Electric Vehicle Infrastructure Cost Analysis Report for Peninsula Clean Energy (PCE) & Silicon Valley Clean Energy (SVCE)

To: Peninsula Clean Energy & Silicon Valley Clean Energy

From: Tim Minezaki, Engineer II

Cassidee Kido, Project Manager

Ed Pike, Senior Engineer[1]

Energy Solutions

Date: November 20, 2019

[1] Ed Pike contributed to this project while an employee at Energy Solutions.

Table of Contents

1. Executive Summary

California and the Bay Area are on the verge of a massive transformation. Current estimates[2] put electric vehicles (EVs) and plug-in hybrid vehicles (PHEVs) at a 5% market share but by 2030, that is expected to grow to 18-20%. Access to electric vehicles (EV) infrastructure is currently a major barrier for consumers' willingness to purchase electric vehicles. Meanwhile, several studies show that installation of EV infrastructure has significant costs, most notably in a retrofit scenario which has multiple cost factors. This report investigates infrastructure costs associated with EV infrastructure reach codes by building an EV cost effectiveness model, which examined three common building types and applied different EV infrastructure penetration rates. The model also studied utility-side infrastructure, such as distribution transformers, that potentially yield additional costs and affect a building owner's ability to comply with expanded EV infrastructure adoption, to understand the scale and frequency of those costs.

EV Infrastructure: New Construction vs. Retrofit: Customer costs

The cost effectiveness model compared three building scenarios: (1) a medium 60-unit multi-unit dwelling (MUD) with 60 parking spaces, (2) a high-density 150-unit MUD with 150 parking spaces, and (3) a medium commercial office building with 60 parking spots. The model compares customer-side electrical infrastructure costs, such as wiring, switch gear, conduit, trenching, and secondary transformer. Primary transformer costs which are usually the responsibility of utilities, were considered separately in a later section[3].The building models were then analyzed to compare the new construction requirements with the retrofit requirements. Results from Table 1 below show that costs for new construction were significantly lower, at almost four times as much per spot compared to the retrofit scenario. This indicates that increasing code requirements for charging infrastructure could potentially save significant amounts of money to building owners in the new construction context rather than waiting for tenants to become interested in electric vehicles, at which point significant costs related to invasive demolition and electrical infrastructure replacement would be necessary.

Table 1. Estimated Cost of Installing EV Infrastructure (price per spot)

Code Scenario:	Market Rate 25% Level 2 75% Level 1		Affordable Housing 10% Level 2 90% Level 1	
Building Type	New Construction	Retrofit[4]	New Construction	Retrofit
60-Unit MUD	$1,410	$4,443	$1,049	+$3,982
150-Unit MUD	$1,197	$4,101	$1,002	+$3,854
60-Space Office Building	$1,166	$3,232	N/A	N/A

2 http://businessportal.ca.gov/wp-content/uploads/2019/07/GoBIZ-EVCharging-Guidebook.pdf

3 Primary transformers are owned and operated by the utility and covered in a subsequent section but have cost components that can spill over to customer fees in multiple ways (PG&E Electric Rule 16).

4 "New Construction" and "Retrofit" costs are relative to a CALGreen 2019 mandatory baseline building

In a retrofit context, there are significant known costs, such as those documented in this infrastructure costing model, but there are a high level of unknown opaque costs that either are born by the utility or by the customer, which while infrequent, can cause significant burden on a small number of building owners and tenants that are not present in New Construction projects. In addition, retrofitting parking structures for Americans with Disabilities Act (ADA) compliance can be a significant source of costs. Recent large-scale pilot studies conducted by the California utilities confirmed these cost burdens. For example, Pacific Gas & Electric's (PG&E) EV Charge Ready program reported an "Average Cost per Port" costs for retrofit projects in their program to be almost $18,000[5] with a range between $10,000 and $31,000[6]. The utility reports specifically call out ADA requirements and inconsistent requirements across jurisdictions, which required significant redesign costs for ADA compliance.

EV Infrastructure: Building size / Transformers

Distribution transformers are a key piece of EV infrastructure and their costs and magnitude are heavily influenced by building size. For most situations, small buildings utilize shared distribution transformers split between multiple electrical accounts; medium buildings feature a dedicated utility-owned transformer and large buildings may feature several transformers, some are utility-owned and some are customer-owned depending on the uses and electrical design of the building. The particular trigger points between building sizes are influenced by the utility rules on electrical infrastructure equipment specifications and are not comparative between utilities. The graph below illustrates when certain costs become important to assist policy makers:

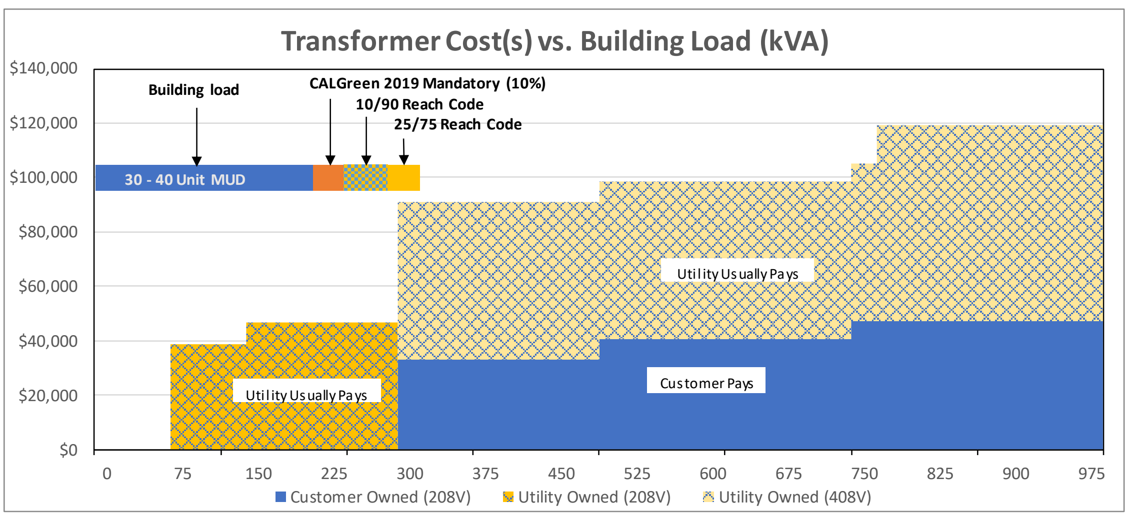


Figure 1: Costs of Transformers vs. Transformer system size (PG&E service territory)[7]

[5] Note that these costs include extensive design and re-design as well as utility side costs: [Pacific Gas and Electric Company EV Charge Network Quarterly Report (Q1-2019)]

[6] [Q2 2019 Clean Transportation Program Advisory Council Meeting]

[7] This graph shows PG&E's specific equipment sizing and is not comparable to other utilities. Calculations are based on estimates from the infrastructure cost model.

Costs of distribution and/or service-line upgrades are partially split between customer and utility. Customers are responsible for excavation, conduits, and protective structures. Utilities are typically responsible for wiring, metering, and transformer(s) (where necessary), however, utility costs can spill over into customer costs anytime that the costs exceed the preset "allowance" for a customer, based on historical energy usage.[8] In addition, if new load, does not materialize, the utility is able to assess additional charges for the difference in expected revenue. Currently, costs are described by California Public Utilities Commission's (CPUC) Electric Rules 2, 15, and 16 which lay out which party is responsible for these costs, however, these costs are complicated, opaque, and hard to predict. Luckily,the CPUC is tracking costs related to EV infrastructure and has found that utility-side infrastructure upgrades triggered by EV-only projects are rare. To date, for PG&E's service territory found only 3% of projects required distribution or service-line upgrades to accommodate EV infrastructure. However those costs spanned a wide cost range from $14 to $338,274 (additional details on this study can be found in the Transformers section below).

Reach Code Context

This study investigated EV-infrastructure reach codes for communities in the jurisdiction of Silicon Valley Clean Energy (SVCE) and Peninsula Clean Energy (PCE), shown in Table 4 below. The study found that increasing the electric vehicle infrastructure requirements for new construction will save significant costs for all buildings when compared to a retrofitting. The study also found that transformer capacity limitations are not expected to occur very frequently and that even in the retrofit context most buildings should be able to meet the added load. For those that do not have significant capacity, utilizing lower power "Level 1" ports or load management may be a promising options.

Buildings near the boundary conditions highlighted above in Figure 1, in particular those that approach the 300 kVA capacity size[9], face added risk of electrical infrastructure upgrade costs. For owners of those new buildings, the electrical systems would have to accommodate a second transformer and associated electrical infrastructure and the owner/developer would need to bear those costs estimated to be approximately $50,000 (or significantly more in a retrofit context).

---

[8] Customers have an "allowance" based on their billing history to fund utility upgrades, but if allowance costs are exceeded, they are charged directly to the customer (PG&E Electric Rule 15 & Rule 16). This allowance is based on the net revenue of the customer account. In addition, if the expected load does not materialize to use the system upgrade, the utility is permitted to recover their costs from the customer.

[9] For example, for a 30-40 unit MUD, this may be a consideration as shown in Figure 1.

2. Background and Purpose

Purpose

The purpose of this report is to provide cost analysis data on electric vehicle infrastructure and to support and inform potential adoption of reach codes for cities and municipalities in Santa Clara and San Mateo counties. This report investigates potential reach codes that would 1) require "EV-ready" parking spaces, parking spaces which are already equipped with wiring and simply need an electric vehicle supply equipment (EVSE) to provide charging, and 2) increase the EV charging space requirements for market-rate housing, affordable housing, and commercial-office buildings. The CALGreen nonresidential code currently requires only that "EV capable" parking spaces be provided, which requires conduit and electrical panel capacity for a 40 ampere, 208/240-volt circuit serving the space, but does not require wiring nor EVSE installation and associated expenses. The following table describes these EV equipment tiers:

EV Capable	Includes conduit / raceways
EV Ready ("Plug and play")	Includes full circuit with a receptacle / outlet
EV Installed	Includes full charging capability with EVSE

This cost report estimates the incremental costs associated with expanding EV infrastructure requirements beyond existing CALGreen 2019 mandatory requirements and compares the incremental construction costs from a new construction project with those of a retrofit project, utilizing an EV infrastructure cost model for three prototype buildings: (1) a 60-unit medium MUD, (2) a 150-unit large MUD, and (3) a medium-sized commercial office with 60 parking spaces. In all residential cases, we assumed one parking space per unit was assumed.

In addition, the report also investigates distribution current transformers, which will be increasingly important as electrical loads increase due to building and transportation electrification. Specifically, the utility rules and electrical load requirements were analyzed to determine boundary conditions where transformers would be required, the relative cost to incorporate them, and points at which multiple current transformers may be required, and the relative magnitude of those costs. The report also delineates specific situations for when transformers are utility owned and when they become a customer costs

California's EV Infrastructure Policy Goals

The increased proliferation of EV charging infrastructure supports many of California's zero-emission vehicle adoption goals, including the objective to deploy 1.5 million zero-emission vehicles and 250,000 publicly available EV charging stations including 10,000 direct current (DC) fast chargers by 2025.[10] California also has a goal of deploying 5 million ZEVs by 2030, which will require an even larger scale-up of public stations in addition to millions of non-public EV charging stations.[11] As of October 2019, California had approximately 18,500 public Level 2 charging ports at over 5,000 locations and approximately 3,200 public DC fast charging stations at over 700 locations.[12] California must make significant progress quickly, including updating CALGreen requirements and for local communities, investigating reach codes and the potential costs.

Parking spaces at workplaces and other non-residential buildings will be needed to accommodate a California vehicle fleet that is expected to have 18%-24% ZEVs in 2030. The future percentage of ZEVs will require a much higher percentage of parking spaces than the current CALGreen code requirements.[13]

EV charging infrastructure is a critical policy to help California reach its climate and EV adoption goals by providing opportunities at homes and workplaces as well as overcoming the critical challenge of “range anxiety” associated with EV adoption.[14] Surveys of communities in the Bay Area have shown that access to vehicle charging remains a main hurdle to wider adoption and in spite of that electric vehicle adoption is expected to grow significantly.

Building codes are an important way to facilitate access to EV charging so that residents, commuters, fleets, and car-sharing services can benefit from the significant operating cost advantages in a way that is cost-effective and accessible for all. Furthermore, because EV capable parking spaces can avoid or greatly reduce several types of costs associated with installing EV charging stations, public and private funding can achieve greater number of EV charging stations faster and more efficiently. Thus, increasing the levels of EV capable parking spaces beyond those set by CALGreen will lead to significant increases in EV charging infrastructure.

CALGreen and Beyond

CALGreen is the first mandatory green building standards code in the nation and often serves as a model for other state and local governments across the county. It was originally developed in 2007 by the California Building Standards Commission (CBSC) to help meet the goals of AB 32 in reducing greenhouse gases to 1990 levels by 2020.[15] Every three years, the CALGreen code is reviewed, revised, and adopted statewide

---

10 Former Governor Edmund G. Brown Jr. Executive Order B-16-2012 set the goal of placing 1.5 million zero-emission vehicles on California’s roads by 2025. Former Governor Edmund G. Brown’s Executive Order B-48-18 set the goal of 250,000 electric vehicle charging stations, including 10,000 DCFC charging stations, by 2025. In addition, the Charge Ahead California Initiative, [SB 1275 (De León), Chapter 530, Statutes of 2014] set a goal of placing 1 million zero- and near-zero-emission vehicles into service on California’s roads by 2023.

11 Former Governor Edmund G. Brown Jr. Executive Order B-48-18 set the goal of 5 million zero-emission vehicles on California’s roads by 2030.

12 Statistics are from the Alternative Fueling Station Locator (August 2019): https://afdc.energy.gov/stations/#/analyze?region=US-CA&fuel=ELEC&ev_levels=dc_fast&country=US

13 The California Air Resources Board’s EMFAC2017 database estimates that 21.0 million “LDA” (automobiles) and “LDT1” (light duty trucks) will be on the road in 2030. The database also estimates that 6.3 million additional “LDT2” (a second category of light duty trucks) will be on the road, some of which could be used for workplace commuting or other trips to non-residential buildings.

14 “Range anxiety” refers to concerns about insufficient range and inability to find EV charging stations.

15 “CALGreen”, Department of General Service, https://www.dgs.ca.gov/BSC/Resources/Page-Content/Building-Standards-Commission-Resources-List-Folder/CALGreen

along with other sections of Title 24 for residential and nonresidential buildings. The latest version of the CALGreen code takes effect on January 1, 2020 and is referred to by CBSC as "CALGreen 2019."

The nonresidential CALGreen EV capable infrastructure requirements (California Code of Regulations, Title 24, Part 11 Sections 5.106 and A5.106) and the multifamily requirements (California Code of Regulations, Title 24, Part 11, Sections 4.106 and A4.106) which will take effect January 1, 2020 are shown in Table 2 and Table 3.

Table 2. Summary of Mandatory and Voluntary CALGreen 2019 EV Capable Parking Space Standards for New Construction (Non-Residential)

Current Mandatory	Voluntary Tier 1	Voluntary Tier 2
6%	8%	10%

Table 3. Summary of Mandatory and Voluntary CALGreen 2019 EV Capable Parking Space Standards for New Construction (Residential)

Current Mandatory	Voluntary Tier 1	Voluntary Tier 2
10%	15%	20%

The California Building Standards allow for more restrictive local amendments that are necessary because of local climatic, geological, or topographical conditions. Currently, two dozen municipalities in California have adopted local building codes that require more EV parking spaces than CALGreen and in many cases already require "EV ready" spaces with complete wiring.[16] Given the findings of this report, local jurisdictions that expand upon CALGreen requirements, could yield improved cost-savings potential for local businesses and developers.

As mentioned above, this report investigated the cost effectiveness of "EV reach codes" for market-rate housing, affordable housing, and commercial-office buildings. Table 4 below shows the following code levels that were investigated. Note that the baseline CALGreen 2019 levels are shown in "()" for comparative purposes.

---

[16] Pike, E. et. al. 2018. Driving Plug-in Electric Vehicle Adoption with Green Building Codes, August 17. ACEEE Summer Conference. Examples of agencies that are proposing local codes include Berkeley, Brisbane, San Jose, San Mateo, and many others.

Table 4. Summary of EV Reach Code Scenarios Analyzed

	MUD Market Rate (25/75)	MUD Affordable Housing (10/90)	Commercial Office
"EV Capable"	(10%)	(10%)	30% (6%)
Level 2	25%	10%	10%, EVSE
Level 1	75%	90%	10%

3. Cost Modeling

Scenarios

The model investigates three prototype building models at the CALGreen 2019 mandatory requirement level. Those models were then analyzed for EV infrastructure installation costs as described in the scenarios described in Table 4 above for a new construction scenario and a retrofit scenario for a total of thirteen runs in the cost model. Table 5 below provides a high-level view of the building prototype models in terms of number of parking spaces, approximate building area, parking lot area, and number of stories. These buildings represent hypothetical building scenarios that are based on several assumptions and may not be reflective of any one building. Please refer to the appendix and methodology for additional details.

Buildings Types Descriptions

60-unit MUD: A 60-unit apartment building with enclosed parking with 60 parking spaces to represent a medium-sized MUD building.

150-unit MUD: A 150-unit apartment building with enclosed parking with 150 parking spaces to representing a large MUD building.

60-space Commercial Office: An open parking lot with 60 spaces, to representing a medium-sized office building.

TRANSFORMER-RELATED DEFINITIONS:

Primary Transformer: A utility-owned transformer used to convert medium voltage utility distribution lines (normally 12kV) to customer level power at either 480V/277V for large buildings or 208V/120V or 240V/120V for medium buildings. Primary transformers are owned and operated by the utility but any upgrade installation costs are partially split with the building owner.

Secondary Transformer: A customer-owned transformer that converts 480V/277V power down to 208V/120V service (or 240V/120V). Usually only necessary for medium-sized or large-sized buildings.

Headroom: Additional space left for transformer sizing to account for future unspecified load, typically 20%.

Table 5. Building Prototypes & Baseline Conditions

Building Type	60-unit MUD	150-unit MUD	60-Space Office
Number of Units	60	150	n/a
Total number of parking spaces required	60	150	60
Building Area [ft²]	65,000	163,000	20,000
Number of Floors	4 to 5	8 to 9	1 to 3
Parking Lot Size [ft²]	14,000	38,800	14,000
Parking Lot Type	1-level structure	2-level structure	stand-alone lot
CALGreen Level 2 Charging Requirement	6	15	4
Building Load [kVA]	292	700	98
CALGreen EV Load [kVA]	43	86	29
Total Load [kVA]	335	786	126
Load with Headroom [kVA]	402	944	152
Percent of load from CalGreen EV Load	11%	11%	18%
Secondary Transformer [kVA] (480V -> 208V / 120V)	500	1000	225
Primary Transformer [kVA] (12kV -> 480V / 277V)	750	1000	300

Table 6. Load Comparisons across Scenarios

Building Type	60-Unit MUD[17]		150-Unit MUD		60-Space Office Building
Baseline Building Load [kVA]	292		700		98
Baseline Level 2 [# of Ports] (CALGreen 2019)	6		15		4
Baseline EV Load [kVA] (CALGreen 2019)	43		86		29
Capacity Requirement (with headroom)	402 kVA		944 kVA		152 kVA
Secondary Transformer Size	500 kVA		1000 kVA		300 kVA
Reach Code Scenario	Market Rate	Affordable Housing	Market Rate	Affordable Housing	10% L2 40% L1
Additional Level 2 Ports	+12 ports	0 ports	+22 ports	0 ports	+2 ports
Additional Level 1 Ports	+45 ports	+54 ports	+113 ports	+135 L1	+24 ports
Additional EV Load [kVA]	+95 kVA	+54 kVA	+257 kVA	+156 kVA	+33 kVA
TOTAL EV Load [kVA]	430 kVA	389 kVA	1043 kVA	942 kVA	160 kVA
Secondary Transformer Size	500 kVA	500 kVA	1500 kVA[18]	1000 kVA	300 kVA
Percent of load from EVs	32%	25%	33%	26%	39%

[17] Some of the capacity loading calculations do not appear additive. For any parking scenario with more than 10 chargers, we utilized a diversity factor of 80% to account for non-coincident charging.
[18] Our cost model assumes that for a retrofit scenario, a second 500 kVA transformer would be installed rather than demolition

Results

The results of the cost analysis model show that installing EV capable spaces as a stand-alone retrofit are close to four times as expensive compared to during new construction. Costs for these project types are shown in Table 7 and Table 9 with detailed breakdowns in Appendix A.

Several factors related to *building types* affect these results:

- Costs per space are generally higher for small buildings with a small number of retrofits for EV capable infrastructure. Smaller projects must divide fixed costs among fewer spaces than larger projects.
- Buildings that are at the cusp of needing an upgraded switch gear or transformers represent **significant cost** increases to add electric vehicles, particularly in a retrofit context where there are large costs from demolition and site disruption. The prototypes we studied were unable to illustrate this point so additional narrative about these costs have been added in the 'Distribution Transformers' section. For this study, the prototype buildings we used only surpassed the baseline transformer capacity on one scenario – and the loading was such that we did not expect significant demolition was not expected. Switch gear and secondary transformer costs were included but did not include added costs for demolition, removal, or expansion of electrical rooms[19] -or- any costs associated with utility-owned primary transformer upgrades[20].
- Our cost model found that enclosed parking was less expensive than an open parking lot. This is because surface-mounted conduit is often less expensive to retrofit than trenching, and repairing surface parking areas. However, enclosed parking is usually much more expensive when considering ADA compliance due to grading, restriping, and accounting for path of travel.

Several factors related to *project type* affect these results:

- Installing conduit in new construction is much less expensive than retrofitting it later for several reasons.
  - Demolition, disposal of materials, and repair of surface parking areas is not required.
  - Conduit can be installed directly underneath parking rather than routing around existing barriers. In addition, less expensive PVC (plastic) conduit can be installed in the parking floor (tied to rebar before concrete is poured) rather than surface mounted later. While wiring of branch circuits is not included in this report, these shorter lengths will also reduce wiring costs.
  - Running conduit through existing buildings will likely require demolition of walls, and potentially through floors as well[21]
  - Requiring that new electrical service panels contain capacity for EV capable infrastructure can achieve economies of scale and avoid the situations where an electrical room must be

---

[19] Demolition, Removal, and expansion of electrical rooms were not considered because they are highly dependent on site-specific factors that are difficult to estimate from the generic building prototypes we developed.
[20] Utility-side transformer costs are analyzed in a separate section
[21] X-ray cameras are usually used to prevent damage to concrete structures.

expanded to add additional charging. This latter cost is not included in the model, and thus, some retrofits for EV capable spaces would be significantly more expensive.

- Compared to stand-alone retrofits, incremental "soft" costs will be lower for new construction. This is because fixed costs not related to EV capable spaces will already be required for construction and the incremental cost will be much lower.[22]
- Equipment needed for trenching of surface parking will likely already be on-site during new construction, limiting costs.

Table 7. Incremental Costs Required to Install EV Infrastructure

Code Scenario	Market Rate 25% Level 2 75% Level 1		Affordable Housing 10% Level 2 90% Level 1	
Building Type	**New Construction**	**Retrofit**	**New Construction**	**Retrofit**
60-Unit MUD	$76,142	$239,909	$56,629	$215,051
150-Unit MUD	$161,550	$553,682	$135,301	$520,227
60-Space Office Building	$34,971	$96,970	N/A	N/A

[22] Pike, Ed and Steuben, Jeff. "Plug-In Electric Vehicle Infrastructure, Cost-Effectiveness Report." 2016

Table 8. Number of EV Charging Ports per Scenario

Code Scenario:	CALGreen 2019	Market Rate 25% Level 2 75% Level 1	Affordable Housing 10% Level 2 90% Level 1
60-Unit MUD	6 L2	15 L2 45 L1	6 L2 54 L1
150-Unit MUD	15 L2	38 L2 112 L1	15 L2 135 L1
60-Space Office Building	4 L2	6 L2 24 L1	N/A

Table 9. Estimated Cost of Installing EV Infrastructure (price per spot)[23]

Code Scenario:	Market Rate 25% Level 2 75% Level 1		Affordable Housing 10% Level 2 90% Level 1	
Building Type	**New Construction**	**Retrofit**	**New Construction**	**Retrofit**
60-Unit MUD	$1,410	$4,443	$1,049	$3,982
150-Unit MUD	$1,197	$4,101	$1,002	$3,854
60-Space Office Building	$1,166	$3,232	N/A	N/A

Figure 2, 3, and 4 summarize the major categories of costs such as: demolishing and repairing parking lots and sidewalks, upgrading electrical service panels, obtaining permits and inspections, and installing conduit and associated equipment. CALGreen is the baseline cost - all other scenarios are costs *in addition* to the CALGreen baseline. Tables showing the specific dollar amounts and percent of total project cost by category are shown in the Appendix A.

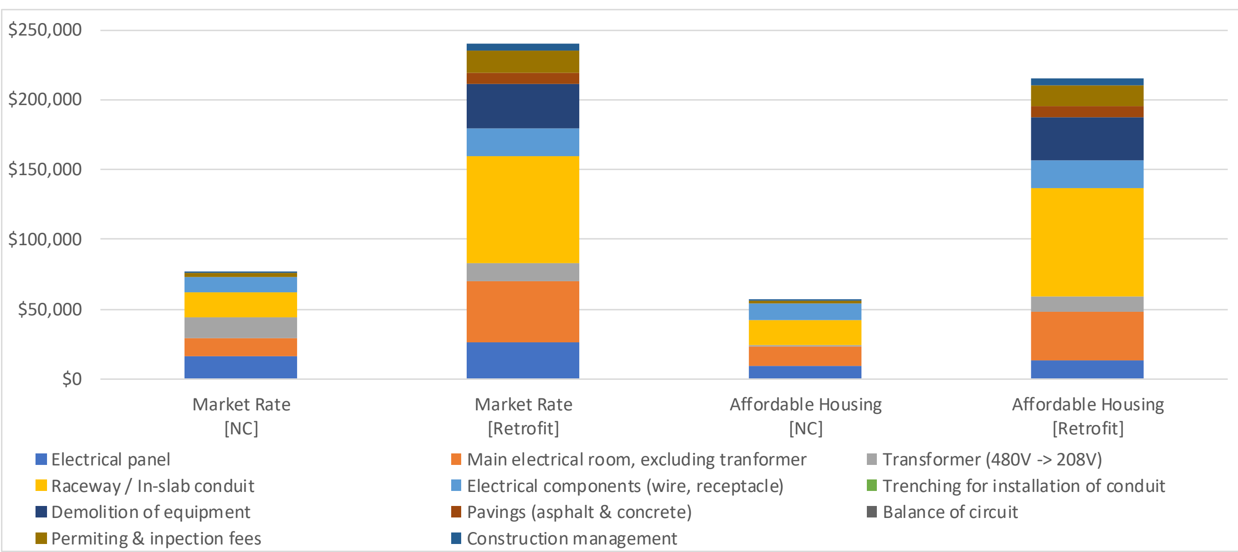


Figure 2. Cost Break-Down for 60-unit MUD

23 Price per spot is calculated against the baseline CALGreen level. For illustrative purposes: 60-unit scenarios are divided by 54 spaces, which represents the incremental number of spaces added for the incremental cost.

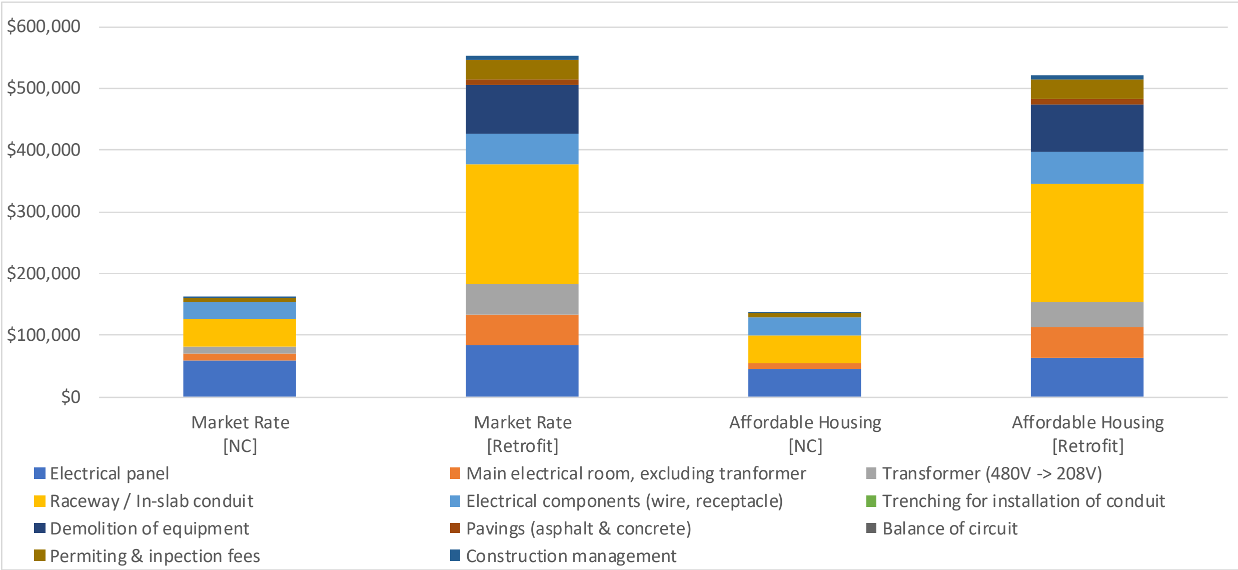


Figure 3. Cost Break-Down for 150-unit MUD

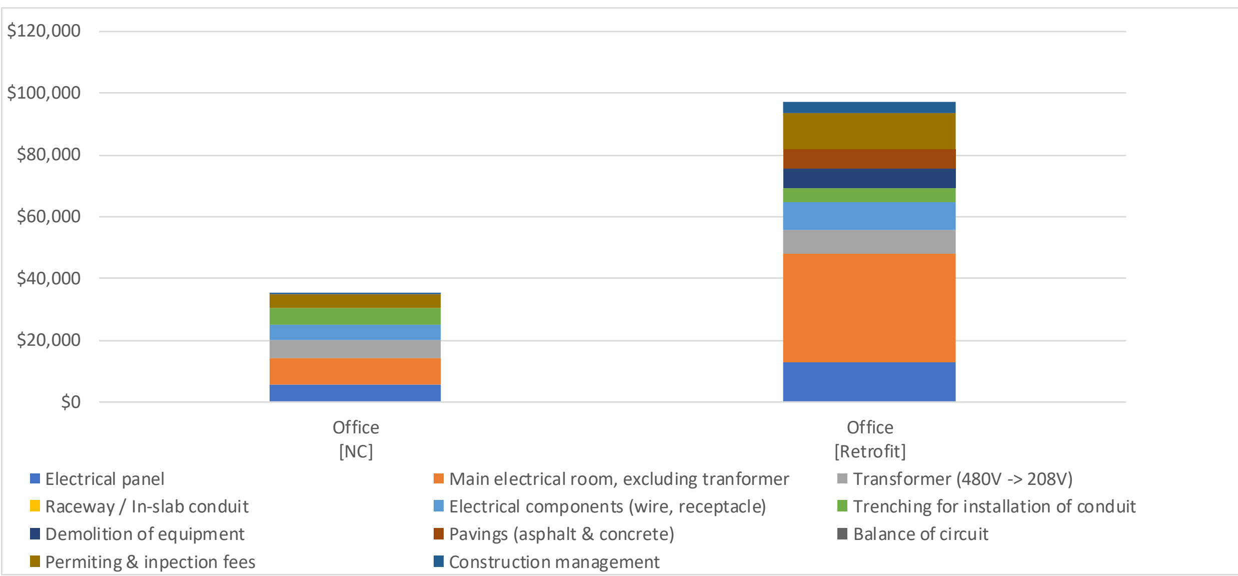


Figure 4. Cost Break-Down for 60-space Commercial Office (assumes surface-level parking)

Building code requirements for EV capable parking spaces can also reduce or avoid non-cost barriers such as coordinating between building owners/operators and tenants, potential loss of productive time for tenants during construction, lack of awareness of EV charging as an option, and the additional time and expense of undertaking a stand-alone EV charging infrastructure construction project. This study does not include specific accessibility requirements such as slope, vertical clearance, and path of travel and any of the associated costs with restriping, curb-cutting, or re-grading to meet ADA requirements, however a rough contingency to account for these ADA requirements has been included. For additional information on ADA compliance, the Governor's Office of Business and Economic Development recently released an Electric

Vehicle Charging Station Permitting Guidebook which highlights several ADA-specific issues around accessibility.[24]

Cost Savings Due to EVSE Installation in New Construction

This section discusses the benefits of requiring EVSE installation in a subset of spaces. This section also discusses the potential benefits of good design practices to greatly reduce the potential for expensive redesign and engineering to meet accessibility requirements for buildings subject to Title 24, Part 2, Chapter 11B.

EVSE Installation

We note that several local jurisdictions already require the complete installation of an EVSE on a complete electrical circuit for some parking spaces in nonresidential new construction including Carlsbad, Contra Costa County, Palo Alto and Santa Cruz. Installing a complete electrical circuit, including wiring and circuit breakers, will achieve better economies of scale and avoid the overhead and time needed to hire an electrician. This includes the need for tenants to get approvals from building owner for an electrical wiring retrofit (for the residential sector, condo owners would typically need approval from the homeowners association).

In addition, many EVSE installation tasks can be completed during new construction at much lower cost than retrofitting later, such as:

- Retrofitting concrete pads for pedestals if needed to mount EVSE (and any associated payment kiosks) and/or bollards if needed, including concrete cutting, excavation, and repair;
- Mounting brackets for EVSE installed on walls or pillars;
- Any conduit or infrastructure needed to provide data for EVSE that are networked;
- Accessibility, as discussed further below in the Good Design Practices section;
- Soft costs such as customer (or customer representative) and contractor project management; project planning including design, engineering, and permitting; contractor mobilization; and any additional retrofit tasks needed for EVSE installations;
- Lighting, if required and not already installed on-site;
- Additional site-specific, real-world contingencies.

Installing a complete circuit with an EVSE installed will reduce burdens on local building officials and thus will tend to increase code compliance. Inspectors can more easily verify that a complete circuit is installed and operating correctly with an EVSE installed, rather than determining the specific electrical components that would be required for EV capable spaces.

Good Design Practices

Several local jurisdictions have adopted building codes that require good design practices to facilitate compliance with accessibility requirements for buildings subject to the CalGreen requirements, California

---

[24] http://businessportal.ca.gov/wp-content/uploads/2019/07/GoBIZ-EVCharging-Guidebook.pdf

Code of Regulations Title 24, Part 2, Chapter 11B Section 11B-812. Section 11B-812 requires that a facility providing Electric Vehicle Charging Stations (EVCS), i.e. a parking spaces with an EVSE installed, for public and common use also provide one or more accessible EVCS, as specified in Table 11B-228.3.2.1. Chapter 11B applies to certain facilities including, but not limited to, public accommodations and publicly-funded housing (see Part 2, Section 1.9 of the California Building Code). It does not require review prior to construction of whether a building is designed to allow compliance with these requirements, and local codes require good design practices to fill this gap.

These local codes typically require that projects subject to the California Code of Regulations Title 24, Part 2, Chapter 11B, document how many accessible EVCS would be required as per Title 24, Chapter 11B to convert all required EV capable or EV ready parking spaces to EVCS. They also typically require that the builder demonstrate that the facility is designed such that compliance with accessibility standards, including Chapter 11B accessible routes, will be feasible for the required accessible EVCS at the time of EVCS installation.[25]

We note that retrofitting spaces that were not designed to facilitate compliance with accessibility requirements can be very expensive. For instance, this study finds that removing and repairing about 100 to 300 linear feet of surface parking that add conduit to non-accessible parking spaces for a small or medium facility can cost $11,500 to $32,000 in demolition and repair costs. While the scope of work for accessibility retrofits may be different from the conduit installation task, this information indicates that the types of costs required for accessibility retrofits (absent good design practices) may be similarly significant and in retrofit contexts may be cost prohibitive, space prohibitive, or both.

Methodology

The methodology for this report is similar to prior 2016 reports for the City of Oakland (with funding from the City of Oakland and grant funding from the California Energy Commission), and for the City and County of San Francisco (with funding from Pacific Gas & Electric and in-kind support from the City and County of San Francisco).[26] [27]

The cost analysis model that breaks each scenario and number of EV capable parking spaces into individual tasks and quantities, as shown in Appendix C. The model also contains estimates for the costs of each job task. Estimates of retrofit and new construction costs per job task are largely based on RS Means, a construction cost reference handbook for residential and nonresidential hardware and related installation

---

[25] For instance, section 11B-812 requires that "Parking spaces, access aisles and vehicular routes serving them shall provide a vertical clearance of 98 inches (2489 mm) minimum." It also requires that parking spaces and access aisles meet maximum slope requirements of 1 unit vertical in 48 units horizontal (2.083 percent slope) in any direction at the time of new building construction or renovation. Section 11B-812.5 contains accessible route requirements. In addition, Title 24 Part 11 Section 4.106.4.2 requires that developers meet certain aspects of accessibility requirements at the time of new construction for a limited number of parking spaces.

[26] Pike, Ed and Steuben, Jeff. "Plug-In Electric Vehicle Infrastructure, Cost-Effectiveness Report." 2016; and Pike, Ed, Jeffrey Steuben , and Evan Kamei. 2016. "Plug-In Electric Vehicle Infrastructure Cost-Effectiveness Report for San Francisco."

[27] Pike, Ed, Jeffrey Steuben , and Evan Kamei. 2016. "Plug-In Electric Vehicle Infrastructure Cost-Effectiveness Report for San Francisco."

costs.[28] Additional costs for contractor labor, permits, architectural drawings, plans, site and/or load studies (for retrofit projects), inspections, and local permit and inspection fees are based on the resources listed in Appendix B and C. Additional information used to model these costs includes feedback from industry and utility experts, engineering estimates, and direct experience. For additional details on the methodology and information specific to the EV capable parking space details, please see Appendix C and Appendix D.

The cost analysis model includes hypothetical installation scenarios to compare costs between different numbers of EV capable parking space for new construction and retrofit projects. Actual project costs and configurations will vary; these cases are intended to provide representative examples for comparison purposes rather than to estimate site-specific costs. The model excludes project-specific costs outside the scope of EV capable parking space building code compliance such as acquisition and installation of the EVSE, signage, lighting, pedestal mounts, bollards, wheel stops, any required accessibility retrofit, and any other factors outside of CALGreen EV capable parking spaces requirements.[29] (Codes that address accessibility during alterations and additions such as the City of Fremont, City of Oakland, and City and County of San Francisco local codes can result in significant cost savings compared to changing these design parameters later as part of a stand-alone retrofit project. [30])

Recent editions to this model have added secondary transformers costs and electrical room costs (switchgear). The model still excludes utility-side infrastructure, such as concrete transformer pads, utility service connections, and associated demolition, to accommodate potential swap-out for a larger capacity primary transformer. Additional information on those costs can be found in the Table 7 of the Transformers section below.

Furthermore, the scenarios do not include sub-metering or separate metering equipment, which are optional, but could be selected by a building owner to access a special electricity rate.[31] Primary model costs are based on the City of Sacramento with a correction for PCE and SVCE's service area based on an average of San Jose and San Mateo's labor and material costs for the first quarter of 2019.

---

[28] For additional information, see www.rsmeans.com.

[29] RS Means specifies a range of potential design costs, while noting that design costs will likely be 50 percent higher for alterations. We note that wheel stops may cost $150-$200 each and bollards may cost $500-$750 each based on input from an installer and RS Means costs for equipment types similar to bollards.

[30] San Francisco Green Building Code 2016: http://library.amlegal.com/nxt/gateway.dll/California/sfbuilding/greenbuildingcode2016edition?f=templates$fn=default.htm$3.0$vid=amlegal:sanfrancisco_ca$anc=JD_GreenBuilding

[31] A sub-meter may be a desirable add-on for some building owners or PEV drivers to allocate electricity costs and/or provide access to utility PEV charging electricity tariffs, though some special electricity rates for PEV owners are available through whole-house rates and utilities are also conducting pilots of metering via electric vehicle service equipment. The authors believe that builders wishing to install a socket for a sub-meter at the time of new construction may achieve cost savings compared to retrofits but have not quantified this potential.

4. Distribution Transformer Study

One important distinction in transformer classifications is between primary transformers (which are owned and operated by the utility) and secondary "step-down" transformers (which are owned and operated by a building owner). The main distinguishing factor between these is the overall building load and the particular utility rules which specify trigger points for the electrical design. For most situations, small buildings utilize shared distribution primary transformers split between multiple electrical accounts; medium-sized buildings feature a dedicated utility-owned primary transformer; and large buildings may feature a dedicated utility-owned primary transformer along with secondary transformer(s) depending on the electrical design of the building.

Primary Transformers (utility-owned, often with customer costs)

Primary transformers are needed to convert medium voltage utility distribution lines (normally 12kV) to customer level power at either 480V/277V for large buildings or 208V/120V or 240V/120V for medium buildings (for the purposes of this report, small buildings are on a shared transformer). Primary transformers are owned and operated by the utility but costs are partially split with the building owner. The costs borne by the utility operate with a ceiling, insulating utilities from the ballooning costs of the upgrades, allowing any excess above to be charged to the customer. This mechanism is known as an "allowance," effectively a budget for infrastructure upgrades funded through the electric rates. For PG&E, it is governed by Electric Rule 2[32], Electric Rule 15[33] & Electric Rule 16[34] which together lay out the rules for expanding service, extending distribution lines, and upgrading transformers. The allowance is dictated by these rules and based on historical electrical usage. The following excerpt is from Electric Rule 15:

$$\text{Allowance} = \frac{\text{Net Revenue}}{\text{Cost-of Service Factor}}$$

where the Cost of Service Factor is the annualized utility-financed Cost of Ownership as (N)
stated in Electric Rule 2. (N)

As written, these formulas and rule exceptions are complex because they apply for all electrical infrastructure situations, including agricultural, industrial, or rural contexts. However, generally-speaking, utility infrastructure upgrades have costs that are broken down between the building owner and the utility. For utility-owned transformers, the building owner will pay for the following nine elements:

1- a load study from the utility's service planning department,
2- trenching,
3- excavation
4- backfill,
5- compaction,
6- conduit,

[32] https://www.pge.com/tariffs/tm2/pdf/ELEC_RULES_2.pdf
[33] https://www.pge.com/tariffs/tm2/pdf/ELEC_RULES_15.pdf
[34] https://www.pge.com/tariffs/tm2/pdf/ELEC_RULES_16.pdf

7- substructures (boxes and pads),
8- pavings (cut, patch, and final repair), and
9- taxes and cost of ownership.

Meanwhile, the utility will pay (up to the allowance) for metering, wiring, and transformers. For any excess work required above the allowance, an advance is required by the customer, but can be converted to a monthly payment. If the revenue for the utility does not end up materializing in the first ten years, utilities have a mechanism to claw back funds called "deficiency billing."

The CPUC has been tracking service and distribution system upgrades for EV-projects from the three major California Investor-Owned Utilities, publishing their 7th annual report in April 2019[35]. The study indicates the relative frequency and magnitude of utility-side infrastructure costs that include both service upgrades and **primary** transformer upgrades. While this equipment is owned and operated by the utility, the customer will pay for upgrade costs until their allowance is exceeded.

In many cases this allowance is insufficient and costs can spread over to the customer in lump sum costs ahead of construction and/or higher monthly costs. The following table is pulled from the CPUC report and provides a high-level summary of these costs:

Table 10: Summary of Service Line and Distribution System Upgrades

	PG&E	SCE	SDG&E	Total
Residential Customers				
Estimated PEV customers through December 31, 2018	216,845	163,594	34,833	415,272
Residential Upgrades				
Number of PEV-related Infrastructure Checks Completed	10,138	Not tracked	Not tracked	N/A
Number of PEV-related Service Line and/or Distribution System Upgrades	323	243	52	618
Total Costs Incurred by Utility for Upgrades	$6,627,544	$351,675	$53,365	$7,032,584
Range of Costs for Upgrades	$14 to $338,274	$1 to $30,067	$47 to $10,958	N/A
Average Cost for Distribution System Upgrade	$19,262	$4,514	$4,089	N/A
Average Cost for Service Line Upgrade	$1,168	$1,382	$730	N/A
Number of Service Line Upgrades Exceeding Residential Allowance	39	33	0	72
Current Residential Allowance	$2,431	$3,084	$3,241	N/A
Amount of Foregone Billings to Customers for Service Line Upgrades Pursuant to "Common Facility Treatment" Policy Excemptiion for PEVs	$190,207	$37,887	$0	$228,094

As shown above, PG&E's service territory indicates just over 3% (323 service line upgrades of 10,138 PEV-related Infrastructure Checks) of sites required distribution or service-line upgrades to accommodate EV infrastructure, demonstrating projects that exceed existing transformer capacity is not common yet. And of these less than 0.4% (39) exceeded the residential allowance resulting in additional costs to the building owner beyond the baseline upgrade costs. Two large caveats should be highlighted here. The first is that most of

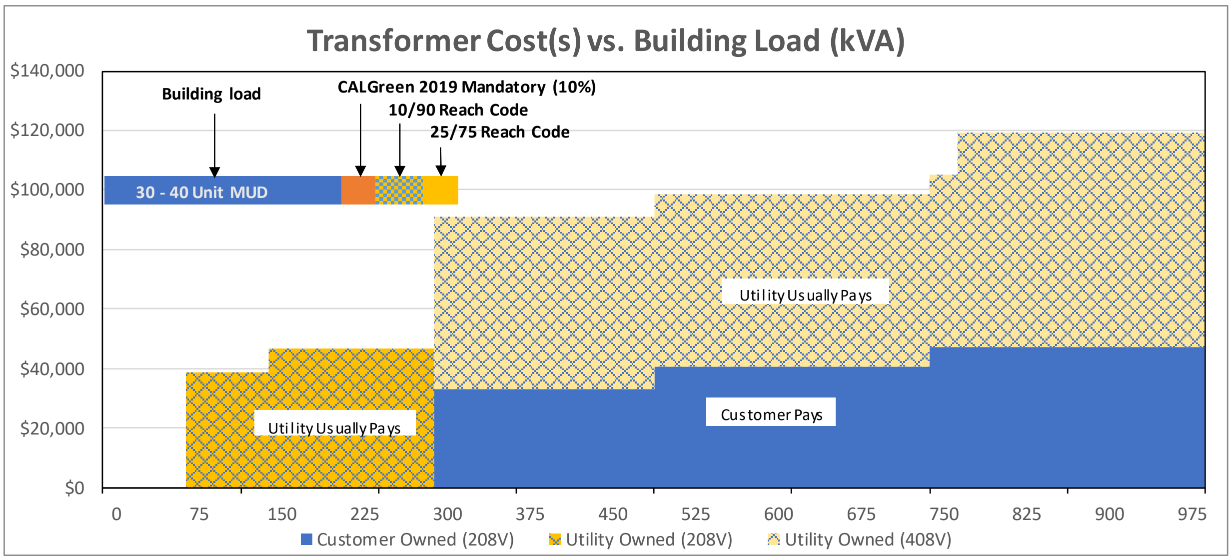
---

35 7th Joint IOU Electric Vehicle Load Research Report: April 2019 (CPUC)

these early EV installations are residential customers and the second is that overall demand for charging infrastructure is increasing and it can be expected that more ports will be installed per parking lot than in the past. In addition, local jurisdictions may have local restrictions regarding placing transformers in public right of ways necessitating alternative siting such as placing transformers within the property line and under owner cost. The most important considerations are the "Range of Costs for Upgrades" ($14 - $338,274) and the "Average Cost for Distribution System Upgrade" ($19,262) which indicate both a very wide range between projects and the average magnitude for transformers upgrades in PG&E territory. It should be noted that the distribution upgrade costs across utilities are significant with PG&E ($19,262) incurring much higher costs than those of SCE ($4,514) and SDG&E ($4,089).

Secondary Transformers (customer-owned)

Secondary transformers are required from larger buildings based on the electrical service being provided by the utility. These rules are pre-determined by the utility's electric rules. In the context of this report, secondary transformers are those that convert 480V/277V power down to 208V/120V service. PG&E's Unit Cost Guide[36], PG&E's Greenbook[37], and RS Means were investigated to develop a characterization of electrical infrastructure costs (transformers) vs. building load (kVA). In the graph below, primary transformers costs are indicated in gold/yellow with blue-accented patterns[38] and secondary transformers costs are indicated in solid blue (costs associated with site preparation are not included). In addition to this, load estimates that were utilized for the cost effectiveness model are overlaid to provide a rough back-of-the-envelope load calculation for MUDs, to illustrate when certain costs become important in order to assist policy makers of the relative situations in which these triggers would occur:



36 PG&E Unit Cost Guide - April 2019
37 2017-2018 PG&E Greenbook: Electric & Gas Service Requirements:(http://www.pge.com/greenbook)
38 The blue accent is to highlight that these costs often end up part of customer costs.

Figure 5: Costs of Transformers vs. Transformer system size (PG&E service territory)[39]

The figure above shows the magnitude of these transformer costs along with boundary points for small/medium and medium/large buildings utilizing rough estimates for number of units in a MUD with electric vehicle charging equivalent CALGreen 2019 mandatory levels. The sample number of MUDs shown in the figure above are meant to point out sizeable non-linear costs associated with transformer upgrades for this climate and this utility. In particular, attention should be paid to the 300kV load point which may cause considerable cost escalation as the electrical service would switch from 208V/120V to 480V/277V. As mentioned previously, this graphic is high-level, intended for policy makers and does not provide appropriate level of detail for a specific microclimate or a specific site.[40]

Transformer-sizing and other considerations

Electrical designers typically oversize transformers for future unspecified loads as "transformer headroom." A typical approach to transformer sizing is to obtain the calculated design load from the electrical schedule (building plan documents) and add 20% spare capacity for future load growth to be shown in the equipment schedule, unless otherwise directed by the facility based on design parameters[41]. Due to the large step-wise nature of transformers, it is possible that after accounting for headroom significantly more capacity is afforded. The table below illustrates this for the building models produced for this report:

Table 11. Transformer Sizing & Capacity

Building Type	60-Unit MUD		150-Unit MUD		60-Space Office Building
Baseline Building Load [kVA]	292		700		95
Baseline EV Load [kVA] (CALGreen 2019)	43		99		29
Capacity Requirement [kVA]	335 kVA		786 kVA		126 kVA
Capacity Requirement (with 20% headroom) [kVA]	402 kVA		944 kVA		152 kVA
Secondary Transformer Size [kVA]	500 kVA		1000 kVA		300 kVA
Overall Unused Capacity [kVA (% unused)]	165 kVA **(33%)**		214 kVA **(21%)**		174 kVA **(58%)**
Code Scenario	**Market Rate**	**Affordable Housing**	**Market Rate**	**Affordable Housing**	**10% L2 40% L1**
Additional Level 2 Ports	+12 L2	0	+22 L2	0	+2 L2
Additional Level 1 Ports	+45 L1	+54 L1	+113 L1	+135 L1	+24 L1
Additional EV Load [kVA]	+95 kVA	+54 kVA	+257 kVA	+156 kVA	+33 kVA
TOTAL EV Load [kVA]	430	389	1043	942	160

[39] This graph shows PG&E's specific equipment sizing and is not comparable to other utilities. Calculations are based on estimates from the infrastructure cost model.
[40] For example: Electrical system loading was developed by averaging climatic design data from Climate Zone 3 (Oakland) and 4 (San Jose) to develop a prototype HVAC system: (https://ww2.energy.ca.gov/maps/renewable/building_climate_zones.html)
[41] https://www.csemag.com/articles/selecting-sizing-transformers-for-commercial-buildings/

In the table above, the scenarios that are able to meet the EV reach codes with the existing headroom have been highlighted in green and the one scenario that would be unable to do so is highlighted in red. In most of these cases, the 20% headroom for the secondary transformer afforded significant flexibility to meet the reach codes. Transformers are sized for a worse-case scenario based on the requirements in the electrical code and very seldom operate near capacity. While it may be tempting to oversize a transformer above the typical industry headroom, significant oversizing should be cautioned because it can result in transformer operation significantly out of the normal efficient operation. As shown in Figure 6 below, load factor (percentage of total rated capacity) can have a significant influence on the transformer efficiency. In most times of the day, the transformer is operating at part load and oversizing a transformer can move performance out of the normal operating range and result in inefficient operation. The following figure shows a generalized transformer efficiency curve for a residential distribution transformer sized and highlights where a 20% load point might fall were the transformer pushed to the next size up, typically 40-55% increase in capacity.

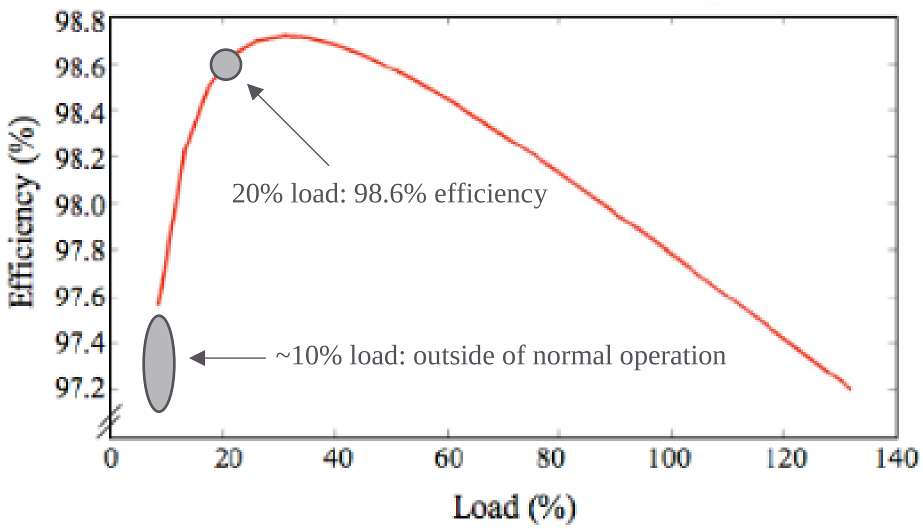


Figure 6: Transformer Efficiency vs. Load Factor[42]

The primary concern around transformers and associated costs pertain to the boundary cases where buildings close to the boundary of (1) needing to host a utility's dedicated primary transformer or (2) will require different utility service (480V instead of 208V) and need to modify their site to provide a secondary transformer. Approximate ranges of which MUDs would need to contend with this are noted in Figure 1 and Figure 5 above. If more capacity is required, it is likely that a combination of solar, energy efficiency measures, or adding battery storage would be able to prevent a transformer upgrades. On the other hand, the interest in electrification of existing gas appliances may compete for the existing capacity.

In the face of all this, load management is a promising option to allow more electric vehicle charging ports without needing to pay for larger infrastructure upgrades. This technology works by managing the amount of

[42] https://www.researchgate.net/publication/224598589_Challenges_of_PHEV_Penetration_to_the_Residential_Distribution_Network

throughput to individual charging ports based on what the control system defines for limitations. To date, this feature has primarily been marketed to limit electrical demand charges but could be utilized to prevent over-loading panels and/or transformers. Load management for electric vehicles is still nascent technology and would benefit with more developed industry standards. However, the National Electric Code has permitted power management since 2014 but industry may need training to create packaged solutions that can reassure plan checkers and building inspectors.[43]

[43] California Electrical Code (Title 24, Part 3): Article 750.30 – Load Management

Appendix A: Cost Estimates by Type of Expense

The following tables (Table 12 through Table 14) summarize model results for each type of expense per building. All costs below represent **incremental** costs compared to a baseline CALGreen 2019 mandatory building. See Appendix B and Appendix C for more details on the individual tasks included in each of the categories below. The per parking space costs are calculated by dividing the total incremental cost of by the number of added EV capable parking spaces. So for example, for the 60-unit MUD scenario shown below, a CALGreen 2019 mandatory baseline model was created to size the electrical use of a 60-unit MUD apartment building including electrical infrastructure associated with switchgear, panels, and secondary transformer. Under the new construction scenario, the additional 54 EV ports were added to the load and the system resized along with conduits added. For the retrofit scenario, the costs to upsize infrastructure, demolish structures, and provide raceways were added. NOTE: This study does not include costs for EVSE, and does not include and has a overall 20% contingency to account for ADA compliance. ADA can be a significant source of cost and in this study is only intended to capture a limited scope of ADA compliance.

Labor costs generally range from half to two-thirds of total project costs. Labor costs for small buildings with two EV capable parking spaces, based on current CALGreen six percent requirements, were estimated at about four fifths of the total project costs in new construction; however, this may not be representative of other projects for this building type with different site-specific circumstances.

Table 12. Estimated Incremental Cost of Installing EV Infrastructure: 60-Unit MUD

	60-Unit MUD			
Retrofit	Market Rate [NC]	Market Rate [Retrofit]	Affordable Housing [NC]	Affordable Housing [Retrofit]
Level 2 Ports Added	9	9	0	0
Level 1 Ports Added	45	45	54	54
Electrical panel	$15,960	$26,008	$9,289	$13,004
Main electrical room, excluding transformer	$13,609	$43,911	$14,055	$35,193
Transformer (480V -> 208V)	$14,164	$12,743	$1,081	$10,897
Raceway / In-slab conduit	$18,059	$77,247	$18,059	$77,247
Electrical components (wire, receptacle)	$11,366	$20,131	$11,307	$20,049
Trenching for installation of conduit	$0	$0	$0	$0
Demolition of equipment	$0	$31,940	$0	$30,918
Pavings (asphalt & concrete)	$0	$7,889	$0	$7,889
Permitting & inspection fees	$2,435	$15,592	$2,435	$15,592
Construction management	$549	$4,449	$403	$4,264
TOTAL	$76,142	$239,909	$56,629	$215,051
TOTAL (Price per Port)	$1,410	$4,443	$1,049	$3,982

Table 13. Estimated Incremental Cost of Installing EV Infrastructure: 150-Unit MUD

	150-Unit MUD			
Retrofit	**Market Rate [NC]**	**Market Rate [Retrofit]**	**Affordable Housing [NC]**	**Affordable Housing [Retrofit]**
Level 2 Ports Added	23	23	0	0
Level 1 Ports Added	112	112	135	135
Electrical panel	$59,785	$83,699	$44,926	$62,896
Main electrical room, excluding transformer	$10,059	$49,276	$10,059	$49,276
Transformer (480V -> 208V)	$11,539	$49,742	$0	$40,621
Raceway / In-slab conduit	$45,147	$193,116	$45,147	$193,116
Electrical components (wire, receptacle)	$28,062	$49,833	$28,407	$50,317
Trenching for installation of conduit	$0	$0	$0	$0
Demolition of equipment	$0	$79,850	$0	$77,294
Pavings (asphalt & concrete)	$0	$8,442	$0	$8,442
Permitting & inspection fees	$5,798	$33,069	$5,798	$33,069
Construction management	$1,159	$6,655	$964	$5,196
TOTAL	$161,550	$553,682	$135,301	$520,227
TOTAL (Price per Port)	$1,197	$4,101	$1,002	$3,854

Table 14. Estimated Incremental Cost of Installing EV Infrastructure: 60-Space Office

	60-Space Office	
Retrofit	**Offce [NC]**	**Office [Retrofit]**
Level 2 Ports Added	2	2
Level 1 Ports Added	24	24
Electrical panel	$5,571	$13,004
Main electrical room, excluding transformer	$8,558	$35,005
Transformer (480V -> 208V)	$5,748	$7,786
Raceway / In-slab conduit	$0	$0
Electrical components (wire, receptacle)	$5,285	$9,031
Trenching for installation of conduit	$5,133	$4,562
Demolition of equipment	$0	$6,211
Pavings (asphalt & concrete)	$0	$6,305
Permitting & inspection fees	$4,448	$11,652
Construction management	$227	$3,414
TOTAL	$34,971	$96,970
TOTAL (Price per Port)	$1,166	$3,232

Appendix B: Permitting and Inspection Costs

Table 15 shows examples of permitting and inspection fees. These fees are not calculated in the model per project but as inputs based on the closest representative level for a project. Table 16 shows the details for these calculations based on the City and County of San Francisco and costs may vary by region.

Table 15. Examples of Total Permit and Inspection Cost Summary

	Stand-alone Retrofit			New Construction (Incremental Costs)		
# of Circuits	**Fee**	**Builder Staff Time**	**Total**	**Fee**	**Builder Staff Time**	**Total**
2	$461	$650	$1,111	$27	$75	$102
4	$1,365	$850	$2,215	$164	$125	$289

Table 16. Electrical and Building Permit and Inspection Cost Data

Electrical and Building Permit and Inspection Cost Data				
Electrical				
Fees				
$335	Minimum inspection fee, which covers from 1 to 3 inspections			
$11	Estimated average application fee per additional circuit beyond minimum			
Builder Time Costs				
New Construction, alterations &	Stand-alone Retrofit			
$25	$100	Builder staff time to obtain new permit (inclusive of travel)		
$25	$100	Builder staff time per inspection (inclusive of travel)		
$0	$150	Electrical engineer staff time for load calculations		
Building				
Fees				
New Construction, alterations, additions		*Stand-alone retrofit*		
Plan	Permitting	Plan	Permitting	
-	-	$ 144.85	$ 62.08	up to $500
-	-	$ 2.93	$ 1.26	per hundred from $500 up to $2000
-	-	$ 1.78	$ 0.76	per hundred from $2000 up to $50,000
$ 0.19	$ 0.10	-	-	per hundred from $5,000,000 to $50m
source: San Francisco Fee Table 1A-A				*note: only costs used in model are listed*
Builder Time Costs				
Incremental Cost, New	Retrofit			
$25	$100	Builder staff time to obtain new permit		
$0	$100	Builder staff time per inspection (inclusive of travel)		

Notes:

- Fees are calculated based on San Francisco Fee Table 1A-A (building) and Table 1A-E (electrical). New construction fees are based on the incremental cost of adding EV charging infrastructure to a project.
- Two building inspections are assumed for small retrofits, and no additional building inspections are assumed for new construction. One electrical inspection is assumed for adding two circuits and three are assumed for adding 12 circuits.

Appendix C: Methodology Details

This appendix provides additional details on the general assumptions used in the models, data sources for per unit equipment and other costs, and the methods used to determine the quantities needed for each expense type. This appendix does not contain data specific to the scenarios that were modeled, but rather a more general overview of the cost model.

General Assumptions

- Cost estimates include a fixed general overhead and profit factor.[44]
- Labor costs and equipment costs are based on cost estimates from RSMeans 2019 Q1 and utilize standard union rates.
- RSMeans cost data specified Sacramento, CA with a geographic correction which averaged the RS Means City Cost Index of San Mateo and San Jose.
- In some cases, RS Means contains minimum retrofit task costs.[45] Where related tasks had separate minimum task costs but the labor crew could likely perform more than one related task, the model applied one minimum labor charge.
- Building electrical infrastructure was sized utilizing W/ft^2 engineering calculations for lighting, air conditioning, and other major appliances.
- Building area was estimated using US Census Data
- Common area is assumed for Laundry usage
- Air Conditioner sizing was calculated based on California Climate Zone data for Zone 3 and Zone 4
- California CEUS[46] data is utilized to determine demand for offices

Data Sources

Estimates of per unit equipment and installation costs were based on retrofit and new construction costs from RS Means, a construction cost reference handbook and online tool for hardware and related installation costs. The City and County of San Francisco rates were used for permit and inspection fee sheets; and the authors estimated costs for contractor labor for permitting, inspections, site inspection, and architectural plans. Cost data from RS Means was for 2018 and was scaled to 2019 using U.S. Bureau of Labor Statistics Producer Price Index statistics. Additional data sources include: feedback from industry experts, engineering estimates, and direct experience to capture different tasks required for the scenarios that were analyzed. This appendix contains a list of all tasks included in the analysis.

---

[44] Individual RS Means line items related to overhead (under General Requirements) are assumed to be addressed by overhead and profit.
[45] Minimum task costs are typically not relevant for new construction due to the overall project scale.
[46] http://capabilities.itron.com/CeusWeb/ChartsSF/Default2.aspx

Soft Costs

Permit and Inspection Fees

Permitting costs for breaking concrete and electrical permit fees are based on available information from the City and County of San Francisco fees.[47] The total estimated costs include rough and final building and electrical permit fees where applicable. The cost for adding EV capable spaces during construction of a new building is assumed to be relatively low. Builder time spent towards permit filing and inspections is included at $100 per hour spent on site. Permit and inspection costs can vary between regions.

The model includes a small amount of labor to accommodate permitting and inspection of elements specific to EV capable parking spaces in new construction and alterations and additions, since these activities are already required and minimal additional effort should be needed to add EV capable infrastructure.

Since economies of scale occur with larger quantities, these fees generally scale up with increasing quantities of EV capable infrastructure, though they are not completely scalable. Costs are higher for outdoor circuits than for indoor circuits due to trenching and are higher for retrofits than for new construction or alterations and additions due to demolition, repaving, and repairs.[48]

ARCHITECTURAL PLAN FEES

Costs to add EV capable parking spaces to architectural plans and drawings will vary between projects based on their overall complexity. They are based on the estimated number of hours for each project and a fee of $150/hour before geographic adjustments. Costs will also vary if the project is new construction or a retrofit. In the former case, costs will be relatively minor because the architectural firm will likely be familiar with the plan of the building and can easily influence relevant design decisions like adding EV capable infrastructure. For retrofit projects, costs will likely be significantly higher due to the need to investigate and accommodate more complex on-site conditions such as: longer conduit runs, demolition and reconstruction, meeting accessibility requirements based on existing conditions, and/or more limited options for electrical room and panel placement.

A minimal incremental cost is required for adding several EV capable parking spaces to a new building or alteration and addition. In contrast, preparing construction plans for large numbers of EV capable parking spaces to an existing building may take a significant amount of time considering the layout and construction details for each parking space and existing site conditions. Costs will partially scale by the number of EV capable parking spaces.

LOAD STUDY/SITE CONDITIONS STUDY

Additional expenses are required for stand-alone retrofits at medium or large buildings to assess existing load and other conditions. The load study is necessary to determine the current electrical supply capacity, such as

[47] See Table 1A-A and Table 1A-E

[48] We note that efforts are underway to streamline permitting and inspections of EV charging infrastructure including EV capable parking spaces.

the transformer and other systems related to the main electrical supply and the current actual load.[49] The study will then determine which on-site upgrades may be needed to install EV capable parking spaces. In addition, site-specific conditions may need to be determined such as current concrete conditions, soils conditions, and/or other conditions. A load study at a facility where other site condition studies aren't needed is assumed to cost $1,000. Factors such as demolition and/or a greater number of EV parking spaces will drive costs up and a more complex study is assumed to cost $5,000 in this report (prior to prime contractor expenses). X-ray costs are roughly $1,000 for a half dozen images, which may be enough for retrofit installations at a medium sized facility, however, more may be required for a 150-space garage.[50] A specific site may require more or less resources depending on actual conditions.

Assuming alterations and additions originally intended for non-EV charging purposes will require an assessment of load and existing conditions, the assessment would also suffice for EV charging as well.

ELECTRICAL PANEL LOCATIONS AND SIZING

Some electrical panels are located in the main electrical room while others are distributed closer to EV parking spaces to reduce branch circuit lengths and costs. Distributed panels are more practical in locations with convenient wall mounting locations protected from weather and vandalism. All panel and sub-panel conduits are assumed to be installed in 1 ½ inch steel surface-mounted conduits for 225 ampere panels (to carry 250 MCM wire) or 2-inch conduits for 400 ampere panels (to carry 600 MCM wire) to provide a high level of protection and allow for easy visual inspection.

In some cases, a panel installed in new construction can be upsized to serve both base loads (such as garage lighting, elevators, and miscellaneous outlets) and EV charging loads. In other cases, panels for EV charging are sized to their maximum practical size (typically 400 amperes) just to meet EV charging needs. (Panels are generally limited by electrical panel capacity rather than physical size for EV electrical infrastructure. A single-phase 400-ampere panel has electrical capacity for 10 circuits and typically has physical space for 15 40-amperes circuits even if they utilize double slot 20-ampere breakers.)

The type of electrical panels will depend on whether a building is served by three-phase (4-wire) electrical service or one-phase (3-wire) electrical service. Medium and large commercial buildings and multifamily buildings usually receive three-phase service. When a panel receives three phases of electricity instead of one, it can accommodate additional EV capable parking spaces. However, the phases must be "balanced", which restricts how many additional circuits for EV capable parking spaces can be accommodated. We assumed that three-phase 225 ampere panels can accommodate 9 40-amp circuits and three-phase 400 ampere panels can accommodate 15 40 ampere circuits based on interviews with contractors and an electrical design firm.

---

[49] Transformers are usually sized based on the typical maximum actual load of a building. Unlike electrical panels and electrical circuits, transformers can be under loaded to extend their lifetime of fully loading, or even occasionally overloaded without causing an immediate reliability issue but with potential reduced long-term lifetime.
[50] Concrete X- Ray Imaging, Penhall, https://www.penhall.com/concrete-x-ray-imaging/ accessed 7-4-2019.

Construction Management

The model also includes a cost factor to represent additional fixed costs incurred by contractors for retrofit installations prior to project initiation. These costs include contractor time spent traveling to a site for surveying, evaluating existing conditions, estimating project costs, and preparing bids. Costs will vary based on the complexity of the project.[51] For new construction, these costs likely do not apply or require minimal additional effort to address EV capable electrical infrastructure. The construction management category also includes general permit application fees.

Raceways, Wire, and Termination Point

PVC materials (i.e. plastic) are included for branch circuit conduits installed in new construction of enclosed parking areas and alterations and additions to enclosed parking that remove the parking surface, while wall and ceiling-mounted metal conduit is assumed for stand-alone retrofits. The authors assumed that intermediate metal conduit was installed for any outdoor raceway in trenches to provide corrosion resistance and for any indoor retrofit cases where walls and floors will not be replaced. Additional raceways may be needed between floors and inaccessible areas.

1¼-inch raceways are generally assumed to carry up to twelve #8 wires rated at 40 amperes (three per circuit) to support 30-ampere EVSE, with the potential to add wiring for a fifth circuit where convenient.[52,53] Some additional raceways are also needed to serve individual termination locations (i.e. a main conduit run carrying four wires may end at one receptacle pair and a local distribution conduit would carry the other pair to its termination point). These short distribution raceways were also sized at one and a quarter inches for simplicity; though they could be sized at one inch or below, we do not expect that this difference would be significant. In some cases, raceways installed in-slab during new construction will accommodate more and/or higher capacity wires than retrofits that are wall mounted and encounter additional bends at corners and obstacles, limiting their capacity. These potential cost savings are site-specific and not included in the model. Wire is not included for branch circuits for EV capable parking spaces. Wires for any distributed panels that are noted in the scenario summary table are included in the costs.

The length of raceways within a given floor for enclosed parking at new construction and repaving are calculated based on direct routes from the electrical panel to the termination point since no obstacles are present during new construction. Retrofitting surface-mounted conduit is generally assumed to be twice as long in new construction because they must follow walls and ceilings with less direct routing. Compared to new construction, raceway distances are increased by 125 percent for gut rehabilitation because significant

---

[51] This estimate assumes that contractors win some of their bids for retrofit projects. The success rate will vary based on specific circumstances. For instance, a sole source contacting mechanism would result in a higher success rate while a contracting mechanism requiring three or more bids would result in a lower success rate. Actual costs will vary from project to project.

[52] Because EV charging is consider a continuous load, the circuit capacity must be at least 25 percent higher than the end load.

[53] We note that higher capacity #6 wire could also be installed at a rate of four sets per 1 ¼ inch conduit without larger sized conduit, unless conduit capacity is limited due to bends that restrict fill rates. For an example of allowable fill rates, see Elliot Electric Supply “Conduit Fill Table” at https://www.elliottelectric.com/StaticPages/ElectricalReferences/ElectricalTables/Conduit_Fill_Table.aspx.

portions of the building are removed while some obstructions may remain. Raceway distances are also increased by 150 percent for stand-alone retrofits in outdoor trenches to account for indirect routing (i.e. avoiding existing infrastructure). Surface mounted retrofit distances are increased by 200 percent, compared to new construction, due to the long distances to follow existing walls and to account for routing around existing obstacles.

Actual configurations can vary based on site-specific circumstances. For instance, if several EV parking spaces are located a significant distance from the main electrical panel, a single (larger) raceway run to an additional electrical panel closer to EV parking spaces can be installed with raceways branching from the panel to the planned EVSE location. This configuration would most likely save costs in buildings where the reduced length of raceways would exceed additional electric panel costs. Raceways for electrical panels outside of the main electrical room are sized (at ½ inch intervals, i.e. 1 ½ inch or 2 inches) based on the wire needed to serve that panel.

Conduits will generally terminate at a receptacle with an outlet box with a face plate and no EVSE (i.e. the unit that connects to the vehicle) installed at the time of construction. Local municipal building codes can also require a specific type of receptacle, which does not have a large impact on the cost-effectiveness of code. Receptacles are assumed to be installed in pairs to serve parking spaces on either side of the pair.

No additional curbs or bollards are assumed at the termination point. Local jurisdictions may wish to include a requirement for anchor points for EVSE near the termination point if the EVSE can be wall-mounted, which should not significantly affect the cost of EV capable building codes.

Demolition, Reconstruction, and Repaving

The model contains several job types related to demolition, construction, and repaving for stand-alone projects and projects where parking areas and/or electrical rooms are undergoing renovations that would allow installation of this equipment without any further demolition and reconstruction.

For both enclosed and surface parking, demolition for electrical rooms includes cutting and/or drilling, breaking large pieces into smaller pieces, minimum equipment/labor costs, loading and disposal. Reconstruction costs include concrete work (cost for pouring slabs is used as a proxy), reinforcing rods, forms, and minimum labor charges.

Demolition for parking areas include cutting a three-foot-wide section of pavement to allow two-foot-wide trenches; backhoe rental to trench, mobilization and operation, and disposal of materials. Some trenching would also be required for adding EV capable parking spaces in new construction, when repaving existing parking or adding parking. In these cases, costs would likely be much lower due to the presence of trenching equipment on-site to meet other project needs unrelated to EV capable parking spaces.

Contingencies

A 20 percent contingency was applied for stand-alone retrofit projects based on RS Means. Contingencies are necessary because specific challenges may not be visible at the start of a stand-alone retrofit project or because existing conditions may be difficult to alter without expanding the scope and cost of a retrofit project - for instance if an electrical room lacks space for additional panel(s) or was originally constructed far from parking spaces. A general contingency was not added for EV capable parking spaces installed as part of a larger retrofit project such as resurfacing or building new parking spaces at an existing site because the conditions will more closely resemble new construction, given their broader scope. In addition, specific cost increases were already included to address higher costs for alterations and additions compared to new construction, such as conservatively assuming that additional parking spaces would be located further from electrical power than existing spaces.

On top of this, another 20 percent contingency was applied to estimate potential costs for accessibility (ADA) compliance associated with restriping, adjusting path of travel, vertical clearances, and slope modifications. ADA compliance costs can be significant but are not the focus of this report.

Transformers

Transformer costs related to secondary or “step down” transformers have been incorporated into this cost model. Only the wiring costs are considered, not the additional costs for a concrete pad, or disposal of the previous transformer. As mentioned previously, these transformers are used to “step down” 480 V service to 208/240 V for buildings connected to 480 V power, which in PG&E’s service area consist of buildings in the 300kVA and up range. CARB has found that EV charging generally represents a relatively small fraction of overall building power demand in multifamily housing with 10% EV Capable parking spaces. These transformer upgrades are often not necessary to support EV charging infrastructure for buildings but may be more likely with the higher EV infrastructure requirements such as those considered in this report.

An electrical engineering firm and several contractors were consulted with and confirmed that they have found that levels of EV capable parking spaces proposed for CALGreen typically would not require a transformer upgrade, noting the typical headroom of 20% is usually sufficient to cover this growth. It was noted that in some cases, a potential off-site utility infrastructure upgrade could be required, as noted in the Primary Transformers section above.

In the case that EV infrastructure would trigger an expensive switchgear or transformer upgrade it should be investigated whether retrofits that include more energy-efficient lighting and other equipment meeting current mandatory California, ENERGY STAR®, and/or federal standards.

We expect that in cases where a transformer upgrade would be required to install EV capable infrastructure, building codes requiring EV capable parking spaces and associated electrical capacity could achieve significant cost savings related to these costs. Stand-alone transformer retrofits could require replacing conduits serving the transformer, replacing the transformer pad or adding a new pad, and adding an additional transformer or upgrading an existing transformer. By comparison, designing the electrical room for adequate capacity would allow the installation of larger sized conduits and/or transformer pads during initial construction at minimal cost. While we have not quantified all of these costs, the incremental cost of installing a 3” conduit instead of a 2” conduit would be very small compared to breaking existing concrete to install a larger sized conduit later.

Task Descriptions

Task descriptions for each scenario are listed below in Table 17. The table lists tasks with a note to designate where the task applies to retrofits, new construction, or both. A negative number indicates the avoidance of smaller electrical panel(s) due to installation of a larger panel. (Tasks that are listed with a “0” quantity were included as an option in detailed calculations used to determine project task descriptions, but the detailed design calculations resulted in a zero quantity for the specific task).

Table 17. Task Descriptions and Quantities

				60-unit MUD			150-unit MUD			Medium Office	
Task Description	Construction Type	Work Type	Unit	CALGreen	Market Rate	Affordable Housing	CalGreen	Market Rate	Affordable Housing	CalGreen	10% L2 40% L1
				Quantity for Each Scenario							
Rent core drill, electric, 2.5 H.P. 1" to 8" bit diameter, includes hourly operating cost	retro	demo	ea.		8	10		20	25		4
Rent mixer power mortar & concrete gas 6 CF, 18 HP, one day including 4 hours operating cost	retro	demo	Ea.		2	2		5	5		
Rent backhoe-loader 40 to 45 HP 5/8 CY capacity, one day including 4 hours operating cost	retro	demo	per day								3
Selective demolition, rubbish handling, dumpster, 6 C.Y., 2 ton capacity, weekly rental, includes one dump per week, cost to be added to demolition cost.	retro	demo	Week		2	2		5	5		0
Deconstruction of concrete, floors, concrete slab on grade, plain, 4" thick, up to 2 stories, excludes handling, packaging or disposal costs	retro	demo	S.F.		24	30		60	75		
Selective concrete demolition, reinforce less than 1% of cross-sectional area, break up into small pieces, excludes shoring, bracing, saw or torch cutting, loading, hauling, dumping	retro	demo	C.Y.		8	10		20	25		5
Selective concrete demolition, minimum labor/equipment charge	retro	demo	Job		2	2		5	5		
Concrete sawing, concrete slabs, rod reinforced, up to 3" deep	retro	demo	L.F.		24	30		60	75		16
Concrete sawing, concrete, existing slab, rod reinforced, for each additional inch of depth over 3"	retro	demo	L.F.		24	30		60	75		16
Selective demolition, concrete slab cutting/sawing, minimum labor/equipment charge	retro	demo	Job		2	2		5	5		1
Concrete core drilling, core, reinforced concrete slab, 2" diameter, up to 6" thick slab, includes bit, layout and set up	retro	demo	Ea.		60	60		150	150		
Receptacle devices, residential, duplex outlet, ivory, EMT & wire, 20', 15 amp, incl box & cover plate	new	electric	Ea.		27	23		68	56		12

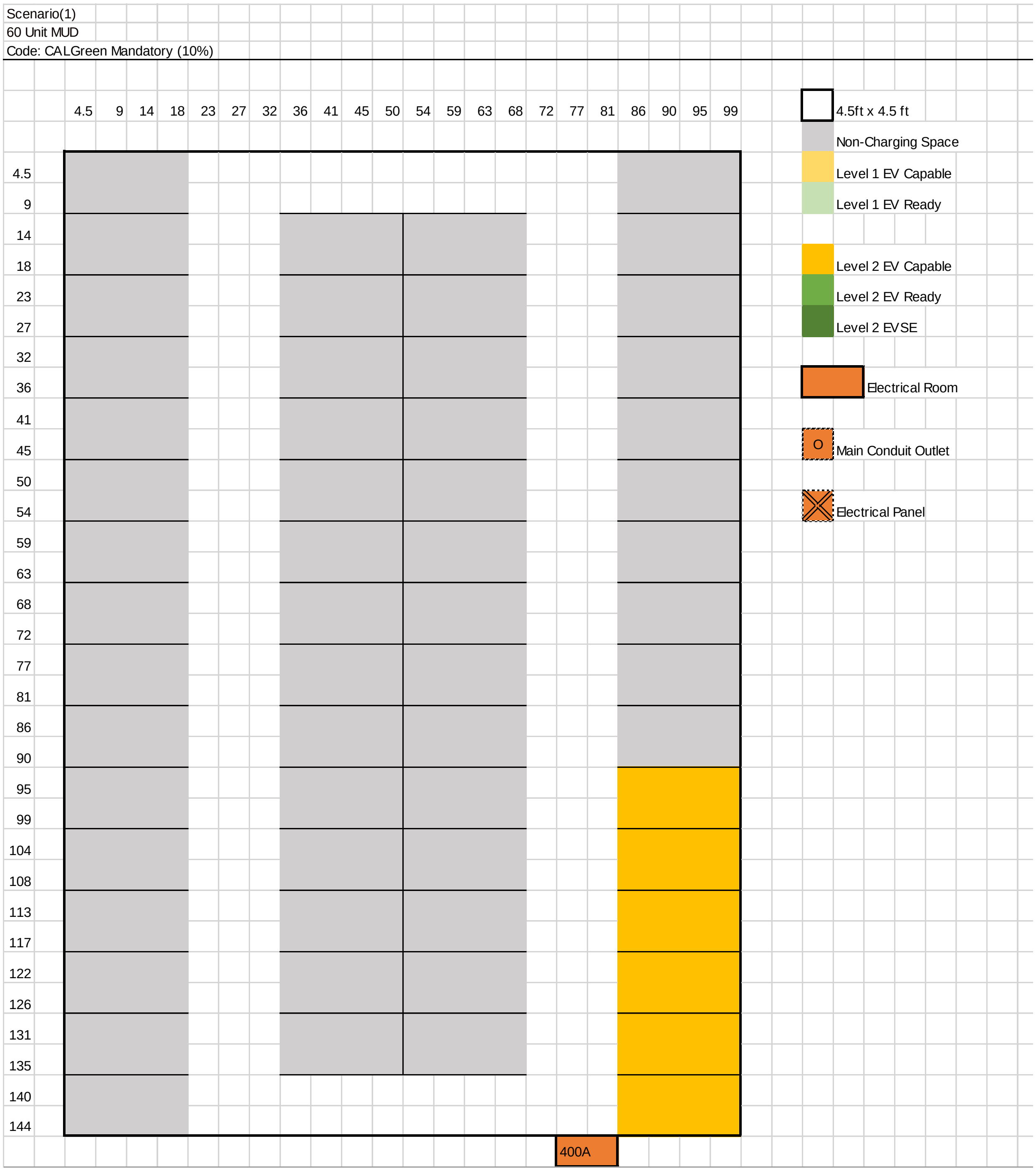
Task Description	Construction Type	Work Type	Unit	60-unit MUD			150-unit MUD			Medium Office	
				CALGreen	Market Rate	Affordable Housing	CalGreen	Market Rate	Affordable Housing	CalGreen	10% L2 40% L1
				Quantity for Each Scenario							
Receptacle, range, 50 Amp	retro	electric	Ea.		6	15		15	38		6
Receptacle devices, residential, duplex outlet, ivory, EMT & wire, 20', 15 amp, incl box & cover plate	retro	electric	Ea.		27	23		68	56		12
permitting & inspection, 2 internal circuits, excludes general building permit fees	new	fee	per job								
permitting & inspection, 4 internal and 2 external circuits, excludes general building permit fees	new	fee	per job							1	5
permitting & inspection, 4 internal circuits, excludes general building permit fees	new	fee	per job	1							
permitting & inspection, 14 internal circuits, excludes general building permit fees	new	fee	per job		1	1	1	1	1	1	1
permitting, per internal circuit over 4, excluding general buildling permit fees	new	fee	per ciruit	2	20	20	1	60	60	2	
permitting & inspection, 14 internal and 7 external circuits, excludes general building permit fees	retro	fee	per job				1	1	1		
permitting & inspection, 14 internal circuits, excludes general building permit fees	retro	fee	per job		1	1					1
permitting, per internal circuit over 4, excluding general buildling permit fees	retro	fee	per circuit		20	20		60	60		20
architectural plans/drawings	retro	fee	per hour	8	14	14	14	38	38	6	9
architectural plans/drawings	new	fee	per hour	2	4	4	4	12	12	2	3
site and load study	retro	fee	per $1000	1	3	3	3	5	5	1	2
Circuit Breakers - 480V 3-pole, 70 to 225Amp	new	main	Ea.	1	-1	-1					
Circuit Breakers - 480V 3-pole, 70 to 225Amp	retro	main	Ea.	1							
Switchboard - 3-pole, 4-wire, 400 Amp	retro	main	Ea.	1						1	
Circuit Breakers - 480V 3-pole, 450 to 600 Amp	retro	main	Ea.		1		1				
Circuit Breakers - 480V 3-pole, 700 to 800 Amp	new	main	Ea.			1					
Circuit Breakers - 480V 3-pole, 700 to 800 Amp	retro	main	Ea.			1					
Circuit Breakers - 480V 3-pole, 125 to 400Amp	new	main	Ea.								1
Circuit Breakers - 480V 3-pole, 125 to 400Amp	retro	main	Ea.								1
Circuit Breakers - 480V 3-pole, 15 - 60 Amp	retro	main	Ea.							1	
Distribution Switchboard Enclosure - 4 wire, 1000 Amp	new	main	Ea.					1	1		
Distribution Switchboard Enclosure - 4 wire, 1000 Amp	retro	main	Ea.					1	1		
Incoming Switchboards - 277/480V, 4 wire, 800 Amp	retro	main	Ea.			1					1
Incoming Switchboards - 277/480V, 4 wire, 800 Amp (w/ Fused Switch & CT Compartment)	new	main	Ea.					1	1		

Task Description	Construction Type	Work Type	Unit	60-unit MUD			150-unit MUD			Medium Office	
				CALGreen	Market Rate	Affordable Housing	CalGreen	Market Rate	Affordable Housing	CalGreen	10% L2 40% L1
				Quantity for Each Scenario							
Incoming Switchboards - 277/480V, 4 wire, 800 Amp (w/ Fused Switch & CT Compartment)	retro	main	Ea.					1	1		
Switchboard - 3-pole, 4-wire, 2000 Amp	new	main	Ea.					1	1		
Switchboard - 3-pole, 4-wire, 2000 Amp	retro	main	Ea.					1	1		
Switchboard - 3-pole, 4-wire, 600 Amp	retro	main	Ea.		1		1				
Switchboard - 3-pole, 4-wire, 800 Amp	new	main	Ea.			1					1
Switchboard - 3-pole, 4-wire, 800 Amp	retro	main	Ea.			1					1
Panelboards, 1 phase 3 wire, main circuit breaker, 120/240 V, 225 amp, 30 circuits, NQOD, incl 20 A 1 pole bolt-on breakers	new	panel						1		1	-1
Panelboards, 1 phase 3 wire, main circuit breaker, 120/240 V, 225 amp, 30 circuits, NQOD, incl 20 A 1 pole bolt-on breakers	retro	panel						1			
Panelboards, 1 phase 3 wire, main circuit breaker, 120/240 V, 400 amp, 30 circuits, NQOD, incl 20 A 1 pole bolt-on breakers	new	panel		1	1	-1			1		
Panelboards, 1 phase 3 wire, main circuit breaker, 120/240 V, 400 amp, 30 circuits, NQOD, incl 20 A 1 pole bolt-on breakers	retro	panel			1	2			1		1
Reinforcing steel, in place, dowels, smooth, 12" long, 1/4" or 3/8" diameter, A615, grade 60	retro	pave	Ea.		90	90		72	72		48
Structural concrete, in place, slab on grade (3000 psi), 4" thick, includes concrete (Portland cement Type I), placing and textured finish, excludes forms and reinforcing	retro	pave	S.F.		30	30		24	24		16
Structural concrete, in place, minimum labor/equipment charge	retro	pave	Job		1	1		1	1		1
PVC conduit, schedule 40, 1-1/4" diameter, in concrete slab, includes terminations, fittings and supports	new	race	L.F.	324	2147	2147	1080	5366	5366		
LV Transformer, Dry Type - 480V primary, 120/208V secondary (112.5 kVA)	retro	trans	Ea.		1						
LV Transformer, Dry Type - 480V primary, 120/208V secondary (75 kVA)	Retro	trans	Ea.								1
LV Transformer, Dry Type - 480V primary, 120/208V secondary (150 kVA)	Retro	trans	Ea.			1				1	
LV Transformer, Dry Type - 480V primary, 120/208V secondary (225kVA)	Retro	trans	Ea.	1							
LV Transformer, Dry Type - 480V primary, 120/208V secondary (300 kVA)	New	trans	Ea.		1						
LV Transformer, Dry Type - 480V primary, 120/208V secondary (500 kVA)	New	trans	Ea.			1					

Task Description	Construction Type	Work Type	Unit	60-unit MUD			150-unit MUD			Medium Office	
				CALGreen	Market Rate	Affordable Housing	CalGreen	Market Rate	Affordable Housing	CalGreen	10% L2 40% L1
				Quantity for Each Scenario							
LV Transformer, Dry Type - 480V primary, 120/208V secondary (500 kVA)	Retro	trans	Ea.					1			
LV Transformer, Dry Type - 480V primary, 120/208V secondary (750 kVA)	Retro	trans	Ea.				2		1		

Appendix D: EV Capable Installation Configurations

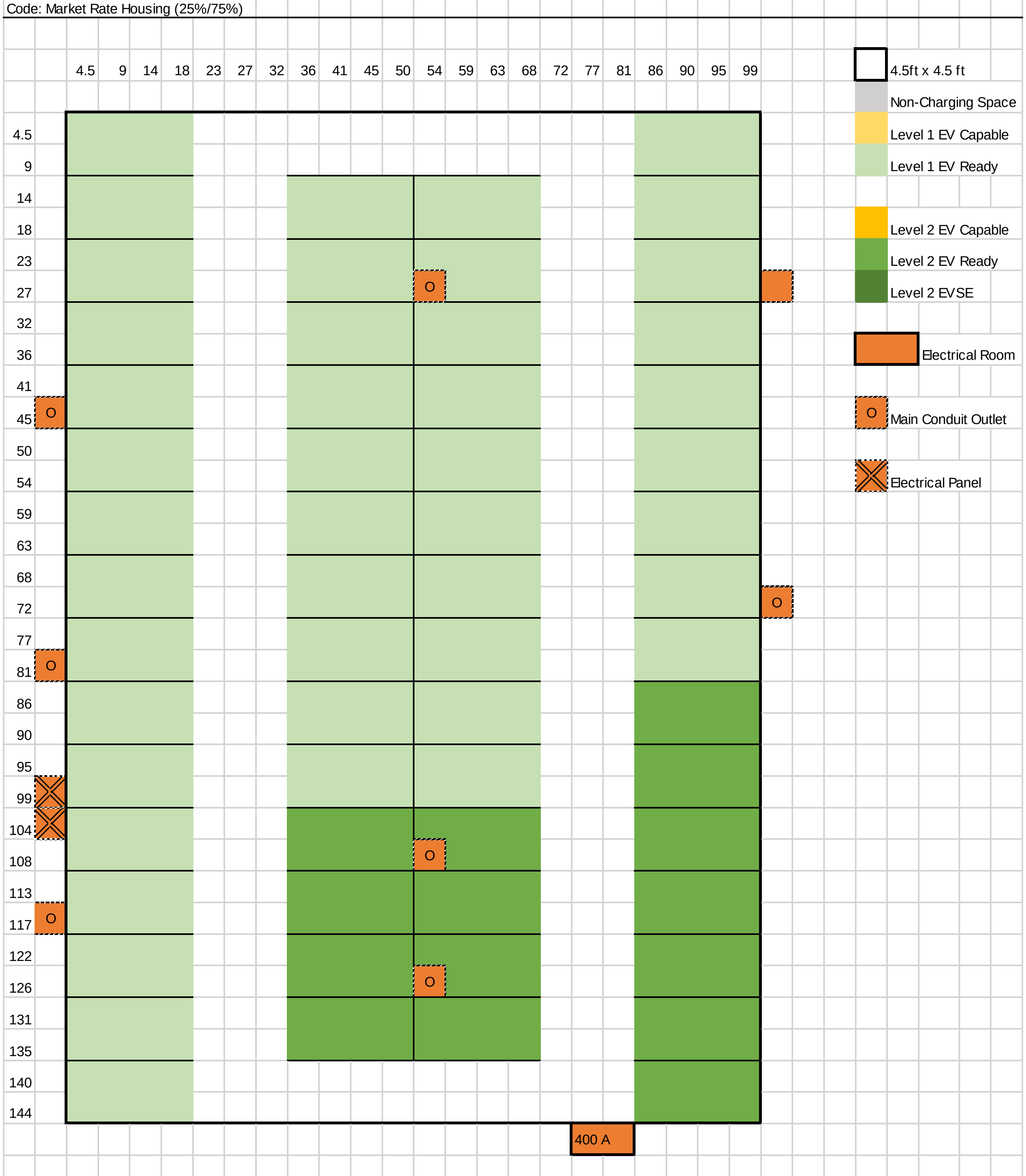
This section includes figures to generally depict the configuration of each scenario that was analyzed. They are not intended to include all details of a particular installation nor are they intended to represent any particular specific installation.



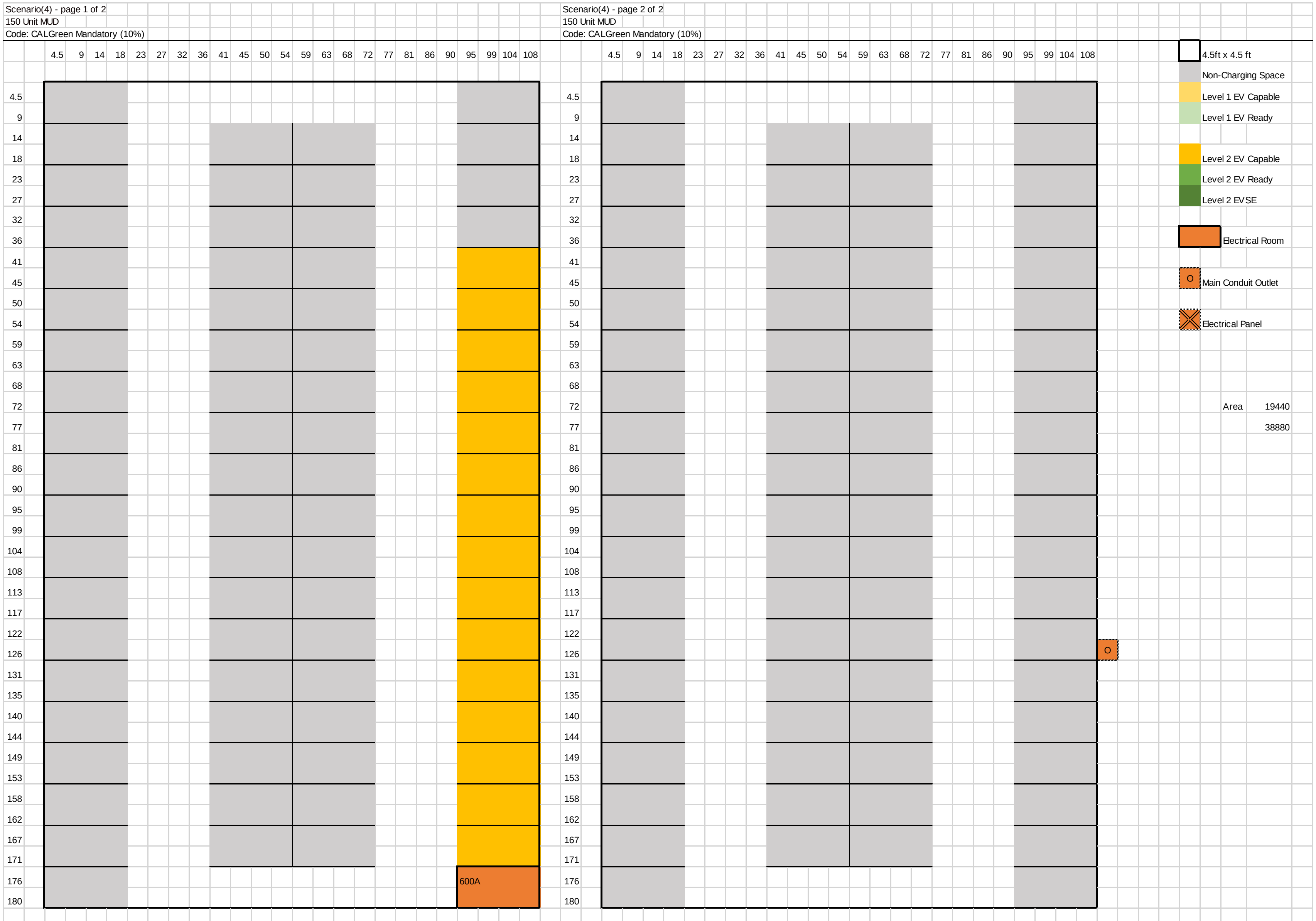
Scenario(2)

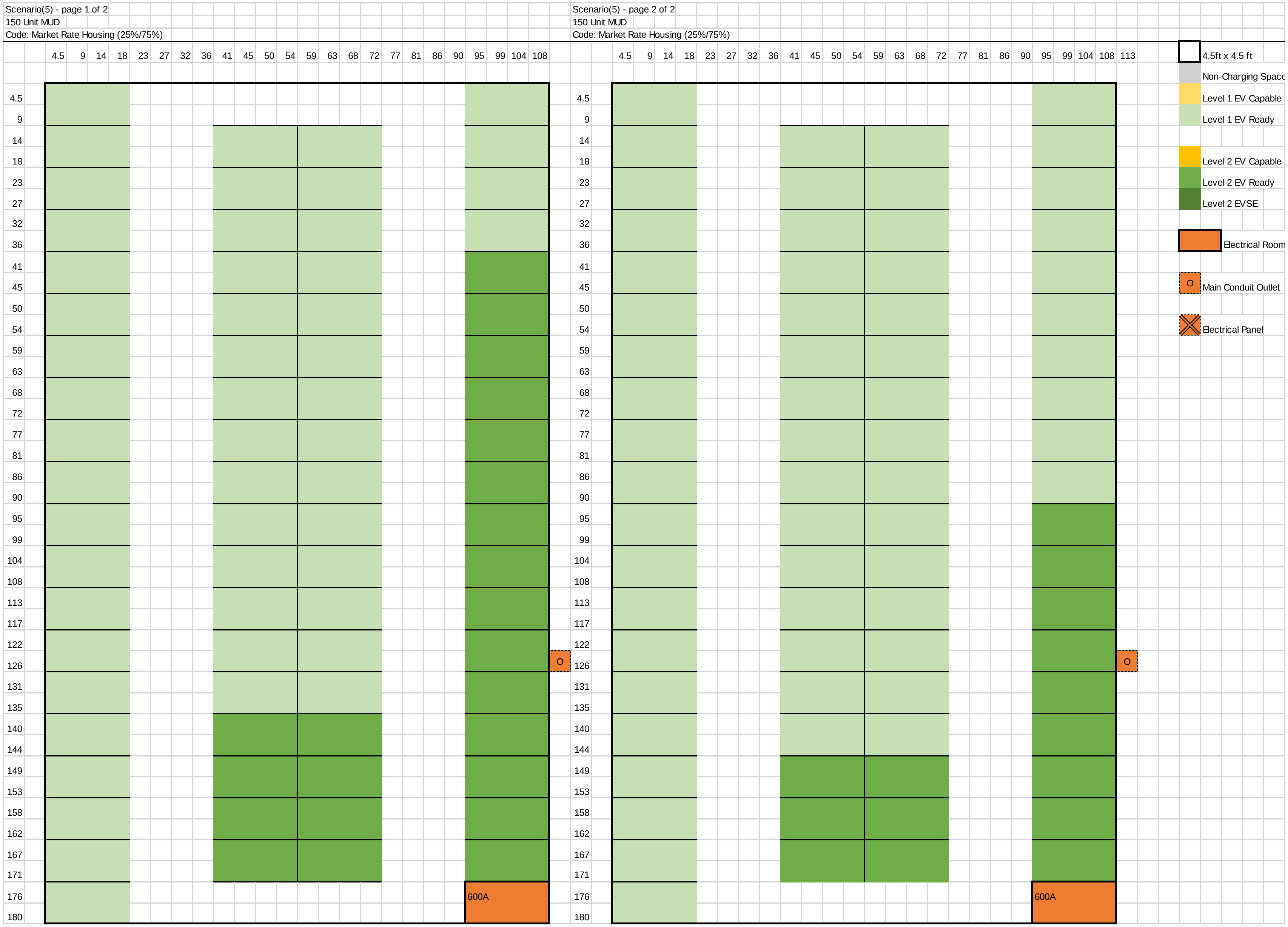
60 Unit MUD

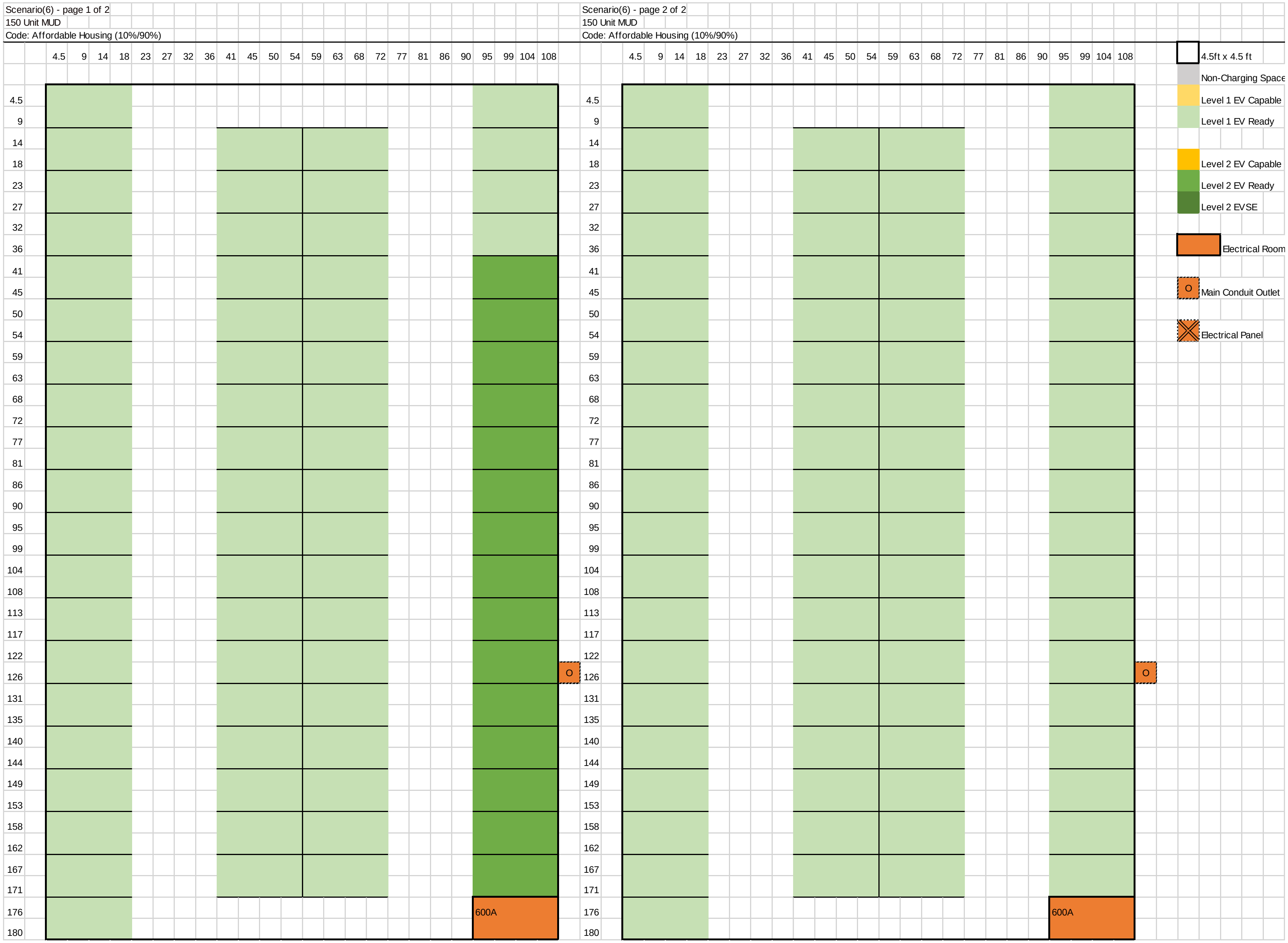
Code: Market Rate Housing (25%/75%)



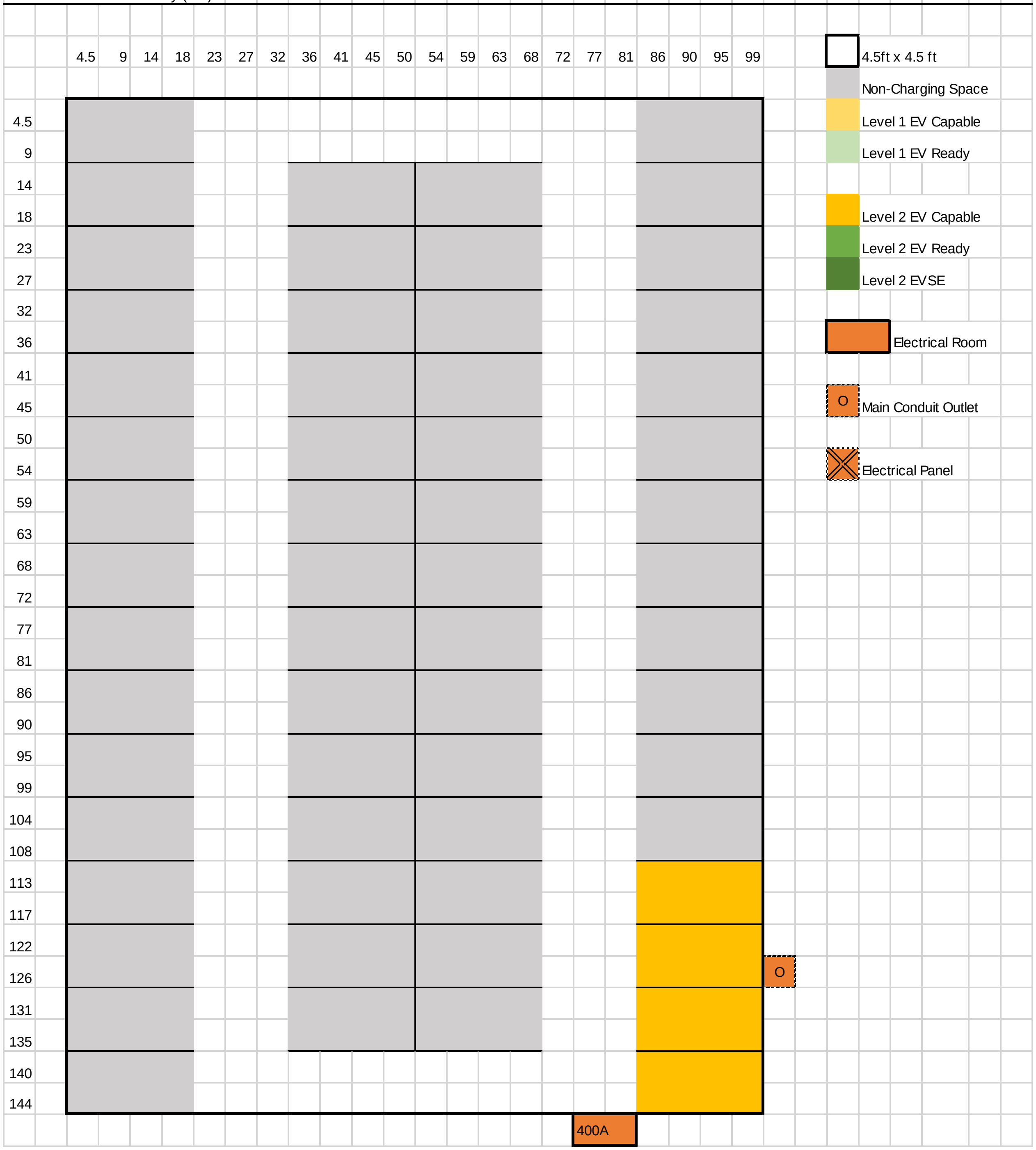
Scenario(3)
60 Unit MUD
Code: Affordable Housing (10%/90%)


Scenario(4) - page 1 of 2
150 Unit MUD
Code: CALGreen Mandatory (10%)
600A
Scenario(4) - page 2 of 2
150 Unit MUD
Code: CALGreen Mandatory (10%)
4.5ft x 4.5 ft
Non-Charging Space
Level 1 EV Capable
Level 1 EV Ready
Level 2 EV Capable
Level 2 EV Ready
Level 2 EVSE
Electrical Room
Main Conduit Outlet
Electrical Panel
Area 19440
38880


Scenario(5) - page 1 of 2
150 Unit MUD
Code: Market Rate Housing (25%/75%)
Scenario(5) - page 2 of 2
150 Unit MUD
Code: Market Rate Housing (25%/75%)
4.5 9 14 18 23 27 32 36 41 45 50 54 59 63 68 72 77 81 86 90 95 99 104 108
4.5 9 14 18 23 27 32 36 41 45 50 54 59 63 68 72 77 81 86 90 95 99 104 108 113
4.5 9 14 18 23 27 32 36 41 45 50 54 59 63 68 72 77 81 86 90 95 99 104 108 113 117 122 126 131 135 140 144 149 153 158 162 167 171 176 180
600A
O
4.5ft x 4.5 ft
Non-Charging Space
Level 1 EV Capable
Level 1 EV Ready
Level 2 EV Capable
Level 2 EV Ready
Level 2 EVSE
Electrical Room
O
Main Conduit Outlet
Electrical Panel


Scenario(6) - page 1 of 2
150 Unit MUD
Code: Affordable Housing (10%/90%)
600A
O
Scenario(6) - page 2 of 2
150 Unit MUD
Code: Affordable Housing (10%/90%)
600A
O
4.5ft x 4.5 ft
Non-Charging Space
Level 1 EV Capable
Level 1 EV Ready
Level 2 EV Capable
Level 2 EV Ready
Level 2 EVSE
Electrical Room
Main Conduit Outlet
Electrical Panel

Scenario(7)
60 Space Office
Code: CALGreen Mandatory (6%)



Scenario(8)

60 Space Office

Code: Reach Code (10%/10%/30%)