacey taking early action, coordination can occur through the regional climate mitigation planning group to potentially establish these as regionally agreed upon standards.

RECOMMENDATION:

No action is required. This is an introductory briefing and discussion by the Planning Commission. Based on the discussion by the Planning Commission, drat amendments to multi-family and electric vehicle charging will be presented and reviewed at a future work session.

Chapter 16.73
ELECTRIC VEHICLE INFRASTRUCTURE

Sections:

16.73.010 Intent.

A. To provide adequate and convenient electric vehicle charging stations to serve the needs of the traveling public;

B. To provide opportunities for Lacey residents to have safe and efficient personal electric charging stations located at their place of residence;

C. To provide the opportunity for commercial and industrial projects to supply electrical vehicle charging station services to their customers and employees;

D. To create standard criteria to encourage and promote safe, efficient and cost effective electric vehicle charging opportunities in a full range of zones and settings for convenience of service to those that use electric vehicles.

16.73.015 General Provisions.

A. Use of specially designated charging stalls: Electric vehicle charging stations should be reserved for parking and charging electric vehicles only.

B. Electric vehicles parking: Electric vehicles may be parked in any space designated for public parking, subject to the restrictions that would apply to any other vehicle that would park in that space.

16.73.020 Definitions.

A. "Battery charging station" means an electrical component assembly or cluster of component assemblies designed specifically to charge batteries within electric vehicles, which meet or exceed any standards, codes, and regulations set forth by Chapter 19.28 RCW and consistent with rules adopted under RCW 19.27.540.

B. “BEV” means a battery electric vehicle. A battery electric vehicle, or BEV, is a type of electric vehicle (EV) that uses chemical energy stored in rechargeable battery packs. As with other electric vehicles, BEVs use electric motors and motor controllers instead of internal combustion engines (ICEs) for propulsion. Sometimes, all-electric vehicles are referred to as BEVs (although a plug-in hybrid vehicle is also a battery electric vehicle).

C. “Battery exchange station” means a fully automated facility that will enable an electric vehicle with a swappable battery to enter a drive lane and exchange the depleted battery with a fully charged battery through a fully automated process, which meets or exceeds any standards, codes, and regulations set forth by Chapter 19.27 RCW and consistent with rules adopted under RCW 19.27.540.

D. “Charging levels” means the electrical force, or voltage, at which an electric vehicle’s battery is recharged. Levels 1, 2, and 3 are the most common EV charging levels, and include the following specifications:

1. Level 1 is considered slow charging. It requires a 15 or 20 amp breaker on a 120-volt AC circuit and standard outlet. This level of charging can fully recharge a BEV between 8 and 32 hours and a PHEV between 3 and 15 hours.

2. Level 2 is considered medium charging. It requires a 40 amp to 100 amp breaker on a 240-volt AC circuit. This level of charging can fully recharge a BEV between 4 and 6 hours and a PHEV between 1 and 2 hours.

3. Level 3 is considered fast charging. It requires a 60 amp or higher dedicated breaker on a 480 volt or higher three-phase circuit with special grounding equipment. Level 3 charging uses an off-board charger to provide the AC to DC conversion, delivering DC directly to the car battery. Charging time ranges from 25-40 minutes for BEVs and less than 20 minutes for PHEVs.

E. “Electric vehicle” means any vehicle that operates, either partially or exclusively, on electrical energy from the grid, or an off-board source, that is stored on-board for motive purpose. “Electric vehicle” includes: (1) a battery electric vehicle; (2) a plug-in hybrid electric vehicle; (3) a neighborhood electric vehicle; (4) medium-speed electric vehicle; and (5) electric motorcycles.

F. “Electric vehicle charging station” means a public or private parking space located together with a battery charging station which permits the transfer of electric energy (by conductive or inductive means) to a battery or other storage device in an electric vehicle. An electric vehicle charging station is permitted as an accessory use to any principal use.

G. “Electric vehicle infrastructure” means structures, machinery, and equipment necessary and integral to support an electric vehicle, including battery charging stations, rapid charging stations, and battery exchange stations.

H. “Electric vehicle parking space” means any marked parking space that identifies the use to be exclusively for an electric vehicle.

I. “Fast charging station” means an industrial grade electrical outlet that allows for faster recharging of electric vehicle batteries through higher power levels, which meets or exceeds any standards, codes, and regulations set forth by Chapter 19.28 RCW and consistent with rules adopted under RCW 19.27.540.

J. "NEV" means a Neighborhood Electric Vehicle. This is an electric vehicle that is capable of traveling at a maximum speed of 25 mph. They come with safety features like headlights, turn signals and seat belts. They may also be referred to as Low Speed Vehicles or LSVs.

K. "Non-Electric Vehicle" means any motor vehicle that does not meet the definition of "electric vehicle."

L. "PHEV" is a plug-in hybrid electric vehicle, also known as a plug-in hybrid. It is a hybrid vehicle with rechargeable batteries that can be restored to full charge by connecting a plug to an external electric power source. A PHEV shares the characteristics of both a conventional hybrid electric vehicle, having an electric motor and an internal combustion engine; and of an all-electric vehicle, also having a plug to connect to the electrical grid. Most PHEVs on the road today are passenger cars, but there are also PHEV versions of commercial vehicles and vans, utility trucks, buses, trains, motorcycles, scooters, and military vehicles.

16.73.030 Where Permitted.

A. *Zones Allowed.* "Electric Vehicle charging stations" shall be considered an allowed use in association with a primary permitted use in every zoning designation;

B. *Compatibility.* For land use compatibility purposes, the charging activity should be proportionate to the associated permitted use; "Electric vehicle charging station(s)" shall be permitted in association with a single family use designed to serve the occupants of the home with a level 1 or 2 charging level. Whereas, charging station(s) installed in a parking lot at a commercial destination, or located in a vehicle service station in close proximity to Interstate 5, is expected to have intensive use and will be permitted to have multiple "fast charging stations" to serve expected demand.

C. *Battery Exchange Stations.* "Battery exchange stations" are permitted in any commercial, industrial or mixed use zone. Provided, all other requirements for the building or space the use occupies can be satisfied, such as design review, fire code and building code requirements. This use is specifically prohibited in exclusively residential zones or zones designated OSI for environmentally sensitive reasons.

16.73.035 Process for Review.

A. *New Residential Construction.* If associated with new residential construction, installation of a charging station shall be processed in association with the underlying permit(s).

B. *Retrofitting Single-Family Residential.* If retrofitting a single family home for a charging station, an electrical permit shall be required.

C. *Retrofitting a Commercial Site, Multifamily Residential or Community Site in a Residential Land Division.*

1. *SPR Required If Impacts Identified.* If the director of community and economic development determines that retrofitting for a charging station(s) in an existing commercial, multifamily, or community site in a residential land division could significantly impact parking, landscaping, signing, drainage or other public

interest concerns, that proposal will be reviewed and approved through the city site plan review (SPR) process (Chapter 16.84 LMC).

2. *Exempted If No Impacts Identified.* If the director of community and economic development determines a retrofit will not adversely impact any issues of public interest, the proposal may be exempted from SPR requirements.

3. *Site Plan Required for Evaluation.* To determine if the application will be processed through SPR or exempted, the applicant shall submit a site plan showing the location and scope of the proposal.

4. *Electrical Permit Required.* All applications, exempted or requiring SPR, shall also require an electrical permit.

D. *Battery Exchange.* If the facility includes a battery exchange station, or is associated with a new commercial activity requiring SPR approval, the application shall be reviewed and approved through SPR (Chapter 16.84 LMC). (Ord. 1539 §122, 2019).

16.73.040 Design Criteria and Guidelines.

A. Design criteria for commercial and multifamily development or common/community owned areas of a residential development: The following criteria should be applied to electric charging facilities:

1. *Number required.* This is an option improvement. No minimum number of stalls applies. Provided, if electric vehicle stalls are reserved for electric vehicles, care should be taken to ensure enough spots are available for all of a site's parking needs.

2. *Generally.* Location and layout of electric vehicle parking is expected to vary based on the design and use of the primary parking lot. It is expected flexibility will be required to provide the most convenient and functional service to users. Standards and criteria should be considered guidelines and flexibility should be allowed when alternatives can better achieve objectives for provision of this service.

3. *Signage to identify.* Each charging station space should be posted with signage indicating the space is only for electric vehicle charging purposes. Days and hours of operations should be included if time limits or tow away provisions are to be enforced by the owner.

4. *Signage to find.* Installation of wayfinding signs at the parking lot entrance and at appropriate decision points to effectively guide motorists to the charging station space(s).

5. *Maintenance.* Charging station equipment should be maintained in all respects, including the functioning of the charging equipment.

6. *Accessibility.* Where Charging Station equipment is provided within an adjacent pedestrian circulation area, such as a sidewalk or accessible route to the building entrance, charging equipment should be located so as to not interfere with accessibility requirements of WAC 51-50-005.

7. *Lighting.* Where Charging Station equipment is installed adequate site lighting should also be provided unless charging is for daytime purposes only.

8. *Notification of station specifics.* Information on the charging station must identify voltage and amperage levels and time of use, fees or safety information.

9. *Avoid the most convenient parking spaces.* Stalls should not be located in the most convenient spots because this would encourage use by non electric vehicles.

10. *Avoid conflict with handicap spots.* Stalls should generally not be located adjacent to handicap spots unless designed for handicap use.

11. *Design for compatibility.* Design should be appropriate to the location and use. Facilities should be able to be readily identified by electric car users but blended into the surrounding landscape/ architecture for compatibility with the character and use of the site.

12. *Size.* Where provided, spaces should be standard size parking stalls.

13. *Public streets.* Generally charging stations should not be located along public streets where it could impact the landscaping and aesthetic components of the streetscape. Sites within the streetscape must be approved by the Public Works Director.

B. *Electric vehicle charging station design standards for single family residential sites.* Installation of vehicle charging stations on single family residential sites shall meet the manufacturing and installation requirements of the International Building Code (IBC) and National Electrical Code (NEC). (Ord. 1351 §1, 2010).

18.50.160 Electric vehicle charging station requirements – Downtown zones.

This section applies to all electric vehicle charging stations located in off-street parking facilities or parking garages in the TC, MC, GC, and MHO zones.

(1) New development located in the TC and GC zones shall provide a minimum of one Level 2 or Level 3 electric vehicle charging station for every 100 vehicle parking spaces.

(2) New commercial development located in the MC and MHO zones shall provide a minimum of one Level 2 or Level 3 electric vehicle charging station for every 50 vehicle parking spaces.

(3) Any new government services (CMC 18.31.080) shall provide a minimum of one Level 2 or Level 3 electric vehicle charging station regardless of the number of vehicle parking stalls required for the site. If the number of required off-street vehicle parking stalls exceed the provisions of subsections (1) and (2) of this section, then those regulations shall apply. (Ord. 19-11 § 1 (Exh. 1))

18.50.170 Electric vehicle charging station requirements – R-18, MR, NC, CC, RCMU, and I zones.

This section applies to all electric vehicle charging stations located in off-street parking facilities or parking garages in the R-18, MR, NC, CC, RCMU and I zones.

(1) New development located in the R-18 and MR zones shall provide a minimum of one Level 2 or Level 3 electric vehicle charging station for every 30 vehicle parking stalls.

(2) New development located in the NC, CC and I zones shall provide a minimum of one Level 2 or Level 3 electric vehicle charging station for every 50 vehicle parking stalls. New development located in the RCMU zone shall provide a minimum of one Level 2 or Level 3 electric vehicle charging station for every 100 vehicle parking stalls.

(3) Any new park (CMC 18.25.040) that is publicly owned and maintained and any new government services (CMC 18.25.060) shall provide a minimum of one Level 2 or Level 3 electric vehicle charging station regardless of the number of vehicle parking stalls required for the site. If the number of required off-street vehicle parking stalls exceeds the provisions of subsections (1) and (2) of this section, then those regulations shall apply. (Ord. 03-14 § 1; Ord. 01-14 § 1 (Exh. A); Ord. 19-11 § 1 (Exh. 1))

18.50.180 Electric vehicle charging station design standards.

(1) An electric vehicle charging station may be included in the calculation for minimum required parking spaces as required in CMC 18.31.110(4) and 18.50.030.

(2) The Director may reduce or waive the requirement for the installation of electric vehicle charging stations if the applicant can demonstrate:

(a) That a shared parking facility provides access to an adjacent parking facility with a minimum of two existing electric vehicle charging stations; or

(b) That the proposed parking facility is providing cross-access to an adjacent parking facility with a minimum of two existing electric vehicle charging stations; and

(c) The applicant has a contract for the shared use of the above-required electric vehicle charging stations between the appropriate property owners. The contract shall be recorded with King County Records and Elections as a deed restriction that cannot be modified or revoked without approval by the Director.

(3) Where electric vehicle charging stations are required in parking lots or parking garages, accessible vehicle charging stations shall be provided.

(a) Accessible electric vehicle charging stations should be located in close proximity to the building or facility entrance and shall connect to a barrier-free accessible route of travel. It is not required to designate the charging station exclusively for the use of disabled persons.

(4) The provision of electric vehicle parking will vary based on the design and use of the primary parking lot. The following required and additional location and design criteria are provided in recognition of the various parking lot layout options. Where provided, parking for electric vehicle charging purposes shall include the following:

(a) Each charging station space shall be posted with signage indicating the space is only for electric vehicle charging purposes. Days and hours of operation shall be included if time limits or tow away provisions are to be enforced. Refer to the 2009 Manual on Uniform Traffic Control Devices (MUTCD) for electric vehicle and parking signs, specifically D9-11b, D9-11bP, R7-2, and R7-108, and as amended.

(b) Charging station equipment shall be maintained, including the functioning of the charging equipment. A phone number or other contact information shall be provided on the charging station equipment for reporting when the equipment is not functioning or when other problems are encountered.

(c) Where charging station equipment is provided within an adjacent pedestrian circulation area, such as a sidewalk or accessible route to the building entrance, the charging equipment shall be located so as not to interfere with ADA accessibility requirements.

(d) Where charging station equipment is installed, adequate site lighting shall exist, unless charging is for daytime purposes only.

(e) Charging station outlets and connector devices shall be no less than 36 inches and no higher than 48 inches from the surface where mounted, and shall contain a retraction device or a place to hang permanent cords and connectors sufficiently above the ground or paved surface.

(f) Except for parallel parking stalls, adequate equipment protection, such as wheel stops or concrete-filled steel bollards, shall be used. Curbing may be used in lieu of wheel stops or bollards if equipment is set back a minimum of 24 inches from the face of the curb.

(5) Parking for electric vehicles should also consider the following:

(a) Information on the charging station identifying voltage and amperage levels and any time of use, fees, or safety information.

(b) Installation of directional signs at the parking lot entrance and at appropriate decision points to guide motorists to the charging station space(s). Refer to the 2009 Manual on Uniform Traffic Control Devices (MUTCD) for electric vehicle and directional signs, specifically D9-11b, D9-11bP and M6-1, and as amended.

(6) To allow for maintenance and notification, the owner of any private new electric vehicle infrastructure station that will be publicly available shall be required to provide information on the station’s geographic location, date of installation, equipment type and model, and owner contact information.

(7) On-street electric vehicle charging stations shall conform to the following:

(a) On-street electric vehicle charging stations are not permitted in the R-1 through R-18 zones.

(b) On-street electric vehicle charging stations in the TC, MC, GC and MHO zone shall be installed at either end of designated on-street parking.

(c) Subsequent on-street electric vehicle charging stations should be installed adjacent to existing stations.

(d) Charging station equipment shall be installed in a well-lit area, on a hard surface, near the front of the designated parking space and should provide a minimum of 24 inches’ clearance from the face of the curb and not impede the required minimum ADA accessible route on the sidewalk. (Ord. 19-11 § 1 (Exh. 1))

Chapter 19.126
ELECTRIC VEHICLE INFRASTRUCTURE

Sections:

19.126.010 Purpose.

The purpose of this chapter is to encourage the transition to electric vehicle use and to expedite the establishment of a convenient, cost-effective electric vehicle infrastructure that such a transition necessitates. (Ord. 2553 § 2, 2010).

19.126.020 Definitions.

For the purposes of this chapter and other chapters of the municipal code that address electric vehicle infrastructure, the following definitions shall apply:

“Accessible electric vehicle charging station” means an electric vehicle charging station where the battery charging station equipment is located within accessible reach of a barrier-free access aisle (minimum 44-inch width) and the electric vehicle.

“Battery charging station” means an electrical component assembly or cluster of component assemblies designed specifically to charge batteries within electric vehicles, which meet or exceed any standards, codes, and regulations set forth by Chapter 19.28 RCW and consistent with rules adopted under RCW 19.27.540.

“Battery electric vehicle (BEV)” means any vehicle that operates exclusively on electrical energy from an off-board source that is stored in the vehicle’s batteries, and produces zero tailpipe emissions or pollution when stationary or operating.

"Battery exchange station" means a fully automated facility that will enable an electric vehicle with a swappable battery to enter a drive lane and exchange the depleted battery with a fully charged battery through a fully automated process, which meets or exceeds any standards, codes, and regulations set forth by Chapter 19.27 RCW and consistent with rules adopted under RCW 19.27.540.

"Charging level" means the standardized indicators of electrical force, or voltage, at which an electric vehicle's battery is recharged. Levels 1, 2, and 3 are defined by the electrical output, per the following specifications:

1. Level 1. Voltage including the range from zero through 120.

2. Level 2. Voltage is greater than 120 and includes 240.

3. Level 3 is considered fast or rapid charging. Voltage is greater than 240.

"Designated accessible space" means an accessible parking space required by WAC 51-50-005 and designated for the exclusive use of parking vehicles with a State Disabled Parking Permit.

"Electric scooters and motorcycles" means any two-wheel vehicle that operates exclusively on electrical energy from an off-board source that is stored in the vehicle's batteries and produces zero emissions or pollution when stationary or operating.

"Electric vehicle" means any vehicle that operates, either partially or exclusively, on electrical energy from the grid, or an off-board source, that is stored on board for motive purpose. "Electric vehicle" includes: (1) a battery electric vehicle; (2) a plug-in hybrid electric vehicle; (3) a neighborhood electric vehicle; and (4) a medium-speed electric vehicle.

"Electric vehicle charging station" means a public or private parking space that is served by battery charging station equipment that has as its primary purpose the transfer of electric energy (by conductive or inductive means) to a battery or other energy storage device in an electric vehicle. An electric vehicle charging station equipped with Level 1 or Level 2 charging equipment is permitted outright as an accessory use to any principal use.

"Electric vehicle charging station – public" means an electric vehicle charging station that is (1) publicly owned and publicly available (e.g., park and ride parking, public library parking lot, on-street parking) or (2) privately owned and publicly available (e.g., shopping center parking, nonreserved parking in multifamily parking lots).

"Electric vehicle charging station – restricted" means an electric vehicle charging station that is (1) privately owned and restricted access (e.g., single-family home, executive parking, designated employee parking) or (2) publicly owned and restricted (e.g., fleet parking with no access to the general public).

“Electric vehicle infrastructure” means structures, machinery, and equipment necessary and integral to support an electric vehicle, including battery charging stations, rapid charging stations, and battery exchange stations.

“Electric vehicle parking space” means any marked parking space that identifies the use to be exclusively for the parking of an electric vehicle.

“Medium-speed electric vehicle” means a self-propelled, electrically powered four-wheeled motor vehicle, equipped with a roll cage or crush-proof body design, whose speed attainable in one mile is more than 25 miles per hour but not more than 35 miles per hour and otherwise meets or exceeds the federal regulations set forth in 49 CFR 571.500.

“Neighborhood electric vehicle” means a self-propelled, electrically powered four-wheeled motor vehicle whose speed attainable in one mile is more than 20 miles per hour and not more than 25 miles per hour and conforms to federal regulations under 49 CFR Part 571.500.

“Nonelectric vehicle” means any motor vehicle that does not meet the definition of “electric vehicle.”

“Plug-in hybrid electric vehicle (PHEV)” means an electric vehicle that (1) contains an internal combustion engine and also allows power to be delivered to drive wheels by an electric motor; (2) charges its battery primarily by connecting to the grid or other off-board electrical source; (3) may additionally be able to sustain battery charge using an on-board internal-combustion-driven generator; and (4) has the ability to travel powered by electricity.

“Rapid charging station” means an industrial grade electrical outlet that allows for faster recharging of electric vehicle batteries through higher power levels and that meets or exceeds any standards, codes, and regulations set forth by Chapter 19.28 RCW and consistent with rules adopted under RCW 19.27.540. (Ord. 2553 § 2, 2010).

19.126.030 Permitted locations.

Electric vehicle infrastructure shall be permitted in zoning districts of the city as identified in MTMC 19.23.100. (Ord. 2553 § 2, 2010).

19.126.040 Required facilities.

A. Beginning July 1, 2011, development for each of the land uses identified in Table 19.126.040 shall be required to provide electric vehicle infrastructure as shown in the table. For purposes of Table 19.126.040, electric vehicle charging stations shall be provided when the development is 10,000 square feet or more and one of the following occurs:

1. A new building or a new off-street parking facility is developed;

2. An addition or improvement to an existing building is made that meets a certain threshold,

pursuant to MTMC 19.120.250; or

3. The parking capacity of an existing building, site, or parking facility is increased by more than 50 percent.

B. The first column in Table 19.126.040 shows the type of land use for which electric vehicle charging stations shall be provided, pursuant to this section. The second column shows the minimum percentage of the facility's parking spaces that shall provide a connection to electric vehicle charging stations.

Table 19.126.040
Required Number of Electric Vehicle Charging Stations

Land Use Type	Percentage of Parking Spaces
Multi-household residential	10%
Lodging	3%
Retail, eating and drinking establishment	1%
Office, medical	3%
Industrial	1%
Institutional, municipal	3%
Recreational/entertainment/cultural	1%
Other	3%

C. Design for Expansion. In order to allow for additional electric vehicle parking in the future as the market for such vehicles grows, beginning January 1, 2011, all development that meets the criteria of subsection A of this section shall be designed to allow for double the amount of electric vehicle parking shown in Table 19.126.040.

Site design must provide electrical, associated ventilation, accessible parking, and wiring connection to transformer to support the additional potential future electric vehicle charging stations. (Ord. 2553 § 2, 2010).

19.126.050 General station requirements.

A. Size. A standard size parking space shall be used for an electric vehicle charging station where such a station is required or planned.

B. Installation and Equipment. The station installation and equipment shall be consistent with the rules and regulations adopted pursuant to RCW 19.27.540, Electric vehicle infrastructure requirements, and with applicable regulations under the City's building code, Chapter 15.05 MTMC, and fire code, Chapter 15.10 MTMC.

C. Location, Design, and Maintenance. Where provided, parking for electric vehicle charging purposes shall meet the standards of subsections (C)(1) through (5) of this section.

1. Signage. Each charging station space shall be posted with signage indicating the space is only for electric vehicle charging purposes. Days and hours of operation shall be included if time limits or tow-away provisions are to be enforced.

2. Clearance. Charging station equipment mounted on pedestals, light posts, bollards or other devices shall be a minimum of 24 inches clear from the face of curb.

3. Charging Station Equipment. Charging station outlets and connector devices shall be no less than 36 inches or no higher than 48 inches from the top of surface where mounted, and shall contain a retraction device and/or a place to hang permanent cords and connectors sufficiently above the ground or paved surface.

4. Charging Station Equipment Protection. When the electric vehicle charging station space is perpendicular or at an angle to curb face and charging equipment, adequate equipment protection, such as wheel stops or concrete-filled steel bollards shall be used.

5. Maintenance. Charging station equipment shall be maintained in all respects, including the functioning of the charging equipment. A phone number or other contact information shall be provided on the charging station equipment for reporting when the equipment is not functioning or other problems are encountered.

D. Data to Be Available. To allow for maintenance and notification, the owners of any private new electric vehicle infrastructure station that will be publicly available (see definition of "electric vehicle charging station – public") shall provide information on the station's geographic location, date of installation, equipment type and model, and owner contact information.

E. Time limits may be placed on the number of hours that an electric vehicle is allowed to charge, prohibiting indefinite charging/parking. If applicable, warnings shall be posted to alert charging station users about hours of use and possible actions affecting electric vehicle charging stations that are not being used according to posted rules.

F. Electric vehicle signage shall be provided pursuant to MTMC 19.126.090.

G. Location. Placement of a single electric vehicle charging station is preferred at the beginning or end stall on a block face. (Ord. 2553 § 2, 2010).

19.126.060 Accessible facilities.

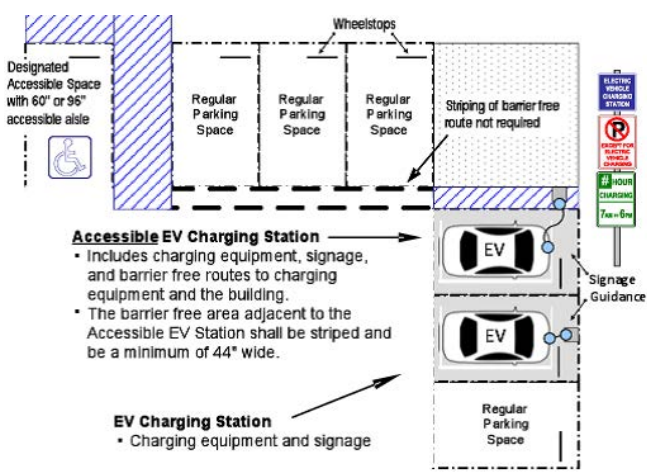
A. Where electric vehicle charging stations are provided in parking lots or parking garages, excluding garages in single-household residential units, accessible electric vehicle charging stations shall be provided according to the ratios shown on Table 19.126.060. The first column indicates the number of electric vehicle stations being provided on site and the second column indicates the number of accessible charging stations that are to be provided for the corresponding number(s) of charging stations.

Table 19.126.060
Minimum Number of Accessible Electric Vehicle (EV) Charging Stations

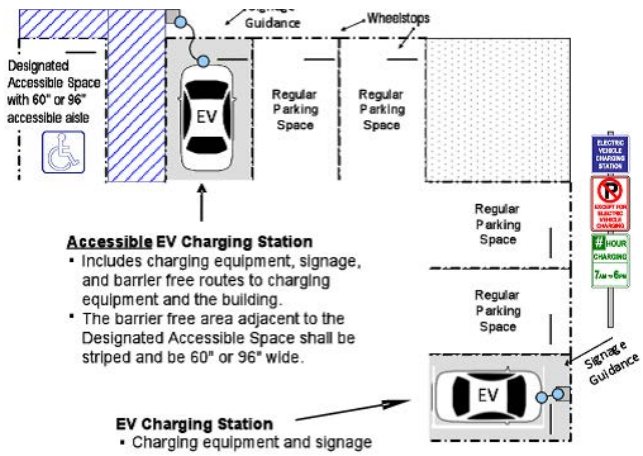
Number of EV charging stations	Minimum accessible EV charging stations
5–50	1
51–100	2
101–150	3
151–200	4
201–250	5
251–300	6

B. Accessible electric vehicle charging stations should be located in close proximity to the building or facility entrance and shall be connected to a barrier-free accessible route of travel. It is not necessary to designate the accessible electric vehicle charging station exclusively for the use of disabled persons. Below are two options for providing for accessible electric vehicle charging stations.

Option 1



Option 2



(Ord. 2553 § 2, 2010).

19.126.070 Charging and parking.

A. Electric vehicle charging stations, where provided for public use, are reserved for parking and charging electric vehicles only, except as otherwise provided by this chapter.

B. Electric vehicles may be parked in any space designated for public parking, subject to the restrictions that would apply to any other vehicle that would park in that space. (Ord. 2564 § 2, 2011; Ord. 2553 § 2, 2010).

19.126.080 Parking restrictions.

A. No person shall stop, stand or park any nonelectric vehicle in a space designated through signage as an electric vehicle charging station. Any nonelectric vehicle is subject to removal by the property owner or the property owner’s agent.

B. Any electric vehicle in an electric vehicle parking stall that is signed exclusively for electric vehicle charging and that either (1) is not electrically charging or (2) is parked beyond the days and hours designated on regulatory signs posted at or near the space shall be subject to removal as posted by the property owner or the property owner’s agent. For purposes of this subsection, “charging” means an electric vehicle is parked at an electric vehicle charging station and is connected to the charging station equipment. (Ord. 2564 § 3, 2011; Ord. 2553 § 2, 2010).

19.126.090 Signage.

A. Electric vehicle charging stations, other than in residential use, shall have posted signage, as identified in this section, allowing only charging electric vehicles to park in such spaces.

(Exception: the Director may allow an exemption for such signage at a portion of electric vehicle parking stalls within a publicly owned transit center upon the public transit agency demonstrating through a utilization study that not all of the electric vehicle charging stalls are needed for commuters using transit and that the amount of nonelectric vehicle parking is inadequate to meet existing needs; such exemption may be renewed by the Director each year, based on a utilization study completed during the prior year.) For purposes of this subsection, “charging” means that an electric vehicle is parked at an electric vehicle charging station and is connected to the charging station equipment.

B. Signage for parking of electric vehicles shall include:

1. Information on the charging station to identify voltage and amperage levels and any time of use, fees, or safety information.

2. As appropriate, directional signs to effectively guide motorists to the charging station space(s).

C. Optional Signage. Optional information may be posted to alert potential charging station users to other expectations. (Ord. 2564 § 4, 2011; Ord. 2553 § 2, 2010).

20.124.050 Electric vehicle parking required.

(1) Beginning January 1, 2020, development for each of the land uses identified in Table 20.124.050(1) shall be required to provide electric vehicle infrastructure as shown in the table. For the purposes of Table 20.124.050(1), electric vehicle charging stations shall be provided when a proposed development contains one or more of the land uses specified in the table, and one of the following occurs:

(a) A new development of 10,000 gross square feet or more is proposed;

(b) A new multifamily residential development containing 10 or more residential units is proposed;

(c) An addition or improvement is made to an existing development that brings the total development to 10,000 gross square feet or more; or

(d) The parking capacity of an existing parking garage, lot or other site is increased by more than 50 percent.

(2) The first column in Table 20.124.050(1) shows the type of land use for which electric vehicle charging stations shall be provided, pursuant to this section. The second column shows the minimum percentage of the facility's parking spaces that shall provide a connection to electric vehicle charging stations.

Table 20.124.050(1)
Required Number of Electric Vehicle Charging Stations

Land Use Type	Percentage of Parking Spaces
Multifamily residential	10%
Overnight lodging (Levels 3 – 4)	3%
Retail establishment	1%
All restaurants (excluding food trucks)	1%
All office	3%
All medical	3%
Industrial	1%

All civic uses	3%
Convenience store with fuel pumps	5%, minimum of 2 spaces.
Other uses	1%

(3) Design for Expansion. In order to allow for additional electric vehicle parking in the future as the market for such vehicles grows, beginning January 1, 2023, all development that meets the criteria of subsection (1) of this section shall be designed to allow for double the amount of electric vehicle parking shown in Table 20.124.050(1).

(4) Site design must provide electrical, associated ventilation, accessible parking, and wiring connection to transformer to support the additional potential future electric vehicle charging stations.

(5) General Station Requirements.

(a) Size. A standard size parking space shall be used for an electric vehicle charging station where such a station is required or planned.

(b) Installation and Equipment. The station installation and equipment shall be consistent with the rules and regulations adopted pursuant to RCW 19.27.540, Electric vehicle infrastructure requirements, and with applicable regulations under the city's building and fire codes.

(c) Location, Design, and Maintenance. Where provided, parking for electric vehicle charging purposes shall meet the standards of subsections (5)(c)(i) through (v) of this section.

(i) Signage. Each charging station space shall be posted with signage indicating the space is only for electric vehicle charging purposes. Days and hours of operation shall be included if time limits or tow-away provisions are to be enforced.

(ii) Clearance. Charging station equipment mounted on pedestals, light posts, bollards or other devices shall be a minimum of 24 inches clear from the face of curb.

(iii) Charging Station Equipment. Charging station outlets and connector devices shall be no less than 36 inches or no higher than 48 inches from the top of surface where mounted, and shall contain a retraction device and/or a place to hang permanent cords and connectors sufficiently above the ground or paved surface.

(iv) Charging Station Equipment Protection. When the electric vehicle charging station space is perpendicular or at an angle to curb face and charging equipment, adequate equipment protection, such as wheel stops or concrete-filled steel bollards, shall be used.

(v) Maintenance. Charging station equipment shall be maintained in all respects, including the functioning of the charging equipment. A phone number or other contact information shall be provided on the charging station equipment for reporting when the equipment is not functioning or other problems are encountered.

(6) Data to Be Available. To allow for maintenance and notification, the owners of any private new electric vehicle infrastructure station that will be publicly available (see definition of “Electric vehicle charging station – Public” in Chapter 20.12 POMC) shall provide information on the station’s geographic location, date of installation, equipment type and model, and owner contact information.

(7) Time limits may be placed on the number of hours that an electric vehicle is allowed to charge, prohibiting indefinite charging/parking. If applicable, warnings shall be posted to alert charging station users about hours of use and possible actions affecting electric vehicle charging stations that are not being used according to posted rules.

(8) Location. Placement of a single electric vehicle charging station is preferred at the beginning or end stall on a block face.

(9) Accessible Facilities. Where electric vehicle charging stations are provided in parking lots or parking garages, excluding garages in single-household residential units, accessible electric vehicle charging stations shall be provided according to the ratios shown on Table 20.124.050(2). The first column indicates the number of electric vehicle stations being provided on site and the second column indicates the number of accessible charging stations that are to be provided for the corresponding number(s) of charging stations.

Table 20.124.050(2)
Minimum Number of Accessible Electric Vehicle (EV) Charging Stations

Number of EV charging stations	Minimum accessible EV charging stations
5–50	1
51–100	2
101–150	3
151–200	4
201–250	5

251–300	6

(10) Accessible electric vehicle charging stations should be located in close proximity to the building or facility entrance and shall be connected to a barrier-free accessible route of travel. It is not necessary to designate the accessible electric vehicle charging station exclusively for the use of disabled persons. Below are two options for providing for accessible electric vehicle charging stations.

Option 1

Option 2

(11) Charging and Parking. Electric vehicle charging stations, where provided for public use, are reserved for

parking and charging electric vehicles only, except as otherwise provided by this chapter.

(12) Electric vehicles may be parked in any space designated for public parking, subject to the restrictions that would apply to any other vehicle that would park in that space.

(13) Parking Restrictions. No person shall stop, stand or park any nonelectric vehicle in a space designated through signage as an electric vehicle charging station. Any nonelectric vehicle is subject to removal by the property owner or the property owner's agent.

(14) Any electric vehicle in an electric vehicle parking stall that is signed exclusively for electric vehicle charging and that either: (a) is not electrically charging; or (b) is parked beyond the days and hours designated on regulatory signs posted at or near the space shall be subject to removal as posted by the property owner or the property owner's agent. For purposes of this subsection, "charging" means an electric vehicle is parked at an electric vehicle charging station and is connected to the charging station equipment.

(15) Signage. Electric vehicle charging stations, other than in residential use, shall have posted signage, as identified in this section, allowing only charging electric vehicles to park in such spaces. (Exception: the director may allow an exemption for such signage at a portion of electric vehicle parking stalls within a publicly owned transit center upon the public transit agency demonstrating through a utilization study that not all of the electric vehicle charging stalls are needed for commuters using transit and that the amount of nonelectric vehicle parking is inadequate to meet existing needs; such exemption may be renewed by the director each year, based on a utilization study completed during the prior year.) For purposes of this subsection, "charging" means that an electric vehicle is parked at an electric vehicle charging station and is connected to the charging station equipment.

(16) Signage for parking of electric vehicles shall include:

(a) Information on the charging station to identify voltage and amperage levels and any time of use, fees, or safety information.

(b) As appropriate, directional signs to effectively guide motorists to the charging station space(s).

(17) Optional Signage. Optional information may be posted to alert potential charging station users to other

expectations.

(18) An applicant may request a modification of the minimum required number of electric vehicle parking spaces by applying for an administrative variance type 2 pursuant to POMC 20.124.030(2). Relief under an administrative variance type 2 pursuant to POMC 20.124.030(2) may include but is not limited to allowing the installation of electrical conduits and sizing panels and electrical services to standard parking stalls in support of the future installation of charging facilities while waiving or delaying requirements for installing wiring and chargers as a condition of the project. (Ord. 011-19 § 5 (Exh. 2)).

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INTERSECTIONS (/PLANNING/SECTION/INTERSECTIONS/) INFRASTRUCTURE

With 3.5 million electric cars expected in the U.S. in less than 10 years, charging infrastructure has to ramp up quickly. Photo by Bryan Derballa/The New York Times.

PART OF THE DISRUPTORS SERIES (/PLANNING/SERIES/DISRUPTORS)

July 1, 2021

By DANIEL C. VOCK

When Shana Bonstin first bought an electric vehicle, a Volkswagen eGolf, in 2017, she didn't realize how few available chargers there actually were. Bonstin, the deputy director of community planning in Los Angeles, knew that many new developments in the city now included charging infrastructure. Plus, the city itself was installing electric vehicle (EV) chargers at city hall, so she should have been able to refuel her car while at work.

But it turned out that city hall did not initially have enough chargers for all the municipal employees who had EVs. The complexities of adding that much power and infrastructure in a historically significant building in downtown Los Angeles caused months of delays. Meanwhile, city employees made do by scheduling time on the few existing chargers on shared Excel spreadsheets.

The city eventually added 100 more EV chargers in 2019 (https://www.ladwpnews.com/new-convenient-ev-chargers-installed-at-city-hall/), making it easier for employees to get a spot. All around the city, in fact, chargers have become much more common, as the number of EVs on the streets continues to climb.

But the episode gave Bonstin a better appreciation for all the logistical issues that need to be taken care of if LA, the state of California, or even the whole country is to successfully replace carbon-spewing gas-powered vehicles with electric ones.

Planners around the country will soon be wrestling with those kinds of considerations and more — if they aren't already — as EVs become more common.

"A lot of municipalities have started to set the framework for electric vehicle chargers to be installed," says Amina Hassen, an associate for WXY Studio in New York, who has worked with both the state and city of New York to develop electric vehicle policies. "Four or five years ago, an electric vehicle charging station wasn't even defined in [building] codes." (https://codes.iccsafe.org/content/CAGBSC2019/chapter-2-definitions)

"Where a lot of places will have to catch up is in the planning phases," she says.

To ensure all individuals can make the choice to switch to an electric vehicle, local governments will have to think about things like the places where people are already using electric vehicles, how placement of charging stations can be used to help economic development, and how to distribute infrastructure equitably, Hassen adds. More broadly, cities, regions, the federal government, and energy producers will also have to think about what kind of electrical power fuels the grid because increased power demand means increased emissions unless renewable energy is used.

Further Impacts: Energy Systems

To facilitate the ongoing transition to renewable sources of energy, governments and communities will need to plan for widespread installation of solar and wind energy systems and infrastructure.

President Joe Biden is trying to speed along the transition by calling for all the federal government's vehicles, including U.S. Postal Service trucks, to be replaced (https://www.reuters.com/article/us-usa-biden-autos/biden-vows-to-replace-u-s-government-fleet-with-electric-vehicles-idUSKBN29U2LW) with electric powered vehicles. The infrastructure plan (https://www.whitehouse.gov/briefing-room/statements-releases/2021/04/22/fact-sheet-biden-administration-advances-electric-vehicle-charging-infrastructure/) also calls for building an extensive network of EV chargers and offering rebates to electric car buyers. (Biden's plan has been criticized for not matching renewable energy with electrical vehicles.)

Meanwhile, the auto industry appears to be moving in the same direction. General Motors, Ford Motor Company, and Volkswagen have all made bold promises about switching from gas and diesel power to electric-powered cars. Tesla, far and away the biggest manufacturer of EVs right now, doesn't even sell gas-powered vehicles.

The coming wave of EVs could change everything from simple parking space requirements for new developments to economic growth opportunities for disadvantaged neighborhoods. Not surprisingly, though, city leaders and planners will have a big role in determining how many vehicles will come to town and where they'll be able to be used.

Charging challenges

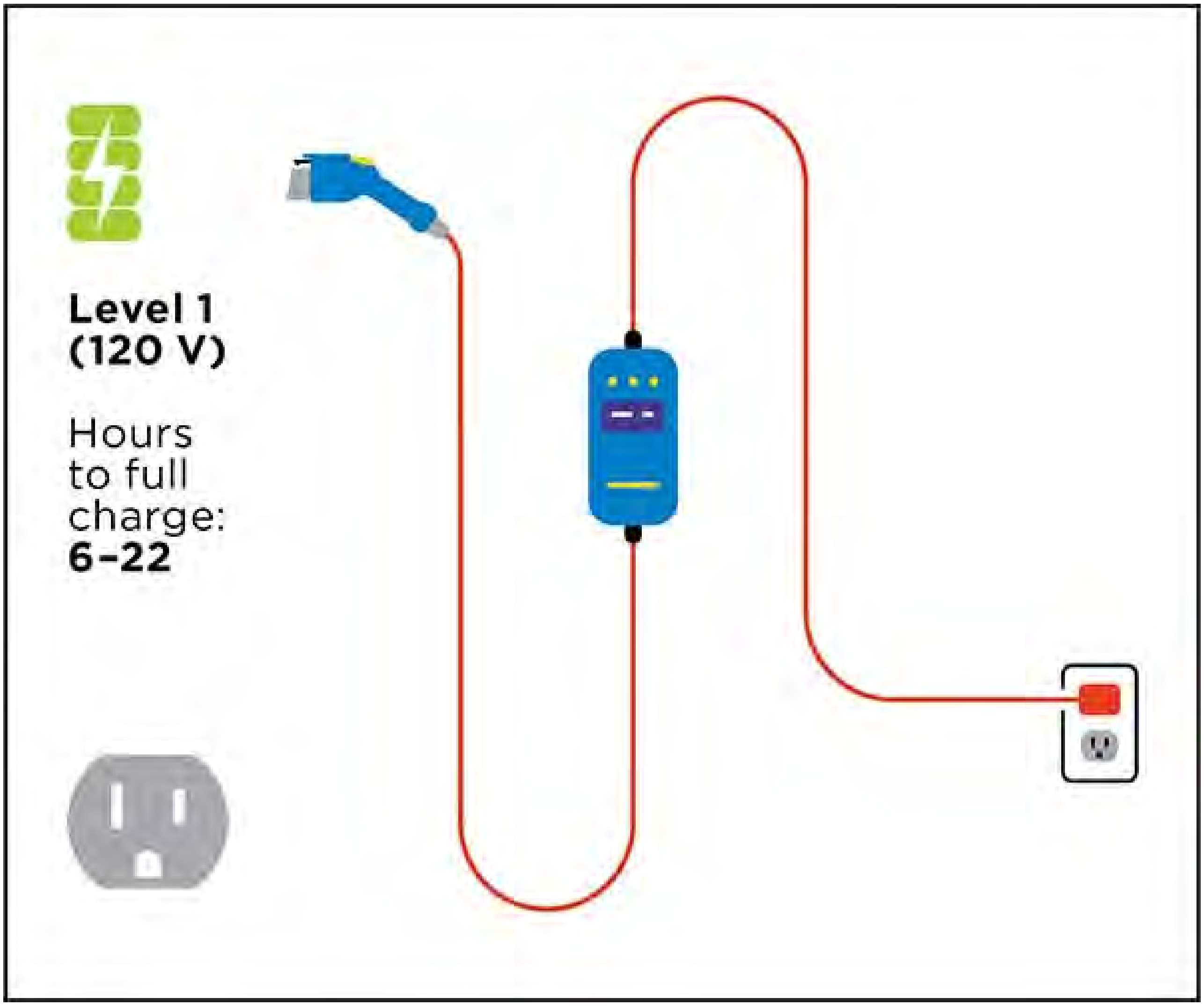
When it comes to the rollout of EVs, the most basic questions for cities will be over siting charging stations. The U.S. will need 9.6 million charging ports by 2030, the Edison Electric Institute, an industry group, predicted nearly three years ago. By comparison, the U.S. Department of Energy says there are currently 42,000 public charging station in the country, offering a combined total of 100,000 charging ports. (That does not include private chargers, like those used for bus fleets or home charging.)

Private companies and many homeowners will continue installing stations on their own, but city officials will face pressures to install publicly available chargers and to ensure people who don't own their own homes can still find a place to charge their vehicles.

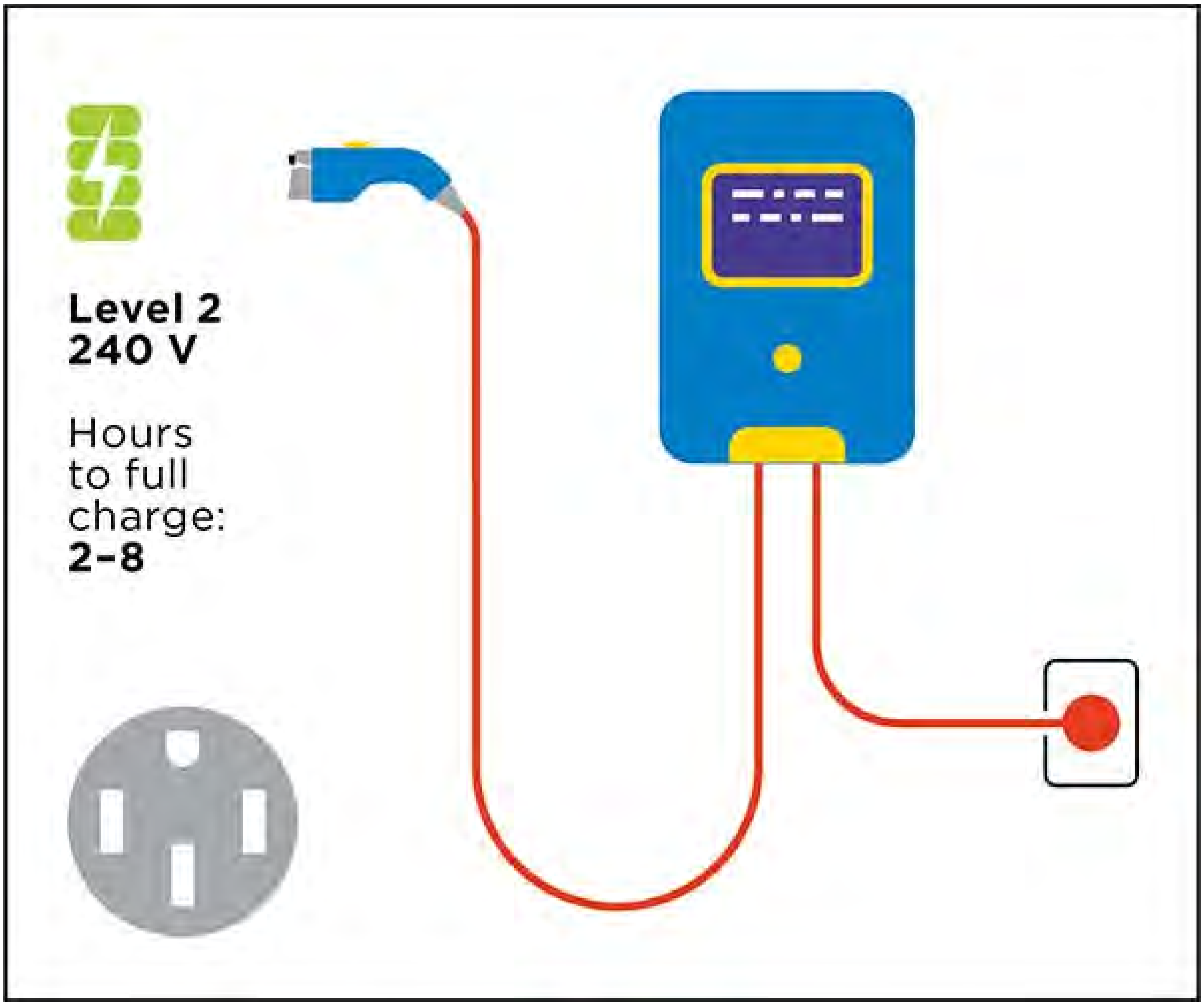
Different types of chargers work better in different settings. Home-owners, for example, can typically rely on Level 2 chargers in their garages. But a restaurant or retail store might want a fast charger so that customers can shop or dine in the half hour it takes their vehicles to charge.

Choosing the Right Charger: Speed and Power

There are three current standards for EV charging stations, each with different charging speeds and different electrical infrastructure needs. That's why it's important to match the charger with the intended use.

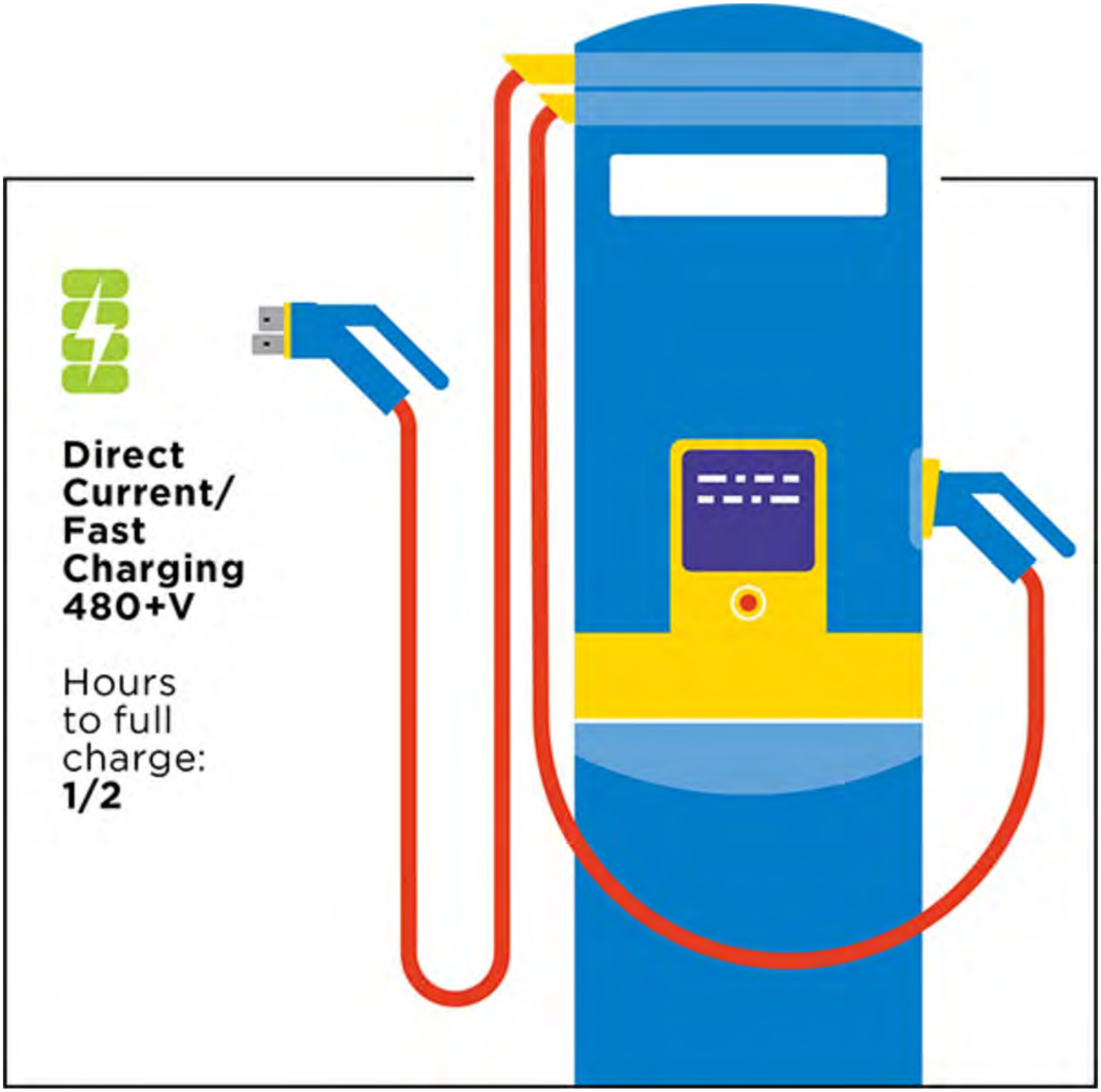


Level 1 (120V)
Essentially universal chargers, these use a standard outlet like those in a home. They are the simplest to use and don't require the installation of new electrical wiring. But they are the slowest charger type, giving cars two to five miles of range for every hour they're plugged in.



Level 2 (240V)

The most common public chargers, these use a higher voltage outlet. Most homes and commercial properties have 240V lines to the building, but installing a charger could require extra electric work on the premises. These chargers add 10 to 20 miles of range for every hour of charging.



Direct current/fast charging (480+V)

By far the fastest — they recharge a car in 20-30 minutes — they also draw the most power. But not all EVs can use these and there are no universal standards for the charging ports, so one carmaker's chargers are often incompatible with other companies' cars. Illustrations by Haisam Hussein

Local governments can help speed the growth of charging networks by allowing, incentivizing, or even requiring property owners to make those improvements. Los Angeles (https://patch.com/california/venice/electric-vehicle-charging-stations-mandatory-new-la-homes) recently passed a change to its building code requiring new apartment buildings and hotels to install chargers, and to install infrastructure that will make it easy to add additional chargers in the future. Atlanta in 2017 required new homes to be "EV-ready," with the conduit, wiring, and electrical capacity necessary to add chargers later.

Installing EV charging infrastructure is much easier for new developments than it is for existing buildings, of course. "For all the buildings to go back and then put in the wiring in a couple of decades is going to be super cost-prohibitive. It's better just to put it in now," says LA's Bonstin. It's also going to be a tough sell, she adds, which is why she and other city leaders are considering a menu of incentives and requirements.

One possible approach would be to readjust parking requirements for property owners who install chargers. Even adding a charger in a parking spot at a gas station can be tricky, Bonstin explains, because parking spots with EV chargers must be larger than regular spots. If a building already has the minimum number of spots, they don't have the space to add charging equipment.

Los Angeles planners are also working with their electric utility (which is owned by the city) to get a better idea of what incentives or disincentives are currently in place. So, deciding when a building needs chargers could determine who gets rebates from the power company. If the city requires chargers up front for a subdivision, for example, the developer would likely receive the rebates. But if the developer only has to make the property "EV-ready," the rebate would go to the homeowner who installs the charger down the line, Bonstin says.

Planners also have to wrestle with the extra infrastructure that may be required from new chargers. If the electric load gets large enough, "suddenly, an applicant or a developer needs this huge transformer to fit somewhere in the parking structure" or somewhere else nearby, and they look ugly, Bonstin says. "These infrastructure components are solving one problem and creating another. So, then the question becomes: How do you store this in a more elegant way?"

Leisure destinations offer good opportunities for top-off charging. And these stations outside Camden Yards in Baltimore blend well with the area's character. Photo by James Brunker/Alamy.

Ensuring widespread access

Meanwhile, cities will also face challenges when installing public chargers on curbs or in municipal parking lots. Hassen, the urban planner from WXY Studio, says cities should make sure the technology they install is universally accessible.

That not only means that the plugs should be able to service vehicles made by different companies, but also that the method of payment is widely accessible as well, she says. Right now, paying for electricity for your car is far more complicated than paying for gas; most charging stations don't take credit or debit cards. Instead, they require you to be a member of a certain network that have their own cards or apps that allow you to pay. The balkanized systems originally impeded London's efforts to build out a robust web of charging stations, Hassen says, and that's why places like New York City have required that their chargers work on several different networks.

Then there's the issue of where to install public chargers. Right now, EV owners tend to be wealthy, because the vehicles are so expensive (a problem states like California and automakers hope will fade as mass production of electric vehicles and new innovations make the prices of new electric vehicles similar to those of gas-powered vehicles). But that doesn't mean that chargers should be concentrated in wealthier areas, cautions Adam Lubinsky, PHD, AICP, WXY's managing principal for planning.

He says cities should account for equity in their siting decisions. Lower-income neighborhoods often have lower air quality and would therefore benefit the most from replacing gas-powered vehicles with zero-emission ones. Those neighborhoods also often host institutions — such as hospitals, community colleges, and schools — that people drive to rather than take transit, he says. That adds to emissions in those neighborhoods.

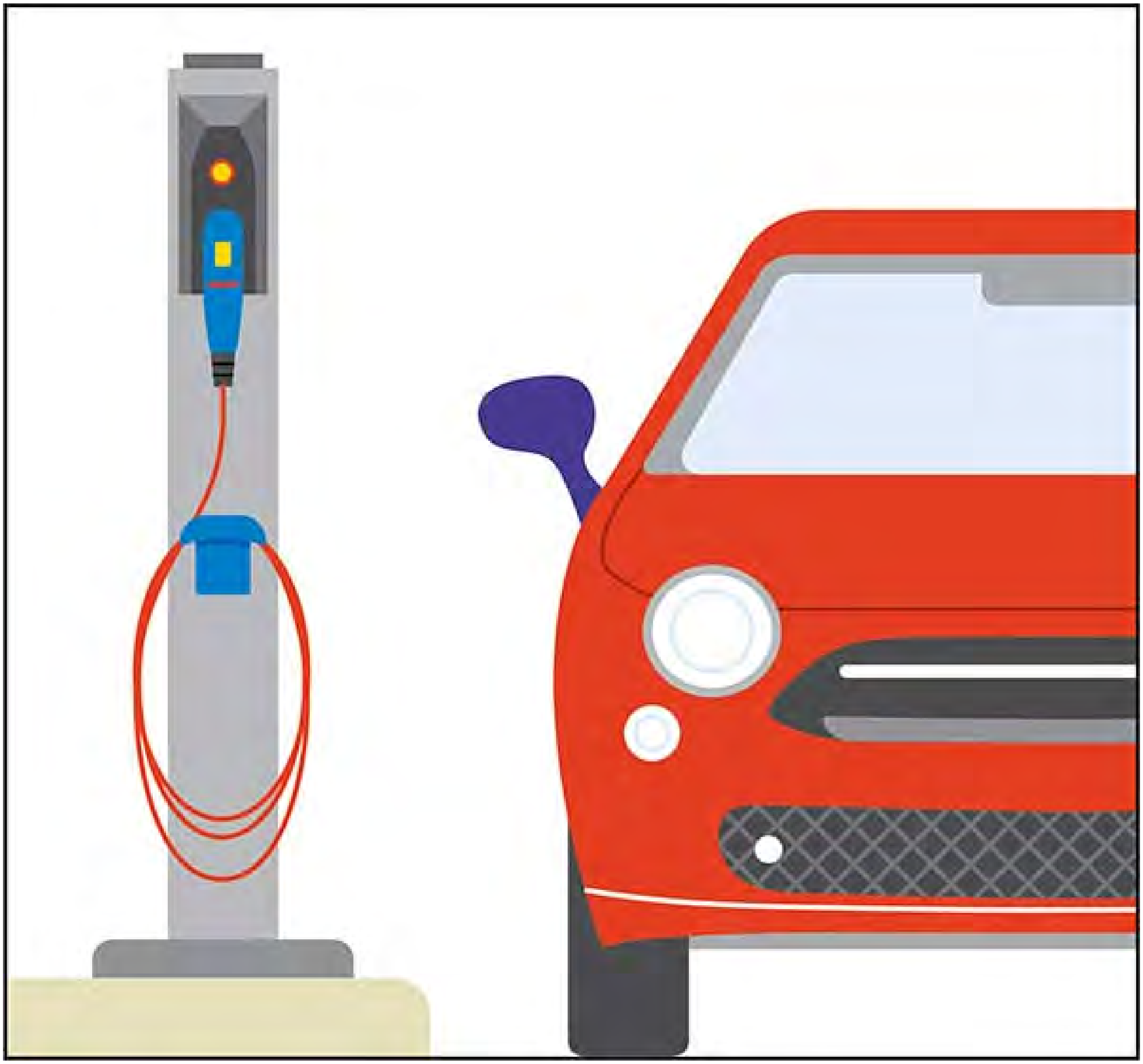
Hassen notes that another equity consideration is putting public chargers on the street or in municipal lots. That would help renters and other people who don't have private chargers to make the switch to electric vehicles when they become more affordable. "If you have no place to charge [an electric vehicle], and there is no developed public access infrastructure, it's not really a viable option for you," she says.

Choosing the Right Charger: Types

The firm WXY created a guidebook for New York City's curbside EV charging efforts that includes a planning framework, identifies deployment zones, and digs into station placement and type.

Source: *Curb enthusiasm:* (https://www.wxystudio.com/projects/urban_design/curb_enthusiasm_deployment_guide_for_onstreet_electric_vehicle_charging *Deployment Guide for On-street Electric Vehicle Charging,* 2018. Illustrations by Haisam Hussein.

Jairo Garcia, a sustainable cities expert who helped Atlanta develop its climate action plan (https://atlantaclimateactionplan.files.wordpress.com/2016/02/atlanta-climate-action-plan-07-23-2015.pdf), says cities and states should encourage suburbanites to use EVs when they commute into the urban core. They can do that by allowing EVs to use carpool lanes on interstate highways and by reserving convenient parking spaces downtown for them.



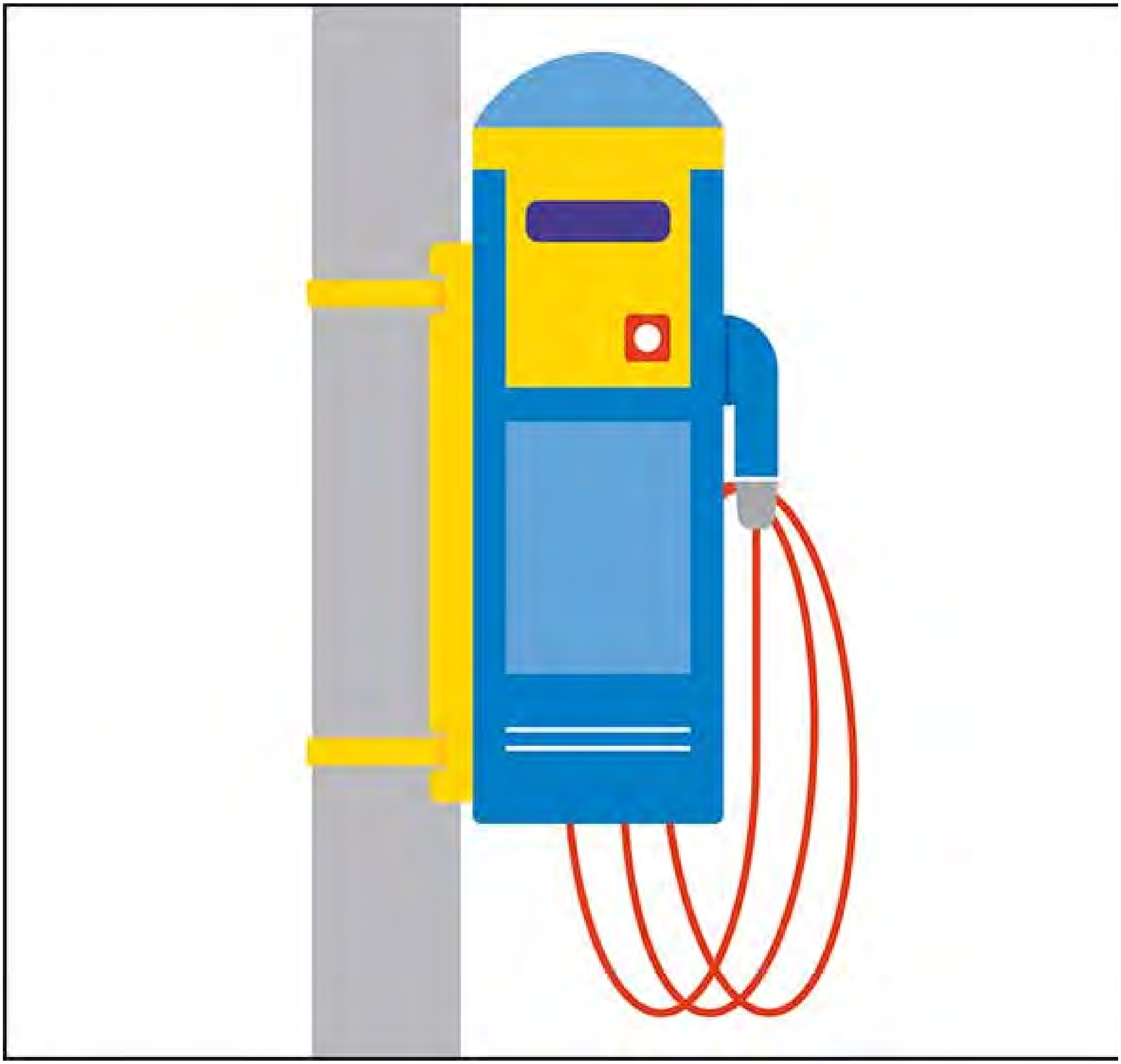
Pedestal

Freestanding charging stations with single or dual charge ports. Station footprints are typically similar to municipal parking meters, although pedestals range in height and bulk. There is a wide variety of commercially available models among electric vehicle supply equipment (EVSE) providers.

"Electric vehicles are more for the people outside the city, because here in the city, we don't drive. The people who live in the suburbs, they are going to be the ones who benefit the most from using electric vehicles," he says. Electric vehicles can easily handle those daily commutes, and suburbanites have "plenty of land" where they can put chargers, Garcia says.

Showing leadership

As Congress considers Biden's push for EVs, state and city governments are already enacting policies to speed the transition. Those range from high-profile promises, like that of California Gov. Gavin Newsom, to ban the sales (https://www.gov.ca.gov/2020/09/23/governor-newsom-announces-california-will-phase-out-gasoline-powered-

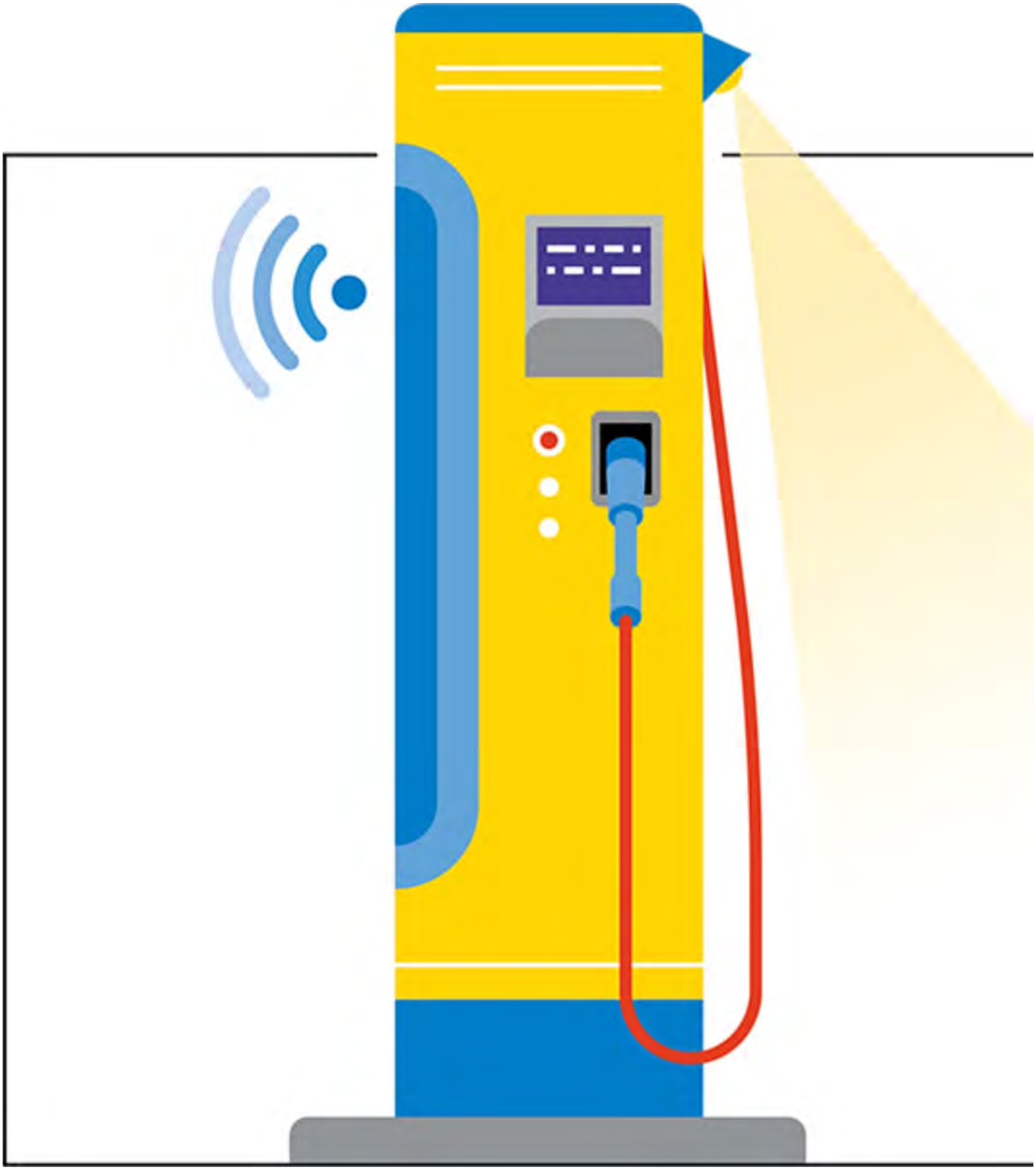


L2 Pole-Mounted

Chargers mounted on existing infrastructure such as a light pole, which makes the height of the unit adjustable. These chargers are slimmer than others, but typically only have one charge port. Installatio costs are low if power to light pole is sufficient (or timed with streetlight upgrades).

cars-drastically-reduce-demand-for-fossil-fuel-in-californias-fight-against-climate-change/) of gas-powered vehicles in the state by 2035, to much lower-key moves that offer rebates or tax credits (https://www.coltura.org/electric-vehicle-rebate-california) for residents who buy EVs.

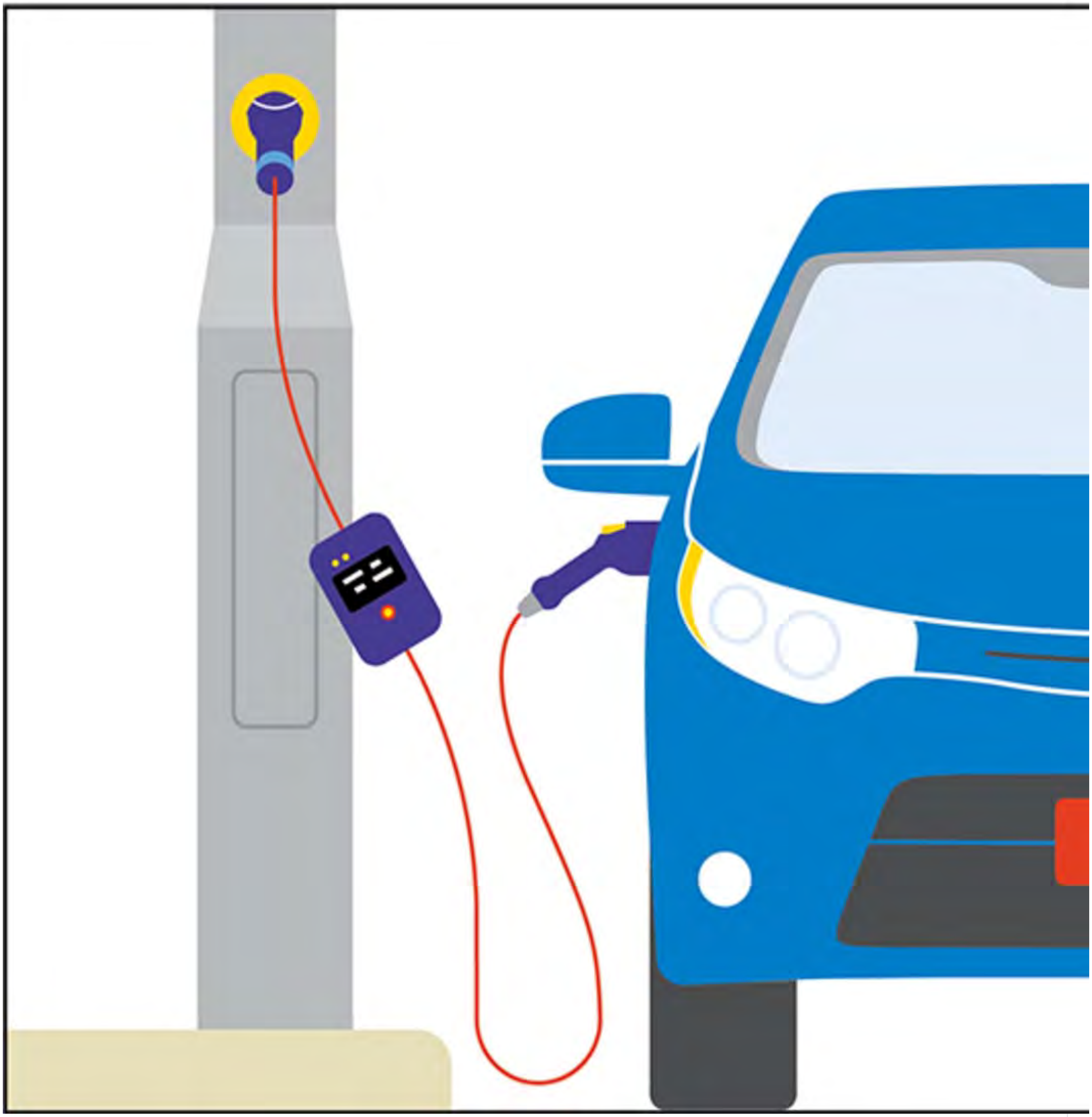
California's heavy-handed approach may not be a good fit for the rest of the country, says Doug Kettles, the director of the Central Florida Clean Cities Coalition. But leadership can come in other ways. In Florida, for example, the state's power companies are working together to encourage more widespread adoption of EVs through a group called Drive Electric Florida (https://www.driveelectricflorida.org/), which some environmental groups support as well. That group helped produce a plan to help municipalities prepare for questions like where to



L2 Tower

Taller than pedestals, these freestanding charging stations feature a built-in cord management system t keeps cords elevated. Modular elements such as lighting or wifi infrastructure can be paired with the to Costs can be high if trenching or other complex installation is required.

put new chargers. And several state agencies are working to produce a master plan that will look at logistical concerns as well as policy ideas that could help Florida's switch to EVs.



User-Supplied Cord (Plug & Socket)

A standard EV socket is mounted onto a freestanding pedestal or light pole and is appropriate for long d
times. Users must supply their own cord. This charging option is popular in Europe, although not used i
America.

Locations Best Suited to Charging Stations

Medical Campus

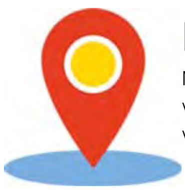
Medical campuses tend to have a largely car-dependent workforce, amplified by shift workers who have fewer and less frequent off-hours public transit options.

Higher Education

Post-secondary education draws employees and students from across the region. Campuses isolated from public transit have high proportions of auto commuters.

Public Sector

Municipal employees drive at higher rates than private sector employees and many work far from transit options, contributing to their car dependency.



Neighborhood Center

Neighborhood centers have a mix of commercial and residential uses. Drivers in neighborhood centers where residential construction lags commercial development are "garage orphans" and need charging where they park: on the street.

Leisure Destination

Parks, public pools, cultural institutions (museums and science centers), stadiums, and other major institutions are leisure destinations that offer a good opportunity for EVSE exposure and top-off charging. These destinations may also have EV fleet charging needs.

Source: *Curb enthusiasm:* (https://www.wxystudio.com/projects/urban_design/curb_enthusiasm_deployment_guide_for_onstreet_electric_vehicle_charging *Deployment Guide for On-street Electric Vehicle Charging,* 2018. Illustrations by Haisam Hussein.

Kettles says that governments will be leading the movement, even if only because of cost considerations. The upfront cost of EVs has been declining, and auto industry experts expect that new electric cars will soon be the same price as new gas-powered cars.

Significantly, the maintenance costs (https://www.greencars.com/post/what-does-it-cost-to-maintain-an-electric-car) for EVs are lower than gas-powered vehicles. That means governments will soon have an obligation to buy them, Nettles says. "The total cost of ownership is going to be dramatically lower than a regular vehicle, and so the fiduciary responsibility of the businesses and the government is going to drive them to getting these vehicles," he says. "You're using taxpayer money or you're using stockholder money. You have to use it in the most efficient and effective way. That's coming, and when it does, it's going to come hard and fast."

Joel Levin, the executive director of Plug In America, a group that advocates for the adoption of EVs, says cities and states have another economic incentive to promote a switch to EVs, because many of them are built locally. States like California, Nevada, and Tennessee all produce EVs. Georgia just reached an agreement to become a major source of the batteries that will go into those vehicles.

Plug In America has catalogued (https://pluginamerica.org/wp-content/uploads/2020/08/AchiEVe-Model-Policies-Toolkit_WebpageFinal_.pdf) the many different approaches that states and cities have taken to promote EVs, but Levin stresses that governments need to model the behavior they want to see in others.

"You better have charging at city hall and at major city facilities. If you don't, you're going to look like a dinosaur pretty quickly," he says. Top officials with city-issued vehicles, like the mayor and city council members, should have EVs. "That models the story you're trying to tell. If the city council is all driving around in Suburbans, that doesn't really tell the story of people converting to EVs."

It's not enough just to buy EVs. City leaders need to bring people along by educating staff about the new vehicles (including test drives) and hosting public events to build excitement, Levin adds. "If your city is going to invest in a big fleet of EVs for the police department, you better make sure that people are bought into it, or else they're going to sit and gather dust."

In Los Angeles, Bonstin says the city and other local governments in the area are pushing the switch to EVs every way they can, including moving its own fleet to electric vehicles. LA already has 900 EVs and has worked with other cities to give it more leverage with automakers to produce more. Local transit agencies are planning to switch their vehicles to electric by the end of the decade, too.

The city now has 10,000 commercial EV charging stations, a milestone it reached in January, two years ahead of a goal set by Mayor Eric Garcetti, thanks in part to a rebate program from the city. City agencies have installed more than 1,300 chargers on their own, including more than 400 that are integrated with streetlights.

"A key tenet of our sustainability plan is that we lead with [the conversion]," Bonstin says, "and I think we did that."

Daniel *C. Vock is a public policy reporter based in Washington, D.C.*

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Estimating electric vehicle charging infrastructure costs across major U.S. metropolitan areas

Author: Michael Nicholas
Date: August 2019
Keywords: electric vehicles; charging infrastructure; United States

The rollout of electric vehicles is aided and enabled by a concurrent rollout of infrastructure at home and in public locations. Home charging provides most of the charging needed for most drivers, whereas public infrastructure improves the electric vehicle proposition for prospective buyers, increases the potential electric miles from electric vehicles, and provides charging for those without home charging. Exactly how much charging infrastructure will be needed and what it will cost are top questions for prospective electric vehicle owners, automakers, policymakers, and electric utilities alike.

The need for much more electric vehicle charging infrastructure across the United States through 2025 is well established by a recent charging gap analysis.[1] Based on that analysis, about 4 times more public charging infrastructure than was in place in 2017 is needed by 2025 to match expected electric vehicle market growth. The analysis finds that at least 100,000 public and workplace chargers will be needed across the 100 most populous U.S. metropolitan areas over 2019–2025. These chargers would help serve the 2.6 million new plug-in hybrid electric vehicle (PHEV) sales and battery electric vehicle (BEV) sales expected by 2025 in those 100 areas.

This paper analyzes the capital costs of the electric vehicle charging infrastructure needed for public, workplace, and home charging for the most populous 100 metropolitan areas in the United States from 2019 through 2025. We review charging equipment cost data, including installation and hardware, for chargers of various charging types and locations. These equipment costs are then applied to our recent estimation of public and workplace charging needs, along with home charging needs that are newly assessed here. Ultimately we quantify the infrastructure costs on a metropolitan-area basis. Excluded from this scope are charging costs outside the 100 largest markets, which is to say in smaller cities and fast-charging corridors linking the cities.

Charging cost by type and location

This section describes the types of electric vehicle charging infrastructure related to the charging location. Cost estimates and research studies were used to estimate installation and hardware-related costs for home and nonhome charging to obtain average hardware and installation costs. These installation and hardware costs are used to construct estimates by metropolitan area in the following section.

Three main categories of electric vehicle chargers are assessed in this paper: Level 1, Level 2, and direct current (DC) fast. Basic information regarding the different levels of chargers evaluated in this report is summarized Table 1. The voltage (V) column shows the voltage at which electricity is delivered to the electric vehicle, and the typical power in kilowatts (kW) is the rate of energy transfer. The associated electric vehicle miles of range per hour of charging and the typical charging locations are also shown. Generally, Level 1 is used in home charging, whereas Level 2 is used in a variety of charging conditions, and DC fast

1 Michael Nicholas, Dale Hall, and Nic Lutsey, *Quantifying the electric vehicle charging infrastructure gap across U.S. markets,* (ICCT: Washington DC, 2019), https://www.theicct.org/publications/charging-gap-US

Table 1. Electric vehicle charging infrastructure specifications in the United States.

Charging level	Voltage	Typical power	Electric vehicle miles of range per charging hour	Location
Level 1	120 V AC	1.2–1.4 kW AC	3–4 miles	Primarily home and some workplace
Level 2	208 V–240 V AC	3.3–6.6 kW AC	10–20 miles	Home, workplace, and public
DC fast	400 V–1,000 V DC	50 kW or more	150–1,000 miles	Public, frequently intercity

Note: AC = alternating current; DC = direct current; kW = kilowatt; V = volt

charging is most commonly used at public charging stations.

For this paper's estimation of charging equipment costs across U.S. metropolitan areas through 2025, several simplifying assumptions are made regarding charger power requirements. Chargers are assumed to be 1.4 kW for Level 1, 6.6 kW for Level 2, and DC fast chargers include a combination of 50 kW, 150 kW, and 350 kW. We define chargers by these listed power levels rather than the number of outlets. For example, two outlets on the same pedestal providing 3.3 kW per outlet when two vehicles are connected are counted as one Level 2 charger, and a 13.2-kW Level 2 charger pedestal with two outlets is counted as two chargers.

Table 2. Per charger public and workplace charger hardware cost.

Level	Type	Chargers per pedestal	Per-charger cost
Level 1	Non-networked	One	$813
Level 1	Non-networked	Two	$596
Level 2	Non-networked	One	$1,182
Level 2	Non-networked	Two	$938
Level 2	Networked	One	$3,127
Level 2	Networked	Two	$2,793
DC fast	Networked 50 kW	One	$28,401
DC fast	Networked 150 kW	One	$75,000
DC fast	Networked 350 kW	One	$140,000

PUBLIC AND WORKPLACE CHARGER HARDWARE COSTS

Public and workplace charging infrastructure hardware costs include the charger and its pedestal. The main cost drivers are the power of the unit, in kW; whether it requires a pedestal; and whether it is networked with communication or payment gathering capability. Table 2 summarizes the costs applied in this analysis, based on the average hardware costs from several studies[2] and manufacturer price quotes.[3] For calculations, we determine an average cost per charger by level and type including mounting pedestal across all quotes and studies. As shown, Level 2 per-charger costs are lower when there are dual chargers, rather than one charger, per pedestal. Adding networking to a charger more than doubles the cost of hardware. For DC fast charging, we use the single charger cost for all calculations. Costs are reported in 2019 dollars, and future-year hardware costs are assumed to decline over time at the rate of 3% per year.

Based on existing trends from our charging gap analysis, future workplace charging is assumed to be 15% Level 1 and 85% Level 2. Networking enables chargers to communicate by WiFi or cellular signal to report usage, charge customers, and collect payment information. These cost estimates are based on workplace Level 1 not being networked and 62% of workplace Level 2 being networked, corresponding to the percentage of workplace charging that is paid.[4] Public charging is assumed to be 80%

2 Avista Utility, "Docket No. UE-160082 – Avista Utilities Semi-Annual Report on Electric Vehicle Supply Equipment Pilot Program" (2018), https://www.utc.wa.gov/_layouts/15/CasesPublicWebsite/CaseItem.aspx?item=document&id=00044&year=2016&docketNumber=160082&resultSource=&page=&query=&refiners=&isModal=&omItem=false&doItem=false; Department of Energy, "Transportation Energy Futures Series, Alternative Fuel Infrastructure Expansion: Costs, Resources, Production Capacity and Retail Availability for Low-Carbon Scenarios" (2013), https://www.osti.gov/biblio/1079728-transportation-energy-futures-series-alternative-fuel-infrastructure-expansion-costs-resources-production-capacity-retail-availability-low-carbon-scenarios ; Pierre Ducharme and Catherine Kargas. *Feasibility of a Pan-Canadian Network of DC Fast Charging Stations for EVs,* (Electric Vehicle Symposium 29: Montréal, Québec, Canada, June 19–22, 2016), https://www.mdpi.com/2032-6653/8/1/1/pdf; Josh Agenbroad, "Pulling back the veil on EV charging station costs," Rocky Mountain Institute, accessed Jan 5, 2019, https://rmi.org/pulling-back-veil-ev-charging-station-costs/

3 "Commercial EVSE: Public, Fleet, Workplace Charging," ClipperCreek, accessed February 1, 2019, https://store.clippercreek.com/commercial ; "Smart charging stations," Chargepoint, accessed February, 1 2019, https://www.chargepoint.com/products/commercial/

4 Gil Tal, Jae Hyun Lee, and Michael Nicholas, Observed charging rates in California, (Research Report – UCD-ITS-WP-18-02, Institute of Transportation Studies: University of California, Davis, 2018), https://itspubs.ucdavis.edu/index.php/research/publications/publication-detail/?pub_id=2993

networked, and all fast charging is assumed to be networked, as these are typical practices. For Level 1 workplace chargers we assume 80% will be simply a wall outlet, but average costs presented above are for the 20% of dedicated Level 1 chargers.

PUBLIC AND WORKPLACE CHARGING INSTALLATION COSTS

Installation costs are composed of labor, materials, permits, taxes, and utility upgrades, as shown in Table 3. These are based on the most recent and detailed cost estimates among the various investigations into costs for nonresidential infrastructure.[5] Notably, the Electric Power Research Institute (EPRI) studied 637 sites with 1,294 Level 2 charging units, including disaggregated costs for labor, materials, permits, and taxes. The EPRI study also shows how per-charger costs decline as more chargers are installed per site (i.e., sites with 3-5 chargers, and those with over 6 chargers). Costs are further disaggregated by sites within California versus those in the rest of the country and are applied as such in this analysis. For our analysis, based on the EPRI study, we assume workplace charging costs are 10% below, and public Level 2 are 11% higher, than the average numbers shown in Table 3. Utility upgrades are included in the materials cost, based on upgrades incurred in southern California.[6] In practice, part of these utility upgrade costs may be covered by the utility company. Typically, a utility provides the customer an upgrade allowance, above which the customer pays for the remainder of the upgrade cost.

Table 3. Installation costs for Level 2 public and workplace charger, by chargers per site.

		1 charger per site	2 chargers per site	3-5 chargers per site	6+ chargers per site
California	**Labor**	$2,471	$1,786	$1,491	$1,747
	Materials	$1,235	$958	$1,014	$908
	Permit	$283	$172	$110	$65
	Tax	$156	$121	$128	$115
	Total	**$4,148**	**$3,039**	**$2,745**	**$2,837**
Outside California	**Labor**	$1,544	$1,827	$1,647	$1,316
	Materials	$1,112	$1,039	$1,272	$874
	Permit	$82	$62	$59	$38
	Tax	$96	$89	$110	$75
	Total	**$2,836**	**$3,020**	**$3,090**	**$2,305**

Our DC fast charger installation costs, shown in Table 4, are based two sources.[7] Data from the Rocky Mountain Institute study are used to estimate costs for 50-kW chargers, and data from Ribberink et al. are used to project how costs scale for multiple chargers per site and for higher power stations. Similar to Level 2 charging, installation costs per charger fall as more chargers are installed per site. Also, costs do not rise proportionally with power so a charger with triple the power does not result in triple the cost. Hence, installation costs are mainly a function of the number of chargers per site.

Table 4 highlights the role power and multi-charger sites play in determining per-charger installation costs. For example, at a site with one 50-kW charger, installation costs are approximately $45,000. Increasing the power by 7 times to 350 kW results in an installation cost of approximately $65,000, reflecting higher material cost and the probability that switchgear and distribution lines may need to be upgraded. Although we show an approximately $20,000 increase, this is highly variable and certain sites with 350 kW require very expensive upgrades whereas other sites require modest upgrades depending on factors related to charging site

5 Idaho National Laboratory, U.S. Department of Energy, Plug-in electric vehicle and infrastructure analysis (INL/EXT-15-35708), 2015, https://inldigitallibrary.inl.gov/sites/sti/sti/6799570.pdf; NC PEV Taskforce, "Plug-in electric vehicle (PEV) roadmap for North Carolina" (2013), http://www.pluginnc.com/wp-content/uploads/2016/06/7-NCPEVRoadmap_April2014_v2.pdf; Ducharme and Kargas, "Feasibility of a Pan-Canadian Network"; Avista, Semi-Annual Report on Electric Vehicle Supply Equipment Pilot Program; Electric Power Research Institute, "Electric Vehicle Supply Equipment Installed Cost Analysis" (December 2013), http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002000577

6 Based on upgrades incurred in the Southern California Edison territory, $36.99 is added to each Level 2 charging installation. See J.R. DeShazo, Overcoming Barriers to Electric Vehicle Charging in Multi-unit Dwellings: A Westside Cities Case Study, (2017), http://innovation.luskin.ucla.edu/sites/default/files/Overcoming%20Barriers%20to%20EV%20Charging%20in%20Multi-unit%20Dwellings%20-%20A%20Westside%20Cities%20Case%20Study.pdf

7 Hajo Ribberink, Larry Wilkens, Raed Abdullah, Matthew McGrath, and Mark Wojdan, "Impact of Clusters of DC Fast Charging Stations on the Electricity Distribution Grid in Ottawa, Canada," (Electric Vehicle Symposium 30: Stuttgart, Germany, October 9–11, 2017); Agenbroad, "Pulling back the veil on EV charging station costs", Rocky Mountain Institute, accessed Jan 5, 2019, https://rmi.org/pulling-back-veil-ev-charging-station-costs/

Table 4. Installation costs per DC fast charger by power level and chargers per site.

	50 kW				150 kW				350 kW			
	1 charger per site	2 chargers per site	3-5 charger per site	6-50 chargers per site	1 charger per site	2 chargers per site	3-5 chargers per site	6-20 chargers per site	1 charger per site	2 chargers per site	3-5 chargers per site	6-10 chargers per site
Labor	$19,200	$15,200	$11,200	$7,200	$20,160	$15,960	$11,760	$7,560	$27,840	$22,040	$16,240	$10,440
Materials	$26,000	$20,800	$15,600	$10,400	$27,300	$21,840	$16,380	$10,920	$37,700	$30,160	$22,620	$15,080
Permit	$200	$150	$100	$50	$210	$158	$105	$53	$290	$218	$145	$73
Taxes	$106	$85	$64	$42	$111	$89	$67	$45	$154	$123	$92	$62
Total	$45,506	$36,235	$26,964	$17,692	$47,781	$38,047	$28,312	$18,577	$65,984	$52,541	$39,097	$25,654

readiness and electrical equipment. Location flexibility is paramount in reducing these costs. There is generally a site limit of 2.5 megawatts of power before a step change in costs. Therefore, the maximum number of chargers per site is 50, 20, and 10 for 50-, 150-, and 350-kW chargers, respectively. Finally, we note that there are some costs that may not be included in the installation costs above including signage, striping, lighting, and security cameras.

Trends in the number of chargers per site allow us to estimate overall future charging developments based on the preceding per-charger cost examples. Recent data on chargers per site from U.S. metropolitan areas with greater electric vehicle uptake serve as a guide for smaller markets. To determine the relationship between electric vehicle market development and chargers per site, markets are first categorized and binned by the status of the electric vehicle market development by metropolitan area at the end of each year from 2014 through 2018. The market development bins are defined by the electric vehicles per million population, ranging from 6,000 (in low electric uptake markets) up to 40,000 (high uptake). Then the associated charger locations and number of chargers per site were analyzed by metropolitan area.[8] These sites are grouped into four categories—one, two, three to five, and six or more chargers per site—to match the categories analyzed above. In areas with low numbers of electric vehicles per million population, sites with six outlets or more are rare but can still account for a large portion of a metropolitan area's chargers.

Figure 1 shows a trend toward more chargers per site in markets with greater electric vehicle uptake. The horizontal axis shows the relative electric vehicle market development in vehicles per million resident population in bins. The vertical axis shows the percentage of chargers per site size category, based on the charger data for all the metropolitan areas in each bin. For example, the lowest level of market development analyzed is 6,000 electric vehicles per million population, where approximately 30% of charging outlets are at sites with two chargers, 30% are with 3–5 chargers, 30% are with 6 or more chargers, and the remaining 10% are at sites with just one charger. Most metropolitan areas fall in the lower bins and the 40,000 electric vehicles-per-million bin is represented by just one metropolitan area, San Jose, in 2018.

The implication of the trend shown in Figure 1, based on Table 3, is that as electric vehicle markets grow, the number of outlets per site increases, and the per-outlet cost drops. Cumulative sales in San Jose by the end of 2018 are what define the highest market penetration category, where there are 40,000 electric vehicles per million population, and 60% of total outlets are located at sites with six or more chargers. The lines in Figure 1 represent the natural log fit of these points (e.g., $y = 0.21 * \ln(x) - 1.57$ for six or more chargers per site), and the equations shown are applied to the infrastructure buildout cost analysis that follows in the cost scenario section.

Compared to Level 2 chargers, DC fast chargers do not show such a clear trend for chargers per site versus electric vehicles per capita. However, overall site size for new installations is growing year by year. To reflect a general increase in the number of chargers per site, we extrapolate the trend from 2014–2018 into the future. In 2018, the percentages of chargers at one, two, three to five, and six or more chargers per site were 11%, 20%, 17%, and 52%, respectively. The corresponding percentages for 2025 are 5%, 13%, 15% and 67%. These percentages are

8 Downloaded from Alternative Fuel Data Center (Alternative fuel stations - electric, Accessed Sept. 1, 2014; Jan 1, 2016; Jan 1, 2017; Jan 1, 2018; and Jan 1, 2019), https://afdc.energy.gov/data_download/

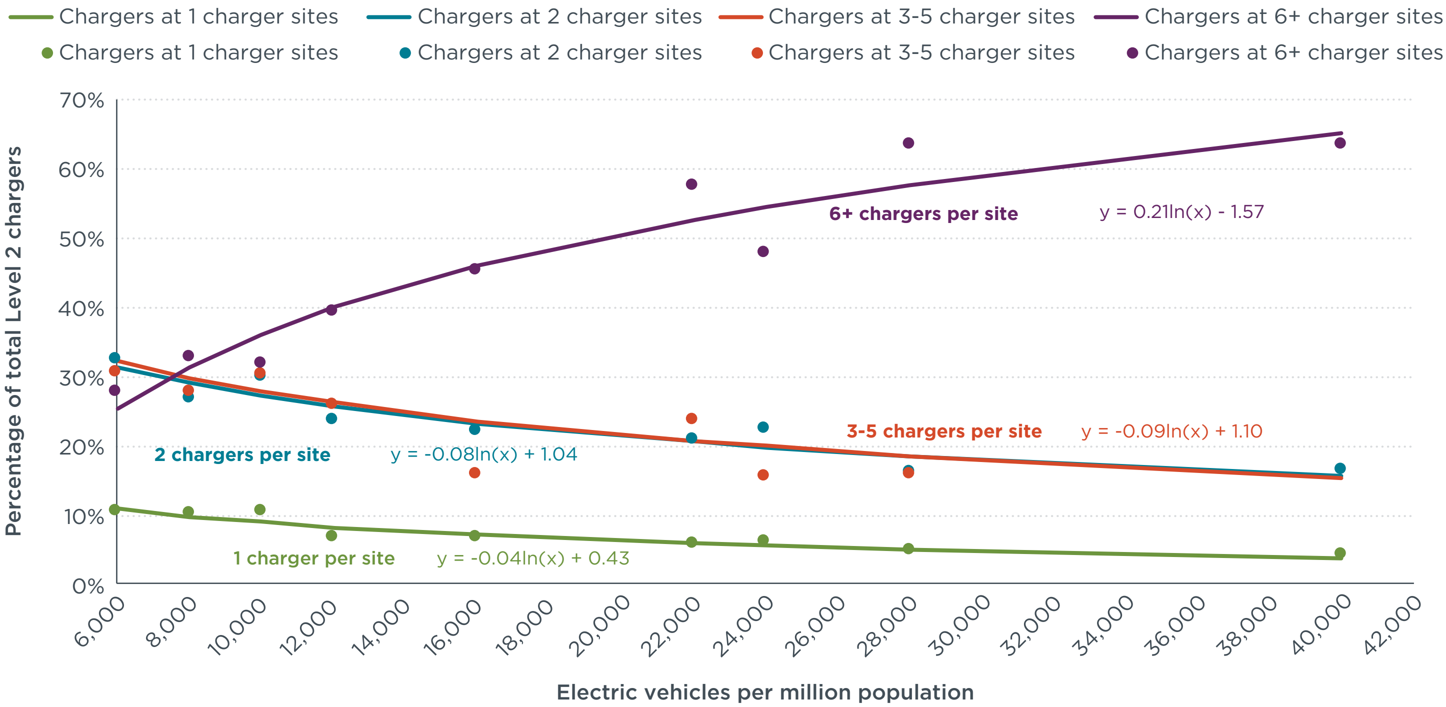

Figure 1. Percentage of public Level 2 chargers by site size as a function of electric vehicles per million population.

not applied as a function of market development, but rather by year across all metropolitan areas. We also assume the breakdown for the distribution of charger power is 44.4% for 50 kW, 44.4% for 150 kW, and 11.1% for 350 kW through our future year scenarios. This breakdown of DC fast chargers of varying power levels reflects our expectation of a continuing tradeoff between electric vehicle range and charger installation cost.[9]

9 Wei Ji, Michael Nicholas, and Gil Tal, "Electric Vehicle Fast Charger Planning for Metropolitan Planning Organizations: Adapting to Changing Markets and Vehicle Technology," Transportation Research Record, 2015, 2502 (1): 134–143, https://doi.org/10.3141/2502-16; Michael Nicholas and Dale Hall, Lessons learned on early electric vehicle fast-charging deployments, (ICCT: Washington DC, 2018), https://www.theicct.org/publications/fast-charging-lessons-learned

HOME CHARGING HARDWARE AND INSTALLATION COSTS

Our charger cost analysis for home charging is similar to the previous discussion of public and home charging but accounts for varying cost by housing types. Home charging hardware and installation is typically less expensive than for public chargers. We separate the cost of home charging into charger level (Level 1 or Level 2) and housing type (detached house, attached house, and apartment). Hardware and installation costs are included, and installation is composed of labor, materials, taxes, utility upgrades, and permits. Some studies provide only installation cost, but not hardware costs, whereas others provide only hardware and installation costs combined.[10] We therefore represent the costs as combined costs for home charging estimates and average these across studies.

Average charger hardware plus installation costs applied to our analysis for 2019 are shown in Table 5. As

10 Idaho National Laboratory, U.S. Department of Energy, Plug-in electric vehicle and infrastructure analysis; Electric Power Research Institute, "Electric Vehicle Supply Equipment Installed Cost Analysis"; NC PEV Taskforce, "Plug-in electric vehicle (PEV) roadmap for North Carolina"; California Air Resources Board, "California's advanced clean cars midterm review: Appendix B: Zero emission vehicles and plug-in hybrid electric vehicles" (California Environmental Protection Agency, Air Resources Board, 2017), https://www.arb.ca.gov/msprog/acc/acc-mtr.htm; California Air Resources Board, "California's advanced clean cars midterm review: Appendix D: Zero emission vehicle infrastructure status in California and Section 177 ZEV states" (California Environmental Protection Agency, Air Resources Board, 2017), https://www.arb.ca.gov/msprog/acc/acc-mtr.htm; DeShazo, Overcoming Barriers; Agenbroad, "Pulling back the veil on EV charging station costs."

shown, the costs vary depending on the electric vehicle home charging situation and the housing type. For the housing types, detached house signifies a house not connected to any others; attached house signifies a house with a shared wall of up to three housing units; and apartments are structures with more than 3 units. We use an average cost across all studies and apply a 3% per year reduction in hardware cost. To give examples of some of the underlying studies, the total installed costs ranged from $650 in the Rocky Mountain Institute study to $2,423 for a networked charger as assessed by Avista Utility. Higher costs for home charging upgrades generally correspond to a greater number of wall and floor penetrations, total circuit distance, or service upgrades. As indicated, attached homes and apartments typically are associated with higher cost upgrades.

Two types of upgrades are shown in Table 5: charger upgrades and outlet upgrades. Charger upgrades refer to new wiring and a charger, whereas outlet upgrades refer to only new wiring and a 120-volt wall outlet (Level 1) or a 240-volt dryer-type outlet (Level 2) with no additional charger. Most vehicle purchases come with a convenience charger that can be plugged into one or both of these outlet types and the convenience charger is not considered an additional infrastructure cost for this analysis. Categories of electric vehicle-owning households that have no additional home cost are also shown for context, as these are discussed in our overall average cost calculations.

The 3% per year hardware reduction is not shown, but as an example, total installed costs for a hardwired Level 2 unit in a detached house drop from $1,445 in 2019 to $1,317 by 2025 and from $4,061 to $3,933 in an apartment over the same period. Outlet upgrades do not decrease in cost over the analysis period. Average outlet upgrade and Level 2 charger installation costs in attached houses are not detailed in any study and are therefore assumed to be the average of apartment costs and costs in detached houses. The Table 5 costs by home charging category and housing type are applied across the U.S. metropolitan area data in the cost assessment that follows.

Table 5. Installation and hardware costs for home chargers by housing type.

Home charging category	Detached house	Attached house	Apartment
Level 1 outlet upgrade	$400	$500	$600
Level 1 charger upgrade	$700	$800	$900
Level 2 outlet upgrade	$680	$2,000	$3,300
Level 2 charger upgrade	$1,400	$2,800	$4,100

Cost scenarios

Costs are estimated for home, public, and workplace charging for approximately 2.6 million new electric vehicle sales in the 100 most populous U.S. metropolitan areas over the 2019–2025 period. In modeling the overall vehicle fleet, which accounts for vehicle retirement, this amounts to a stock increase of 2.3 million vehicles, and a total stock of 3.2 million electric vehicles in 2025 in the top 100 metropolitan areas. This represents 88% of the estimated 3.6 million electric vehicles on the road in the United States in 2025. The cost scenarios presented below are shown in terms of the aggregated costs for all the metropolitan areas combined and on a per-electric-vehicle-sold per year basis.

HOME CHARGING

Home charging is an important part of the charging ecosystem. Its associated cost to support new electric vehicle sales in the top 100 most populous metropolitan areas for the years 2019–2025 is analyzed here. We apply electric vehicle charging dynamics and sales across the metropolitan areas and the areas' housing stock as in our previous analysis[11] to provide a breakdown of electric vehicles by home charging category and housing type.

Our overall U.S. estimates for the number of electric vehicle sales from 2019–2025 in each type of home charging situation, and across housing types, are summarized in Table 6. There are seven home charging categories, two vehicle types (BEV and PHEV), and three housing types. The first row shows drivers who do not use home charging, primarily relying on workplace and public charging. Level 1 users are divided into those who have an existing outlet with no upgrades needed, those who install a new upgraded 120-volt household outlet for their electric vehicle, and those who install a dedicated Level 1 charger (charger upgrade). Level 2 home charging has categories similar to Level 1, but includes those with existing 240-volt dryer-type outlets and upgrades for new outlets and new dedicated chargers (charger upgrade). Ratios for determining the outlets and upgrades by charging level were determined from the results of a California Air Resources Board survey.[12]

The categories in Table 6 have two broad classifications—those that

11 Nicholas, Hall, and Lutsey, Quantifying the electric vehicle charging infrastructure gap.

12 California Air Resources Board, "California's advanced clean cars midterm review: Appendix B."

Table 6. California electric vehicle drivers by home charging category and housing type for 2019–2025.

Home charging category	Detached house PHEV	Detached house BEV	Attached house PHEV	Attached house BEV	Apartment PHEV	Apartment BEV	Totals
No home charging	124,429	67,272	46,129	30,467	102,185	89,171	**459,653**
Level 1 no upgrade	484,233	234,054	121,330	60,841	66,920	37,426	**1,004,803**
Level 1 outlet upgrade	36,228	18,606	6,709	4,824	5,905	3,364	**75,636**
Level 1 charger upgrade	8,296	10,927	2,236	4,020	3,543	3,154	**32,177**
Level 2 no upgrade	38,195	89,917					**128,112**
Level 2 outlet upgrade	48,644	180,114	12,281	44,473	5,200	16,212	**306,925**
Level 2 charger upgrade	132,960	312,477	23,026	43,375	12,712	27,731	**552,282**
Total	**872,985**	**913,367**	**211,712**	**188,001**	**196,465**	**177,058**	**2,559,588**

Note: BEV = battery electric vehicle, PHEV= plug-in hybrid electric vehicle

require electrical work and those that do not. As indicated, approximately 967,000, or 38%, of the 2.6 million electric vehicle owners are estimated to either need to install a dedicated charger or do an outlet upgrade. These include the four categories of Level 1 outlet upgrades, Level 2 outlet upgrades, Level 1 charger upgrades, and Level 2 charger upgrades. This also highlights that more than 1.1 million electric vehicle owners (or 44%) will use existing 120-volt or 240-volt outlets, and the remaining 18% either do not plug in or exclusively use workplace and public charging infrastructure.

In Figure 2, the data from Table 6 are represented graphically to show the fraction of electric vehicle drivers in our 2019–2025 analysis by home charging investments needed. The figure shows the percentage of electric vehicle drivers in three housing types (detached, attached homes, apartments) and home charging categories (No home charging, Level 1 home charging, and Level 2 home charging). The hashed bars indicate that there is no additional cost incurred for home charging for these drivers. For example, in the leftmost column, 70% of electric vehicle drivers in the analysis are in detached homes, and this includes 29% that are estimated to be complete home charging upgrades (26% Level 2 and 3% Level 1) and 41% without any upgrades. Electric vehicle buyers in attached houses and apartments are less likely to use home charging than those in detached houses, likely reflecting challenging installations and lack of control over upgrades.

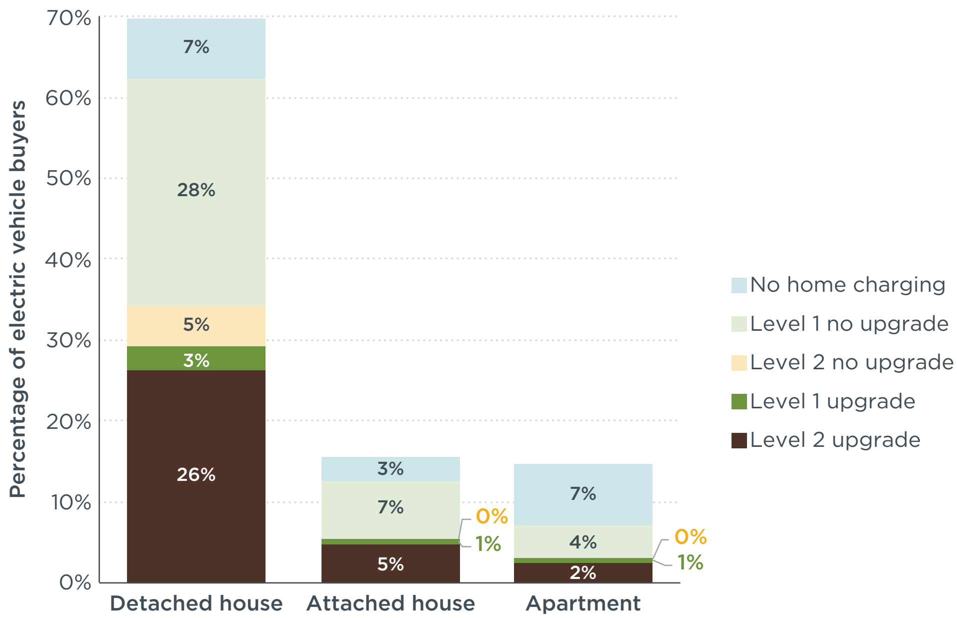

Figure 2. Percentage of new electric vehicle drivers by home charging access and upgrade.

Based on Figure 2 the majority of electric vehicle drivers will not be installing additional home infrastructure given current trends. Approximately 39% will simply use existing Level 1 (28% in detached houses, 7% in attached houses, and 4% in apartments), and 5% will use existing Level 2 charging (i.e., dryer outlet, largely in detached houses). The approximately 18% of all drivers not using home charging includes 5% of electric vehicle drivers rarely charging at all (primarily using PHEVs as hybrids) and the remainder relying on public and workplace charging.

Costs for the above electric vehicle driver, housing, and home charging calculations include the charging equipment costs from Table 5 and Table 6 for the 100 metropolitan areas.

The total cost for the 38% of customers assumed to undertake upgrades including upgraded outlets and installed chargers totals $1.3 billion. Averaged over all the new electric vehicle drivers, this represents $520 per new electric vehicle, decreasing from about $540 to $510 over the 2019–2025 period. A weighted average over only those electric vehicle drivers that had an upgrade at their residence results in $1,400 per vehicle. If costs are calculated separately for electric vehicles by housing type, and once again assigned only to those undergoing upgrades, we estimate $1,100 for those in detached houses, $2,100 for those in attached houses, and $3,100 for those in apartments.

PUBLIC AND WORKPLACE CHARGING

Total public and workplace charging infrastructure costs across the 100 metropolitan areas over the 2019–2025 period are estimated from the per-charger costs from Table 2, Table 3, and Table 4 and the distribution of outlets per site shown in Figure 1. Although overall costs are tallied based on the specific needs across the 100 areas, the results are presented here for all the areas combined to inform the overall charging infrastructure costs, the primary underlying cost components, and the costs on a per-electric-vehicle basis.

Figure 3 shows the overall 2019–2025 costs for workplace, public Level 2, and DC fast charging disaggregated by labor, materials, permits, taxes and hardware. The vertical axis shows the total costs for that charger category, which are approximately $190 million, $360 million, and $390 million for workplace, public Level 2, and DC fast, respectively. As indicated, hardware costs are the largest cost component in each case, representing 43%, 40%, and 68% of the total costs, respectively, for the three charging types. Workplace chargers and public Level 2 charger costs are similar in terms of the breakdown by cost component, but DC fast charging hardware is more expensive, especially for the highest power stations driving a relatively high hardware cost, as indicated on a per-charger basis in Table 2. Summing the costs by cost component, hardware costs are about $490 million, followed by labor at $230 million, materials at $190 million, taxes at $12 million, and permits at $9 million.

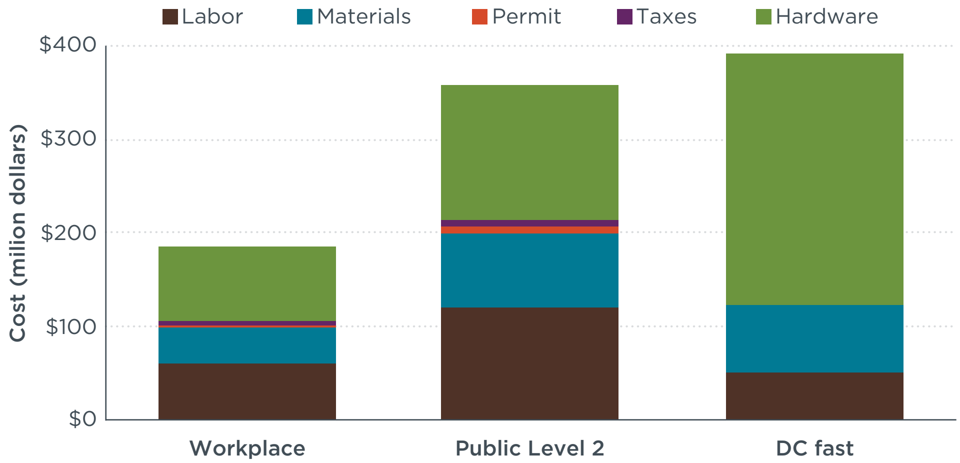

Figure 3. Workplace, public Level 2, and DC fast charger costs from 2019 through 2025.

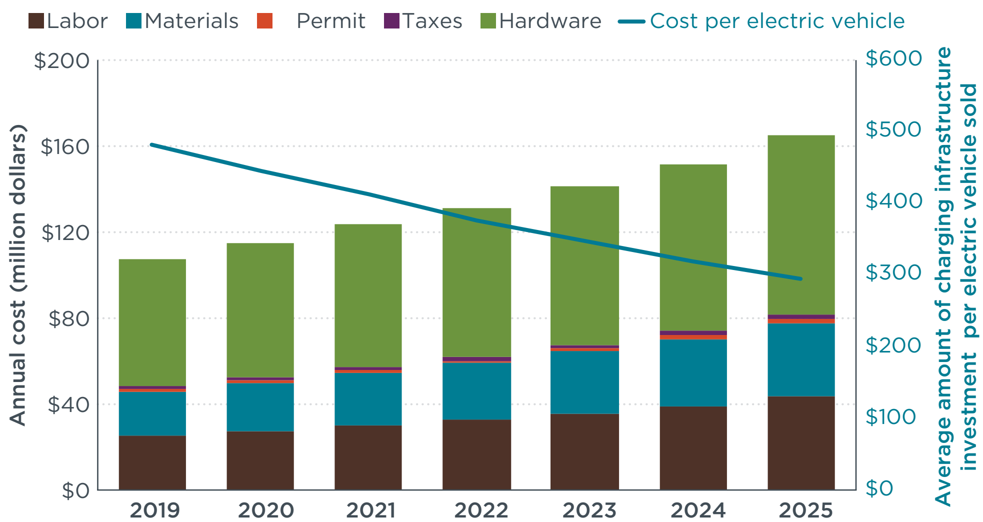

Figure 4. Total cost of public and workplace infrastructure and associated average aggregate charger cost per new electric vehicle sold for 2019 through 2025.

Figure 4 shows how annual charging infrastructure costs increase over time with higher electric vehicle sales volumes, and also how average charging costs for additional charging needed in each year decline on a per-electric-vehicle-sold basis. This decline is due to three factors. First, higher utilization of chargers, in terms of hours of active charging per day per charger, results in fewer chargers needed per electric vehicle. Second, installation costs decline as the number of chargers per site increases with growing market penetration. Third, we assume a 3% decline in per-charger hardware cost per year. The figure shows the installation and hardware costs increase from approximately $110 million to $165 million dollars in 2025. The blue line (right vertical axis) shows the average cost per electric vehicle, calculated by dividing public and workplace charging costs in each year by the number of electric vehicles sold in that year, and declines from $480 in 2019 to $300 in 2025.

To provide a more detailed understanding of how the charging infrastructure costs differ by electric vehicle type, Figure 5 shows the average cost of home and nonhome infrastructure separately for BEVs and PHEVs. The nonhome costs include workplace, public Level 2, and DC fast charging. The figure shows the average cost per new electric vehicle in the year sold and according to the year in which costs are incurred. Per BEV, the average home charger cost declines from $760 to $720 over 2019–2025, and the average nonhome charger cost declines from $690 to $420. Per PHEV, the average home charger cost declines from $320 to $300 over 2019–2025, and the average nonhome charger cost declines from $260 to $180. The BEV nonhome line includes DC fast charging cost whereas the PHEV nonhome line does not.

DC fast charging adds a significant cost to the average nonhome costs for BEVs. This is largely driven by the high cost of 150 kW and 350 kW hardware as shown in Table 2. Although a 3% cost reduction per year is applied to all nonhome charging hardware costs, the higher power DC fast charging hardware is relatively new and its cost may decrease faster as suppliers recoup development costs and move to higher production volume. Home costs are also greater for BEVs because more of the BEVs upgrade to Level 2 rather than use existing Level 1.

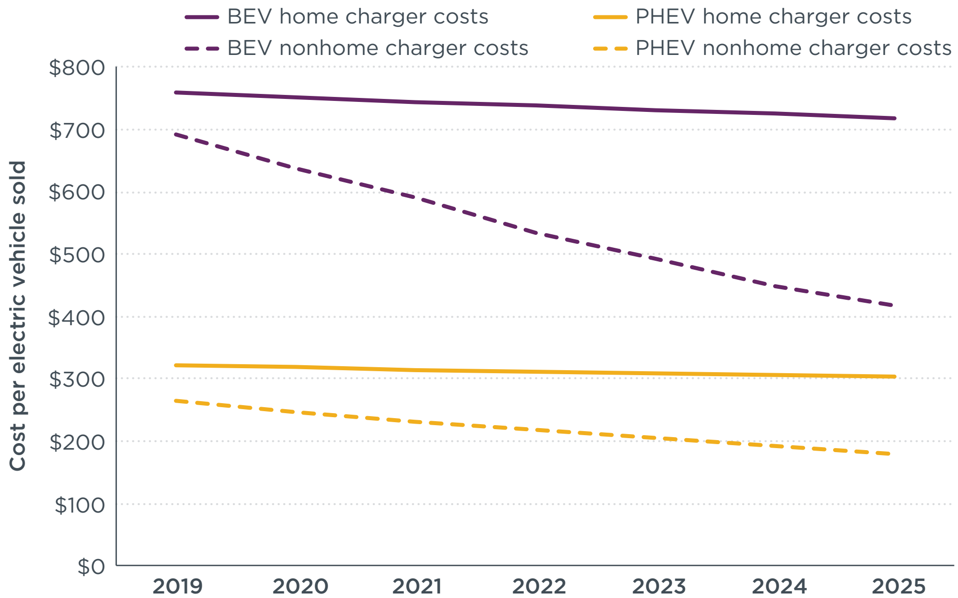

Figure 5. Average home and nonhome charger costs for BEVs and PHEVs.

Table 7. Summary of needed charging infrastructure and associated costs across 100 U.S. metropolitan areas over 2019–2025, by charging category.

Charging category	Chargers	Total 2019–2025 cost	Average 2019–2025 capital cost per charger
Home Level 1 no upgrade	1,005,000		
Home Level 1 outlet upgrade	76,000	$33 million	$440
Home Level 1 charger upgrade	32,000	$24 million	$735
Home Level 2 no upgrade	128,000		
Home Level 2 outlet upgrade	307,000	$339 million	$1,104
Home Level 2 charger upgrade	552,000	$948 million	$1,716
Workplace	48,000	$186 million	$3,880
Public Level 2	66,000	$359 million	$5,440
DC fast charging	5,000	$392 million	$81,818

Table 7 summarizes the total home, workplace, and public charging needed and the associated costs for the 2.6 million new electric vehicles in the 100 most populous U.S. metropolitan areas over 2019–2025. The home charging needs are shown by charging category (i.e., availability of Level 1 and Level 2) in the top six rows. Nonhome charging is shown in rows seven to nine. Counts refer to the number of new chargers in that category. As shown, the analysis finds that 5,000 DC fast, 66,000 public Level 2, 48,000 workplace, and 967,000 home charger upgrades will be needed from 2019–2025. In addition, within this analysis there are 1.1 million electric vehicle drivers who will use existing home charging outlets. Although not shown, there are another 460,000 electric vehicle drivers in this analysis who do not have home charging and will rely on public and workplace charging.

The costs in Table 7 show the relative contributions of the various charging types to the overall charging infrastructure costs for the major U.S. electric vehicle markets. The home charging costs ultimately result in more than half of the overall costs ($1.3 billion of $2.3 billion), followed by DC fast charging ($392 million), public Level 2 ($359 million), and workplace charging ($186 million). As indicated by the far right column, the average cost per charger is much higher for the DC fast charging ($81,818), followed by public Level 2 ($5,440), workplace ($3,880), and various home charging types. Home charging costs are a weighted average across housing types, and cost differences for those housing types are detailed in Table 5. Nonhome charging costs are similarly averaged across all years and metropolitan areas. This summary reinforces that there is a significant number of new electric vehicle buyers who will not need home upgrades.

In addition to the preceding summary analysis, similar results for two specific metropolitan areas are provided as examples of underlying analysis on charging infrastructure needs and the associated costs evaluated across the 100 metropolitan areas. Table 8 summarizes the home, workplace, public, and DC fast chargers needed over 2019–2025 and the associated estimated charger costs for the Portland and San Francisco metropolitan areas. These two examples are chosen because they represent large and growing electric vehicle markets and also are areas where there are many utility, state policy, and city activities to actively fill the charging needs.

In the Portland area, our scenario has the total electric vehicle stock increasing by 75,000 electric vehicles from 2019–2025. As shown in Table 8, the associated Portland area charging costs for home, DC fast, public Level 2, and workplace charging are $43 million, $13 million, $10 million, and $6 million, respectively. In the San Francisco area, our scenario has the total electric vehicles increasing by 220,000 vehicles from 2019 to the end of 2025. The respective San Francisco area home, DC fast, public Level 2, and workplace charging costs are $143 million, $36 million, $30 million, and $17 million, respectively. These two cases provide examples and local-level context for the level of investment this analysis implies for electric vehicle owners, electric utilities, governments, and private charging providers.

Table 8. Example results for amount of needed charging infrastructure and associated costs over 2019–2025 by charging category for two metropolitan areas.

	Portland area		San Francisco area	
Charging category	**Charger outlets**	**Total 2019–2025 cost**	**Charger outlets**	**Total 2019–2025 cost**
Home Level 1 no upgrade	29,000		90,000	
Home Level 1 outlet upgrade	2,000	$1 million	7,000	$3 million
Home Level 1 charger upgrade	1,000	$1 million	3,000	$2 million
Home Level 2 no upgrade	5,000		13,000	
Home Level 2 outlet upgrade	10,000	$10 million	32,000	$37 million
Home Level 2 charger upgrade	19,000	$32 million	57,000	$101 million
Workplace	1,600	$6 million	4,300	$17 million
Public Level 2	2,000	$10 million	5,400	$30 million
DC fast charging	160	$13 million	440	$36 million

Note: Metropolitan areas are the core-based statistical areas and represent populations of approximately 2.5 million residents in the Portland area and 4.7 million in the San Francisco area.

Conclusions

In this analysis, we evaluate the capital costs, including installation and hardware, for a scenario with 2.6 million new electric vehicle sales in the top 100 U.S. metropolitan areas over the 2019–2025 period. Our basic findings here are that home charging costs to support these electric vehicles total $1.3 billion, whereas new workplace, public Level 2, and DC fast charging costs total $940 million.

The home and public charging costs analyzed here exclude several major aspects of a comprehensive charging ecosystem. This analysis excludes the necessary charging infrastructure for fast-charging corridors to link cities, which has been the early focus of some auto industry efforts.[13] The 100 metropolitan areas analyzed here represent 88% of all new electric vehicles sold and 75% of the overall U.S. vehicle market, but smaller markets are outside the scope of this analysis. Also excluded from this analysis are the project management and land-related costs, which can be highly variable and location-specific. Finally, charging infrastructure for the potential increased electrification of ride-hailing services is not included in these cost estimates. Nonetheless, the estimates provided here are important to provide capital cost estimates to inform the scale of infrastructure investment needed in major markets.

We also note that investments are underway for substantial fractions of the necessary charging buildout. Electric utility charging infrastructure activities are proliferating and

13 For example see "Charge on the Road," Tesla, accessed June 11, 2019, https://www.tesla.com/supercharger; "About Ionity," Ionity, accessed June 11, 2019, https://ionity.eu/en/about.html; General Motors, "General Motors to collaborate with EVgo, ChargePoint and Greenlots to enhance the charging experience for customers," news release January 9, 2019, https://media.gm.com/media/us/en/gm/home.detail.html/content/Pages/news/us/en/2019/jan/0109-charging.html

increasingly including direct support for infrastructure to partially fill charging gaps.[14] For example, three California utilities received approvals in 2018 to invest $738 million in charging infrastructure although some of it is dedicated to heavy duty vehicle infrastructure and items outside the scope of this report.[15] Volkswagen dieselgate settlement funds are also substantial. Volkswagen's Electrify America funding has allocated $360 million for fast charging corridors, $330 million for public and workplace charging, and $14 million for home charging.[16] In addition, up to 15% of the settlement's $2.7 billion environmental mitigation funding can be spent by states on charging infrastructure.[17]

However, this analysis of charging indicates there remains a need for charging infrastructure funding to support electric vehicle growth trends in the United States through 2025. We make the following conclusions regarding our analysis of electric vehicle charging infrastructure costs in the 100 most populous U.S. metropolitan areas.

Substantial charging infrastructure investments are needed to fill the charging gap. Our findings indicate that, to serve the growing electric vehicle market, necessary investments in workplace, public Level 2, and DC fast charging infrastructure would increase from approximately $110 million in 2019 to $270 million in 2025, amounting to a total of about $940 million. In addition, home charging investments of $1.3 billion are needed, largely for the upgrades and installation of Level 2 charging in houses and apartment buildings. These charging infrastructure costs are approximately 25% for hardware, 50% for labor, 20% for materials, and 5% for permits.

Infrastructure costs are relatively modest—and steadily decrease—on a per-electric-vehicle basis. Costs for public charging infrastructure decrease substantially on a per-electric-vehicle basis. This is due to public chargers becoming more heavily utilized, the shift to more outlets per charging site, and decreased hardware costs as the market grows. The result is that the total public infrastructure costs per electric vehicle decline from $480 per electric vehicle in 2019 to $300 in 2025. Averaged over all electric vehicles, some of which need home charging upgrades, home infrastructure costs are around $510–$540 per electric vehicle sold.

Investing in home charging will remain important. More than half of electric vehicle owners are expected to continue using their existing home charging options without home upgrades. Around 38% of electric vehicle owners are expected to have upgrades to improve their home charging, with an average cost of $1,400 to install home outlets or chargers. However, this average includes charging costs that are typically much higher in apartments. Incentives such as off-peak electricity rates and smart charging could remain important as the market expands to ensure more charging at apartment complexes and ensure home charging is mutually beneficial to drivers and utilities. Although many will utilize Level 1 charging with existing 120-volt outlets, higher power Level 2 charging at home will become increasingly important as battery size and vehicle range increase.

Based on these findings, charging infrastructure buildout is a strong candidate for large-scale federal funding. Although state-level utility support is growing, city and state funding for charging is generally limited. Cost-sharing federal and local funding would help leverage limited funding to help fill the charging gap and allow local authorities to align the federal support with their own action plans. Federal grants, perhaps directed at cities that demonstrate high electric vehicle uptake, comprehensive electric vehicle action plans, and city policies (e.g., streamlined infrastructure permitting, aggressive electric vehicle-ready building codes) could also be effective.

Many related questions remain. These charging infrastructure costs, clearly substantial, are presented here in the absence of vehicle electrification benefits. Follow-on analysis of how electric vehicle costs decline and fuel-saving and emission benefits increase, would likely show a strongly positive case for charging infrastructure investments.[18] Determining the lowest-cost pathways for a sufficient charging ecosystem will require persistent tracking of developments with electric vehicle charging speeds, electric range, charging preferences, and charger utilization. Finally, if the electrification of ride-hailing fleets were to ramp up, this would greatly increase the need for charging infrastructure investments.

14 Smart Electric Power Alliance, "Utilities and electric vehicles: Evolving to unlock grid value," (March, 2018), https://sepapower.org/resource/utilities-electric-vehicles-evolving-unlock-grid-value/

15 Decision on the transportation electrification standard review projects, California Public Utility Commission May 31, 2018, http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M215/K380/215380424.PDF

16 The Electrify America funds are referred to as "Appendix C" funds per the settlement. "Our Investment Plan," Electrify America, accessed April 25, 2019, https://www.electrifyamerica.com/our-plan

17 These are "Appendix D" environmental mitigation funds. See U.S. District Court, Northern District of California, San Francisco Division, Case No: MDL No. 2672 CRB (JSC), Third Partial and 3.0L Second Partial and 2.0L Partial and Amended Consent Decree, retrieved from https://www.epa.gov/enforcement/third-partial-and-30l-second-partial-and-20l-partial-and-amended-consent-decree

18 Previous analysis with much higher electric vehicle costs than today indicated as much, with benefits many times greater than the infrastructure costs. See National Research Council, Transitions to Alternative Vehicles and Fuels (Washington, DC: The National Academies Press, 2013), https://doi.org/10.17226/18264.