Light-Duty Electric Vehicle Charging Infrastructure Analysis for California's CALGreen Building Code

PREPARED FOR:

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Acronyms

A	Amperes (Amps)
AC	Alternating Current
ALMS	Automatic Load Management Systems
BSC	California Building Standards Commission
BEV	Battery Electric Vehicle
CalETC	California Electric Transportation Coalition
CALGreen	California Green Building Code Title 24, Part 11
CARB	California Air Resources Board
CBIA	California Building Industry Association
CEC	California Energy Commission
CPUC	California Public Utilities Commission
DC	Direct Current
DC FC	Direct Current Fast Charger EVSE (typically 50kW and higher)
DOE	U.S. Department of Energy
DR	Demand Response
DSA	The Division of the State Architect
eMPG	Equivalent Miles Per Gallon
EV	Electric Vehicle
EVCI	Electric Vehicle Charging Infrastructure
EVSE	Electric Vehicle Supply Equipment (EV Charger)
HCD	California Department of Housing and Community Development
ICC	International Code Council
IEBC	International Existing Building Code
IECC	International Energy Conservation Code
kVA	kilo Volt-Ampere (Apparent Power)
kW	kilo Watt (Real Power)
kWh	kilo Watt Hours (Energy)
L1	Alternating Current Level 1 EVSE (typically 1.4-1.8 kW)
L2	Alternating Current Level 2 EVSE (typically 7kW to 20kW)
NBI	New Buildings Institute
NEC	National Electric Code
NEMA	National Electrical Manufacturers Association
OSHPD	The Office of Statewide Health Planning and Development
PHEV	Plug-in Hybrid Electric Vehicle
TE	Transportation Electrification
UL	Underwriters Laboratories
V	Voltage (Volts)
VGI	Vehicle-Grid Integration
ZEV	Zero-Emission Vehicle

1. Executive Summary

California has a target to achieve 1.5 million zero-emission vehicles (ZEVs) by 2025 and 5 million ZEVs by 2030, supported by the installation of 250,000 chargers and 10,000 DC fast chargers (DC FC) by 2025 (Brown 2018). The California Energy Commission (CEC) AB 2127 staff report estimates that California will need nearly 1.2 million public and shared private chargers by 2030 in order to meet its goal of 100 percent light-duty vehicle sales by 2035 (CEC 2021b). The building code plays an important role in ensuring electric vehicle charging infrastructure (EVCI) for new construction and major renovations continues to grow and expand in a way that supports transportation electrification equitably and does not leave residents behind. Additionally, building codes present an opportunity to limit infrastructure burden on the grid by taking advantage of power management technology as well as aligning charging with peak renewable energy generation.

1.1 Background

California first established voluntary electric vehicle charging infrastructure building codes for residential buildings in the 2013 California Green Building Code Title 24, Part 11 ("CALGreen"). The 2015 supplement code established mandatory residential requirements. Under a mandate from Assembly Bill 1092 (Chapter 410, Statutes of 2013), authored by Assembly Member Levine, the California Building Standards Commission (BSC) was directed to develop mandatory standards for nonresidential buildings for the 2016 CALGreen code. Subsequent updates have occurred for residential and nonresidential buildings in the 2018 supplement (hotels & motels), 2019 code (new schools & multifamily revisions), and 2019 supplement (commercial revisions). Thus far, all the EV charging infrastructure building codes have focused on infrastructure to support light-duty EV charging.

California Health and Safety Code Section 18930.5(b) as amended by Assembly Bill 341 allows BSC and other state agencies that propose building standards to allow for input by state agencies that have expertise in green building subject areas. The California Air Resources Board (CARB) has expertise in air quality, climate change, and EV charging infrastructure, and has been working with the adopting agencies BSC and the Department of Housing and Community Development (HCD) on expanding requirements for light-duty vehicles in multifamily and nonresidential buildings. In addition, CARB staff has initiated a separate proposal that addresses medium- and heavy-duty vehicle charging infrastructure.[1]

1.2 Approach

To support the development of 2022 CALGreen light-duty EV proposals, the California Investor-Owned Utilities provided research and supporting analysis via 2050 Partners and EV technical expertise and reach code design experience via New Buildings Institute (NBI). The research team performed a comparison of 37 local jurisdiction EV reach codes throughout California based on interviews with key city staff members and stakeholders as well as review of

[1] The focus of this report is on light-duty vehicles. A separate report sponsored by the California Statewide Codes and Standards utility program focuses on medium- and heavy-duty vehicles.

available stakeholder engagement materials from the ordinance adoption process. Additionally, a comprehensive technical comparison of available EV cost studies and reports was conducted in order to provide nuanced pricing data.

1.3 Results and Recommendations

Access to charging remains a critical barrier to widespread EV adoption, especially for residents in rental housing, particularly in multifamily buildings, where installation of an EV charger requires the building owner's approval and often, their financial investment to upgrade and install equipment.

This also creates an important equity concern for low-income housing since a major advantage of EV ownership is the reduction in operating and maintenance expenses compared to internal combustion vehicles. Vehicle assistance programs have been established to help address up-front costs of acquiring an EV, however access to charging remains a significant barrier to transportation affordability for many low-income Californians.

As statewide EV adoption rates continue to grow, potential for significant grid impacts arise. In order to collectively move towards a decarbonized future, EV charging infrastructure must continue to grow in an equitable way which does not leave disadvantaged residents behind, while also thoughtfully limiting strain on the grid.

In order to accomplish these goals, we recommend targeting several strategic areas for further development of EV requirements for both nonresidential and multifamily buildings in future code updates. Recommendations include:[2]

- Promote load shaping in order to align charging power demand with renewable energy generation,
- Futureproof buildings to reduce the cost and impact of charging infrastructure expansion,
- Avoid potential restrictions on technology advancement,
- Revise technical power requirements for clarity and consistency,
- Incorporate automatic load management systems (ALMS) and apply minimum ALMS performance requirements,
- Accommodate variations in typical building parking duration (dwell-times), and
- Fill data gaps in support of future code enhancement.

This report also summarizes the findings from a comparison of EV reach codes throughout California, results of an EV cost study comparison, and a summary of existing building EV charging requirements found in local ordinances and selected international codes.

[2] See Section 6 for detailed recommendations.

2. Introduction

2.1 Electric Vehicle Infrastructure and Charging Definitions

While technical details for the same terminology often vary between national, state, and local codes, EV charging infrastructure requirements are generally described in three terms of completeness:

- **EV Capable**: the first step in preparing a building for future accommodation of EV charging infrastructure, "EV Capable" typically includes preinstalling conduit and often includes reservation of electrical capacity and dedicated circuits at the panel level. This requirement is sometimes referred to as "make-ready."
- **EV Ready**: EV Capable plus installation of dedicated circuits, breakers, wiring, and other electrical components. Termination requirements vary but typically include a receptacle, blank cover, or junction box. This requirement is sometimes referred to as an "energized circuit."
- **Electric Vehicle Supply Equipment (EVSE)**: EV Ready terminating in an installed EV charger. This requirement is sometimes referred to as "EV Installed."

These variations in EV charging infrastructure (EVCI) are illustrated and summarized in Figure 1 below. We expand our discussion of these definitions in Section 4.

Figure 1. Levels of EV Charging Infrastructure "Completeness"[3]

As summarized in Table 2 below, light-duty EVs typically use three levels of charging: Level 1, Level 2, and Direct Current Fast Charger (DC FC). Levels 1 and 2 provide single-phase alternating current (AC) electricity to the vehicle, while DC FC uses high-voltage direct current. Level 1 charging typically delivers either 1.44 kW at 12-amperes ("amps", or A) or 1.92 kW at 16A. While Level 2 charging can provide up to 19.2 kW, the most common configuration is to provide 32A for a total delivered power of 6.7 kW at 208-volts (V) or 7.7 kW at 240V. We expand our discussion of these definitions in Section 4.

[3] City of Sacramento 2020.

Table 1. EV Charging Levels for Light-duty EVs[4]

	Level 1	Level 2	DC Fast Charger
Voltage	120 Volts AC	208-240 Volts AC	50-1000 Volts DC
Maximum power output in kilowatts (kW)	1.9 kW	19.2 kW	450 kW
Typical added range per hour of charging*	~4 miles at 1.44 kW	~23 miles at 7.2 kW	~90 miles in 30 mins at 55 kW ~204 miles in 30 mins at 150 kW

*** Range estimates based on a 110 MPGe vehicle**

2.2 Regulatory Landscape for Light-duty Electric Vehicles

On January 26, 2018, former California Governor Brown signed Executive Order B-48-18, introducing a new target for 5 million ZEVs by 2030, along with 250,000 charging stations by 2025. On September 23, 2020, Governor Newsom signed Executive Order N-79-20 requiring all new car and passenger truck sales to be ZEVs by 2035 (Newsom 2020). In order to align with California's transportation electrification goals, BSC and HCD continue to take the lead on developing CALGreen EV requirement updates with support from state agencies with staff expertise such as CARB.

2.2.1 CALGreen

The California Building Standards Commission (BSC) works with the Department of Housing and Community Development (HCD), the Division of the State Architect (DSA), the California Energy Commission (CEC), and the Office of Statewide Health Planning and Development (OSHPD) to establish the California Building Standards Code (Title 24). California was the first state in the nation to adopt state-mandated green building standards with Part 11 of Title 24, "California Green Building Standards Code" (CALGreen). The purpose of CALGreen is "to improve public health, safety, and general welfare through enhanced design and construction of buildings using concepts which reduce negative impacts and promote those principles which have a positive environmental impact and encourage sustainable construction practices" (HCD n.d.). The code applies to every newly constructed commercial and residential building or structure, including additions and alterations to existing buildings which increase the building's conditioned area or size (with some exceptions). The code includes multiple requirements that encourage sustainable practices, such as those related to solar photovoltaic systems, energy and water conservation, and recycling. CALGreen includes requirements for EV charging, such as

[4] California Energy Commission (CEC) 2021.

the number of parking spaces that are required to have EV charging infrastructure when a new building is constructed.

Since 2013, the State of California has mandated EV charging measures through CALGreen, which individual jurisdictions may amend to be more stringent through the adoption of local ordinances or "reach codes." In addition to mandatory requirements, CALGreen provides voluntary recommendations for adopting above-code provisions. In the current standards, these are qualified as "Tier 1" and "Tier 2." Local governments are responsible for ensuring that building department personnel are properly trained to carry out the enforcement of CALGreen (except where state agencies have specific authority, such as with school or hospital construction). CALGreen EV language and requirements are divided between three chapters: Chapter 2 includes definitions which apply universally throughout the code; Chapter 4 describes residential building requirements; and Chapter 5 describes nonresidential building requirements. While BSC oversees the final adoption process for all sections of CALGreen, HCD manages stakeholder engagement, proposals, and draft submittals for all Chapter 4 (residential) updates, while BSC manages all equivalent Chapter 5 (nonresidential) activities.

While the 2019 CALGreen requirements can apply to both new construction and alterations/additions, the specific EV-related requirements currently only apply to new construction projects.

2.2.1.1 Triennial Code Adoption Cycle

BSC oversees a triennial code adoption cycle to update CALGreen. The 2021 Triennial Code Adoption Cycle will develop updates to the "2019 CALGreen" code for inclusion in "2022 CALGreen," which becomes effective January 1, 2023. California Health and Safety Code Section 18930.5(b) allows BSC and other state agencies that propose building standards to allow for input by state agencies that have expertise in green building subject areas. Given's CARB's expertise in air quality, climate change, and support for the statewide expansion of EV charging infrastructure, it is a key state agency providing subject matter expertise for EV charging infrastructure code development. Figure 2 provides a timeline for the current code cycle. In general, the code cycle begins with stakeholder workshops to discuss initial proposals, which are ultimately posted as "Initial Express Terms." The Code Advisory Committees then meet to discuss the proposals and make recommendations to BSC. After that, regulatory notice is given and there is a 45-day public review period. For CALGreen, the 45-day public review period is expected to be August 13, 2021 through September 27, 2021. The adoption hearing is expected to occur in December 2021 or January 2022, and the effective date will be January 1, 2023.

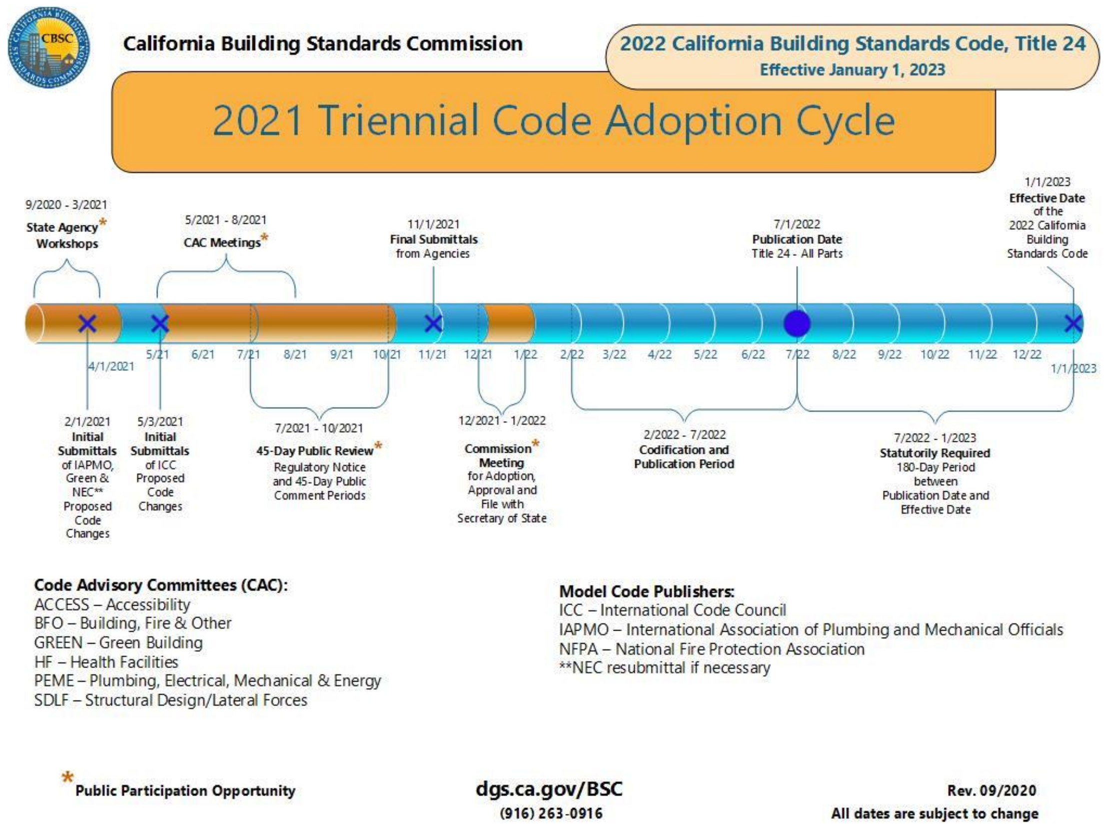


Figure 2. CA BSC 2021 Triennial Code Adoption Cycle[5]

2.2.2 Local CA Reach Codes

Local governments play an important role in reducing vehicle-source carbon emissions as they have authority over building and zoning codes, permitting and inspection processes, parking, and signage. Many local jurisdictions aim to adopt EV charging infrastructure ordinances that assure ample charging opportunities for EVs and plug-in hybrid vehicles (PHEVs) at public and private parking areas across their jurisdictions.

We conducted an evaluation of 37 adopted reach codes for local jurisdictions throughout California which included an EV component. This evaluation included interviews with key city staff members and reviews of approved local ordinances and available supporting documents. Based on our evaluation, nearly all jurisdictions used the CALGreen requirements as a starting point. While some directly adopted the CALGreen requirements, others made changes – sometimes substantial – to the underlying CALGreen language. CALGreen requirements were originally written and structured for low percentages of EVCI, and some jurisdictions found a need to make structural code changes to accommodate issues that emerge when considering higher percentages of EV charging spaces. These changes fell into one of two categories:

[5] CA BSC 2021.

1) changes to stringency, and
2) changes to the underlying approach to EVCI requirements.

Twenty-eight jurisdictions made substantial increases in EVCI stringency above CALGreen with requirements of up to 20% EVSE spaces, 100% EV Ready spaces, and 70% EV Capable spaces. Seventeen jurisdictions made major changes to the approach to EVCI in CALGreen, generally driven by a desire for higher percentages of EVCI parking spaces.

Examples of technical limitations which motivated some reach codes to deviate from CALGreen include the following:

- "EV Capable" spaces in CALGreen are required to reserve 40A of capacity at 208/240V per required space. When jurisdictions require high percentages of EV Capable spaces, this can equate to substantial additional electrical capacity for the building site. Therefore, some jurisdictions reduced (or eliminated) the capacity requirements to retain the significant future-proof advantages of the conduit without the substantial cost of the reserved electrical capacity. Nine of the fifteen jurisdictions that created a definition of "EV Capable" used a definition that varied from CALGreen requirements through the reduction or elimination of capacity requirements. There was a common concern over customer-side costs (service size, panels, onsite transformers, etc., as well as monthly connection fees for a larger service size) and utility-side electric infrastructure cost for a large number of full-capacity EV Capable spaces. For example, one city required 40-70% EV Capable spaces depending on building type. One building official felt that this could result in multifamily projects that required a larger electrical service for the parking lot than the building itself if capacity were maintained at 40A per EV Capable space. Combined with the belief that the future of EV charging would include load management, this particular city decided to only require 8A at 208/240V of capacity for each EV Capable space.
- CALGreen does not include automatic load management systems (ALMS) since it does not require the installation of chargers in the mandatory sections or voluntary tiers. However, some jurisdictions have required substantial percentages of parking spaces to have chargers and allowed the use of ALMS in order to reduce total required electrical capacity and project cost.
- While CALGreen requires minimum circuit capacity for EV spaces, it does not include a minimum delivered power requirement for EVSEs. This means that low-cost chargers delivering substantially lower power (e.g., 16A) than the capacity requirements for EV Capable and EV Ready spaces in CALGreen could be installed while still complying with code.
- The requirements in CALGreen appear to have originated as requirements for dedicated EV spaces and include requirements for parking space dimensions. However, these dimensions could conflict with the dimension requirements for non-dedicated spaces. As some jurisdictions shifted from requiring a specific number of dedicated spaces to requiring percentages of total parking spaces, they found a need to remove the dimension requirements to eliminate potential conflict between the EV requirements and their specific parking requirements.

As a result of local jurisdictions significantly altering their EV code language, there is diversity in technical requirements and even in the meaning of similar terms. The definitions of terms such as EVSE, EV Capable, and EV Ready are jurisdiction specific, and often vary between jurisdictions. There are meaningful differences in technicalities and specifications. For example, definitions of an "EV Ready Space" differ between jurisdictions including the following variations:

- The installation of a full circuit with minimum of 40A 208/240V capacity per EV space, including listed raceway, sufficient electrical panel service capacity, overcurrent protection devices, wire, and suitable listed termination point such as a receptacle. The termination point shall be in close proximity to the proposed EV charger location.
- At minimum: (1) a panel capable of accommodating a dedicated branch circuit and service capacity to install a 208/240V, 50A grounded AC outlet; (2) a two-pole circuit breaker; (3) raceway with capacity to accommodate a 100A circuit; (4) 50A wiring; terminating in (5) a 50A National Electrical Manufacturers Association (NEMA) receptacle in a covered outlet box.
- Level 1 EV Ready Space: A parking space served by a complete electric circuit with a minimum of 110/120 volt, 20A capacity including electrical panel capacity, overprotection device, a minimum 1" diameter raceway that may include multiple circuits as allowed by the California Electrical Code, wiring, and either 1) a receptacle labelled "Electric Vehicle Outlet" with at least a ½ inch font adjacent to the parking space, or 2) electric vehicle supply equipment (EVSE).
- Level 2 EV Ready Space: A parking space served by a complete electric circuit with 208/240 volt, 40A capacity including electrical panel capacity, overprotection device, a minimum 1" diameter raceway that may include multiple circuits as allowed by the California Electrical Code, wiring, and either 1) a receptacle labelled "Electric Vehicle Outlet" with at least a 1/2" font adjacent to the parking space, or 2) electric vehicle supply equipment (EVSE) with a minimum output of 30A.

Additionally, some jurisdictions utilized explicitly defined terms while others integrated the definitions into the code language itself. These definitions generally included technical requirements; however, code definitions are meant to be descriptive rather than prescriptive and are not intended to include requirements. The inclusion of requirements in definitions is one of the main drivers of the differences between local reach codes and may be a major contributor to the lack of standardization. One designer that was interviewed specifically stated that definitions are confusing and that all codes across the state need to have standardized language for terms such as EV Ready and EV Capable. They suggested that CALGreen should dictate these terms and then all jurisdictions should utilize the same standardized language.

A summary of the comprehensive analysis of 37 reach codes is included in Appendix A of this report.

2.2.3 National Model Codes

EVCI requirements were proposed for the 2021 edition of the International Energy Conservation Code (IECC) and passed based on the final vote. As passed by vote, the requirement includes "EV Ready" spaces (40A circuit at 208/240V) for single family homes, and one or two "EV Ready" spaces with up to 20% "EV Capable" spaces (conduit and 40A at 208/240V of panel capacity) in multifamily and commercial occupancies. However, these proposals were appealed and the International Code Council board (ICC, the body that maintains the IECC and the other model "I-Codes") ruled that EVCI was outside of the allowable scope of the IECC (ICC n.d.). A similar proposal has been submitted for the 2024 edition of the International Building Code (IBC) by the Southwest Energy Efficiency Partnership, the proponent of the 2021 IECC proposal. Through the public comment process for revising proposals, this proposal has been updated to move requirements out of the definitions and into the requirements section of the code.

2.3 EVCI Requirements for Existing Buildings

While 2019 CALGreen does not include any EV requirements for additions or alterations of existing buildings, several local jurisdictions have adopted them into their reach codes in order to help accelerate pace of EVCI growth. A summary of reach code EV requirements for existing buildings at the time of writing this report follows, with additional details and links to each ordinance in Appendix A[6]:

2.3.1 Single Family

- **Carlsbad:** EVCI requirements also apply to alterations and additions to existing residential structures and construction sites where either:
    - There is a building permit valuation equal to or greater than $60,000, or
    - There is an electrical service panel upgrade.

2.3.2 Multifamily

- **Carlsbad:** EVCI requirements also apply to building alterations having permit valuation equal to or greater than $200,000 and one of the following:
    - Interior finishes are removed,
    - Site alterations that require a grading permit,
    - Installation of 2,500 square feet (ft^2) or more of landscaping, or
    - Repave, replace, or add 2,500 ft^2 or more of vehicle parking and drive area.
- **San Francisco:** Includes requirements for "major alterations" in addition to new construction. Major alterations are defined as "alterations and additions where interior finishes are removed and significant upgrades to structural and mechanical, electrical, and/or plumbing systems are proposed where areas of such construction are 25,000 gross square feet or more in Group B, M, or R occupancies of existing buildings" (City and County of SF 2017).
    - Major alterations that include an electrical service upgrade must comply with all of the EVCI requirements for new construction.
    - Major alterations that do not include an electrical service upgrade must comply with the requirements to the greatest extent possible without upgrading the electrical service.

[6] For regularly updated information on adopted ordinances see the Statewide Reach Codes Program at https://localenergycodes.com/.

- **Fremont**: Building additions where additional parking spaces are provided must include "EV Ready" parking spaces equipped with the electrical raceway, wiring, and electrical circuit. Multifamily residential projects of three units or more must provide "EV Readiness" for approximately 10% of the total number of new parking spaces. This is equivalent to the Tier 2 CALGreen 2019 option for nonresidential developments.
- **Menlo Park:** Additions and alterations of 10,000 to 25,000 ft^2 must have 5% "EV Ready" and at least one EVSE. Additions and alterations over 25,000 ft^2 must have 10% "EV Ready", at least one EVSE, and the remainder of spaces must be "EV Capable."

2.3.3 Nonresidential

- **Encinitas**: 8% EVSE required for alterations (including hotel/motel) larger than 10,000 ft^2 that require a building permit.
- **San Francisco**: Includes requirements for "major alterations" in addition to new construction. Major alterations are defined as: "Alterations and additions where interior finishes are removed and significant upgrades to structural and mechanical, electrical, and/or plumbing systems are proposed where areas of such construction are 25,000 gross square feet or more in Group B, M, or R occupancies of existing buildings" (City and County of SF 2017).
    - Major alterations that include an electrical service upgrade must comply with all of the EVCI requirements for new construction.
    - Major alterations that do not include an electrical service upgrade must comply with the requirements to the greatest extent possible without upgrading the electrical service. Group B & M occupancies are basically office and retail occupancies.
- **Fremont**: Building additions where additional parking spaces are provided must include "EV Ready" parking spaces equipped with the electrical raceway, wiring, and electrical circuit. All nonresidential projects must provide "EV Readiness" for approximately 10% of the total number of new parking spaces. This is equivalent to the Tier 2 CALGreen 2019 option for nonresidential developments.

2.3.4 Beyond California

Existing building EVCI requirements are beginning to appear in other cities and countries. The following are examples of existing building code requirements outside of California:

- **City of Atlanta, GA:** Per the adoption of Ordinance 17-0-1654 in November 2017, Atlanta requires all new and expanded parking for existing buildings to include EVSE infrastructure at an EV to non-EV ratio of 1:5. Atlanta defines "EVSE infrastructure" to include:
    - Continuous raceway from the branch circuit/feeder panel to the future EV parking space, including pull rope or line, and clear labeling for future use.
    - Dedicated space marked in the electrical equipment room for future EVSE panels.
    - Placement of future EV spaces to comply with ADA requirements of 42 U.S.C. §12101.

- **European Union:** The European Commission's 2016 revision of the Energy Performance of Building Directive includes EV requirements for nonresidential buildings as follows:
  - For major renovations with more than 10 parking spaces, at least one of every ten parking spaces be equipped with a charging point.
  - Charging points must include capability to dynamically modulate charging process in reaction to price or load signals.
  - The above requirements shall apply to all existing nonresidential buildings with more than 10 parking spaces (with no construction related trigger) as of January 1, 2015, unless Member States show this is not feasible.
  - For major renovations with more than 10 parking spaces, every non-EV space should be equipped with conduits for later installation of EVSE. Conduits should be sized to accommodate any standard normal power, from 3.7 to 22 kW.

3. Future CALGreen EV Requirements for Existing Buildings

3.1 Authority to Adopt Existing Building Requirements

During a 2022 CALGreen code cycle public focus group meeting on February 10, 2021, HCD staff, which oversees the residential portion of CALGreen (Chapter 4), expressed a statutory limitation prohibiting them from including existing building requirements within the code. California Health and Safety Code requires residential buildings be maintained to the code they were constructed under, absent the event of additions or major renovations that trigger code updates for all or a portion of the building. This currently prohibits EV requirements for existing multifamily buildings from being incorporated into CALGreen. Nonresidential buildings do not share this same restriction and are therefore the primary focus for the recommendations in this report.

As of February 17, 2021, California legislation was introduced in the form of AB 965 by Assembly Member Levine proposing to amend Section 18941.10 of the Health and Safety Code relating to building standards, specifically to enforce EV requirements for existing buildings. As proposed, this would grant authority and impose mandates for both HCD and BSC to research, develop, and propose CALGreen mandatory EV requirements for existing multifamily and nonresidential buildings. Language also states that these organizations shall actively consult with interested parties, including, but not limited to, investor-owned utilities, municipal utilities, community choice aggregators, electric vehicle and electric vehicle supply equipment manufacturers, local building officials, commercial building and apartment owners, and the building industry.

3.2 Stakeholder Support for Existing Building EV Requirements

During multifamily 2022 CALGreen focus groups on December 17, 2020 and February 10, 2021, and a nonresidential 2022 CALGreen working group meeting on December 9, 2020, several stakeholders commented in favor of including existing building EV requirements. Justification for inclusion was centered around a need to expand EV infrastructure to the existing building stock to meet California EV adoption targets, especially given the expected lifetime of buildings.

Stakeholder comments related to existing building EV requirements made during these meetings are summarized as follows:

1. California Electric Transportation Coalition (CalETC)
    a. Commented publicly in favor of existing building EV requirements at both multifamily (HCD) and nonresidential (BSC) working groups.
    b. Proposed trigger points include major renovation, additions, parking lot repaving, electrical upgrades, and addition of new parking spaces.
2. Tesla
    a. Commented publicly in favor of existing building EV requirements at both multifamily (HCD) and nonresidential (BSC) working groups.
    b. Proposed trigger points include new electrical paneling, parking lot repaving, and major renovations.
3. Sven Thesen & Associates
    a. Commented publicly that new construction requirements are an incremental step towards mitigating the effects of climate change through transportation electrification, while existing buildings represent the next big step which are not yet being pursued.

3.3 Potential EVCI Trigger Points

Implementing building renovation/alteration construction activities which require mandatory code upgrades (referred to as "trigger points") is one of the most established ways of applying code requirements to existing buildings. The primary trigger points considered for existing building EV charging requirements are as follows, with recommendations for each:

- New parking for existing buildings
    - New parking lots added to existing buildings should be treated as new construction and therefore comply with the requirements of CALGreen Section 5.106.5.3.
- Parking lot expansions
    - When existing parking lots are expanded to include additional parking spaces, we recommend applying minimum requirements for new construction to the total number of final parking spaces (existing plus additional). Per current CALGreen 2019 requirements, 10% of nonresidential new construction parking spaces must be EV capable; therefore, under these conditions 10% of the combined existing and additional spaces would be required to be EV Capable. This approach preserves developer flexibility to locate EVCI anywhere in the parking lot rather than mandating the newly added parking spaces be EV spaces.
- Resurfacing of existing parking
    - When parking surfaces are repaved or resurfaced, this is ideal time to lay conduit for future EVSE infrastructure. Trenching, demolition, disposal of materials, and repaving are some of the most expensive components of EV retrofit projects and require specialized repaving equipment be brought onsite (Energy Solutions 2016). When these costs are fully born by EV retrofit projects, the cost per

    - charger can reach five times the cost of an EVSE installed during an alteration project which already includes repaving. For the purposes of CALGreen requirements, we recommend resurfacing be defined as projects where "paving material and curbing are removed and replaced."
- Building alterations where electric service is upgraded
    - Projects involving replacement of electrical service panels or transformers present an opportunity to plan for future EV infrastructure needs. This can help avoid potentially significant electrical capacity upgrades required when EVCI projects are pursued. When existing building alterations involve replacing panels and/or transformers, we recommend additional capacity be provided and reserved for future EV charging in alignment with code requirements for new construction.
- Building alterations over a certain threshold, such as:
    - Percent of building area altered – for example, the Work Area Compliance Method from the 2018 International Existing Building Code (IEBC) is separated into the following three alteration levels, each with distinct requirements (ICC 2017):
        - Level 1: replacement of building components with new
        - Level 2: less than 50% of building area is altered
        - Level 3: over 50% of building area is altered
    - Percent of alteration value – based on the substantial improvement approach in the CA-IEBC flood hazard mitigation requirements
    - Total permit valuation
        - Such as CALGreen 2019 Chapter 3 requirements which apply to nonresidential building alterations with a permit valuation of $200,000 and above.

3.4 Frequency of Trigger Points in the California Market

Several sources of existing building permit data were explored to support a future cost-benefit analysis for existing nonresidential building requirements. A summary of the sources evaluated is as follows:

1. **California Building Industry Association (CBIA)**

Owned by the California Industry Research Board, which is itself a service provided by the California Homebuilding Foundation, CBIA offers permitting statistics for residential and nonresidential construction through all 58 counties and incorporated areas within the state. Based on our evaluation of sample data, the major limitation with CBIA construction data is that it reports total assessed value of new construction at a county level only. There is no publicly accessible way of identifying the number of projects or buildings this value represents. For the assessed value data to support EV trigger points, it would be necessary to understand cost on a per project basis to identify the frequency of projects which would qualify for requirements based on total permit value.

2. **State of California Department of Finance**

The California Department of Finance offers publicly available construction permit data for multifamily and nonresidential projects (State of California. n.d.). This data is provided as total monthly permit valuations dating back to 2010. While total number of new residential units is included, the data does not indicate the number of buildings represented in total permit valuations or provide any means of segregating permit data by valuation ranges. We attempted contacting the Department of Finance to request access to backend (nonpublic) data, however they were unable to complete this request.

3. ConstructConnect

A subscription-based online database, ConstructConnect is a platform for bidding on projects, researching construction data, and reviewing plans and specifications. Project details can be searched using a variety of approaches including keywords, specification numbers, and project data including bid dates, total permit value, and other criteria.

From our evaluation and conversations with technical support at ConstructConnect, their database of addition/alteration projects is geared heavily toward the education and government sectors which are typically required to perform open bid processes. While ConstructConnect is valuable for assessing *new construction* projects for private nonresidential or multifamily projects, it's likely not reflective of statewide projects for addition/alteration projects. Based on a ConstructConnect database query for California nonresidential addition/alteration projects with a minimum project value of $150,000 and a bid date between October 1, 2018, and November 1, 2019, a total of 5,771 projects were identified with only 282 (or 5 percent) classified as commercial building projects.

4. Other State Agency Reports

Reports sponsored by the CEC, CARB, and CPUC in recent years have all touched upon the importance of including existing building EVCI requirements to meet California's adoption targets. Several key insights are as follows:

- "As recognized in assessments by state agencies, it may not be enough to focus solely on new buildings. Codes that address alterations and additions of existing buildings would likely result in significant increases in transportation electrification (TE) infrastructure. In fact, new construction represents about one percent of total nonresidential buildings. Only about 10 percent of nonresidential buildings are projected to be EV capable by 2030 if building standards are limited to new construction" (CEC 2021a).
- "Support of CALGreen revisions to address alterations and additions of existing buildings would likely also result in significant increases in TE infrastructure. Alterations and additions represent about 21 percent of the value of permitted construction for both residential and nonresidential construction statewide, indicating that such building codes would significantly expand TE infrastructure and provide broader access to TE infrastructure" (Energy Solutions 2016).

5. Local Jurisdictions with Existing Building EV Requirements

As part of the reach code city staff interviews, we asked local jurisdictions with existing building EV requirements whether they had retrofit/alteration cost analysis and frequency data to share. Responses were all similar, namely that the reach code adoption process generally does not require detailed cost-benefit analysis and therefore this data and analysis was never assembled.[7]

[7] This gap is addressed in "Future Recommendations" section 6.6.

When asked how trigger points were decided, several jurisdictions indicated that they made professional judgements based on existing building thresholds already established within CALGreen as well as referencing other reach codes.

4. EV Definitions and Technical Considerations

This section outlines definitional components for charging levels and EV space requirements, discusses advantages and disadvantages of charging levels, and reviews the benefits and considerations for incorporating automatic load management systems (ALMS) into future code.

4.1 Charging Levels

4.1.1 Level 1 Charging

For the purposes of this analysis, Level 1 charging is considered to consist of a 15 or 20A, 120V circuit capable of providing up to 1.92 kW to a connected EVSE.

Advantages:

- Slightly reduced install cost per space due to marginally cheaper components (circuit breaker, wiring, and receptacle or EVSE).
- Ability to install more EV spaces before requiring expensive electrical service upgrades (panel and/or transformer).
- Presents a viable path forward for EV Ready parking spaces using 20A, 120V outdoor rated receptacles. Based on discussions with electrical engineers, these receptacles are typically able to withstand repeated daily plugging and unplugging without safety concerns, making them a viable solution even with portable chargers.
- Most, if not all, EVs are provided with a portable Level 1 charger, so no additional equipment is needed for the consumer to plug into available receptacles.
- If site host provides a receptacle, other types of e-mobility devices could benefit (e-bike, e-scooters, e-motorcycles).
- Well matched for very long dwell time applications including airport parking lots.

Disadvantages:

- Slow charging rate (2 to 5 miles of range per hour) leading to concerns over practicality for rural areas as well as equity concerns for long distance commuters. For drivers with daily roundtrip distances greater than 50 miles overnight Level 1 charging is insufficient and would require supplemental charging (either workplace or paid public charging). As larger EV models come to market with reduced energy economy, Level 1 charging may be insufficient to provide adequate charge for daily driving.
- Low power levels will limit future ability to meaningfully participate in DR programs. Many industry experts and stakeholders have voiced the opinion that Level 1 charging will not be a good candidate for vehicle-grid integration (VGI) and other demand response (DR) applications.
- It is highly uncertain whether Level 1 charging will be able to accommodate ALMS. If compatible with ALMS, cost to install this additional technology will be harder to

justify due to the limited power range between Level 1 at full charge and minimum charge, as well as the additional cost of ALMS relay devices and control wiring which will likely render Level 2 EVSE equally priced. Also, some vehicle types may not charge reliably during reduced power load-managed sessions.

4.1.2 Level 2 Charging

For the purposes of this analysis, Level 2 charging is considered to consist of a 208/240V, 40A circuit capable of providing 32A or up to 7.68 kW to a connected charger. However, it should be noted that Level 2 charging can operate as low as 16A and up to 80A and 19.2 kW.

Advantages:

- Higher charge rate, with 10 to 20 miles of range added per hour of charging, making this solution much more viable for EV drivers living in remote areas or with longer commutes.
- Can support multiple forms of ALMS when equipped with a compatible EVSE and ALMS site controller, including circuit sharing and panel load management.
- When equipped with a compatible EVSE, Level 2 is considered by industry experts and stakeholders as a prime candidate for Vehicle-Grid Integration (VGI) applications, including DR program participation and bi-directional charging/power export (Vehicle-to-Building or Vehicle-to-Grid).

Disadvantages:

- Presents complications for EV Ready parking spaces with circuits terminating into receptacles, primarily due to lack of standardization of 208/240V outlets and safety concerns over daily usage of these receptacles, such as:
  - There are nearly a dozen 208/240V receptacle types, which can result in compatibility issues between charger plugs and receptacles.
  - These receptacles are typically intended for appliances with limited plugging and unplugging.
  - Many 208/240V receptacles are not rated for all-weather use.

4.1.3 Direct-Current Fast Charging (DC FC)

DC FC equipment enables rapid charging at installed stations. As of 2020, over 15% of EV charging outlets in the United States were DC fast chargers (DOE n.d.). Currently available DC fast chargers for light-duty vehicles require inputs of 480+ volts and 100+ amps (50-60 kW) and can produce a full charge for an EV with a 100-mile range battery in slightly more than 30 minutes (178 miles of electric drive per hour of charging) (CALeVIP. n.d.). However, new generations of DC fast chargers for light-duty vehicles are gaining traction and can supply 150-350 kW of power.

Advantages:

- Highest charge rate, with ability to provide substantial charging for most EV models in 15-30 minutes, making DC FC the best option for short dwell-time commercial applications (e.g., retail, fast dining) as well as along heavy traffic corridors.

Disadvantages:

- Significantly more expensive to install. Charger costs alone were anecdotally reported to be $35,000 per charger for 50 kW DC FC and $100,000 per charger for 175 kW DC FC.
- Not all EVs are capable of accepting the higher power offered by DC FC, especially older model BEVs and PHEVs.
- Requires 480V 3-phase power while many light commercial and multifamily buildings use 208/240V electrical service.
- Large power requirements limit application for existing buildings, especially older buildings (pre-1980s). Installations will be limited by available electrical capacity and may require transformer and/or panel upgrades.
- Increased power requirements may have local grid capacity implications and require detailed evaluation from the utility which may result in significant additional project costs.
- In order to make the most use of the infrastructure investment, DC FC spaces are more likely to become dedicated EV charging spaces rather than parking spaces where charging is available, reducing the overall number of general parking spaces available.

4.2 EV Capable vs. EV Ready

EV Capable and EV Ready provide different levels of electrical infrastructure for the future installation of EVSE. Neither term is formally defined in 2019 CALGreen, although the code does require the label of "EV CAPABLE" as part of its requirements for EVCI. Many of the local California reach codes as well as national efforts at EVCI code requirements have defined these terms, leading to diversity among definitions.

See Appendix A for a comparison of these definitions and EVCI requirements in the California reach codes.

4.2.1 EV Capable

There is great diversity in the application of "EV Capable" across the various EVCI code requirements. Generally, EV Capable spaces are provided with conduit (or raceways) and physical space in the panel. The requirements around reserved capacity are much more diverse, ranging from no capacity requirements to requirements for 40A at 208/240V of reserved capacity.

The following are key considerations and issues for the application of EV Capable requirements:

- **Cost:** One of the biggest concerns for including reserved capacity for EV Capable spaces is the cost. There are two potential costs: increased up-front costs and increased service costs. Requiring the reserved capacity can potentially increase the construction costs for the electrical service connection, transformers, and other switchgear. Increasing the service size can also increase the monthly connection fee for a building. In the case of reserved capacity, this means that building occupants could be paying increased monthly fees for capacity that may be underutilized.

- **Unused capacity:** Some utilities may not allow unused capacity to be installed in buildings. Even when allowable, customer charges typically include capacity-related fees and customers carrying a large volume of unused capacity may face significant monthly charges. There is also risk that unused capacity intended for future EVCI will be used for other purposes before it can be utilized for EV charging.
- **Separating building capacity from utility capacity:** Some of the most impactful cost savings are when capability is pre-installed within the building and the parking lot. Code requirements could be written to allow delay of the utility capacity upgrade until the EVSE is installed.

4.2.2 EV Ready

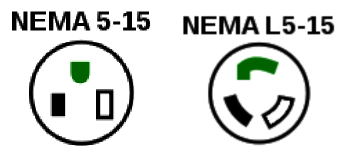
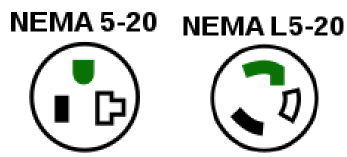
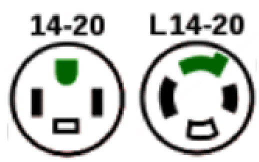
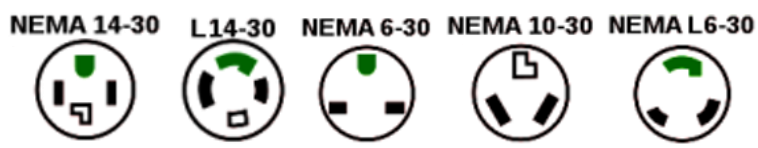
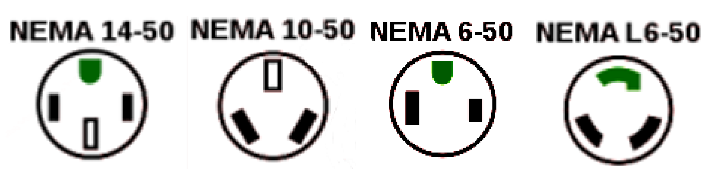
Generally, an EV Ready space is defined as a space that is provided with a branch circuit that terminates in either a junction box, EVSE, or receptacle. The required capacity for these branch circuits is most often set at 40A for Level 2 charging, but some reach codes have set EV Ready capacity at Level 1 charging levels.

The following are key considerations and issues for the application of EV Ready requirements:

- **Termination at a junction box**: Most EV Ready requirements specify that the branch circuit terminate at a receptable or junction box. When an EV Ready space terminates at a junction box, an electrician must be brought in to install an EVSE or receptacle before that space can provide charging to an EV.
- **Receptacles**: While 120V receptacles are designed for multiple connects and disconnects each day, 208/240V receptacles are not. These receptacles were developed for use with appliances that would only be plugged or unplugged occasionally and were not intended for frequent plugging and unplugging. Additionally, many 208/240V receptacles lack a ground wire, which increases the hazard of using these receptacles, particularly outdoors.
- **Plugs:** there are multiple potential issues with plugs:
    - **Plug Diversity:** While the plug on the car side of EVSE is relatively standardized, the plug on the grid side is not. Different NEMA plugs are used for different branch circuit capacities. Even within the same branch circuit capacity, multiple NEMA plugs can be utilized. The result is significant diversity among the plugs on the grid side of EVSE, as seen in Table 2 below. And while an EV Ready space with an available plug means that an EV driver could theoretically just plug in their own portable Level 2 EVSE, the diversity of plugs means that there could be a mismatch between the EVSE and the plug.
    - **Plug Adapters:** Many portable Level 2 chargers come with plug adapters to address the plug diversity issue. However, EV owners may also use non-test-lab-certified adapters which may create a possible safety hazard.
    - **Plug Capacity:** The same NEMA plugs are used for both 40A and 50A circuits. This can create a mismatch between the circuit and the load. A 40A charger on a 50A circuit uses the same plug and receptacle as a 32A charger on a 40A circuit, but if a 40A charger is plugged into a 40A circuit, the circuit breaker will trip under sustained full charging. The NEMA 14-50 is also a common plug for RVs, which could lead to the same situation if the RV has a 50A service behind the

plug. These tripped breakers are unlikely to be quickly reset, decreasing the availability of EV charging.

Table 2. Common NEMA Plugs for EVCI[8]

Branch Circuit	Capacity	Max Charging Rate	Receptacle[1]
120V @ 15A	1.8 kVA	1.4 kW	
120V @ 20A	2.4 kVA	1.9kW	
208V @ 20A 240V @ 20A	4.2 kVA 4.8 kVA	3.3 kW 3.8 kW	
208V @ 30A 240V @ 30A	6.2 kVA 7.2 kVA	5.0 kW 5.8 kW	
208V @ 40A 240V @ 40A	8.3 kVA 9.6 kVA	6.7 kW 7.7 kW	
208V @ 50A 240V @ 50A	10.4 kVA 12.0 kVA	8.3 kW[2] 9.6 kW	

1. There are more receptacles used for EVCI, including NEMA 6-15R and 6-20R, but some of them are generally not allowed by the electrical code anymore. Some local jurisdictions may prohibit the use of some NEMA 6 and 10 receptacles since they lack a neutral. Note that "L" designates twist locking plugs.

[8] NEMA 2016.

2. This is a very common size for aftermarket L2 chargers, since only Tesla charged at a higher rate until recently. The NEMA L6-30 is a common plug used for L2 chargers that are meant to be used with adapter plugs.

4.3 Automatic Load Management Systems (ALMS)

An Automatic Load Management System (ALMS) allows the charging rate of EVSEs to be monitored and dynamically varied in order to manage total electric load. The ALMS can reduce the rate of charging to individual EVs to manage the total circuit and/or panel load. When fewer EVs are charging, they are allowed to charge at the maximum rate. As more EV charging loads are added, the ALMS can reduce the charging rate to each EV, or turn off charging to specific EVs, in order to constrain the total EV charging load. ALMS is important for EVCI regulations for two primary reasons:

- **Capacity management:** An ALMS allows more chargers to share a smaller capacity. This means that more EV spaces can be installed with a smaller impact on electricity infrastructure, both on-site and for the grid. This can reduce the infrastructure costs for EVCI.
- **Load shaping:** Some ALMS technology can also respond to overall building electrical demand or grid conditions, decreasing or increasing the charging rates of EVs based on current conditions. This load flexibility can provide value to the building owner by mitigating demand charges and to the grid operator by adding or subtracting load to align with GHG reduction or grid stability goals.

There are some important considerations and issues for utilizing ALMS:

- **Chargers:** Most ALMSs only work with network-connected Level 2 EVSE. This means that Level 1 charging will generally not be able to take advantage of ALMS. It also means that an ALMS generally cannot be used to manage the capacity requirements for EV Ready spaces utilizing receptacles and customer provided portable EVSE.
- **Minimum power:** There are reports that if charging drops below a certain power transfer rate the connected EV will stop charging. If an ALMS reduces charging below that threshold, the EV will enter a “sleep” mode and would essentially be turning charging off. Based on stakeholder input at a California Public Utilities Commission (CPUC) ALMS workshop on January 29, 2021, this threshold is believed to be 6A for many EVs; however, this lower charging limit needs to be better understood through more comprehensive testing.
- **ALMS certification:** There is currently no standard for listing certified ALMS. As a result, it may be difficult for local jurisdictions to determine if installed ALMS with EVSE(s) would be safe for public use. Given the diversity in ALMS product fail-safe design protocols, this places a large burden on the local jurisdiction who may be unfamiliar with ALMS technology and application.
- **ALMS compliance and maintenance:** Once ALMS is installed, local jurisdictions are no longer responsible for inspection and validation, and responsibility for proper maintenance and performance compliance is primarily left to the building owner and equipment vendor. Items that need to be considered after installation include hardware updates, configuration, or other changes, including firmware changes, to the ALMS to

ensure any such changes are still in compliance with the performance standard and electrical load requirement set forth for ALMS.

- **Need for education:** Given the relative nascency of ALMS technology, it will be critical to promote awareness of ALMS function, design, safety, and best practices, particularly with local jurisdictions tasked with reviewing and approving installations.

5. Cost Analysis

5.1 Comparison of EV Cost Studies

A detailed review of 11 different EV cost studies and reports in order to compare price differences for equivalent charging level infrastructure was conducted. Results were provided as a summary table to CARB, including cost ranges per EVCI installation scenario, references, and detailed notes. Due to many differences in building assumptions, EVCI definitions, and construction costs, it is difficult to reach comparative normalization between studies. Instead, the comparison study was intended to inform supporting analysis by identifying the most relevant sources to reference for specific installation scenario cost data.

A summary of the EV Cost Data Matrix can be found in Appendix B of this report. Project costs on a per parking space basis are summarized in Table 3 below for the most common scenarios: EV Capable, EV Ready, and EVSE, including both new construction and retrofit scenarios. Table 3 includes cost data for both multifamily and nonresidential studies across a range of project sizes and is intended to reflect the overall cost range from lowest to highest, as well as average cost per EV charging scenario. Additional scenarios such as load management are not reflected in Table 3, but are included in Appendix B, as well as titles of all reports evaluated as part of this comparison study.

Table 3. Summary of EVCI Costs per Space by Charging Level and Construction Type[9]

	Lowest Reported Cost	Highest Reported Cost	Average Reported Cost
EV Capable - New Construction	$586	$1,161	$830
EV Capable - Retrofit[10]	$904	$2,069	$1,487

[9] Retrofit costs presented typically represent upgrades required by cost-effective trigger points. Stand-alone retrofit costs may be substantially greater.

[10] Values for EV Capable retrofits expected to underrepresent actual project costs due to overall lack of study for this scenario. Typically, retrofit scenarios assumed installation of EV Ready or EVSE, or in one case a combination of EV Capable and EVSE with costs not clearly disaggregated.

EV Ready - New Construction	$288	$3,023	$1,277
EV Ready - Retrofit	$860	$10,273	$3,620
EVSE - New Construction	$1,361	$2,768	$1,885
EVSE - Retrofit	$2,826	$9,800	$5,191

6. Future Recommendations

The EV landscape continues to grow and develop, and technologies such as ALMS and VGI are emerging as solutions to help expand charging infrastructure without overburdening the grid or host facility. However, it became clear through 2022 CALGreen stakeholder workshops that there is insufficient data and a general lack of consensus regarding how to best incorporate these technologies into code. Additionally, as jurisdictions throughout California push to reach higher percentages of charging infrastructure, charging access equity concerns and barriers exist which must be addressed. Many equity concerns were raised by stakeholders through public workshops, with CARB, HCD, and BSC staff acknowledging the importance of properly addressing them; however, work remains to collectively move forward with EV adoption growth without leaving disadvantaged residents behind.

With updates to CALGreen every eighteen months through primary and supplemental code cycles, we recommend targeting several strategic areas for further development of EV requirements for both nonresidential and multifamily buildings in future code updates. These include load shaping to align charging demand with renewable generation, futureproofing new construction to reduce EVCI installation cost and impact later in the building's lifetime, avoiding restrictions on EV development, reconsidering technical power requirements, incorporating ALMS technology in a strategic way, recognizing variations in typical building occupant parking time (dwell-time), and filling research and data collection gaps to support future code development.

6.1 Load Shaping

With California targeting 5 million ZEVs by 2030, significant new load will be added to the electric grid. Without charging management strategies beyond time-of-use (TOU) rates, the California Energy Commission (CEC) has projected an additional 3,600 megawatts (MW) at midnight on a typical weekday added to daily statewide electricity demand (CEC 2021a). Rather than aligning with daytime solar generation, this would result in overall electricity demand growth of 15% at midnight when renewable energy sources are limited, as illustrated in Figure 3 below.

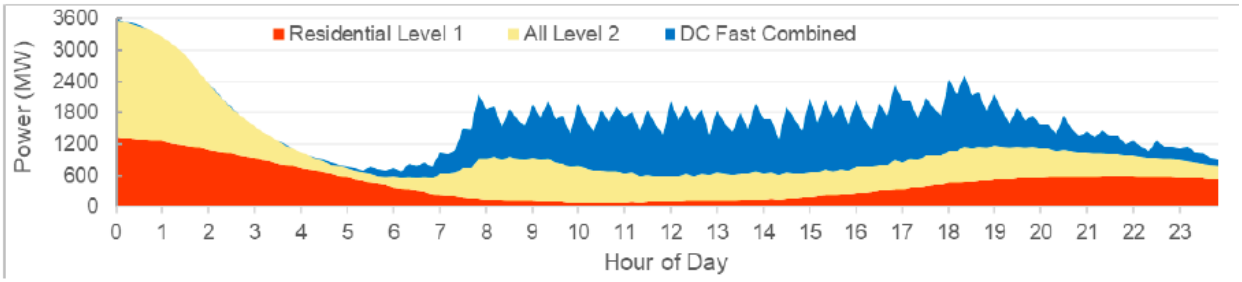


Figure 3. Projected Statewide Power for Unmanaged Light-duty Charging on a Typical Weekday in 2030[11]

While technologies such as vehicle-grid integration (VGI) will play a role in helping to re-shape the EV load profile, building codes can play an important role in this process by more aggressively expanding charging infrastructure requirements for nonresidential buildings in order to encourage greater frequency of daytime charging. In combination with incentive programs to assist building owners and developers, particularly in developmentally disadvantaged locations, this approach can help relieve some equity barriers by providing a charging location for potential EV drivers without access to charging at their place of residence. This type of charging infrastructure growth is consistent with CEC staff's projections to meet 2030 needs, which indicate a significantly larger volume of workplace and public charger infrastructure as compared to multi-dwelling unit (35% and 39% vs 20%, respectively), as illustrated in Figure 4 below (CEC 2021a).

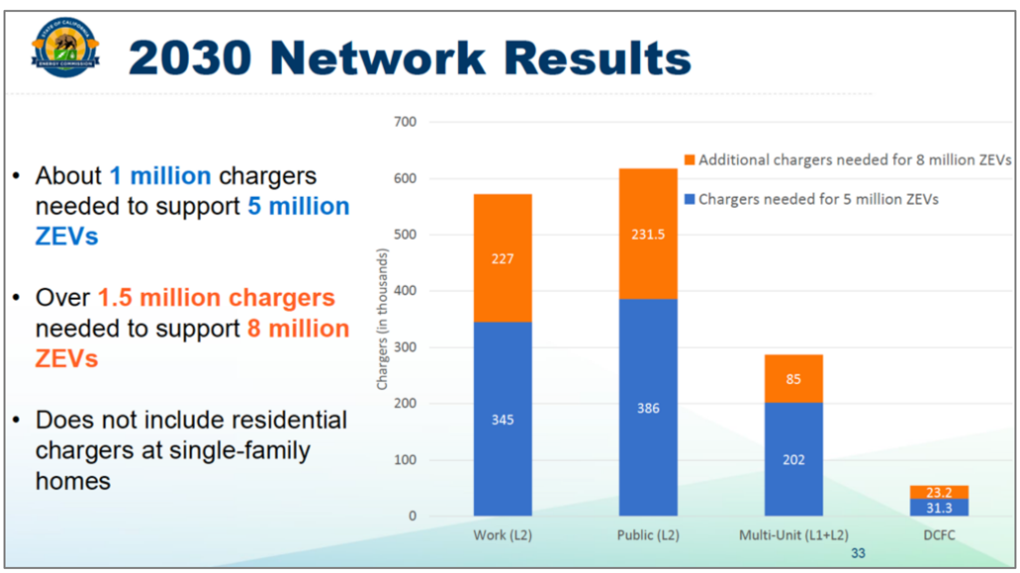


Figure 4. CEC Modeled 2030 EV Charging Infrastructure Needs by Building Type and Charging Level[12]

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[11] CEC 2021a.

[12] CEC 2021a.

Recommendations:

- Significantly increase workplace and public nonresidential charging infrastructure requirements in future CALGreen code cycles.
- Incorporate ALMS into nonresidential requirements to reach higher percentages of EV parking spaces while mitigating electrical system capacity and cost impacts.
- Incorporate futureproofing recommendations (see Section 6.2 below) to allow growth and expansion of EVCI while reducing project costs and impact to building operation.

6.2 Futureproofing

Multiple, widely cited EV cost studies have indicated that stand-alone retrofit costs are typically 3-5 times the cost of new construction infrastructure (see Energy Solutions 2016, City of Oakland 2019, CARB 2019, and Energy Solutions 2019). As illustrated in Figure 5 below, the two primary drivers of retrofit cost increases are demolition activities related to laying conduit and running raceways (e.g., trenching, repaving, and demolishing and repairing walls) and expanding electrical rooms to create space for new electrical panels and transformers (Energy Solutions 2016). These two retrofit items combined typically account for a greater cost than the total project cost for EV charging installations for new construction.

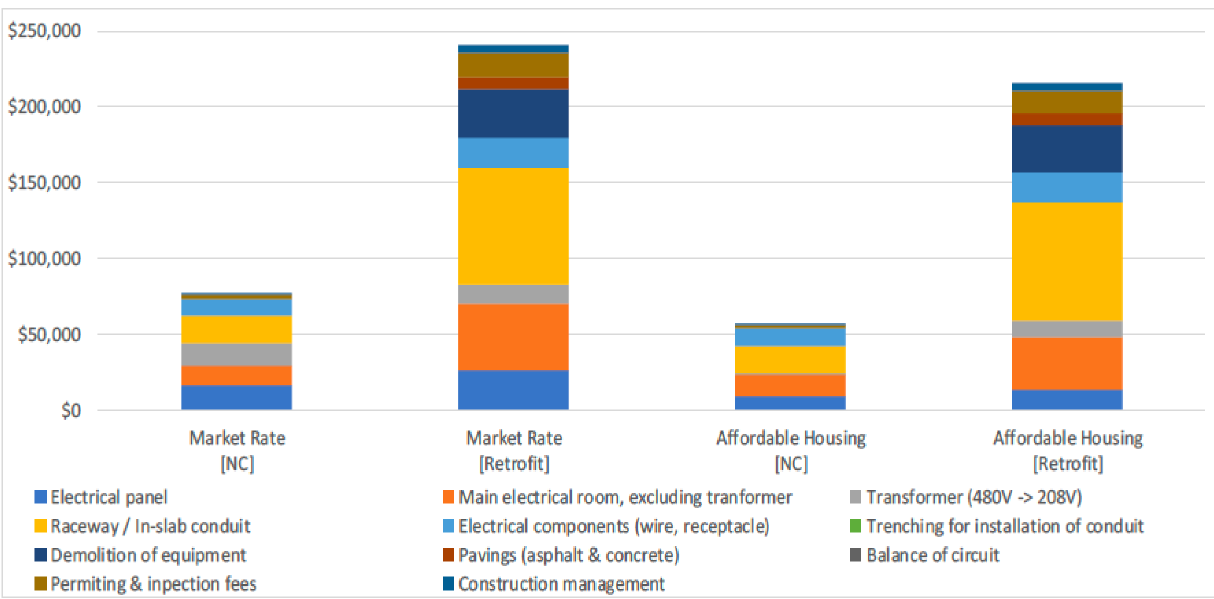

Figure 5. Total Cost Summary for EVCI in a 60-unit MUD for New Construction (NC) vs Stand-alone EV Retrofit[13]

[13] Energy Solutions 2016.

Recommendations:

- Increase new construction requirements for futureproofing elements of EV infrastructure in future code cycles. Specifically, we recommend requiring the following for multifamily and nonresidential buildings:
    - 100% of non-EV spaces to include conduit from the electrical room to the parking space. Conduits should be sized to accommodate circuits providing up to 22 kW to each space to provide the flexibility to accommodate future power increases without the need for retrenching.
    - Electrical rooms to include dedicated space for future panels and transformers capable of providing adequate system capacity to serve 100% of remaining (non-EV) parking spaces with a minimum of 3.3 kW to each space simultaneously.
    - Where EV Ready or EVSE are installed on a circuit smaller than 40A (30/32A delivered power), wiring and electrical panels should be upsized to accommodate full 40A circuits. If no ALMS is used, circuit breakers may be sized to match current capacity limitations of the existing panel.
- Building code requirements for existing nonresidential and multifamily buildings should explore including a requirement for conduit to 100% of parking spaces affected by typical alteration trigger points including repaving/resurfacing activities.

6.3 Market Development

Based on EV market development and growth trends in recent years, it is anticipated that vehicle battery sizes will continue to increase to accommodate longer travel distances and overcome remaining consumer "range anxiety," or fear that the EV has insufficient capacity to reach the destination and would potentially strand the vehicle's occupants. Additionally, EV charging power has been increasing and will continue to do so. Early battery electric vehicle (BEV) models and PHEV models were limited to a maximum charge power of 3.3 kW; however, newer BEVs are reaching charging powers up to 17.2 kW as illustrated in the Table 4 below.

Table 4. Comparison of 2019 EV Specifications[14]

Model	MSRP	Range (mi)	mi/kWh (low)	mi/kWh (high)	Battery Capacity (kWh)	Max AC Level 2 Charge Power (kW)
Audi e-tron	$75,795	204	2.2	2.2	95	3.3
BMW i3	$45,445	153	3.0	3.7	42	7.4
I3s	$48,645	153	3.0	3.7	42	7.4
Chevrolet Bolt EV	$37,495	238	3.3	3.8	60	7.2
Fiat 500e	$34,705	84	3.1	3.6	24	6.6
Honda Clarity Electric	$37,540	89	3.1	3.7	26	6.6
Hyundai Ioniq Electric	$31,235	124	3.6	4.5	28	7.2

14 MyEV n.d.

Hyundai Kona Electric	$37,995	258	3.2	3.9	64	7.2
Jaguar i-Pace	$70,495	234	2.1	2.4	90	7.0
Kia Niro EV	$39,495	239	3.0	3.6	64	7.2
Kia Soul EV	$34,945	111	2.8	3.7	30	7.2
Nissan Leaf	$30,885	150	2.9	3.7	40	6.6
Plus	$37,445	226	2.9	3.5	62	6.6
Smart EQ ForTwo	$24,650	58	2.8	3.7	18	7.2
Tesla Model 3	$39,900	240	3.7	4.1	50	7.7
Long Range AWD	$49,900	310	3.3	3.6	75	9.6
AWD Performance	$59,900	310	3.3	3.6	75	9.6
Tesla Model S	$75,000	285	3.0	3.0	100	9.6
Long Range	$85,000	370	3.2	3.4	100	11.5
Performance	$96,000	345	3.1	3.1	100	17.2
Tesla Model X	$81,000	250	2.7	2.8	100	17.2
Long Range	$91,000	325	2.6	2.6	100	17.2
Performance	$102,000	305 mi	2.5	2.6	100	17.2
Volkswagen eGolf	$32,790	125 mi	3.3	3.7	36	7.2

Public comments during CALGreen working group meetings included suggestions for ALMS technical power limitations bounded by both lower and upper limits (e.g., 3.3 kW to 7.7 kW). While the majority of Level 2 technology on the market today has an upper charging limit of 7.7 kW, this could very likely change, and it is important code does not impede market development by becoming overly prescriptive.

Recommendations:

- Avoid code requirements that may restrict development of EV technology and charging capacities. Specifically, avoid placing upper charging limits on ALMS technology intended for Level 2 charging. L2 charging may reach up to 19.2 kW; while many codes currently focus on 40A 208/240V L2 charging, building owners and developers may soon prefer installing higher power infrastructure to accommodate newer EVs.

6.4 Technical Power Requirements

CALGreen Level 2 EV charging power requirements for branch circuits and electrical system capacity are described in terms of voltage and amps, specifically single-phase 208/240V and 40A. This approach could potentially restrict market development as EVs continue to evolve by prohibiting charging with three-phase power. While this technology does not currently exist in the U.S. auto market, it is widely seen across Europe and has potential advantages for integration and balancing within larger commercial and industrial building electrical systems. Additionally, state and national electrical code requirements for system capacity is described in terms of power (kW or kVA). This is consistent with electrical engineering design and specification, as well as manufacturer product ratings for power system components.

While current CALGreen requirements include minimum branch circuit capacity to EV spaces, no capacity requirements have been proposed for the actual EVSE connected to these circuits. Under current language, a building owner could install low-powered EVSEs (16A) to EV charging spaces intended to provide Level 2 charging at 30/32A.

Recommendations:

- Revise minimum electrical capacity requirements for branch circuits and electrical systems (transformers and panels) to be stated in terms of power (kW for power delivery or kVA for electrical infrastructure capacity) rather than voltage and amperage. For example, a minimum capacity of 208/240V at 32A could be revised to a minimum 6.7 kW.
- Incorporate minimum power requirements for EVSE. Recommend specifying minimum 6.2 kW power requirement for L2 EVSE in both multifamily and nonresidential code requirements (equivalent to 30A at 208V).
- Initiate conversations with industry experts, EV manufacturers, charge providers, electrical designer engineers, and other key stakeholders to better understand technical requirements of upgrading charging points (receptacles and EVSE at any level) to support VGI demand flexibility. Specifically, identify potential technical barriers presented by EVCI code requirements and opportunities to support future VGI adoption through code requirements.

6.5 ALMS Performance Requirements

Discussion for the 2022 CALGreen code proposals around ALMS included specifying minimum power requirements for connected EVSEs, with the intent of ensuring adequate charge delivery without overbuilding electrical systems. Proposed language typically included a 3.3 kW minimum power requirement per load managed EVSE.

Based on conversations with ALMS designers and manufacturers, setting a minimum power level such as 3.3 kW would prevent ALMS technology from performing as intended. As vehicles near full state-of-charge, the power delivered is designed to decrease to a minimum before shutting off when the battery reaches full charge. Additionally, a key feature of ALMS software is accommodating differences in charging needs – how long a driver intends to remain parked, how much charge they want to receive to reach their next charging destination, and the initial battery state of charge are important considerations which may influence the ALMS's algorithm for allocating delivered power per vehicle. Operating an ALMS without a minimum power restriction also provides flexibility for the system to provide demand management services by setting panel- or meter-based power limits by throttling supplied power to all EVSEs as needed to avoid exceeding system capacity or setting max or peak demand.

While code minimum power requirements are important in ensuring adequate power system capacity is installed, ALMS requirements should be separated from transformer and panel requirements. A better approach for ALMS would be establishing a minimum performance requirement, either as average power delivered (kW) when all vehicles are charging simultaneously, or as minimum energy delivered (kWh) over a period of time. The latter approach was adopted by the City of Vancouver, British Columbia, which requires a minimum charge performance of 12 kWh per electric vehicle over an eight-hour period (equivalent to 1.5 kW average delivered power) when all vehicles are charging simultaneously (City of Victoria 2020). This approach has been combined with the adoption of a diversity table to increase the ratio of EVSE per shared circuit as the circuit capacity increases. Including diversity factors in electrical demand calculations is an effective way of limiting infrastructure size by recognizing that not all connected devices will operate simultaneously most of the time. As the number of

EVSE per circuit increases, diversity increases, and the amperage allocated per EVSE decreases, as displayed in Table 5 below.

Table 5. City of Vancouver Maximum Number of EVSE per Circuit with ALMS[15]

Circuit Breaker Amperage	Maximum Number of Electric Vehicles
20	1
30	2
40	4
50	5
60	6
70	7
80	8
90	10
100	11
125	14

Using an average charging fuel-economy of 108 MPGe, or 0.312 kWh per mile, 12 kWh of charge would provide a travel distance of 38.5 miles. Based on data collected by the Metropolitan Transportation Commission shown in Figure 6 below, the average total daily commute distance across all Bay Area counties was 24.8 miles in 2015, with a peak average of 33.0 miles for Marin County in 2010 (Vital Signs n.d.). Based on this averaged data, a daily charge of 12 kWh or 38.5 miles would be sufficient for the majority of commuters in the Bay Area.

[15] City of Victoria 2020.

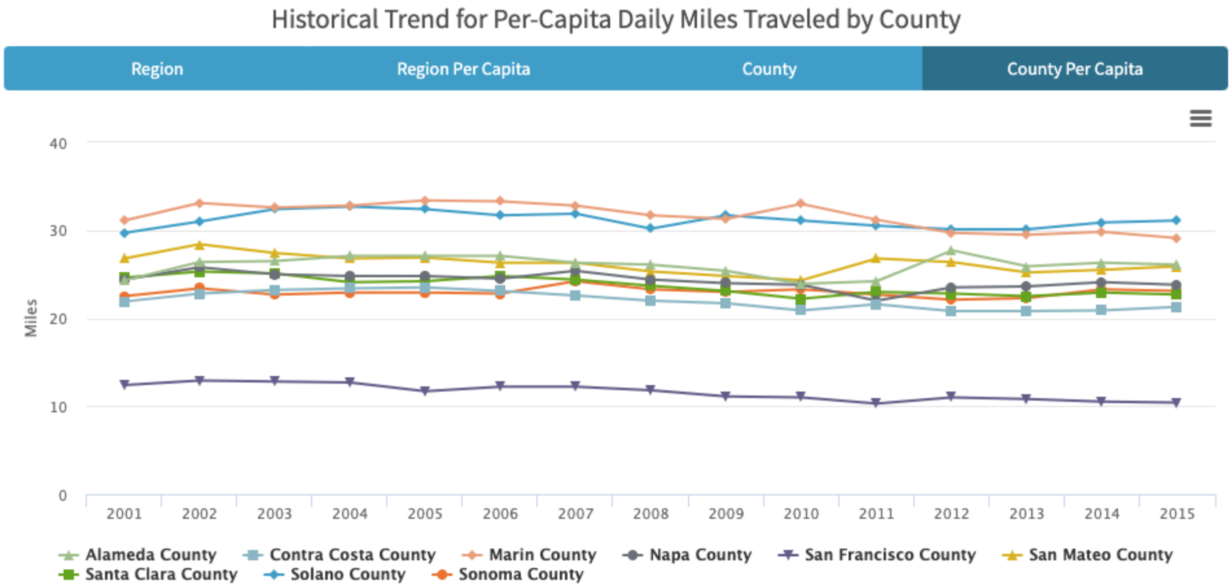

Figure 6. Bay Area Historical Average Daily Commute Miles per County[16]

Data for statewide commuting is available from the U.S. Census Bureau for 2019 in the form of one-way minutes traveled, as displayed in Figure 7 below (U.S. Census Bureau n.d.). Making the conservative assumption that one minute traveled is equal to one vehicle mile traveled and doubling the commute times for round-trip travel, a charge of 12 kWh or 38.5 miles would only meet the needs of approximately 37% of daily statewide commuters. While this is very likely understated due to the real-world difference in travel time compared to vehicle miles traveled, it illustrates the importance of considering a higher charging minimum performance requirement for rural communities and communities whose residents may experience longer-than-average commutes.

[16] Vital Signs n.d.

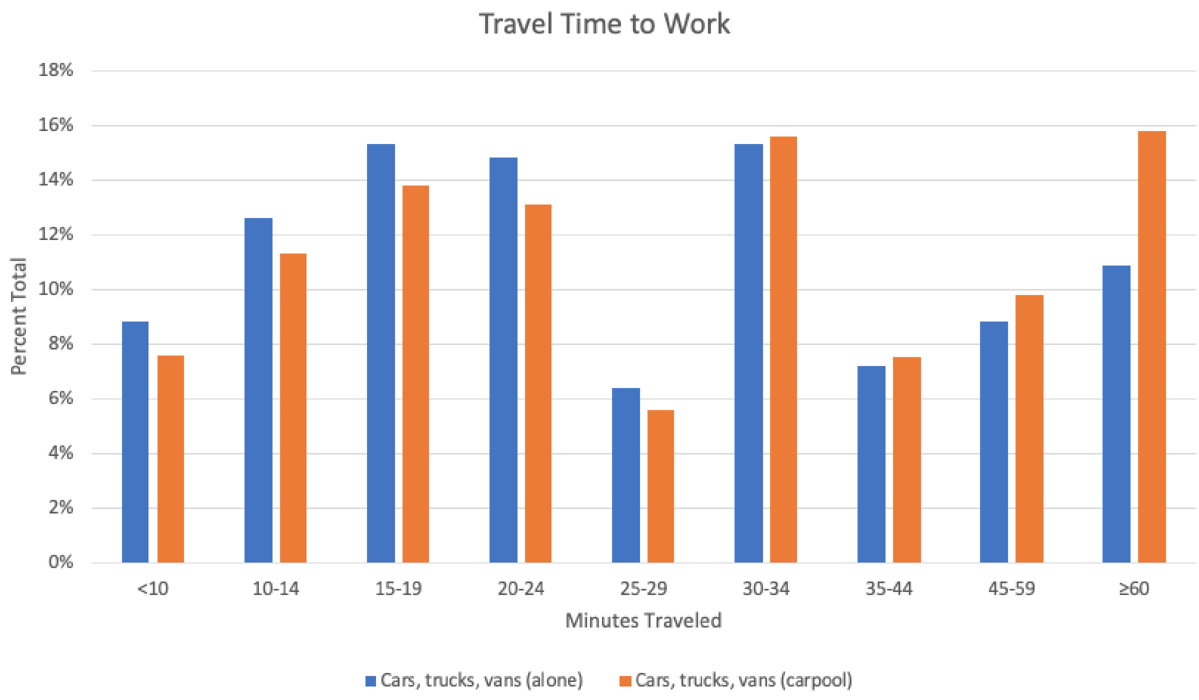

Figure 7. 2019 Survey of California Commuter Travel Times[17]

A 26-kWh minimum energy requirement over an 8-hour continuous charging period (equivalent to 3.3 kW average delivered power) would provide close to 85 miles of charge capacity, enough to satisfy 80% of statewide commuters using these same overly conservative assumptions. Keeping in mind that these minimum ALMS performance requirements represent the least amount of charge a vehicle would receive if 100% of installed EVSE are actively charging the entire 8 hours, lower power charging levels are seen to offer a viable solution for both nonresidential and multifamily charging needs, especially as buildings look to reach higher percentages of EVCI in their parking lots while reducing cost impacts that may be passed on to residents. As illustrated in Table 6 below, all charging levels above Level 1 at 12A delivered (15A rated circuit) are capable of providing over 38.5 miles of travel capacity after 8-hours of charging (based on the mileage assumptions previously described). For rural communities and those with residents who typically experience above-average commute distances, "Low Power Level 2" charging can be seen to provide at least 85 miles of travel capacity after 8-hours of charging.

An additional consideration is the impending increase in battery electric pickup trucks and SUVs available as more EV models come to market. The energy economy of the Ford F-150 Lightning pickup truck is advertised at 85 miles per gallon of gasoline-equivalent (MPGe) (Green Car Reports n.d.), representing over a 25% decrease in efficiency compared to the average of higher

[17] U.S. Census Bureau n.d.

MPGe values reported for models on the market in 2019 (MyEV n.d.). As energy economy of EVs decreases, their ability to receive adequate charge capacity from lower power levels over an 8-hour period also diminishes. This may be at least partially offset by advances in battery technology which lead to increases in economy and provide more travel range with the same sized batteries.

Table 6: EV Travel Capacity (Miles) based on Hours Charged

	1 hr	2 hrs	3 hrs	4 hrs	5 hrs	6 hrs	7 hrs	8 hrs
Level 1 - 12A, 120V	5	9	14	18	23	28	32	37
Level 1 - 16A, 120V	6	12	18	25	31	37	43	49
Low Power Level 2 - 16A, 208V	11	21	32	43	53	64	75	85
Low Power Level 2 - 16A, 240V	12	25	37	49	62	74	86	98
Level 2 - 32A, 208V	21	43	64	85	107	128	149	171
Level 2 - 32A, 240V	25	49	74	98	123	148	172	197

Recommendations:

- Separate code requirements for system capacity (circuits, panels, and transformers) from ALMS performance requirements. Establish minimum electrical system design capacity requirements per EV space to ensure adequate capacity is designed into the electrical system. However, code should avoid placing minimum power requirements on EVSE connected to ALMS systems in order to allow ALMS software the flexibility to satisfy driver expectations as well as providing demand management services for building owners and operators.
- Increase developer flexibility and potential to install more charging stations in parking lots by basing ALMS minimum performance requirements on either average power delivered (kW) or energy transferred over time (kWh) rather than minimum power levels. Consider a minimum performance requirement of 12 kWh per electric vehicle over an eight-hour period (or 1.5 kW average power delivered) when all vehicles are charging simultaneously for most cities and suburbs, and a minimum 26 kWh per electric vehicle over an eight-hour period (or 3.3 kW average power delivered) in rural communities and those with residents experiencing higher-than-average commute distances. Consider incorporating code language specifying ALMS capability rather than defining how the system operates – for example, "the ALMS shall be capable of delivering a minimum rate of simultaneous charging of 1.5 kW when all vehicles are charging simultaneously."
- Work with ALMS manufacturers, utilities, and charging service providers to evaluate ALMS charging data for existing systems in order to begin developing appropriate load factors for ALMS design. Consider pursuing this effort through NEMA, EPRI, or other appropriate organizations.

- Include requirements to oversize branch circuits to EVSE served by ALMS. For example, consider requiring branch circuits (wire, conduit, and overcurrent protection devices) to be sized for a minimum of 40A at 208/240V even when average power delivered is designed for 16A (3.3 kW). This will provide flexibility for the ALMS to deliver faster charging rates to vehicles with shorter anticipated parking times and/or greater energy needs. It will also allow the option to provide faster charging to all connected vehicles when the system is not fully utilized. This approach will also provide futureproofing through improved ability to adapt to higher powered EVs, future charger expansion, and participation in vehicle-grid integration (VGI) technology. Ideally conduit should be oversized with ability to accommodate conductors providing up to 22 kW to each charging location.
- Work with ALMS manufacturers, a safety standards organization such as Underwriters Laboratories (UL), and relevant stakeholders to develop a standard listing of certified ALMS systems in order to facilitate local jurisdictions in their review of ALMS design and installation.
- Promote education around ALMS technology, primarily focusing on engineering design best practices as well as training and resources for contractors and building officials, with an emphasis on fail-safe design approaches, electrical system integration, and other safety-related measures.

6.6 Accommodating Variations in Dwell-Times

"Dwell-time" describes the length of time building occupants or visitors typically leave their vehicles at a provided parking space. CALGreen does not currently differentiate nonresidential EV parking requirements by building type, despite significant variations in parking needs between short-dwell buildings (e.g., retail and grocery stores), long-dwell buildings (e.g., offices), and very-long-dwell locations (e.g., airports and long-term parking). A DC FC compliance option has been presented in the 2022 CALGreen proposals which would introduce a 5:1 exchange of required Level 2 EVSE per DC FC installed. This represents an important step towards incorporating developer flexibility to meet specific building needs, however the code could benefit by further movement in this direction. Compliance pathways offer an alternative to overly prescriptive requirements which may struggle to address buildings that deviate from traditional use cases.

Recommendations:

- Include a compliance option for very-long dwell-time locations (e.g., airports and other locations with parking that lasts at least 24 hours), allowing reduced minimum performance requirements for ALMS and/or reduced minimum power requirements for EVSE.
- Maintain a minimum number of required EV spaces intended for 8-hour workplace charging for employee vehicles. This should apply equally at very-long-dwell locations as well as short-dwell locations served by DC FC.

6.7 Filling Gaps in Supporting Data

As part of the submittal documents required for CALGreen update proposals, an economic and fiscal impact report is required. This document includes a comparison analysis of estimated costs and benefits of the proposal, calculated using CEC projections of new construction projects impacted after the updated code effective date, projected new parking spaces to be affected by the proposal, and incurred and avoided construction costs of the proposal requirements. Since CALGreen EV requirement updates have followed a similar projection up to this point – gradually increasing the new construction EV space percentage – a similar methodology could be followed for developing the economic and fiscal impact report, including relying on much of the data from previous reports with updates based on effective code date.

Incorporating existing building EV requirements and ALMS technology into CALGreen would be new territory for the code and would therefore require additional supporting data not previously included in proposal submittals. While new construction forecasts are generally readily available, data on additions and alterations is more difficult to obtain, especially in the level of detail necessary to evaluate cost and benefit impact of existing building EV requirements triggered by specific construction activity. To fully understand the potential benefit and appropriate application of ALMS technology, models will be required which evaluate various building and parking lot sizes to further explore cases where ALMS might help avoid service size updates, building off of the infrastructure study created for Peninsula Clean Energy and Silicon Valley Clean Energy (Energy Solutions 2019). Further research in the form of gathering construction data, consulting with electrical designers, and performing technical cost studies will be necessary to sufficiently address gaps that previous proposal analysis leave uncovered.

Recommendations:

- Perform a detailed cost study of nonresidential and multifamily EVCI scenarios including ALMS and non-ALMS (full capacity dedicated branch circuits) connected EVSE. The study should capture edge-cases where EV requirements are at risk of requiring electrical service size upgrades, including scenarios where a second electrical service may be required.
- Collect existing building retrofit cost data specific to EV "trigger point" construction activities, such as electrical system upgrades and resurfacing/repaving parking lots.
- Research and collect construction activity frequency data to reflect potential impact of existing building EV requirements.
- Work with stakeholders to better understand CALGreen authority to enforce various trigger points – for example, whether resurfacing/repaving is an enforceable trigger points or whether these activities are considered as property maintenance activities.
- Collect data from municipalities using reach codes with broader list of trigger points including change of ownership, change of use, repositioning of parking lot lighting, etc.

7. Conclusion

California is in the midst of a significant evolution in transportation, led by electrification of passenger vehicles. As manufacturers race to introduce new EVs to the market, product diversity will continue to grow with more options available at prices competitive with internal combustion engine vehicles. A growing inventory of used EVs will present even more accessibility for residents looking to make a change away from gasoline. However, charging infrastructure remains a significant concern for many would-be EV drivers, especially those living in multifamily residences where installation of an EV charger would require approval from the building owner and hiring an electrician. The growing number of EVs also presents potential for a significant increase in electric demand on the grid overnight when the majority of renewable energy generation is not available. As EV infrastructure continues to grow and develop, it is essential we get it right so that it is scaled in an equitable way that doesn't leave residents behind, and that takes advantage of carbon-free energy while minimizing strain on the electric grid as much as possible.

Building codes present an important tool to help address both of these concerns. By incorporating better futureproofing requirements for new construction, we are setting ourselves up for less disruptive and more affordable charging infrastructure expansion as EV adoption continues to grow. By aligning a wider range of EV charging definitions with stakeholders and incorporating them into CALGreen, the opportunity for statewide standardization would be created in place of the diversity and fragmentation that currently exists between local jurisdiction reach codes. Separating requirements for building electrical infrastructure capacity (panels and transformers) from dedicated EV charging space capacity will allow greater developer flexibility, as well as potential to take advantage of lower levels of charging which can reduce costs while increasing access to charging. Planning for the future dynamic grid that expects large loads like EV charging to be fully connected is essential and presents opportunities such as coordinating to meet the needs of buildings, neighborhood distribution grids, and regional networks. Incorporating performance-based requirements for ALMS technology presents opportunity to reduce building and grid electrical infrastructure impact while providing access to power to more building occupants and residents. And accelerating the expansion of nonresidential charging infrastructure can both help alleviate inequities faced by multifamily residents without access to charging as well as encourage load shaping by better aligning charging times with peak renewable generation, helping California take a significant step towards its climate goals. By preparing for future code cycles in advance through focused research, further studies, and stakeholder engagement, there is opportunity to effect meaningful change towards building out EV charging infrastructure in a way which benefits all residents for many years to come.

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Appendix A: California Reach Code Requirements

The following table provides a summary from a comparison of 37 local jurisdiction EV reach codes throughout California based on interviews with key city staff members and stakeholders as well as review of available stakeholder engagement materials from the ordinance adoption process. Local ordinance references are included, as well as a summary of EV requirements for low-rise multifamily, high-rise multifamily, and nonresidential office buildings. The following table is not intended to be comprehensive – additional building types and requirements were included in some jurisdictions' reach codes. This table reflects the requirements of approved ordinances at the time this report was written, however new ordinances are being approved regularly, and existing ordinances may be updated at any point. Requirements should be confirmed before assuming they are current.

Jurisdiction	Ordinance	Low-Rise Multifamily	High-Rise Multifamily	Nonresidential - Office
Berkeley	Ord. 7678-NS § 7 See chapter 19.37 (pg. 51)	New: 20% EV-Ready + 80% EV-capable Hotel/Motel: 10% EVSE + 40% EV-Capable	New: 10% EVSE + 40% EV-Capable	New: 10% EVSE + 40% EV-Capable
Beverly Hills	EV Amendments requirements	n/a	n/a	0-9 total - 1 EV-Capable 10-25 total - 1 EV-Capable 26-50 total - 2 EV-Capable 51-75 total - 4 EV-Capable 76-100 total - 5 EV-Capable 101-150 total - 7 EV-Capable 151-200 total - 10 EV-Capable 201+ total - 6% EV-Capable

Jurisdiction	Ordinance	Low-Rise Multifamily	High-Rise Multifamily	Nonresidential - Office
Brisbane	Ord. 643	New: Level 2 EV-Ready space per unit / min. 50% required guest spaces EVCS spaces	New: Level 2 EV-Ready space per unit / min. 50% required guest spaces EVCS spaces	administrative office, R&D, industrial, hotels and school uses >10 spaces- 15% equipped with Level 2 EVCS + 10 % Level 1 EV-Ready + 25% Level 1 EV-Capable
Burlingame	Ord. 1979/1980/1981	New: 10% of units with Level 2 EV-Ready space; remaining units with Level 1 EV-Ready	New: 10% of units with Level 2 EV-Ready space; remaining units with Level 1 EV-Ready	New Office: >10 spaces- 10% equipped with Level 2 EVCS + 10 % Level 1 EV-Ready
Carlsbad	Ord. CS-349	New: 10% of units with Level 2 EV-Capable space AND 50% of those spaces installed with EVSE Add/Alts: >$200k Hotels/Motels: 0-9 total - 1 EV-Capable 10-25 total - 2 EV-Capable 26-50 total - 4 EV-Capable 51-75 total - 6 EV-Capable 76-100 total - 9 EV-Capable 101-150 total - 12 EV-Capable 151-200 total - 17 EV-Capable 201+ total - 10% EV-Capable 50% of those EVSE	0-9 total - 1 EV-Capable 10-25 total - 2 EV-Capable 26-50 total - 4 EV-Capable 51-75 total - 6 EV-Capable 76-100 total - 9 EV-Capable 101-150 total - 12 EV-Capable 151-200 total - 17 EV-Capable 201+ total - 10% EV-Capable 50% of those EVSE	0-9 total - 1 EV-Capable 10-25 total - 2 EV-Capable 26-50 total - 4 EV-Capable 51-75 total - 6 EV-Capable 76-100 total - 9 EV-Capable 101-150 total - 12 EV-Capable 151-200 total - 17 EV-Capable 201+ total - 10% EV-Capable 50% of those EVSE

Jurisdiction	Ordinance	Low-Rise Multifamily	High-Rise Multifamily	Nonresidential - Office
Contra Costa County	Ord. 2016-22 / 2019-31 (title 7, 74-4.006)	10% EV, 50% of those EVSE	0-9 total - 0 10-25 total - 1 EVSE 26-50 total - 2 EVSE 51-75 total - 3 EVSE 76-100 total - 5 EVSE 101-150 total - 6 EVSE 151-200 total - 12 EVSE 201+ total - 6% EVSE	0-9 total - 0 10-25 total - 1 EVSE 26-50 total - 2 EVSE 51-75 total - 3 EVSE 76-100 total - 5 EVSE 101-150 total - 6 EVSE 151-200 total - 12 EVSE 201+ total - 6% EVSE
Cupertino	Ord. 19-2193 See pg. 16, Section 16.58.400	New: < 20 units: Level 2 EV-Ready space per unit; remaining spaces Level 1 EV-Ready / > 20 units: 25% of spaces Level 2 EV-Ready	New Other NR: >10 spaces- 6% equipped with Level 2 EVCS + 5 % Level 1 EV-Ready	New Office: >10 spaces- 20% equipped with Level 2 EVCS + 10 % Level 1 EV-Ready + 30% Level 1 EV-Capable
Davis	Ord. 2554	5% Level 1 spaces + 1% Level 2 (where >20 spaces) + 25% L1 EV Capable + 25% L2 EV Capable	5% Level 1 spaces + 1% Level 2 (where >20 spaces) + 25% L1 EV Capable + 25% L2 EV Capable	"Non-Retail" 0-10 total - 0 11-26 total - 1 L2 EVSE 27-42 total - 2 L2 EVSE Every Addl 15 - 1 L2 EVSE 50% of "workplace" chargers may be L1
East Palo Alto	Ord. 373 / Ord. 07-2020	New: 10% of units with Level 2 charging + 90% of units with Level 1 charging. Outlets may be shared between two units.	n/a	New: Office: >10 spaces- 10% equipped with Level 2 EVCS + 10% Level 1 EV-Ready + 30 % EV-Capable
Emeryville	CAL GREEN Buildings Standards Code	shared	n/a	n/a
Encinitas	Ord. 2019-22	New: 15% EVSE Hotel/Motel: 8% EVSE	n/a	8% EVSE

Jurisdiction	Ordinance	Low-Rise Multifamily	High-Rise Multifamily	Nonresidential - Office
Fremont	EV Readiness Requirements	0-9 total - 1 EV-Ready 10-25 total - 2 EV-Ready 26-50 total - 4 EV-Ready 51-75 total - 6 EV-Ready 76-100 total - 9 EV-Ready 101-150 total - 12 EV-Ready 151-200 total - 17 EV-Ready 201+ total - 10% EV-Ready	0-9 total - 1 EV-Ready 10-25 total - 2 EV-Ready 26-50 total - 4 EV-Ready 51-75 total - 6 EV-Ready 76-100 total - 9 EV-Ready 101-150 total - 12 EV-Ready 151-200 total - 17 EV-Ready 201+ total - 10% EV-Ready	0-9 total - 1 EV-Ready 10-25 total - 2 EV-Ready 26-50 total - 4 EV-Ready 51-75 total - 6 EV-Ready 76-100 total - 9 EV-Ready 101-150 total - 12 EV-Ready 151-200 total - 17 EV-Ready 201+ total - 10% EV-Ready
Hayward	Ord. 20-05 See pg. 8	New: < 20 units: 1 Level 2 EV-Ready space per unit/ > 20 units: 75% of spaces Level 2 EV-Ready; remaining units Level 2 EV-Capable	Other NR seems to apply: >10 spaces- 15% equipped with Level 2 EVCS	New: Office: >10 spaces- 20% equipped with Level 2 EVCS + 30 % Level 2 EV-Ready Capable
Lancaster	Ord. No. 989 See Article V, 17.08.330	<10 units: 20% EV-Capable >20 Units: 10% EV-Capable	n/a	n/a

Jurisdiction	Ordinance	Low-Rise Multifamily	High-Rise Multifamily	Nonresidential - Office
Long Beach	Ord. 19-0031 See Chapter 18.47	MF: 25% EV Capable + 5% EVSE Hotel/Motel: 0-9 total - 0 10-25 total - 3 EV-Cap / 1 EVCS 26-50 total - 8 EV-Cap / 3 EVCS 51-75 total - 16 EV-Cap / 6 EVCS 76-100 total - 23 EV-Cap / 8 EVCS 101-150 total - 31 EV-Cap / 11 EVCS 151-200 total - 41 EV-Cap / 16 EVCS 201+ total - 30% EV-Cap / 10% EVCS	0-9 total - 0 10-25 total - 3 EV-Cap / 1 EVCS 26-50 total - 7 EV-Cap / 2 EVCS 51-75 total - 13 EV-Cap / 3 EVCS 76-100 total - 19 EV-Cap / 4EVCS 101-150 total - 26 EV-Cap / 6 EVCS 151-200 total - 38 EV-Cap / 8 EVCS 201+ total - 25% EV-Cap / 5% EVCS	0-9 total - 0 10-25 total - 3 EV-Cap / 1 EVCS 26-50 total - 7 EV-Cap / 2 EVCS 51-75 total - 13 EV-Cap / 3 EVCS 76-100 total - 19 EV-Cap / 4EVCS 101-150 total - 26 EV-Cap / 6 EVCS 151-200 total - 38 EV-Cap / 8 EVCS 201+ total - 25% EV-Cap / 5% EVCS
Los Angeles	Ord. 186485	10% EVCS + 30% EV Capable	10% EVCS + 30% EV Capable	10% EVCS + 30% EV Capable
Marin County	Ord. 3712	New: Level 2 EV-Ready space per dwelling unit Add/Alts: Panel upgrade must include capacity for 20% Level 2 EV-Capable spaces	n/a	New: 10% of spaces to be Level 2 EV-Ready + remaining spaces EV-Capable **OR** 20% spaces Level 2 EV-Ready + EVCS in 5% spaces (min. 2) Add/Alts: Panel upgrade must include capacity for 20% Level 2 EV-Capable
Menlo Park	Ord. 1049 See pg. 6	EVSE for 15% of dwelling units EV Capable for 85% of dwelling units 1 EV-Ready per carport column	<10k sf: 0-9: 0 10-25 total: 1 EV-Cap 26-50 total: 2 EV-Cap 51-75 total: 4 EV-Cap >10k sf: 15% EV-Spaces: 10% of those EVSE, the rest EV-Cap	<10k sf: 0-9: 0 10-25 total: 1 EV-Cap 26-50 total: 2 EV-Cap 51-75 total: 4 EV-Cap >10k sf: 15% EV-Spaces: 10% of those EVSE, the rest EV-Cap
Mill Valley	Ord. 1313	1 EV-Ready space per dwelling unit	n/a	n/a

Jurisdiction	Ordinance	Low-Rise Multifamily	High-Rise Multifamily	Nonresidential - Office
Milpitas	Ord. 65 148	New: < 20 units: Level 2 charging at 15% of spaces + Level 1 EV-Capable at 35% of spaces / >20 units: Level 2 charging at 20% of spaces + Level 1 EV-Capable at 35% of spaces	n/a	New Office: 5% equipped with Level 2 EVCS + 10 % Level 1 EV-Ready + 20% Level 2 EV-Capable
Mountain View	Ord. 17.19 See pg. 36	New: Level 2 charging at 15% of spaces + remaining spaces EV-Ready + Level 3 EVCS for every 100 spaces	n/a	New Mixed Use: Level 2 charging at 15% of spaces + remaining spaces EV-Ready + Level 3 EVCS for every 100 spaces New Commercial/Hotel/Motel: < 10 spaces- Level 2 EVCS + EV-Ready remaining spaces / >10 spaces - 15% equipped with Level 2 EVCS + EV-Ready remaining spaces / >100 spaces - Level 3 DC EVCS
Oakland	Ord. 13576 pg. 96	n/a	n/a	n/a
Palo Alto	Ord. 5481 See Chapter 16.14.420	n/a	n/a	n/a
Pasadena	Ord. 7355 See Title 14, 14.04.507	n/a	n/a	n/a

Jurisdiction	Ordinance	Low-Rise Multifamily	High-Rise Multifamily	Nonresidential - Office
Redwood City	Ord. 522 See pg. 10	New: <20 units- Level 2 EV-Ready space per unit; remaining spaces Level EV-Ready / >20 units- 25% of spaces Level 2 EV-Ready	n/a	New Office: >10 spaces- 10% equipped with Level 2 EVCS + additional 10 % Level 1 EV-Ready + additional 30% EV-Capable
San Anselmo	Ord. 1145	New: Level 2 EV-Ready space per dwelling unit Add/Alts: Panel upgrade must include capacity for 20% Level 2 EV-Capable spaces	n/a	New: 10% of spaces to be Level 2 EV-Ready + remaining spaces EV-Capable **OR** 20% spaces Level 2 EV-Ready + EVCS in 5% spaces (min. 2) Add/Alts: Panel upgrade must include capacity for 20% Level 2 EV-Capable
San Francisco	Ord. 92-17	n/a	n/a	n/a
San Jose	Ord. 30311 See pg. 5	New: 10% EVSE + 20% EV-Ready + 70% EV-Capable Hotel/Motel: 10% EVSE + 50% EV-Capable	New: 10% EVSE + 40% EV-Capable	New: 10% EVSE + 40% EV-Capable
San Mateo	Mandatory Green Building Measures	New: 15% EV Capable spaces	n/a	10% EV Capable spaces and 5% EVSE installed spaces
San Mateo County	Ord. 4824	New: 10% of units with Level 2 EV-Ready space + 40% of units Level 1 EV-Ready spaces	n/a	New Office: >10 spaces- 10% equipped with Level 2 EVCS + 10 % Level 1 EV-Ready + 30% Level 1 EV-Capable
San Rafael	Ord 1892 / 1923	n/a	n/a	n/a

Jurisdiction	Ordinance	Low-Rise Multifamily	High-Rise Multifamily	Nonresidential - Office
Santa Clara	Ord. 1960 /2008	n/a	n/a	n/a
Santa Clara County	Ord. NS-1001.131	New: 10% of units capable. If >100 then + 1% Level 2 EVSE. "Shared Parking" (existing and new)-pre-wiring and/or EVSE among both existing and new pkg lots.	New: 10% of units capable. If >100 then + 1% Level 2 EVSE. "Shared Parking" (existing and new)-pre-wiring and/or EVSE among both existing and new pkg lots.	Non-res: 5% EV capable (references Table A5.106.3.1 which does not exist in CALGreen 2019) >100 spaces- Level 2 EVSE @ 1% New Office: ≥10 spaces-10% Level 2 EVCS +10 % Level 1 EV-Ready + 30% EV-Capable
Santa Cruz	2017-02	n/a	n/a	n/a
Santa Monica	Ord. 2634	New: EVSE charging at 10% of spaces + 20% of spaces EV-capable	New: EVSE charging at 10% of spaces + 20% of spaces EV-capable	New Office: EVSE charging at 10% of spaces + 20% EV-Ready + 30% EV-Capable Hotel/Motel: EVSE charging at 10% of spaces + 30% EV-Capable
Santa Rosa	Ord. 2019-022 See pg. 43, 18-69.040	NA	NA	NA
Sunnyvale	Ord. 3149-19 / 3100-16 / 3015-13	Shared parking (condos/apartments): 12.5% of spaces pre-wired for Level 2 EV chargers	Shared parking (condos/apartments): 12.5% of spaces pre-wired for Level 2 EV chargers	NC: Industrial, research and development, and office bldgs w/100+ parking spaces: 3% must be pre-wired for Level 2 EV chargers.

Appendix B: EV Cost Data Matrix Summary

The following table provides a summary of a comprehensive technical comparison of available EV cost studies and reports conducted in order to provide CARB staff with additional references for supporting analysis of proposals. This table includes the report title, reference (as listed in Section 8 of this report), and a summary of price(s) per EV charging space type.

Background Information		Cost Data Per Space		
Report Title & Reference	Scenario Description	EV Capable or Equivalent	EV Ready	EVSE
EV Charging Infrastructure: **Nonresidential Building Standards** (**CARB 2019**)	· New construction costs per space · Nonresidential · scenario includes 10% requirement	Range of $870-960[1] per space	-	· $1,800 for single L2 charger
CARB 2019	· Retrofit costs per space · nonresidential	-	-	· One year[2]: $9,800 for single L2 charger · Five years: $11,000 · Ten years: $12,800
City of Carlsbad Electric Vehicle Ordinance Cost Analysis[3] (Not publicly available)	· new construction cost to upgrade · baseline[4] · single family · surface	$738	-	-
City of Carlsbad Electric Vehicle Ordinance Cost Analysis	· new construction cost to upgrade · baseline · single family · enclosed	$586	-	-

Background Information		Cost Data Per Space		
Report Title & Reference	Scenario Description	EV Capable or Equivalent	EV Ready	EVSE
City of Carlsbad Electric Vehicle Ordinance Cost Analysis	· new construction · proposed ordinance[5] · single family · surface	-	$1,046	-
City of Carlsbad Electric Vehicle Ordinance Cost Analysis	· new construction · proposed ordinance · single family · enclosed	-	$874	-
City of Carlsbad Electric Vehicle Ordinance Cost Analysis	· new construction · incremental[6] · single family · surface	-	$308	-
City of Carlsbad Electric Vehicle Ordinance Cost Analysis	· new construction · incremental · single family · enclosed	-	$288	-
City of Carlsbad Electric Vehicle Ordinance Cost Analysis	· new construction · retrofit[9] · single family · surface	-	$483	-
City of Carlsbad Electric Vehicle Ordinance Cost Analysis	· new construction · retrofit · single family · enclosed	-	$463	-
City of Carlsbad Electric Vehicle Ordinance Cost Analysis[3]	· new construction · baseline[4] · multifamily · surface and enclosed	baseline for multifamily is no requirement		

Background Information		Cost Data Per Space		
Report Title & Reference	Scenario Description	EV Capable or Equivalent	EV Ready	EVSE
City of Carlsbad Electric Vehicle Ordinance Cost Analysis	· new construction · proposed ordinance[5] · multifamily · surface	-	-	$1,820 [7, 10]
City of Carlsbad Electric Vehicle Ordinance Cost Analysis	· new construction · proposed ordinance · multifamily · enclosed	-	-	$1,361
City of Carlsbad Electric Vehicle Ordinance Cost Analysis	· new construction · incremental[6] · multifamily · surface	-	-	$1,820
City of Carlsbad Electric Vehicle Ordinance Cost Analysis	· new construction · incremental · multifamily · enclosed	-	-	$1,361
City of Carlsbad Electric Vehicle Ordinance Cost Analysis	· new construction · retrofit[9] · multifamily · surface	-	-	$2,621
City of Carlsbad Electric Vehicle Ordinance Cost Analysis	· new construction · retrofit · multifamily · enclosed	-	-	$1,630
City of Carlsbad Electric Vehicle Ordinance Cost Analysis[3]	· Major Renovations · proposed · single family AND Multifamily · surface	2069 [11]	-	-

Background Information		Cost Data Per Space		
Report Title & Reference	Scenario Description	EV Capable or Equivalent	EV Ready	EVSE
City of Carlsbad Electric Vehicle Ordinance Cost Analysis	· Major Renovations · proposed · single family AND multifamily · enclosed	$904	-	-
City of Carlsbad Electric Vehicle Ordinance Cost Analysis	· Major Renovations · retrofit · single family AND multifamily · surface	-	$2,828	-
City of Carlsbad Electric Vehicle Ordinance Cost Analysis	· Major Renovations · retrofit · single family AND multifamily · enclosed	-	$1,663	-
City of Carlsbad Electric Vehicle Ordinance Cost Analysis[3]	· Major Renovations · proposed · single family AND Multifamily · surface	-	-	$4,829
City of Carlsbad Electric Vehicle Ordinance Cost Analysis	· Major Renovations · proposed · single family AND multifamily · enclosed	-	-	$2,826
City of Carlsbad Electric Vehicle Ordinance Cost Analysis	· Major Renovations · retrofit · single family AND multifamily · surface	-	-	$5,242

Background Information		Cost Data Per Space		
Report Title & Reference	Scenario Description	EV Capable or Equivalent	EV Ready	EVSE
City of Carlsbad Electric Vehicle Ordinance Cost Analysis	· Major Renovations · retrofit · single family AND multifamily · enclosed	-	-	$3,259
City of Carlsbad Electric Vehicle Ordinance Cost Analysis[3]	· new construction · baseline · nonresidential · surface	$1,161	-	-
City of Carlsbad Electric Vehicle Ordinance Cost Analysis	· new construction · baseline · nonresidential ·enclosed	$665	-	-
City of Carlsbad Electric Vehicle Ordinance Cost Analysis	· new construction · proposed · nonresidential · surface	-	-	$2,768
City of Carlsbad Electric Vehicle Ordinance Cost Analysis	· new construction · proposed · nonresidential · enclosed	-	-	$2,176
City of Carlsbad Electric Vehicle Ordinance Cost Analysis	· new construction · incremental · nonresidential · surface	-	-	$1,608
City of Carlsbad Electric Vehicle Ordinance Cost Analysis	· new construction · incremental · nonresidential · enclosed	-	-	$1,511

Background Information		Cost Data Per Space		
Report Title & Reference	Scenario Description	EV Capable or Equivalent	EV Ready	EVSE
City of Carlsbad Electric Vehicle Ordinance Cost Analysis	· new construction · retrofit[9] · nonresidential · surface	-	-	$2,543
City of Carlsbad Electric Vehicle Ordinance Cost Analysis	· new construction · retrofit · nonresidential · enclosed	-	-	$1,963
Plug-In Electric Vehicle Infrastructure Cost-Effectiveness Report for San Francisco (Energy Solutions 2016)	· new construction · nonresidential · 2 EV spaces per 10 space building	-	$920	-
(Energy Solutions 2016)	· retrofit · nonresidential · 2 EV spaces per 10 space building	-	$3,710	-
(Energy Solutions 2016)	· retrofit · nonresidential · 12 EV spaces per 60 space building	-	$860	-
(Energy Solutions 2016)	· retrofit · nonresidential · 12 EV spaces per 60 space building	-	$2,370	-

Background Information		Cost Data Per Space		
Report Title & Reference	Scenario Description	EV Capable or Equivalent	EV Ready	EVSE
Costs Associated With Non-Residential Electric Vehicle Supply Equipment (DOE 2015)	· These are ballpark ranges that includes unit installation and unit cost (see Table 4 in document and data table in data tables tab here for calcs) · single port · nonresidential	-		Level 1: $300-$4,500 [12] Level 2: $1,000-19,200 DC Fast Charger: $14,000-$55,000
Electric Vehicle Charging Infrastructure in New Multifamily Developments - Requirement Options and Costing Analysis[14] (AES Engineering Ltd. 2017)	· new construction · multifamily - High Rise - City Center · 100% AC L1 energized[13] (dedicated)	-	$1,443	-
(AES Engineering Ltd. 2017)	· new construction · multifamily - Mid Rise - City Center · 100% AC L1 energize[3] (dedicated)	-	$847	-
(AES Engineering Ltd. 2017)	· new construction · multifamily - Mid Rise - Outside City Center · 100% AC L1 energized (dedicated)	-	$881	-

Background Information		Cost Data Per Space		
Report Title & Reference	Scenario Description	EV Capable or Equivalent	EV Ready	EVSE
(AES Engineering Ltd. 2017)	· new construction · multifamily - Townhouse - Outside City Center · 100% AC L1 energized (dedicated)	-	$126	-
(AES Engineering Ltd. 2017)	· new construction · multifamily - High Rise - City Center · 100% AC L2 energized (dedicated)	-	$3,023	-
(AES Engineering Ltd. 2017)	· new construction · multifamily - Mid Rise - City Center · 100% AC L2 energized (dedicated)	-	$2,448	-
(AES Engineering Ltd. 2017)	· new construction · multifamily - Mid Rise - Outside City Center · 100% AC L2 energized (dedicated)	-	$2,314	-
(AES Engineering Ltd. 2017)	· new construction · multifamily - Townhouse - Outside City Center · 100% AC L2 energized (dedicated)	-	$2,655	-

Background Information		Cost Data Per Space		
Report Title & Reference	Scenario Description	EV Capable or Equivalent	EV Ready	EVSE
(AES Engineering Ltd. 2017)	· new construction · multifamily - High Rise - City Center · 100% AC L2 energized (dedicated, load managed)	-	$2,446	-
(AES Engineering Ltd. 2017)	· new construction · multifamily - Mid Rise - City Center · 100% AC L2 energized (dedicated, load managed)	-	$1,929	-
(AES Engineering Ltd. 2017)	· new construction · multifamily - Mid Rise - Outside City Center · 100% AC L2 energized (dedicated, load managed)	-	$1,778	-
(AES Engineering Ltd. 2017)	· new construction · multifamily - Townhouse - Outside City Center · 100% AC L2 energized (dedicated, load managed)	-	$307	-

Background Information		Cost Data Per Space		
Report Title & Reference	Scenario Description	EV Capable or Equivalent	EV Ready	EVSE
(AES Engineering Ltd. 2017)	· new construction · multifamily - High Rise - City Center · 100% AC L2 energized (2-way load shared)	-	$1,641	-
(AES Engineering Ltd. 2017)	· new construction · multifamily - Mid Rise - City Center · 100% AC L2 energized (2-way load shared)	-	$1,256	-
(AES Engineering Ltd. 2017)	· new construction · multifamily - Mid Rise - Outside City Center · 100% AC L2 energized (2-way load shared)	-	$1,067	-
(AES Engineering Ltd. 2017)	· new construction · multifamily - Townhouse - Outside City Center · 100% AC L2 energized (2-way load shared)	-	$733	-
(AES Engineering Ltd. 2017)	· new construction · multifamily - High Rise - City Center · 100% AC L2 energized (4-way load shared)	-	$1,005	-

Background Information		Cost Data Per Space		
Report Title & Reference	Scenario Description	EV Capable or Equivalent	EV Ready	EVSE
(AES Engineering Ltd. 2017)	· new construction · multifamily - Mid Rise - City Center · 100% AC L2 energized (4-way load shared)	-	$628	-
(AES Engineering Ltd. 2017)	· new construction · multifamily - Mid Rise - Outside City Center · 100% AC L2 energized (4-way load shared)	-	$638	-
(AES Engineering Ltd. 2017)	· new construction · multifamily - Townhouse - Outside City Center · 100% AC L2 energized (4-way load shared)	-	$733	-
(AES Engineering Ltd. 2017)	· new construction · multifamily - High Rise - City Center · 100% AC L2 energized (4-way load shared & load managed)	-	$760	-
(AES Engineering Ltd. 2017)	· new construction · multifamily - Mid Rise - City Center · 100% AC L2 energized (4-way load shared & load managed)	-	$612	-

Background Information		Cost Data Per Space		
Report Title & Reference	Scenario Description	EV Capable or Equivalent	EV Ready	EVSE
(AES Engineering Ltd. 2017)	· new construction · multifamily - Mid Rise - Outside City Center · 100% AC L2 energized (4-way load shared & load managed)	-	$566	-
(AES Engineering Ltd. 2017)	· new construction · multifamily - Townhouse - Outside City Center · 100% AC L2 energized (4-way load shared & load managed)	-	$307	-
(AES Engineering Ltd. 2017)	· new construction · multifamily - High Rise - City Center · 100% AC L2 energized (panel shared)	-	$1,617	-
(AES Engineering Ltd. 2017)	· new construction · multifamily - Mid Rise - City Center · 100% AC L2 energized (panel shared)	-	$1,186	-

Background Information		Cost Data Per Space		
Report Title & Reference	Scenario Description	EV Capable or Equivalent	EV Ready	EVSE
(AES Engineering Ltd. 2017)	· new construction · multifamily - Mid Rise - Outside City Center · 100% AC L2 energized (panel shared)	-	$1,199	-
(AES Engineering Ltd. 2017)	· new construction · multifamily - Townhouse - Outside City Center · 100% AC L2 energized (panel shared)	-	$733	-
(AES Engineering Ltd. 2017)	· new construction · multifamily - High Rise - City Center · 100% AC L2 energized (12-way load shared, 150A)	-	$1,563	-
(AES Engineering Ltd. 2017)	· new construction · multifamily - Mid Rise - City Center · 100% AC L2 energized (12-way load shared, 150A)	-	$1,309	-

Background Information		Cost Data Per Space		
Report Title & Reference	Scenario Description	EV Capable or Equivalent	EV Ready	EVSE
(AES Engineering Ltd. 2017)	· new construction · multifamily - Mid Rise - Outside City Center · 100% AC L2 energized (12-way load shared, 150A)	-	$1,167	-
(AES Engineering Ltd. 2017)	· new construction · multifamily - Townhouse - Outside City Center · 100% AC L2 energized (12-way load shared, 150A)	-	$733	-
(AES Engineering Ltd. 2017)	· new construction · multifamily - High Rise - City Center · 100% AC L2 energized (18-way load shared, 80A)	-	$770	-
(AES Engineering Ltd. 2017)	· new construction · multifamily - Mid Rise - City Center · 100% AC L2 energized (18-way load shared, 80A)	-	$572	-

Background Information		Cost Data Per Space		
Report Title & Reference	Scenario Description	EV Capable or Equivalent	EV Ready	EVSE
(AES Engineering Ltd. 2017)	· new construction · multifamily - Mid Rise - Outside City Center · 100% AC L2 energized (18-way load shared, 80A)	-	$768	-
(AES Engineering Ltd. 2017)	· new construction · multifamily - Townhouse - Outside City Center · 100% AC L2 energized (18-way load shared, 80A)	-	$733	-
(AES Engineering Ltd. 2017)	· new construction · multifamily - AVERAGE OF ALL 4 ARCHETYPES · 100% AC L1 energized[13] (dedicated)	-	$824	-
(AES Engineering Ltd. 2017)	· new construction · multifamily - AVERAGE OF ALL 4 ARCHETYPES · 100% AC L2 energized (dedicated)	-	$2,610	-

Background Information		Cost Data Per Space		
Report Title & Reference	Scenario Description	EV Capable or Equivalent	EV Ready	EVSE
(AES Engineering Ltd. 2017)	· new construction · multifamily - AVERAGE OF ALL 4 ARCHETYPES · 100% AC L2 energized (dedicated, load managed)	-	$1,615	-
(AES Engineering Ltd. 2017)	· new construction · multifamily - AVERAGE OF ALL 4 ARCHETYPES · 100% AC L2 energized (2-way load shared)	-	$1,174	-
(AES Engineering Ltd. 2017)	· new construction · multifamily - AVERAGE OF ALL 4 ARCHETYPES · 100% AC L2 energized (4-way load shared)	-	$751	-
(AES Engineering Ltd. 2017)	· new construction · multifamily - AVERAGE OF ALL 4 ARCHETYPES · 100% AC L2 energized (4-way load shared & load managed)	-	$561	-

Background Information		Cost Data Per Space		
Report Title & Reference	Scenario Description	EV Capable or Equivalent	EV Ready	EVSE
(AES Engineering Ltd. 2017)	· new construction · multifamily - AVERAGE OF ALL 4 ARCHETYPES · 100% AC L2 energized (panel shared)	-	$1,184	-
(AES Engineering Ltd. 2017)	· new construction · multifamily - AVERAGE OF ALL 4 ARCHETYPES · 100% AC L2 energized (12-way load shared, 150A)	-	$1,193	-
(AES Engineering Ltd. 2017)	· new construction · multifamily - AVERAGE OF ALL 4 ARCHETYPES · 100% AC L2 energized (18-way load shared, 80A)	-	$711	-
Technical and Policy Guidebook – EVCI (Not publicly available)	· new construction · nonresidential · 5-10 spaces	-	$920 [15]	-
Technical and Policy Guidebook – EVCI	· new construction · nonresidential · 26+ spaces	-	$860 [15]	-

Background Information		Cost Data Per Space		
Report Title & Reference	Scenario Description	EV Capable or Equivalent	EV Ready	EVSE
Technical and Policy Guidebook - EVCI	· retrofit · nonresidential · 5-10 spaces	-	$10,273	-
Technical and Policy Guidebook - EVCI	· retrofit · nonresidential · 26+ spaces	-	$3,634	-
Technical and Policy Guidebook - EVCI	· new construction · residential (does not specify but I suspect multifamily) · Regulation for 10% of spaces to be EV (CALGreen Building Code (3%) + San Mateo Ordinance (+7% Net Increase))	-	$4010 [16]	-
Technical and Policy Guidebook - EVCI	· new construction · nonresidential · Regulation for 10% of spaces to be EV (CALGreen Building Code (3%) + San Mateo Ordinance (+7% Net Increase))	-	$4010 [16]	-

Background Information		Cost Data Per Space		
Report Title & Reference	Scenario Description	EV Capable or Equivalent	EV Ready	EVSE
"EV Readiness" Requirements Framework **(McEwen 2019)**	· new construction · multifamily - AVERAGE OF ALL 4 ARCHETYPES · 100% AC L2 energized (4-way load shared)	-	$751 [17]	-
(McEwen 2019)	· new construction · residential (does not specify but I suspect multifamily) · Level 2, Dedicated Circuits · 20% of all stall feature dedicated circuits capable of Level 2.	-	$1150 [18]	-
(McEwen 2019)	· new construction · residential (does not specify but I suspect multifamily) · Level 2, Energy Management Systems · 100% of all stall feature dedicated circuits capable of Level 2.	-	$1300 [18]	-

Background Information		Cost Data Per Space		
Report Title & Reference	Scenario Description	EV Capable or Equivalent	EV Ready	EVSE
(McEwen 2019)	· new construction · residential (does not specify but I suspect multifamily) · Level 2, Dedicated circuits · 100% of all stall feature dedicated circuits capable of Level 2	-	$4040 [18]	-

Appendix B Table Footnotes

1. Range includes installing raceway and panel capacity to support dedicated branch circuits for Level 2 chargers.
2. Average Incremental Future Level 2 Charger Retrofit Costs per Space.
3. Data assumes that the city would require infrastructure compatible with Level 2 EV chargers.
4. Baseline Costs: 2016 CALGreen Mandatory requirements for new construction. Existing residential buildings are assumed as not being prepared for EV charging infrastructure, so no baseline was considered for existing residential.
5. Proposed Ordinance Costs: The cost of installing EV charging infrastructure to meet the requirements of the proposed ordinance as part of residential or nonresidential new construction or as a retrofit in existing residential major alterations.
6. Incremental Costs: The cost difference between the proposed ordinance costs and the respective baseline costs.
7. Cost provided in the document for multifamily and nonresidential is technically for the requirement of two spaces so the cost reflected here is that amount split in half. This is the same for all multifamily and nonresidential costs in Carlsbad study.
8. Major alteration data for residential only.
9. Retrofit, also referred to as Untriggered Retrofit: The cost of retrofitting a baseline building with EV charging infrastructure to meet the proposed ordinance requirements as an isolated retrofit.
10. The cost data for multifamily and nonresidential is for both EVSE Capable + EVSE Installed.

11. These calculations are not divided by 2 to account for 2 spaces because MF and SFH data is combined into this table.

12. Price ranges reflects the different tiers/types of the Level Chargers. For example, Level 2 could be basic wall mount (cheapest), basic pedestal, pedestal with low level data collection or pedestal with advanced features (most expensive). It additionally reflects the level of installation needed - For example, the $0 installation cost assumes the site host is offering an outlet for PEV users to plug in their Level 1 EVSE cord sets and that the outlet already has a dedicated circuit.

13. "Energized": All infrastructure required for charging of an electric vehicle (EV), including all electrical equipment (including metering), cabling and associated raceways, and connections, with exception of the Level 2 EVSE equipment.

14. This report studied EVCI costs for 4 different multifamily archetypes and 9 different scenarios.

15. This data is cited from the SF Report. Note that this data is portrayed differently in this study than in the SF study. In the SF Study they reference the data for 2 EV spaces per 10 regular spaces ($960) and 12 EV per 60 spaces ($860).

16. This data references a cost of $40,100 for 10% of 100 spaces being converted to EV Ready. Thus one space = $4,010. This data is cited from a San Mateo Study.

17. Cited from the AES Study.

18. Cited from a study called the Prism Engineering Study.