PNNL-31576

Electric Vehicle Charging for Residential and Commercial Energy Codes

Technical Brief

July 2021

V R Salcido
M Tillou
E Franconi

U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
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Pacific Northwest National Laboratory
Richland, Washington 99354

Preamble

The U.S. Department of Energy (DOE) and Pacific Northwest National Laboratory (PNNL) are developing a series of technical briefs supporting national, state and local initiatives to update and advance building energy codes. These technical briefs represent specific technologies, measures or practices that can be incorporated as module-based “plug-ins” via the national model energy codes, such as the International Energy Conservation Code (IECC) or ASHRAE Standard 90.1, or adopted directly by state and local governments pursuing advanced energy savings and greenhouse gas (GHG) emissions reductions. The collection of technical briefs is part of a larger effort to provide technical assistance supporting states and local governments in order to help them realize their policy goals.

This technical brief presents a compilation of information on electric vehicles (EVs), examining market trends, benefits to consumers and society, and means of expanding the EV charging infrastructure by way of energy codes for new construction. A description of the concept is provided along with supporting justification and examples of similar concepts which have been adopted by states and local jurisdictions, as well as technical information on expected costs and benefits. In addition, the brief provides sample energy code language developed by PNNL following consultations with the International Code Council (ICC) that can be overlaid directly onto model energy codes for EV charging infrastructure (Section 3). A technical brief is intended to be a resource for interested and affected stakeholders, particularly those charged with considering the impacts of proposed code updates.

Additional assistance may be available from DOE and PNNL to support states and local governments who are interested in adding EVs and other “stretch” provisions to their building codes, such as technical guidance, customized analysis of expected impacts (e.g., based on state-specific building stock, climate considerations or utility rates), and further tailored code language to overlay state building codes or other standards. DOE provides this assistance in response to the Energy Conservation and Production Act (ECPA), which directs the Secretary of Energy to provide technical assistance “to support implementation of state residential and commercial building energy efficiency codes.” (42 USC 6833) PNNL supports this mission by evaluating concepts for future code updates, conducting technical reviews and analysis of potential code changes, and providing assistance to states and local jurisdictions who strive to adopt, comply with and enfoce energy codes. This helps to ensure successful implementation of building energy codes, as well as a range of advanced technologies and construction practices, and encourages building standards which are proven practical, affordable and efficient.

DOE Building Energy Codes Program

The U.S. Department of Energy supports the advancement of building energy codes. Modern building codes and standards offer cost-effective solutions, contributing to lower utility bills for homes and businesses, and helping to mitigate the impacts of climate change. Learn more at energycodes.gov.

Executive Summary

Numerous studies show that sales of electric vehicles (EVs) have grown consistently over recent years in the U.S. Edison Electric Institute (EEI) estimates one million EVs on the road in 2018 and forecasts a total of 18.7 million EVs on the road by 2030. Based on this forecast, EEI projects the need for an additional 9.6 million EV charging stations by 2030. It is imperative that the EV charging infrastructure keeps pace with sales of EVs to to enhance overall EV growth, and to ensure that lack of access to EV charging stations is minimized as a critical barrier to EV adoption.

EVs provide substantial benefits to the consumer and society. EVs are less expensive to operate than conventional gas vehicles, have lower maintenance costs, and have the convenience of fueling (charging) at home or work. EVs likewise reduce GHG emissions. EV market growth combined with a cleaner grid will support goals of reduced GHG emissions established across the U.S. and others by federal agencies, as well as many states and local governments. According to the U.S. Environmental Protection Agency (EPA), the transportation sector (cars, trucks, trains, ships, airplanes, and other vehicles) accounts for 29% of total U.S. GHG emissions. Globally, road travel accounts for 75% of transportation emissions. Studies conducted in California show that costs associated with installing EV charging infrastructure can be substantially more expensive for retrofit scenarios compared to new construction.

Many states and local governments have added EV provisions to their building codes, local ordinances and zoning requirements. This technical brief summarizes current market trends, costs and benefits, and provides sample code language for EV charging infrastructure for inclusion in future model codes, such as the International Energy Conservation Code (IECC) and ASHRAE Standard 90.1, as well as directly by states and local governments in their building codes. The current brief summarizes related efforts undertaken by states and local governments, and builds upon language considered for the 2021 IECC[1], and includes additional requirements developed by both PNNL staff and ICC staff. The Code Council is developing an additional resource considering multiple approaches to EV charging infrastructure and recently released a public review draft for comments[2]. Comments on that resource are due August 16, 2021.

[1] A similar concept was originally approved for inclusion in the 2021 IECC but removed upon appeal.

[2] www.iccsafe.org/energy/EVresource

Contents

Figures

Tables

1.0 Electric Vehicle Charging in Residential and Commercial Energy Codes

The electric vehicle market is growing dramatically and emerging as the future of transportation. In the U.S., EV sales increased 80% from 2017 to 2018 (Edison Electric Institute). In fact, EV sales in the U.S. reached a new milestone in 2021. The Bureau of Transportation Statistics (BTS) indicated EV sales reached more than 120,000 in March 2021 marking an overall record high in EV sales.[3] BTS data indicate that EV sales have been growing consistently for the past 12 months. While EVs represent less than 0.5% of vehicles on the road in the U.S., that percentage is expected to reach 7% in 2030 and this demand necessitates expanding EV charging infrastructure.

Approximately half of all vehicles in the U.S. belong to residents of single-family or duplex homes that have access to a dedicated off-street parking space, such as a garage or driveway, which can typically be used for overnight EV charging. New homes are built to last for decades, thus they represent a unique opportunity to be equipped to handle future technologies, including the ability to charge EVs. As half of vehicles in the U.S. do not have reliable access to dedicated off-street parking, the EV market must move beyond single-family detached homes and expand EV charging access in other feasible locations, such as multifamily unit dwellings, workplaces, and commercial properties. EV-ready building codes support this expansion and can save consumers thousands of dollars in installation costs when included in initial construction.[4]

Incorporating EV requirements into building codes is an effective and low-cost strategy that supports local and state efforts to reduce carbon emissions and achieve a clean resilient grid. Doing so also supports future efforts to use battery storage to manage utility peak demand. This includes using EVs as a distributed energy resource and realizing vehicle-to-grid integration (VGI), where bidirectional chargers allow electricity to flow from the electric vehicle back to the grid. Thus in the near future, EVs will provide added value to the grid and to car owners without the outlay of new capital. According to E3, the expected additional revenue to the consumer is $345/year for managed unidirectional charging that ramps up and down. The additional benefits of VGI resulting from other grid services, such as frequency regulation, increase the value by about $500 per year.[5]

The concept of incorporating EV charging infrastructure into the model codes was considered, and initially approved, for the 2021 International Energy Conservation Code (IECC), but later removed in response to appeals.[6] DOE, the International Code Council (ICC), and other interested stakeholders have coordinated to update the concept such that it could be considered directly by states and local governments interested in adopting EV provisions into their codes, as well as for future model code development via the IECC. The EV charging infrastructure requirements included in this technical brief build upon the language considered for the 2021 IECC, and adds further information, analysis and suggested code language as developed by PNNL and ICC staff. These model requirements are intended to support consistency in approach and provide a degree of certainty for building owners, designers, contractors, manufacturers and building and fire safety professionals., As each State and municipality is

[3] https://www.bts.gov/data-spotlight/electric-vehicle-use-grows
[4] https://www.swenergy.org/cracking-the-code-on-ev-ready-building-codes
[5] https://gridworks.org/wp-content/uploads/2019/05/VGI_4.12-Slides.pdf.
[6] https://www.iccsafe.org/building-safety-journal/bsj-technical/code-development-a-process-of-evolution-and-improvement/

different the recommended number of required spaces designed with EV charging infrastructure included in the model code language should be adjusted to reflect the local needs of your jurisdiction. Feedback is actively being sought on this proposal, and both DOE and ICC are evaluating ways to engage interested and affected stakeholders to coordinate a final concept in the coming months. The Code Council is developing an additional resource considering multiple approaches to PEV charging infrastructure and recently released a public review draft for comments.[7] Comments on that resource are due August 16, 2021.

1.1 Consumer and Societal Benefits

According to the U.S. Environmental Protection Agency (EPA), the transportation sector (cars, trucks, trains, ships, airplanes, and other vehicles) accounts for 29% of total U.S. greenhouse gas (GHG) emissions.[8] Figure 1 shows the total GHG emissions by sector. Globally, road travel accounts for 75% of total transportation emissions.[9] Increasing EV sales now and those projected by 2030 will help reduce U.S. GHG emissions produced by moving goods and people. DOE will support the growth of the EV market to meet its objective of reduced GHG emissions. GHG emission reductions derived by using EVs in the U.S. will continue to improve as the electric grid becomes cleaner. EVs charged exclusively by renewable energy will run emission free.

The manufacturing and sales of EVs, hybrids, and plug-in hybrids supported 266,384 jobs in the U.S. in 2019, representing 10% of the total motor vehicle workforce. Furthermore, alternative fuel vehicle jobs have grown 39% since 2015 and auto manufacturers and component parts employers anticipate a job growth rate of 3.0% in 2020.[10] The projected growth in demand for EV and EV infrastructure will continue to support future job growth in alternative fuel vehicle-related jobs.

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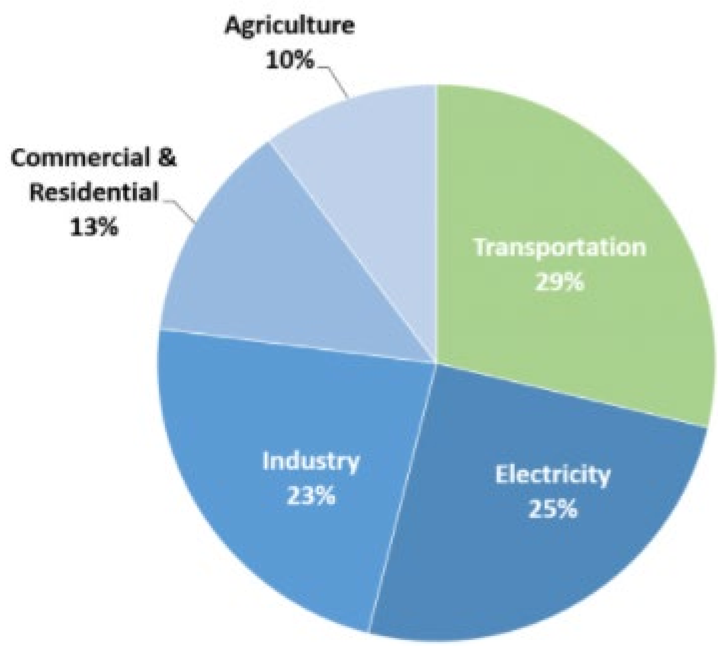
[7] www.iccsafe.org/energy/EVresource

[8] https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions#transportation

[9] https://ourworldindata.org/co2-emissions-from-transport

[10] https://static1.squarespace.com/static/5a98cf80ec4eb7c5cd928c61/t/5ee78423c6fcc20e01b83896/1592230956175/USEER+2020+0615.pdf



Source: U.S. Environmental Protection Agency – Sources of GHG Emissions

Figure 1. Total U.S. Greenhouse Gas Emissions by Economic Sector in 2019 (6,558 MT CO_2)

EVs benefit the consumer through lower operational and maintenance costs. It is cheaper to fuel an EV; its fuel efficiency is equivalent to up to 100 miles per gallon for a gas-powered vehicle.[11] This translates to an annual average cost savings of $800. In addition, EVs have no gasoline engine, oil, spark plugs, or timing belts that require annual maintenance, and electric engines require little to no maintenance, which translates into additional average annual savings of around $1,500.[12]

EVs provide an enhanced driving experience over gas-powered vehicles with silent drive and instant torque that provides smooth and quick acceleration. EVs also provide convenience by fueling at home or work rather than driving to a gas station.

Finding the nearest charging station is becoming easier with new EV charging applications. In addition to numerous online resources, the United States Department of Energy Alternative Fuels Data Center maintains a comprehensive station locator for the United States and Canada. Each station location includes information about the business where the station is found, charging speeds, and port types.[13]

[11] https://afdc.energy.gov/fuels/electricity_benefits.html#savings

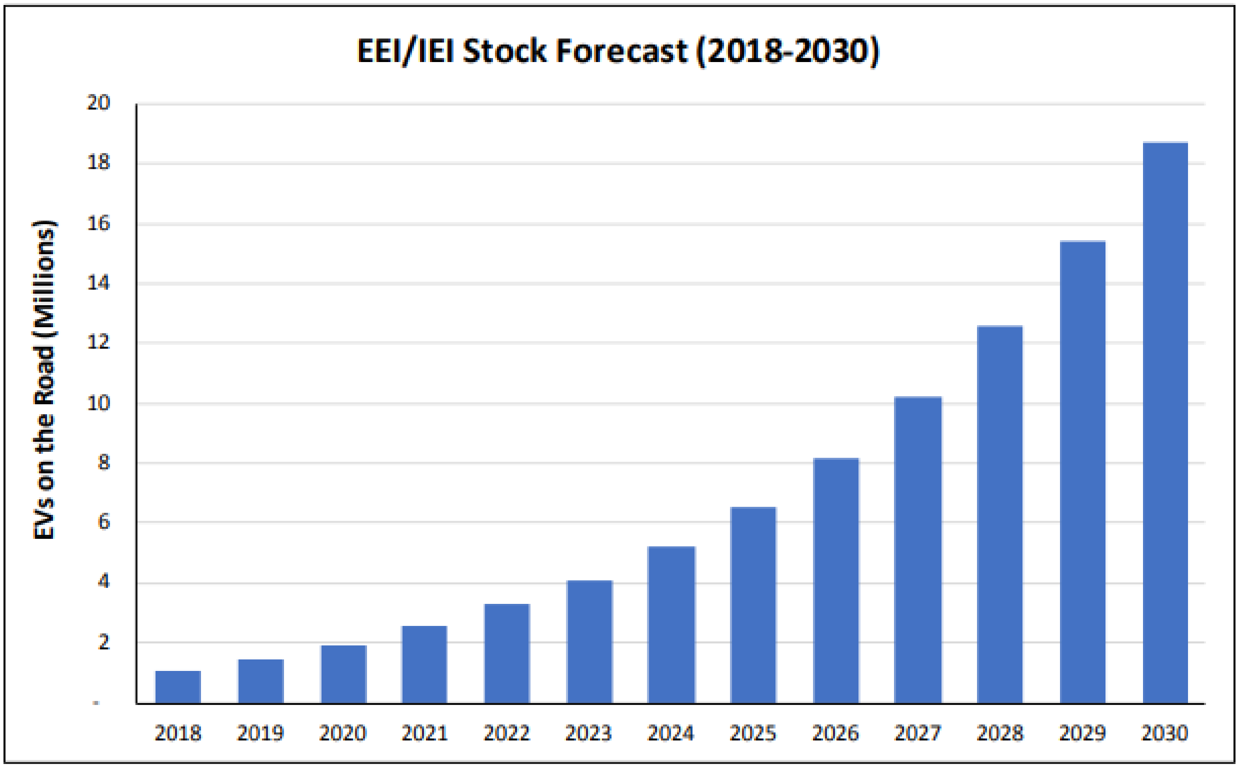
[12] https://public.tableau.com/app/profile/dave.reichmuth/viz/EVsavingsmap/Dashboard1

[13] https://afdc.energy.gov/stations/#/find/nearest

1.2 EV Market Trends

All reports of EV purchases show record sales and a growing market illustrating that EVs are the future of transportation. Over 1 million EVs are on U.S. roads as of October 2018.[14] By 2030, EEI forecasts the number of EVs on the road to reach 18.7 million. This represents approximately 7% of the 259 million vehicles on the road in the U.S. Figure 2 and Figure 3 show the EV stock forecast and EV sales forecast as a percentage of all vehicle sales, respectively[14].

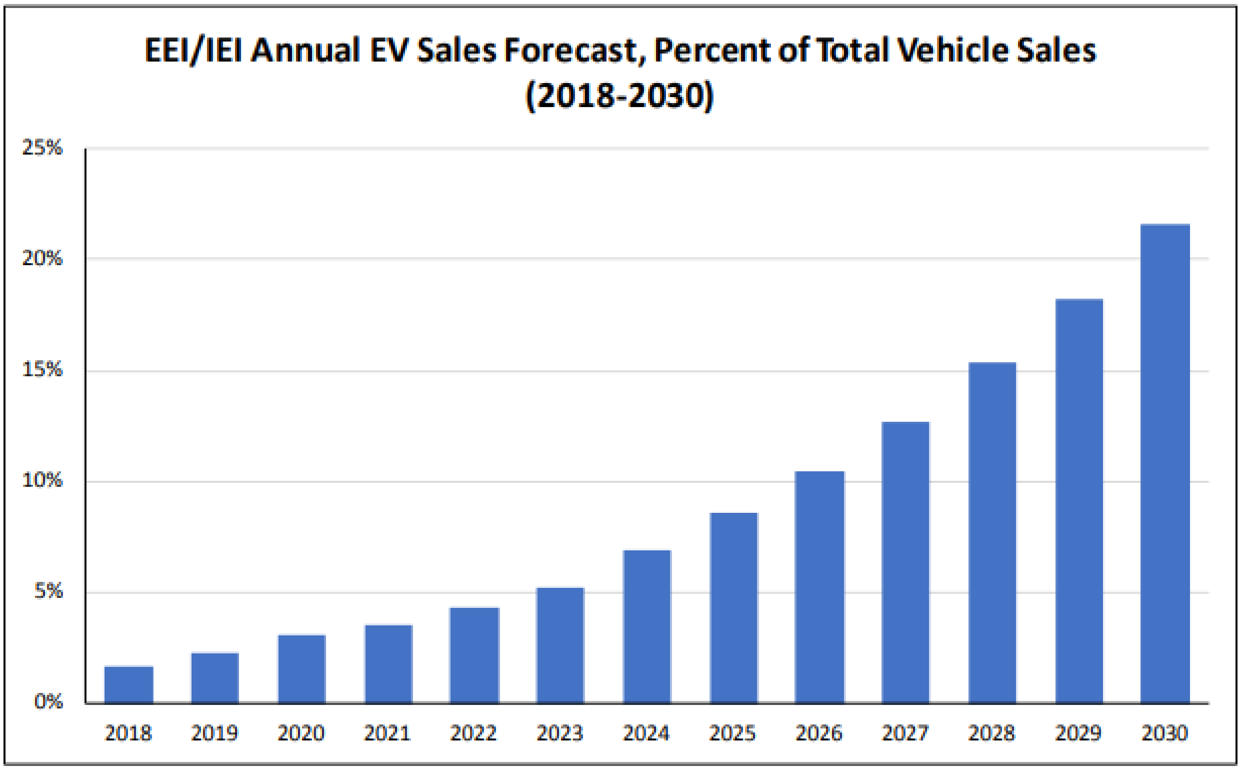
All major auto manufacturers have announced plans to electrify a significant portion of their vehicle fleets over the next 3–5 years.[14] The interest in EVs has grown together with greater model availability and increased vehicle range. The success of the EV market is directly related to the availability of the EV charging infrastructure in private and public settings. It is vitally important to increase the amount of EV charging stations to support the transition to EVs.



Source: Edison Electric Institute 2018

Figure 2. EV Stock Forecast to 2030

[14] https://www.edisonfoundation.net/-/media/Files/IEI/publications/IEI_EEI-EV-Forecast-Report_Nov2018.ashx



Source: Edison Electric Institute 2018

Figure 3. EV Sales Forecast

1.3 EV Charging

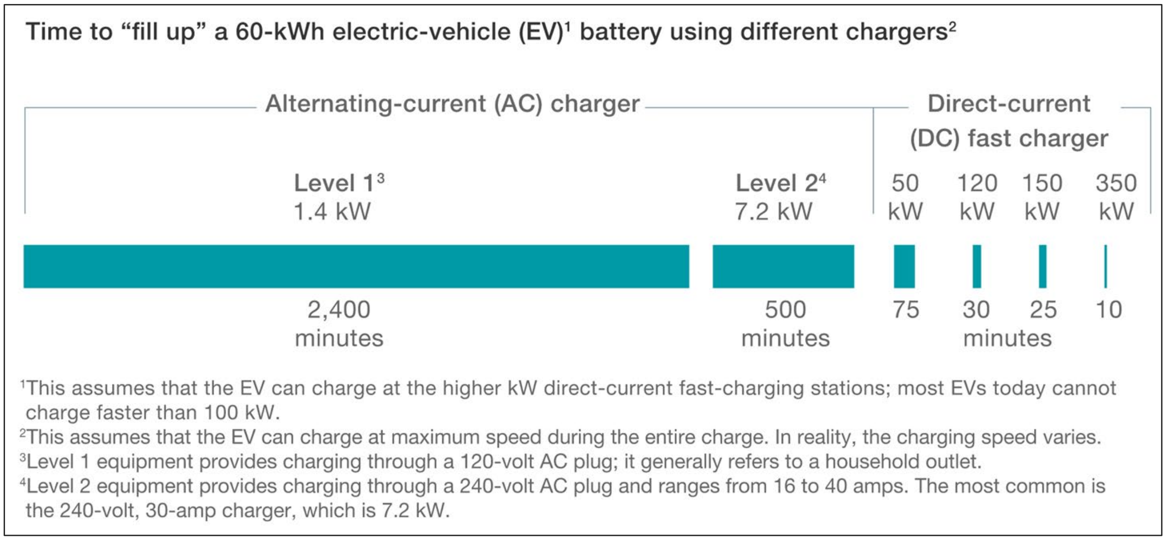
In order to fuel a EV, a connection to the grid or power source is required in the form of a charging station also known as electric vehicle supply equipment (EVSE). EVSEs come in a variety of configurations but are typically separated by power level. There are three levels of ESVE: Level 1, Level 2, and DC Fast Charging (DCFC).

- **Level 1**: Level 1 charging uses a common 120-volt household outlet. Every electric vehicle or plug-in hybrid can be charged on Level 1 by plugging the charging equipment into a regular wall outlet. Level 1 is the slowest way to charge an EV. It adds between 3 and 5 miles of range per hour. Level 1 EV charging stations are located typically at home, workplace or public parking[15].
- **Level 2**: Level 2 charging is the most widely used level for daily EV charging. Level 2 ESVE can be installed at home, at the workplace, as well as in public locations like shopping plazas, train stations, and other destinations. Level 2 charging can replenish between 12 and 80 miles of range per hour, depending on the power output of the Level 2 charger, and the vehicle's maximum charge rate.[16]
- **DC Fast Charging (DCFC)**: DCFC (sometimes referred to as Level 3) is the fastest type of charging available and can recharge an EV at a rate of 3 to 20 miles of range per minute (or 180 to 1,200 miles of range per hour). Unlike Level 1 and Level 2 charging that uses alternating current (AC), DCFC charging uses direct current (DC). The voltage is also much

[15] https://afdc.energy.gov/fuels/electricity_infrastructure.html
[16] https://afdc.energy.gov/fuels/electricity_infrastructure.html

higher than Level 1 and 2 charging, which is why you don't see DCFC chargers installed at home. Very few residential locations have the high-voltage supply that is required for DCFC charging.[16]

According to JD Power's U.S. Electric Vehicle Experience (EVX) Home Charging Study, 88% of EV-owners prefer to charge their vehicle at home where charging can take place overnight.[17] Installment of Level 2 or DCFC EVSE at workplaces or in public settings allows EV-owners to drive more miles on electricity and enables longer trips while reducing range anxiety.[18] Figure 4 compares EV charge time based on EV charging level.



Source: Mckinsey & Company – https://www.mckinsey.com/business-functions/sustainability/our-insights/how-battery-storage-can-help-charge-the-electric-vehicle-market

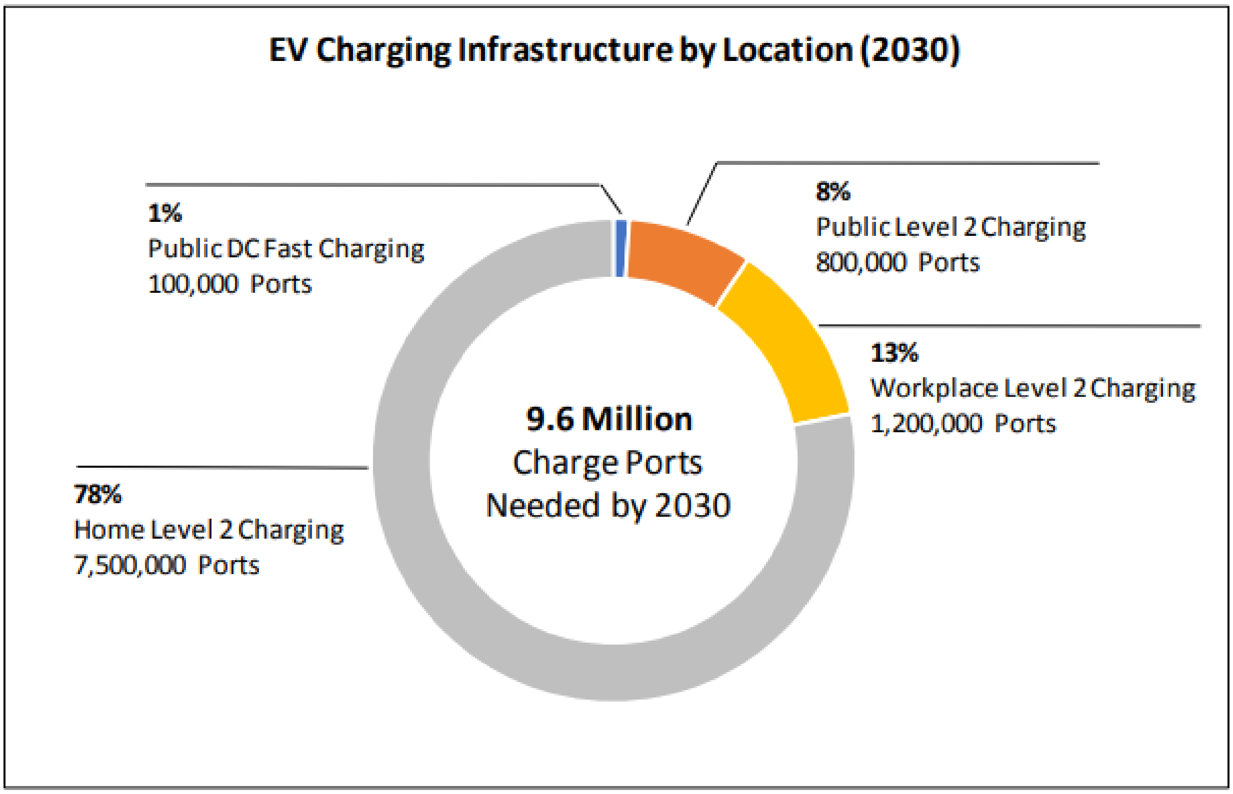
Figure 4. EV Charge Time Based on EV Charging Power

1.4 EV Charging Infrastructure

As mentioned earlier, EEI forecasts the number of EVs on U.S. roads to reach 18.7 million by 2030.[2] To support this growth, an additional 9.6 million EV charging stations will be required by 2030. This includes 9.5 million Level 2 public and private charging stations and 0.1 million Level 3 public fast charging stations. Given the extensive charging time of a Level 1 ESVE, Level 2 chargers are currently prioritized as the solution until newer and more advanced residential charging methods are available. Figure 5 shows the projected mix of EV charging stations needed by location.

[17] https://afdc.energy.gov/fuels/electricity_infrastructure.html

[18] https://www.edisonfoundation.net/-/media/Files/IEI/publications/IEI_EEI-EV-Forecast-Report_Nov2018.ashx



Source: Edison Electric Institute 2018

Figure 5. EV Charging Infrastructure in 2030 Based on the EEI Forecast

The availability and ease of access to Level 2 and DCFC EVSE is a critical barrier to EV adoption.[19] A lack of pre-existing EV charging infrastructure, such as electrical panel capacity, raceways, and pre-wiring, can make the installation of a new charging station cost-prohibitive for a potential EV-owner[20].

State and local governments around the country have led the way on EV-Ready Building Codes, with requirements that have been adapted to best fit the needs of each community. Three basic options for EV infrastructure requirements are shown in Figure 6Figure 6. For one- and two-family dwellings with dedicated off-street parking, Level 2 EV-capable or EVSE-Ready outlet provisions are required for at least one parking space per residence. For multifamily dwellings and commercial properties, EV charging infrastructure requirements are applied as a percentage of total parking spaces (e.g., 5% of total parking spaces are to be EV-capable for parking lots with over 10 parking spaces).[21]

The DOE Alternative Fuel Data Center provides additional resources to support the development of EV charging infrastructure. Resources include procurement and installation checklists, operation and maintenance costs, and access to the EVI-Pro Lite Tool, which can help jurisdictions identify the number and type of EV charging stations required for their area.[22]

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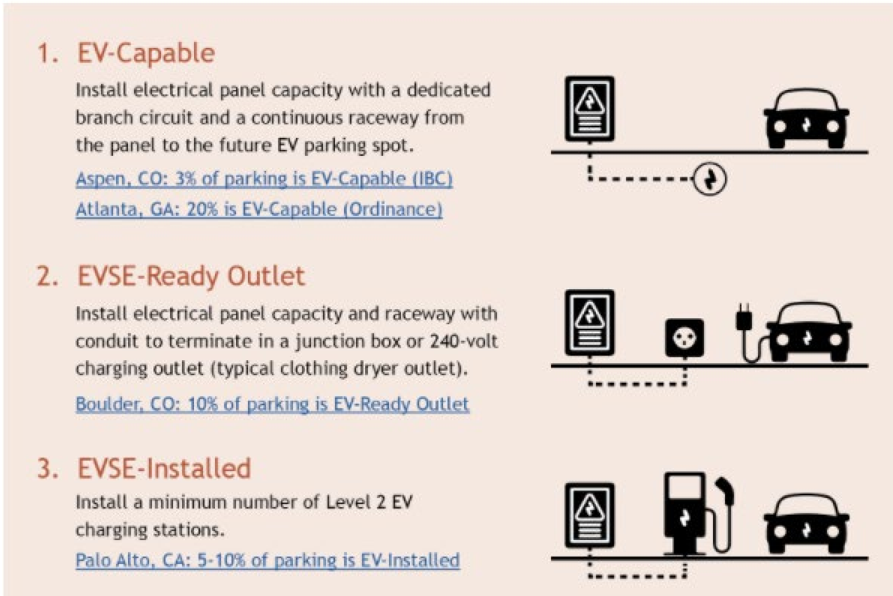
[19] https://afdc.energy.gov/files/u/publication/56898.pdf
[20] Francfort et al. 2015
[21] https://www.swenergy.org/cracking-the-code-on-ev-ready-building-codes
[22] https://afdc.energy.gov/fuels/electricity_infrastructure_development.html



Source – Southwest Energy Efficiency Project 2018

Figure 6. Options for EV Infrastructure Requirements

1.5 Existing EV Charging Requirements in Energy Codes

This section highlights some of the various approaches to EV-integrated building codes that are harnessed by different local governments in more depth. Table 1, incorporated below, highlights sample EV infrastructure code provisions that are currently implemented across North America. These approaches can influence future code adoption for local jurisdictions seeking to meet GHG reduction targets.

International Green Construction Code – Model Code

The 2021 International Green Construction Code (IgCC) includes the following requirements for the installation of EVSE:

501.3.7.3 Electric vehicle charging facilities.

Where 20 or more on-site vehicle parking spaces are provided for International Building Code (IBC) Occupancy Group A, B, E, F, I, M, and S buildings, not less than 4% of the total number of parking spaces or not less than 8% of designated employee only parking spaces shall be EV-Ready spaces. Where 10 or more on-site vehicle parking spaces are provided for IBC Occupancy Group R-1, R-2, and R-4 buildings, not less than 20% of the total number of parking spaces shall be EV-Ready spaces. The required number of EV-Ready spaces shall be rounded up to the next highest whole number.

California – State Level

California set ambitious targets for ZEH charging infrastructure to support their mission of having 5 million ZEHs by 2030. The state plans to install 250,000 shared plug-in electric vehicle chargers, including 10,000 DCFCs and 200 hydrogen stations by 2050. The 2020 California Green Building Code's (CALGreen) includes provisions for EV infrastructure requirements in new multifamily, residential and non-residential buildings, as well as stretch code requirements.

Local governments can adopt or surpass the CALGreen stretch codes for EV-Capable or EV-Ready spaces, although it is not required.

CALGreen requires new construction of multi-unit dwellings to include EV-Capable infrastructure in at least 10 percent of parking spaces. The two-tiered reach codes enable cities to adopt requirements for EV-Capable infrastructure in 15 percent or 20 percent of multi-unit development (MUD) parking spaces. CALGreen has also established requirements for new construction single-family residences, duplexes and townhouses with private garages. The residential provisions require EV-Capable capacity to support Level-2 charging station installations. CALGreen also requires new construction non-residential buildings to have 6 percent of parking spaces EV-Capable, with reach codes supporting 8 percent and 10 percent capacity.

Local governments have shown support of the CALGreen EV infrastructure building code requirements, with 20 jurisdictions exceeding the minimum code requirements in their local code adoptions. Some municipalities are also implementing parking ordinances to encourage the installation of EV charging stations, specifically for new construction. Some jurisdictions have gone even farther to explore adoption of EV infrastructure codes that address existing buildings including the City of Marin, City of Menlo Park, and the City and County of San Francisco. Such stretch codes target alterations and additions to provide opportunities for EV infrastructure installation in existing buildings.[23]

Denver, Colorado – City Level

Denver, Colorado amended the 2018 IECC and IRC to include the following EV charging infrastructure requirements to meet its goal of electrifying 30% of all vehicles by 2030:

One- and two-family dwellings: At least one EV-Ready parking space per dwelling unit.

Multi-family dwellings (3+ dwellings) with 10+ spaces: 5% of parking spaces to be EV-Installed, 15% EV-Ready Parking Spaces, and 75% EV-Capable Parking Spaces.

Commercial buildings (Groups A, B, E, I, M, S-2) with 10+ spaces: 5% of parking spaces to be EV-Installed, 10% EV-Ready Parking Spaces, and 10% EV-Capable Parking Spaces.

Building Alterations: 'Level-3 Alterations', where the work area exceeds 50 percent of the original building area or more than 10 parking spaces are substantially modified, are subject to the EV infrastructure requirements for both residential and commercial buildings.

DC Fast-charger provision: For MUD and Commercial buildings, allow developers to substitute up to five Level-2 charging spaces with one DC fast-charging space (minimum 20kW).[24]

Winter Park, Florida – City Level

The City of Winter Park adopted an EV-Readiness Ordinance that amends both its Land Development Code and Building Code. Winter Park amended Section 58-86 "Off-street Parking

[23] California Governor's Office of Business and Economic Development, "Electric Vehicle Charging Station Permitting Guidebook," (First Edition: July 2019).
[24] City of Denver Community Planning and Development, "Code Amendment Proposal," (2019).

and Loading Regulations" of its Land Development Code to include EV charging station infrastructure and parking space requirements. Under this amendment, non-residential properties with surface parking or parking structures are required to have a minimum of 10 percent of total parking spaces to be Level-2 EV-Ready. The EV charging infrastructure is required to be installed in accordance with the technical amendment made to the Florida Building Code (Chapter 22, Section 2703 of the City of Winter Park Code of Ordinances). The Land Development Code amendment also requires non-residential properties to provide, at minimum, 1 parking space equipped with a Level-2 EV charging station per every 20 required off-street parking spaces.

Vancouver, BC – International/City Level

The City of Vancouver adopted Building Code Bylaw 10908, which requires EV charging infrastructure installation in new construction residential and commercial buildings. Single-family dwellings with garages are required to have at least one EV-Ready parking space per dwelling unit. Multi-family dwellings are required to have 100 percent of parking spaces be EV-Ready, while commercial buildings must have 10 percent of parking spaces be EV-Ready.[25]

Although the code requires EV-Ready for 100 percent of parking spaces in MUDs, there is no requirement to install the electrical capacity to charge all spaces at full power. Vancouver's code requirements encourage the use of charging management technology to achieve a high level of plug-in electric vehicle readiness without the need for larger capacity upgrades.

Table 1. Cities with EV Charging Infrastructure Requirements

Municipality	Year	Type	One- or Two-family Dwellings	Multifamily Unit Dwellings	Commercial
Avon, CO	2021	Ordinance	1 EV-Ready Space per dwelling Unit	5% EV-Installed, 10% EV-Ready, 15% EV-Capable (7+ spaces)	5% EV-Installed, 10% EV-Ready, 15% EV-Capable (10+ spaces)
St. Louis, MO	2021	Ordinance	1 EV-Ready Space per dwelling Unit	2% EV-Installed, 5% EV-Ready (increases to 10% in 2025)	2% EV-Installed, 5% EV-Ready
Madison, WI	2021	Ordinance	-	2% EV-Installed, 10% EV-Ready (increases by 10% every 5 years)	1% EV-Installed (increases by 1% every 5 years), 10% EV-Ready (increases by 10% every 5 years)
Washington D.C.	2021	Legislation	-	20% EV-Ready (3+ spaces)	20% EV-Ready (3+ spaces)
Summit County, CO	2020	IBC / IRC	1 EV-Ready Space per dwelling Unit	5% EV-Installed, 10% EV-Ready, 40% EV-Capable (10+ spaces)	5% EV-Installed, 10% EV-Ready, 40% EV-Capable (25+ spaces)
Dillon, CO	2020	IBC / IRC	2 EV-Ready Space per dwelling Unit	5% EV-Installed, 10% EV-Ready, 40% EV-Capable (10+ spaces)	5% EV-Installed, 10% EV-Ready, 40% EV-Capable (25+ spaces)
Breckenridge, CO	2020	IBC / IRC	3 EV-Ready Space per dwelling Unit	5% EV-Installed, 10% EV-Ready, 40% EV-Capable (10+ spaces)	5% EV-Installed, 10% EV-Ready, 40% EV-Capable (25+ spaces)
Frisco, CO	2020	IBC / IRC	4 EV-Ready Space per dwelling Unit	5% EV-Installed, 10% EV-Ready, 40% EV-Capable (10+ spaces)	5% EV-Installed, 10% EV-Ready, 40% EV-Capable (25+ spaces)

[25] City of Vancouver Building Policy Branch, "Electric Vehicle Charging of Buildings," (2021).

Municipality	Year	Type	One- or Two-family Dwellings	Multifamily Unit Dwellings	Commercial
Salt Lake City, UT	2020	Ordinance	-	20% EV-Ready (5+ spaces)	-
City of Boulder, CO	2020	IBC / IRC	1 EV-Ready Space per dwelling Unit	5% EV-Installed, 15% EV-Ready, 40% EV-Capable (25+ spaces)	5% EV-Installed, 10% EV-Ready, 10% EV-Capable
Denver, CO	2020	IBC / IRC	1 EV-Ready Space per dwelling Unit	5% EV-Installed, 15% EV-Ready, 80% EV-Capable	5% EV-Installed, 10% EV-Ready, 10% EV-Capable
Honolulu, HI	2020	Ordinance	1 EV-Capable Space per dwelling unit	25% EV-Ready (8+ spaces)	25% EV-Ready (12+ spaces)
Chicago, IL	2020	Ordinance		20% EV-Ready (5+ spaces)	20% EV-Ready (30+ spaces)
Lakewood, CO	2019	Zoning Ordinance	1 EV-Capable Space per dwelling unit	2% EV-Installed, 18% EV-Capable (10+ spaces)	2% EV-Installed, 13% - 18% EV-Capable (10+ spaces)
Flagstaff, AZ	2019	IBC / IRC	1 EV-Ready Space per dwelling Unit	3% EV-Ready	3% EV-Ready
Massachusetts	2019	-	-	-	1 EV-Ready space (15+ spaces)
Seattle, WA	2019	Ordinance	1 EV-Ready Space per dwelling Unit	100% EV-Ready up to 6 space, 20% for parking lots with 7+ spaces	10% EV-Ready
Sedona, AZ	2019	Appendix	1 EV-Capable Space per dwelling Unit	-	5% EV-Capable
Golden, CO	2019	Ordinance	-	1 EV-Installed Space per 15 parking space, 15% EV-Capable	
San Jose, CA	2019	Ordinance	1 EV-Ready Space per dwelling Unit	10% EV-Installed, 20% EV-Ready, 70% EV-Capable	10% EV-Installed, 40% EV-Capable
Fort Collins, CO	2019	IBC / IRC	1 EV-Capable Space per dwelling Unit	10% EV-Capable	-
Vancouver, BC	2019	IBC / IRC	1 EV-Ready Space per dwelling Unit	100% EV-Ready	10% EV-Ready
Oakland, CA	2018	IBC / IRC	-	10% EV-Ready, 90% "Raceway Installed", 20% total panel capacity	10% EV-Ready, 10% "Raceway Installed", 20% total panel capacity
Atlanta, GA	2017	Code of Ordinances	1 EV-Capable Space per dwelling Unit	20% EV-Capable	
Aspen, CO	2017	IBC / IRC	1 EV-Capable Space per dwelling Unit	3% EV-Capable (240V individual circuit branch with EV CAPABLE labelling)	-
San Francisco, CA	2017	IBC / IRC	1 EV-Ready Space per dwelling Unit	10% EV-Ready, Panel Capacity for 20%, Raceway for 100%	
Palo Alto, CA	2017	IBC / IRC	1 EV-Capable Space per dwelling Unit	1 EV-Ready Space per Unit, 20% EV-Capable for Guest Parking with 5% EV-Installed	20% EV-Capable, 5% EV-Installed
Oregon	2017	IBC / IRC	-	5% EV-Ready	
Boulder County, CO	2015	IBC / IRC	1 EV-Ready Space per dwelling Unit	2% EV-Ready (for new construction and 50% or 5,000 SF additions)	
Washington	2015	State Building Code	-	For Group B, Group R-1 hotel and motel only, Group R-2 occupancies: 5% of parking spaces shall be EV Capable. Size electrical room to serve 20% of spaces.	
New York City, NY	2013	IBC / IRC	-	20% EV-Capable	-
California (CALGreen)	2010	IBC / IRC	1 EV-Capable Space per dwelling Unit	10% EV-Capable	

Source – Southwest Energy Efficiency Project 2020

2.0 Economic Analysis

The costs associated with installing EV charging infrastructure during new construction are substantially lower than during a retrofit. A cost-effectiveness study for the City and County of San Francisco conducted by Pacific Gas & Electric (PG&E) showed costs for installing Level 2 EV charging stations as a retrofit are several times more expensive than installing them during new construction.[26] Installing infrastructure during new construction avoids the retrofit costs of breaking and repairing walls, installing longer raceways, and using more expensive methods of upgrading service panels. A study conducted by DOE determined the installed costs of a single port ESVE unit ranges from $0-$3,000 for Level 1, $600-$12,700 for Level 2 and $4,000-$51,000 for DC fast charging. Various elements lead to the high variability of costs due to the type of unit, applications and cost factors to determine if a ESVE unit will be on the low or high end of the range.[27]

Table 2 compares the cost of installing Level 2 EV charging infrastructure during new construction and during a retrofit. Figure 7 shows the cost breakdown of the Level 2 EV charging infrastructure installation.

Table 2. Cost of EV Charging Infrastructure

	Per EV Parking Space with Electric Circuit		**Total Incremental Cost of Building**	
	New	Retrofit	New	Retrofit
Scenario A – 10 Parking Space Building, two EV Parking Spaces	$920	$3,710	$1,840	$7,420
Scenario B – 60 Parking Space Building, 12 EV Parking Spaces	$860	$2,370	$10,320	$28,440

Source: PG&E 2016

For multifamily residential (three or more units), the San Francisco analysis compares the cost of installing the necessary electrical infrastructure to support Level 2 EV-ready spaces (complete circuit) at the time of new construction versus a building retrofit. In one example, the cost estimate to retrofit an existing building with two EV-ready spaces is $3,710, while new construction cost for the same EV-ready spaces is $920. Thus $2,790 (75%) of the retrofit cost would be avoided if EV-ready infrastructure was included during the initial construction of the parking lot. These additional retrofit costs typically include labor expenses for demolition, trenching and boring, balancing the circuits, and new permitting costs.

A similar cost analysis conducted by the California Air Resources Board (CARB) demonstrated significant avoided retrofit costs for installing EV charging stations during new construction. CARB staff reviewed multiple sources to obtain the average retrofit costs of installing EV charging infrastructure to support Level 2 charging stations in existing buildings. An estimated $7,000 per parking space can be avoided with multiple installations of Level 2 charging stations. An estimated $8,000 per parking space can be avoided when an individual Level 2 charging

[26] http://evchargingpros.com/wp-content/uploads/2017/04/City-of-SF-EV-Infrastructure-Cost-Effectiveness-Report-2016.pdf
[27] https://afdc.energy.gov/files/u/publication/evse_cost_report_2015.pdf

station is installed. These retrofit costs do not include the cost of the EVSE. Retrofit costs are focused on parking lot trenching, adding electrical service, and/or panel upgrades. CARB staff estimates avoided retrofit costs for installing Level 2 EV charging stations during new construction range from $272 million to $386 million between 2020 and 2025.[28]

Source – EV Infrastructure Cost-Effectiveness Report for San Francisco, November 17, 2016

Figure 7. Cost Breakdown of EV Charging for New Construction and Retrofit

For one- and two-family dwellings, costs for Level 2 charging stations include the price and labor associated with the installation of one 40-ampere, 208/240-volt dedicated branch circuit and a circuit terminating in a receptacle, junction box, or EVSE. The average cost to install (exclusive of charger cost) a Level 2 EVSE in an existing home was $1,354 across 13 cities in the U.S. based on more than 25,000 installations. The average maximum installation cost across these 13 locations was approximately $4,000. The key factors affecting the cost of installing EVSE in an existing home included insufficient electrical panel capacity for a dedicated 40-ampere charging circuit, location of the electric panel relative to the garage, and permit costs, which averaged 8.6% of the installed cost. The capacity limitation was found to be more prevalent in less-affluent areas.[29] The proposed code would reduce the cost impact for a home-owner to make the switch to EV by requiring EVSE infrastructure to be included in new homes.

Table 3. Cost of EV Charging Infrastructure – Single Family

	New[a.]	**Avg. Retrofit**[b.]	**Avg. Max. Retrofit**[b.]
Single Family Home	$860-920	$1,354	$4,000

Notes: (a).Source PG&E 2016, (b) Source Francfort et al. 2015

[28] https://ww2.arb.ca.gov/sites/default/files/2020-08/CARB_Technical_Analysis_EV_Charging_Nonresidential_CALGreen_2019_2020_Intervening_Code.pdf
[29] Francfort et al. 2015

Studies show similar conclusions that Level 2 EV-ready charging infrastructure is significantly less expensive to install during new construction than during a building retrofit. Additional efforts are needed on a national, state and local scale to support the growing EV market and expand EV charging access for single-family, multifamily, workplace, and commercial land uses. EV-ready building codes support this expansion and can save consumers thousands in installation costs.[30] New residential and commercial buildings are constructed to last for decades, so it is critical that EV charging infrastructure be incorporated at the pre-construction stage to ensure that new buildings can accommodate the charging needs of future EV-owners.

[30] https://www.swenergy.org/cracking-the-code-on-ev-ready-building-codes

3.0 Sample Code Language

Appendix A contains model code language for any state or local government to overlay the 2021 IECC or existing codes with EV charging infrastructure requirements for both residential and commercial buildings.

3.1 Definitions

The following definitions shall be added to Section R202 of the 2021 IECC residential energy code and Section C202 of the 2021 IECC commercial energy code.

ELECTRIC VEHICLE (EV). An automotive-type vehicle for on-road use, such as passenger automobiles, buses, trucks, vans, neighborhood electric vehicles, and electric motorcycles, primarily powered by an electric motor that draws current from a building electrical service, EVSE, a rechargeable storage battery, a fuel cell, a photovoltaic array, or another source of electric current.

ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE). The conductors, including the ungrounded, grounded and equipment grounding conductors, and the EV connectors, attachment plugs, and all other fittings, devices, power outlets, or apparatuses installed specifically for the purpose of transferring energy between the premises wiring and the EV.

EV-CAPABLE SPACE. A dedicated parking space which is provided with electrical panel capacity and space to support a minimum 40-ampere, 208/240-volt branch circuit for each EV parking space, and the installation of raceways, both underground and surface mounted, to support the EVSE.

EV-READY SPACE. A designated parking space which is provided with one 40-ampere, 208/240-volt dedicated branch circuit for future dedicated Level 2 *EVSE* servicing EVs. The circuit shall terminate in a suitable termination point such as a receptacle, junction box, or an *EVSE*, and be located in close proximity to the proposed location of the EV parking spaces. The circuit shall have no other outlets. The service panel shall include an over-current protective device and provide sufficient capacity and space to accommodate the circuit and over-current protective device and be located in close proximity to the proposed location of the EV parking spaces.

3.2 Residential Buildings

The following EV charging infrastructure requirements shall be placed in Section R401.4 of the 2021 IECC residential energy code or existing code.

R401.4 (IRC N1101.15) Plug-in electric vehicle charging.

Where parking is provided, new construction shall provide EVSE-installed spaces and facilitate future installation and use of EVSE through the provision of *EV-Ready Spaces* and *EV-Capable Spaces* provided in compliance with Sections R401.4.1 through R401.4.4 (IRC N1101.15.1 through IRC N1101.15.3). Where more than one parking facility is provided on a site, electric vehicle ready parking spaces shall be calculated separately for each parking facility. The service panel or subpanel circuit directory shall identify the spaces reserved to support EV charging as “EV-Capable” or “EV-Ready”. The raceway location for *EV-Capable Spaces* shall be permanently and visibly marked as “EV-Capable”.

Exception: This section does not apply to parking spaces used exclusively for trucks or delivery vehicles.

R401.4.1 (IRC N1101.15.1) Electric vehicle service equipment (EVSE) ready circuit.

Each *EV-Ready Space* shall be provided with a minimum 40-ampere branch circuit to accommodate a future dedicated Level-2 EVSE. The service panel shall provide sufficient capacity and space to accommodate the circuit and over-current protective device. A permanent and visible label stating “EV-READY” shall be posted in a conspicuous place at both the service panel and the circuit termination point.

R401.4.2 (IRC N1101.15.2) One- to two-family dwellings and townhouses. For each dwelling unit, provide at least one *EV-Ready Space*. The branch circuit shall be identified as “EV-Ready” in the service panel or subpanel directory, and the termination location shall be marked as “EV-Ready.”

Exception: *EV-Ready Spaces* are not required where no parking spaces are provided.

R401.4.3 Multifamily dwellings (three or more units). EVSE-Installed, EV-Ready Spaces and EV-Capable Spaces shall be provided in accordance with Table R401.4.3. EV-Ready Spaces that terminate with an installed Level 2 EVSE shall count as spaces under the EV-Ready Space requirements Where the calculation of percent served results in a fractional parking space, it shall round up to the next whole number.

Exception: Where the number of *EV-Ready Spaces* exceeds the required minimum in Table R401.4.3, the additional *EV Ready Spaces* shall be used for compliance with the minimum *EV-Capable Spaces* requirement.

Table R401.4.3 EVSE Installed, EV-Ready and EV-Capable Space Requirements for New Multifamily Buildings

Total Number of Parking Spaces	Minimum Number of Spaces with EVSE Installed[a]	Minimum Number of EV-Ready Spaces	Minimum Number of *EV-Capable Spaces*
1	1	1	-
2 – 10	1	2	-
11 – 15	1	2	1
16 – 19	1	2	2
21 – 25	2	3	2
26+	5% of total parking spaces	10% of total parking spaces	10% of total parking spaces

(a). Spaces that terminate with a Level 2 EVSE are considered *EV-Ready Spaces* and count towards the minimum number of *EV-Ready Spaces*.

R401.4.4 (IRC N1101.15.3) Identification. Construction documents shall indicate the raceway termination point and proposed location of future EV spaces and EV chargers. Construction documents shall also provide information about the amperage of future EVSE, raceway methods, wiring schematics, and electrical load calculations to verify that the electrical panel service capacity and electrical system, including any on-site distribution transformers, have sufficient capacity to simultaneously charge all EVs at all required EV spaces at the full rated amperage of the EVSE.

Notes for jurisdictions adopting residential language:
Recommended minimum EV parking space requirements in Table R401.4.3 may be adjusted based on the needs of each jurisdiction.

There are other important code references to examine in parallel to IECC/IRC Chapter 11 requirements. If not consistent with the latest editions, update:

- Section 625 of the National Electrical Code (NFPA 70)
- Section E3702.13 of the International Residential Code

See Section R328.10 of the International Residential Code and Section 1207.11.10 of the International Fire Code for provisions on the use of electric vehicles as energy storage systems.

3.3 Commercial Buildings

The following EV charging infrastructure requirements shall be placed in Section C401.4 of the 2021 IECC commercial energy code or existing code.

C401.4 Electric Vehicle ready parking. Where parking is provided, new construction shall provide EVSE installed spaces and facilitate future installation and use of *EVSE* through the provision of *EV-Ready Spaces* and *EV-Capable Spaces* provided in compliance with Sections C401.4.1 through C401.4.3, Where more than one parking facility is provided on a site, *EV-Ready Spaces* and *EV-Capable Spaces* shall be calculated separately for each parking facility.

C401.4.1. New commercial and multifamily buildings. *EVSE* Installed spaces, *EV-Ready Spaces* and *EV-Capable Spaces* shall be provided in accordance with Table C401.4.1 for commercial buildings and Table C401.4.2 for multifamily buildings. Where the calculation of percent served results in a fractional parking space, it shall be shall rounded up to the next whole number. The service panel or subpanel circuit directory shall identify the spaces reserved to support EV charging as “EV-Capable” or “EV-Ready.” The raceway location shall be permanently and visibly marked as “EV-Capable.”

Exception: Where the number of *EV-Ready Spaces* exceeds the required minimum, the additional *EV Ready Spaces* shall be used for compliance with the minimum *EV-Capable Spaces* requirement.

C401.4.2 Identification. Construction documents shall indicate the raceway termination point and proposed location of future EV spaces and EV chargers. Construction documents shall also provide information about the amperage of future EVSE, raceway methods, wiring schematics, and electrical load calculations to verify that the electrical panel service capacity and electrical system, including any on-site distribution transformers, have sufficient capacity to simultaneously charge all EVs at all required EV spaces at the full rated amperage of the EVSE.

Table C401.4.1 EVSE Installed, EV-Ready Space and EV-Capable Space Requirements for New Commercial Buildings

Total Number of Parking Spaces	Minimum number of Spaces with EVSE Installed[a.]	Minimum Number of EV-Ready Spaces	Minimum Number of EV-Capable Spaces
1	1	1	-
2 – 10	1	2	-
11 – 15	1	2	1
16 – 19	1	2	2
21 – 25	2	3	2
26+	5% of total parking spaces	10% of total parking spaces	10% of total parking spaces

(a). Spaces that terminate with a Level 2 EVSE are considered *EV-Ready Spaces* and count towards the minimum number of *EV-Ready Spaces*.

Table C401.4.2 EVSE Installed, EV-Ready Space and EV-Capable Space Requirements for New Multifamily Buildings

Total Number of Parking Spaces	Minimum number of Spaces with EVSE Installed[a.]	Minimum Number of EV-Ready Spaces	Minimum Number of EV-Capable Spaces
1	1	1	-
2 – 10	1	2	-
11 – 15	1	2	1
16 – 19	1	2	2
21 – 25	2	3	2
26+	5% of total parking spaces	10% of total parking spaces	10% of total parking spaces

(a). Spaces that terminate with a Level 2 EVSE are considered *EV-Ready Spaces* and count towards the minimum number of *EV-Ready Spaces*.

Notes for jurisdictions adopting commercial language:
Recommended minimum EV parking space requirements in Table C401.4.1 and Table C401.4.2 may be adjusted based on the needs of each jurisdiction.

There are other important code references to examine in parallel to IECC/IBC Chapter 11 requirements. If not consistent with the latest editions, update:

- *Section 625 of the National Electrical Code (NFPA 70)*
- *Section 406.2.7 of the IBC*

Jurisdictions adopting EV provisions that have not adopted the 2021 IBC must also amend earlier versions of the International Building Code to renumber Section 1109.14 Fuel-dispencing Systems and add the following language into Chapter 11:

SECTION 1107
MOTOR-VEHICLE-RELATED FACILITIES

1107.1 General. Electrical vehicle charging stations shall comply with Section 1107.2. Fuel-dispensing systems shall comply with Section 1107.3.

1107.2 Electrical vehicle charging stations. Electrical vehicle charging stations shall comply with Sections 1107.2.1 and 1107.2.2.

> **Exception:** Electrical vehicle charging stations provided to serve Group R-2, R-3 and R-4 occupancies are not required to comply with this section.
>
> **1107.2.1 Number of accessible vehicle spaces.** Not less than 5 percent of vehicle spaces on the site served by electrical vehicle charging systems, but not fewer than one for each type of electric vehicle charging system, shall be accessible.
>
> **1107.2.2 Vehicle space size.** Accessible vehicle spaces shall comply with the requirements for a van accessible parking space that is 132 inches (3350 mm) minimum in width with an adjoining access aisle that is 60 inches (1525 mm) minimum in width.

There are other important code references to examine in parallel to IECC/IRC Chapter 11 requirements. If not consistent with the latest editions update:

- Section 625 of the National Electrical Code (NFPA 70)
- Section 406.2.7 of the IBC

1107.3 Fuel-dispensing systems.

Fuel-dispensing systems shall be *accessible*.

4.0 References

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