



A STATEWIDE UTILITY PROGRAM

Title 24, Part 11
Local Energy Efficiency Ordinances

Plug-In Electric Vehicle Infrastructure Cost-Effectiveness Report for San Francisco

Prepared for:
Codes and Standards Program
Pacific Gas and Electric Company

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Last Modified: November 17, 2016



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ACKNOWLEDGEMENTS

The PEV Infrastructure cost-effectiveness model used for this report leverages prior experience from research funded by the California Energy Commission.

The authors wish to express appreciation to the following reviewers:

- Shayna Hirschfield-Gold, City of Oakland
- Barry Hooper, City and County of San Francisco

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Executive Summary

This report estimates the costs associated with including Plug-in Electric Vehicle (PEV) charging infrastructure during initial construction for multi-family and nonresidential projects compared to retrofitting this infrastructure at a later date. The City and County of San Francisco is currently considering potential local building codes that would require PEV charging infrastructure as part of new construction and certain renovations.

This report finds that installing PEV charging infrastructure during initial construction is very cost-effective. Table ES-1 below shows that the cost for installing complete or nearly complete 240-volt 40-amp electric circuits as a retrofit is several times more expensive than installing this infrastructure during new construction. Installing infrastructure during new construction can avoid retrofit costs including breaking and repairing walls, longer raceways (also referred to as conduit) using more expensive methods and upgrading electric service panels. In addition, the soft costs such as permitting and inspections and project management are much lower for new construction.

Table ES-1. Estimated Cost-Effectiveness of San Francisco Proposal, Two Scenarios

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

The cost estimates in this report are based on the scenarios described below and cost factors from industry reference materials. These cost estimates are not intended to represent the costs of any specific installation and the report does not discuss costs outside of building code compliance. These additional costs can include Electric Vehicle Supply Equipment (EVSE) that plugs into the PEV, associated lighting, signage, any required bollards, etc.



Purpose and Policy Background

The purpose of the Plug-in Electric Vehicle Infrastructure Cost-Effectiveness model and summary report is to document the expected cost-effectiveness of installing PEV charging electric circuit infrastructure during new construction and major alterations of multi-family and nonresidential buildings. A lack of PEV charging infrastructure is a key challenge for meeting California PEV adoption goals as noted in the 2016 California Zero Emission Vehicle (ZEV) Action Plan. This documentation will help local governments such as the City and County of San Francisco and others consider local building code requirements that support PEV charging infrastructure installation to address this challenge. This infrastructure will facilitate PEV adoption and thus also reduce greenhouse gases and other pollutants as well as petroleum dependence.¹

The California Green Building Code (CALGreen) is formally adopted statewide by the California Building Standards Commission (BSC) for residential and nonresidential buildings and contains statewide minimum PEV charging electrical infrastructure requirements summarized in Table 1. The residential section is authored by the California Department of Housing and Community Development (HCD) and the nonresidential section is authored by the BSC. CALGreen requirements for PEV-ready parking spaces in new construction (Title 24 Part 11 sections 4.106 and 5.106) include sufficient electrical panel capacity and installing raceways through locations that are much easier and more economical to access during construction than as a retrofit.

Table 1. Summary of CALGreen Mandatory and Voluntary PEV Readiness Standards

	Nonresidential				Multi-family dwelling	
	Mandatory		Tier 1	Tier 2		
	Current	Effective Jan. 1, 2017	Effective Jan. 1, 2017		Current Mandatory	Current Voluntary
Minimum threshold	51 parking spaces	10 parking spaces	10 parking spaces	One parking space	17 units	17 units
Percent of new parking spaces that must be EV Ready	3%	~6% ²	~8%	~10%	3%	5%

CALGreen also contains voluntary model requirements for some sections of the code including PEV charging infrastructure (Title 24 Part 11 sections A4.106 and A5.106). Local governments may choose to adopt the model requirements (or “Tiers”) as-is, which then become mandatory in

¹ Avoided emissions from displacing a typical vehicle’s 15,600 miles annual range with electrically powered miles include 2.6 tons per year of avoided greenhouse gases. This value accounts for upstream emissions from electricity and oil production. Annual mileage is from “Factors Influencing Vehicle Miles Traveled in California: Measurement and Analysis”, Kent M. Hymel, 2014. Emissions rates for a conventional vehicle and for a 2012 Nissan Leaf powered on California electricity are from “[Calculating Electric Drive Vehicle Greenhouse Gas Emissions](#)”, Ed Pike, 2012.

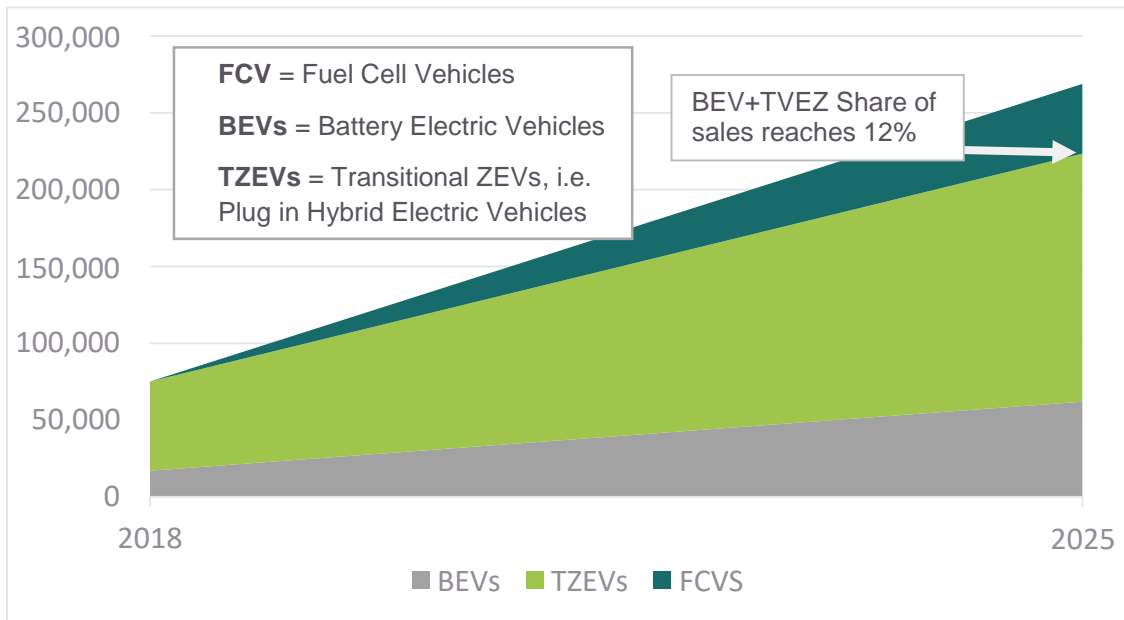
² The number of parking spaces that must be PEV-ready are assigned based on total parking spaces in a batch allocation system rather than an exact percentage, so percentages shown here are approximate.



their jurisdiction, or adopt tailored local codes based on specific local findings.

A number of jurisdictions in the Bay Area and beyond have adopted local code or are considering local code adoption because CALGreen minimums are not high enough to meet California PEV deployment goals and expected local demand. California will need to achieve a 12% statewide PEV market share by 2025 to meet the California Air Resources Board Zero Emission Vehicle program target of 1.5 million zero emission vehicles on the road by 2025 as shown in Figure 1.³ California is already ahead of CARB’s expected trajectory to that goal; as of November 2016, there were already more than 250,000 PEVs on the road in California, nearly half of all electric vehicles in use nationally.⁴ The current sales rate of approximately 4% exceeds CARB’s expected trajectory by about 50%,⁵ so 12% may represent a floor with actual PEV market share potentially much higher. In addition, the 2016 ZEV Action Plan notes that upwards of 1,000,000 charge points will likely be needed at homes, workplaces and public locations by 2020. Furthermore, nearly 100% of new passenger vehicles sold in California between 2040 and 2050 must be ZEVs in order to meet the state’s long-term climate goals, and similar goals in cities such as San Francisco. Thus, a dramatic increase in PEV charging infrastructure is needed immediately, and to provide flexibility for growth over the life of each new building.

Figure 1. Annual Electric Vehicle Sales Under CARB Most Likely Compliance Pathway⁶



In addition, Bay Area communities such as San Francisco currently have much higher PEV demand than statewide averages, despite challenges such as very limited PEV charging infrastructure in multi-family housing. Figure 2 below shows that the Bay Area forms a PEV

³ The California fleet consists of 27 million vehicles per the 2013 California Energy Commission draft IPER report page 173, leading to an estimated 5% PEV deployment in 2025 and sales percentages much higher.

⁴ California PEV Collaborative - <http://bit.ly/capevcollabnov2016>

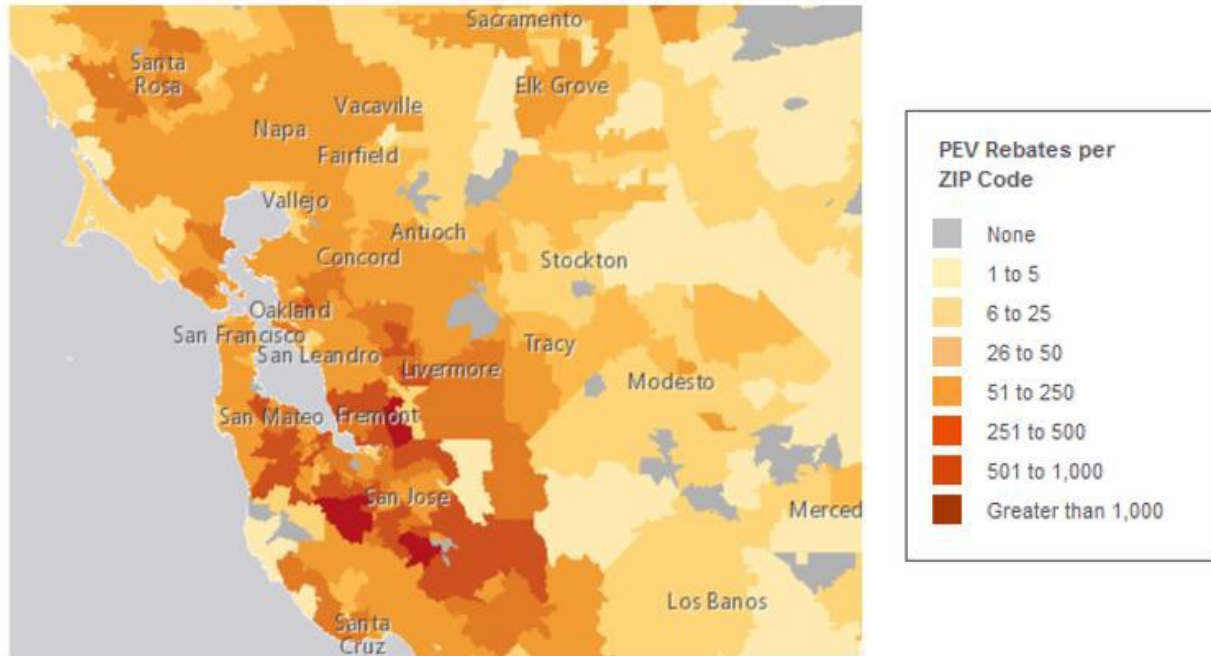
⁵ See CARB “[Staff Report: Initial Statement of Reasons for Rulemaking](#)”, September 2013, and the Plug in Electric Vehicle Collaborative “[Detailed Monthly Sales Chart](#)”, April 2016.

⁶ This figure is based on CARB’s “Staff Report: Initial Statement of Reasons Advanced Clean Cars 2012 Proposed Amendments to the California Zero Emission Vehicle Program Regulations” December 7, 2011.



adoption “hot spot.” This figure is based on PEV rebates per zip code. (The number of households per zip code may vary.)

Figure 2: Clean Vehicle Rebate Program Rebate Heat Map by ZIP Code⁷



Building codes can provide significant benefits towards meeting these goals locally due to the considerable potential for new construction in San Francisco. At the time of this report, San Francisco’s development pipeline includes more than 71,000 housing units proposed or under construction, and 32 million square feet of new nonresidential uses. While future development trends may vary, this information indicates that adopting local building codes would affect a significant number of future parking spaces.⁸

Building codes will also benefit landlords and tenants. Electric vehicle charging infrastructure is an amenity that can help residential and commercial landlords attract tenants. In addition, the California legislature mandated in 2015 that building owners allow residential tenants in buildings with 6 or more parking spaces to install electric vehicle charging equipment at their own expense upon request. Since the cost of supplying power to an electric vehicle charger is much less when included in new construction, providing electrical infrastructure during original construction will better serve tenants. Thus, building codes will facilitate convenient access to electricity so that residents, commuters, fleets and car sharing services can benefit from the significant operating cost advantages that PEVs provide.

⁷ Downloaded November 15, 2016 from [California Clean Vehicle Rebate Program](#). Please note that not all PEVs sold in California are in the CVRP database, as not every vehicle is eligible and not every owner applies for a rebate.

⁸ Totals are calculated from data available in the [San Francisco Planning Department Pipeline Report](#) accessed 11-15-2016. While the local code proposal would not apply to units already under construction, developers could voluntarily choose to meet these requirements.



Scenarios

The PEV Infrastructure Cost-Effectiveness model has been adapted from the July 2016 PEV Infrastructure Cost-Effectiveness report developed by Energy Solutions for the City of Oakland. The updated version focuses on the effect of a local code proposal summarized below in Table 2. The City and County of San Francisco is currently considering adoption of this proposal and other jurisdictions are considering similar proposals.

Table 2. Potential Local Building Code Requirements⁹

	Full Circuit	Full Circuit Minus Wire	Inaccessible Raceways	Electric Panel Capacity
Greater than 20 parking spaces	10 percent of parking spaces (rounded up)	10 percent of parking spaces (rounded up)	Install inaccessible raceways at all remaining parking spaces	sufficient to supply 20 percent of spaces at a time (rounded up)
16-20 parking spaces	2 parking spaces	2 parking spaces		sufficient to supply 4 parking spaces
11-15 parking spaces	2 parking spaces	1 parking spaces		sufficient to supply 3 parking spaces
2-10 parking spaces	2 parking spaces	NA		sufficient to supply 2 parking spaces
1 parking space	1 parking space	NA		sufficient to supply 1 parking space

Table 3. Scenario Descriptions

	Scenario A – 10 Parking Spaces	Scenario B – 60 Parking Spaces
Parking Type	one level enclosed garage	two level enclosed garage
PEV Parking Spaces	two	twelve
Base Case Panel	100-amp	two 100-amp
PEV-readiness Panel	200-amp	two 400-amp
Raceway length*	new construction: 40 feet retrofit: 80 feet	new construction: 188 feet retrofit: 360 feet

*Scenario B includes eight feet of raceways for inaccessible locations. The length of raceways for inaccessible locations will vary significantly based on site-specific circumstances.

Two scenarios are included in the model. The first scenario, as summarized in Table 3, is a multi-family or nonresidential building with a ten space enclosed parking area. The electric service panel would be upgraded from 100-amp to 200-amp to support two 240-volt 40-amp circuits. Additional PEV charging infrastructure would include installing in-slab raceways, breakers, an outlet box, and wire to serve two PEV parking spaces. The raceways needed for additional PEV parking spaces could be located in accessible areas and thus would not be required at the time of construction in

⁹ Each element is tailored to serve a specific purpose. Full electrical circuits will provide the most convenient solution for installing EVSE. Including some full electric circuits except for wire could provide additional flexibility to support different levels of charging in the future since raceways are typically oversized and thus could potentially support larger wire for faster charging rates. Installation of raceways in locations that are only readily accessible during new construction is a low cost method of enabling future expansion. Some buildings have assigned or deeded parking spaces, reinforcing the benefits of enabling PEV charging infrastructure for each parking space.



this scenario. In both scenarios, raceways installed in the concrete slab during new construction result in more direct routing and shorter lengths, as well as less expensive materials and installation.¹⁰

The second scenario is a larger building with a two level, 60-space enclosed parking area. Six PEV parking spaces would be served by full 240-volt 40-amp electric circuits and six PEV parking spaces would be served by full electric circuits minus wire. Two 100-amp main circuit breakers (3 wire, 3 pole) would be required to support lighting and other loads in the base case and would be upgraded to two 400-amp panels, one on each level, to achieve support PEV charging infrastructure. Electrical circuits would pass through a six-inch-thick wall. Raceways to support the additional 48 parking spaces would be installed through the electrical room wall (with relatively minimal cost), and additional raceways for these parking spaces could be added in accessible areas as needed.

Modeling for the two scenarios does not include accessibility requirements such as slope, vertical clearance, and path of travel.¹¹ Local codes that address accessibility at the time of new construction, such as the City and County of San Francisco code proposal, can result in significant cost savings compared to retrofitting parking areas later.

While most parking associated with multi-family and nonresidential buildings in San Francisco is located in enclosed garages, some parking is located in surface lots. The July 2016 PEV Infrastructure Cost-Effectiveness report demonstrates that installing PEV charging infrastructure during new construction is even more cost-effective in the case of surface parking areas than the results shown below for enclosed garages.

Results

The results of the cost-effectiveness analysis for this report show that installing a complete electric circuit for PEV charging during new construction provides major cost savings compared to the cost of retrofitting this equipment. This study estimates that retrofitting installation of full electric circuits for PEV charging at an existing building costs about \$2,370-\$3,710 per parking space as shown below in Table 4. The same infrastructure would cost about \$860-\$920 per space if installed during new construction. To determine the cost per parking space, the total incremental cost of increasing PEV charging infrastructure due to the City and County of San Francisco code proposal was divided by the number of PEV parking spaces with complete or nearly complete electrical circuits.

¹⁰ Some sections of raceways can likely be shared and some will be dedicated to one specific circuit. Half of raceways are assumed to be shared by two wires, with the other half holding a single wire, for Scenario B. The sharing of raceways varies based on infrastructure configuration in Scenario A.

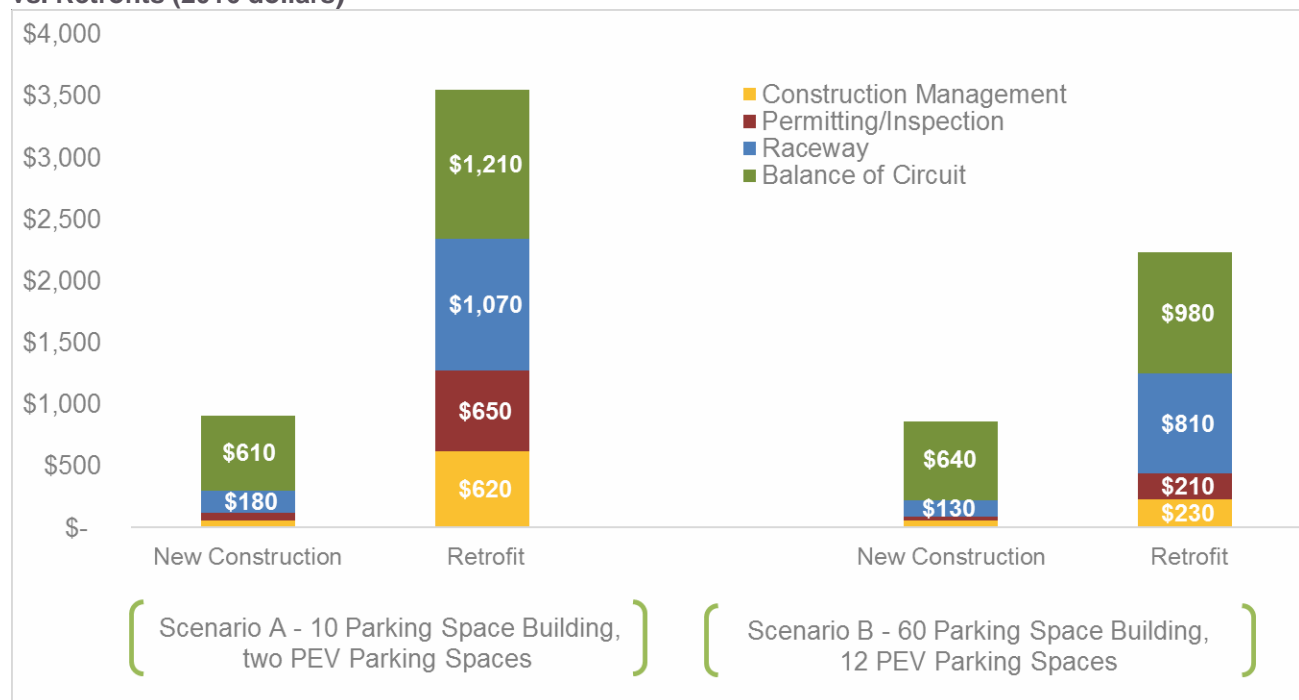
¹¹ For instance, see Chapter 11B and the residential section of CALGreen. The City and County of San Francisco is considering local code requirements to address these requirements in addition to local code requirements that address electrical charging infrastructure.

Table 4. Estimated Cost-Effectiveness of San Francisco Proposal, Two Scenarios

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

Figure 3 below summarizes the major categories of costs, which include breaking and repairing parking lots and sidewalks, upgrading electrical service panels, obtaining permits and inspections, and installing electrical circuits or elements of electric circuits. Permitting and inspection are a common expense for all building types, though higher for retrofits as explained in Appendix B and Appendix C. Electrical panel upgrades will be required in some cases depending on existing panel capacity and PEV charging capacity needs. This analysis is not intended to address every possible site-specific cost. Actual costs for any specific installation will vary due to site-specific conditions.

Figure 3. Relative Cost per PEV Charging Space of PEV Charging Infrastructure in New Construction vs. Retrofits (2016 dollars)



The results indicate that applying PEV-charging infrastructure building codes to building alterations would also provide potential cost savings. For instance, installing underground raceways during parking area expansion or renovation could potentially achieve much or all of the cost savings for conduit installation during new construction. Requiring that new electrical service panels contain capacity for PEV charging could similarly avoid significant costs for retrofitting expanded electrical service later. Data from the Construction Industry Research Board indicates that alterations and additions represent about 21% of the value of permitted construction for both residential and



nonresidential new construction statewide.¹² The share of alterations and additions is likely to be higher in San Francisco since most land is already developed, leading to significant potential for PEV charging infrastructure in alterations and additions as well as in new construction as noted earlier.

Methodology

The cost-effectiveness model was developed in Microsoft Excel and utilizes spreadsheets that break each scenario and level of PEV charging infrastructure 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, which is a construction cost reference handbook, for hardware and related installation costs. Additional costs are based on staff estimates for contractor labor for permits and inspections and City and County of San Francisco listed permit and inspection fees. Additional information used in the model includes feedback from industry and utility experts, engineering estimates, and direct experience to capture different tasks required for the scenarios that were analyzed. For additional details on the methodology and information specific to the PEV charging infrastructure details, please see Appendix C.

The cost-effectiveness model includes hypothetical installation scenarios to allow easy comparison of costs between different levels of PEV charging infrastructure for both new construction and retrofit projects. Actual project costs and configurations will vary; thus these cases are intended to provide representative examples for comparison purposes rather than to estimate site-specific costs. PEV charging infrastructure building code requirements can also reduce or avoid non-cost barriers such as coordinating between building owners/operators and tenants, lack of awareness of PEV charging as an option, and the effort of undertaking a construction project in order to be able to fuel a PEV. The modeled costs exclude design work and also other project-specific costs outside the scope of PEV charging infrastructure building code compliance such as signage, lighting, pedestal mounts, bollards, wheel stops, longer raceways, and contingencies.¹³

The model also does not include utility-side infrastructure such as sizing transformer pads and connections to accommodate potential swap-out for a larger capacity transformer.¹⁴ Furthermore, the scenarios also 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.¹⁵

¹² [“Non-Residential Building Permits By Month”](#), accessed 6-15-2016 and [“Residential Building Permits By Month”](#), accessed 6-15-2016.

¹³ RS Means specifies a range of potential design costs, while noting that design costs will likely be 50% higher for alterations.

¹⁴ Sizing a transformer pad and connections for a transformer with the capacity to accommodate expected future PEV charging load is a significant source of cost savings, even if a larger transformer is not actually installed until later when required to accommodate PEV load. A report prepared by HCD – “Report on Electric Vehicle Readiness” (November 2013) provides some data on transformer costs.

¹⁵ 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. We 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 we have not quantified this potential.



Appendix A: Cost Estimates by Type of Expense

The table below summarizes model results per parking space with a complete or nearly complete PEV charging electrical circuit. 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 cost per building, including in some cases some small additional cost for PEV-readiness at additional spaces as explained earlier, by the number of PEV parking spaces with complete or nearly complete electrical circuits.¹⁶ The additional cost for PEV-readiness beyond parking spaces with complete or near complete circuits affects only Scenario B and does not affect the results presented below by more than five percent.

The individual expense types for Scenario B reflect a PEV parking space with a full circuit including wire, while the total is slightly different because it is an average of all PEV parking spaces including some without wire.

Table 5. Cost Results by Type of Expense

	PEV Circuits Retrofit	PEV Circuits New Construction
<i>Scenario A - 10 Parking Space Building, two PEV Parking Spaces</i>		
Construction Management	\$619	\$64
Permitting/Inspection	\$654	\$62
Raceways	\$1,065	\$178
Excavation	\$0	\$0
Concrete/Paving	\$0	\$0
Demolition	\$160	\$0
Balance of Circuit	\$1,214	\$613
Total	\$3,713	\$917
<i>Scenario B - 60 Parking Space Building, 12 PEV Parking Spaces</i>		
Construction Management	\$228	\$61
Permitting/Inspection	\$207	\$27
Raceways	\$810	\$133
Excavation	\$0	\$0
Concrete/Paving	\$0	\$0
Demolition	\$140	\$0
Balance of Circuit	\$1,021	\$655
Total	\$2,369	\$858

¹⁶ Half of spaces in Scenario B do not include wire based on the City and County of San Francisco proposal.



Appendix B: Permitting and Inspection Costs

Table 6. Total Permit and Inspection Cost Summary

Scenario	# of Circuits	Retrofit			New (Incremental Costs)		
		Fee	Builder Staff Time	Total	Fee	Builder Staff Time	Total
A	2	\$ 461	\$ 650	\$1,111	\$ 27	\$ 75	\$ 102
B	12	\$1,365	\$ 850	\$2,215	\$ 164	\$ 125	\$ 289

Table 7. Electrical and Building Permit and Inspection Cost Data

Electrical and Building Permit and Inspection Cost Data					
<i>Electrical</i>					
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					
Retrofit	New Construction (Incremental Cost)				
\$100	\$25	Builder staff time to obtain new permit (inclusive of travel)			
\$100	\$25	Builder staff time per inspection (inclusive of travel)			
\$150	\$0	Electrical engineer staff time for load calculations			
<i>Building</i>					
Fees					
<i>New Construction</i>			<i>Alterations</i>		
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					
Retrofit	Incremental Cost, New				
\$100	\$25	Builder staff time to obtain new permit			
\$100	\$0	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 PEV charging infrastructure to a project. Plan check fee are included for the incremental cost for adding PEV charging infrastructure in new construction (the total project cost would exceed plan check thresholds) and for retrofitting 6 or more spaces. Two building inspections are assumed for 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

General Assumptions:

- Cost estimates include a fixed general overhead and profit factor.¹⁷
- Labor costs are based on union labor. The use of union labor will vary from project to project.
- Geographic adjustments are based on 2010 RS Means Electrical Cost Data page 465. Table 8 shows San Francisco adjustments to RS Means national construction costs for labor and materials.
- In a number of cases RS Means contains minimum retrofit task costs.¹⁸ In these cases the lesser of the minimum task cost or the sum of the actual task costs was applied. Where related tasks had separate minimum task costs but the labor crew could likely perform more than one related task, the model applies one minimum labor charge.

Table 8. Regional Factors Compared to National Average¹⁹

	San Francisco	
	labor	materials
Cost Multiplier	1.44	1.107

Data Sources:

Estimates of retrofit and new construction costs are based on data from RS Means Quarter 3 2013, a construction cost reference handbook and online tool, for hardware and related installation costs; City and County of San Francisco permit and inspection fee sheets; and the authors' estimates for contractor labor for permitting and inspection. Costs were escalated to 2016 using US Bureau of Labor Statistics Producer Price Index statistics for materials²⁰ and California Director of Industrial Relations labor costs for San Francisco from 2013 to 2016.²¹ Additional data sources included feedback from industry experts, engineering estimates and direct experience to capture different tasks required for the scenarios that were analyzed. Table 9 below contains a list of all tasks included in the analysis.

¹⁷ Individual RS Means line items related to overhead (under General Requirements) are assumed to be addressed by overhead and profit.

¹⁸ Minimum task costs are typically not relevant for new construction due to the overall project scale.

¹⁹ Data is sourced from RS Means Electrical Cost Data 2010 p482. The national average =1.0. The regional factor is also adjusted to account for the faster escalation in San Francisco labor costs from 2013 to 2016 compared to other regions.

²⁰ Material cost adjustments from 2013 to 2016 are based on the Producer Price Index category 1175 "[Switchgear, switchboard and industrial controls](#)" relative index from Nov 2013 to March 2016 which shows virtually no change.

²¹ See <http://www.dir.ca.gov/OPRL/main.htm> for prevailing wage and superseded prevailing wage determinations for electrical job categories.



Soft Costs:

Permit and Inspection Fees

Permitting costs for breaking concrete and electrical permit fees are based on City and County of San Francisco fees in Table 1A-A and Table 1A-E. The total estimated costs include rough and final building and electrical permit fees where applicable. The cost for adding PEV infrastructure tasks to construction of a new building is assumed to be relatively low. Builder staff time for permit filing and inspections are included at \$100 per hour spent on site. Permit and inspection costs may vary between regions.

The model includes a small amount of labor to accommodate permitting and inspection of PEV infrastructure-specific elements in new construction because permitting and inspection are already required and minimal additional effort is expected to add PEV charging infrastructure. Please see Appendix B for more details.

Construction Management

The model includes a general overhead rate of 7.5% for both new and retrofit projects.

The model also includes a cost factor to represent additional fixed costs incurred by contractors for retrofit installations prior to project initiation. This additional cost represents contractor time spent on-site and traveling to survey and evaluate existing conditions as well as time spent estimating project costs and preparing bids. The estimated cost is \$300 per contractor bid and \$600 per successful project.²² For new construction, these costs likely do not apply or require minimal additional effort to address PEV charging electrical infrastructure.

Raceways, Wire, and Termination Point:

The length of raceways within a given floor are assumed to be half as long in new construction compared to wall and ceiling mounted retrofits with less direct routing. PVC materials are included for raceways installed in new construction compared to more expensive materials and installation methods for retrofits. Additional raceways may be needed between floors, and for inaccessible areas.

Raceways are each assumed to serve 40-amp electric circuits. We note that wire serving higher capacity Level 2 chargers (i.e. up to 19.2 W) could likely be accommodated by the 1 ¼ inch raceways, and if slightly higher size raceways were required the cost differential would be small. Raceways installed in-slab during new construction will in some cases accommodate more and/or higher capacity wires than retrofits that are wall mounted due to additional bends at corners and obstacles at many retrofits. This potential cost savings is site-specific and not included in the model.

We note that actual configurations can vary based on site-specific circumstances. For instance, if a number of PEV parking spaces are located a significant distance from the main electrical panel, a single raceway run to an additional electrical panel closer to PEV parking spaces could be installed with raceways branching from the panel to the planned EVSE location. This configuration would

²² This estimate assumes that contractors win half of their bids for retrofit projects. The success rate will vary based on specific circumstances. For instance, a sole source contracting 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.



most likely save costs in buildings where the reduced length of raceways would exceed additional electric panel costs.

Some sections of raceways can likely be shared and some will be dedicated to one specific circuit. The model is based on an assumption that half of raceways in larger buildings are shared by two wires, with the other half holding a single wire. For the smaller building, a single raceway will carry either one or two wires. The actual ratio of shared raceways vs. raceways dedicated to a specific circuit for any specific installation will vary based on site specific circumstances.

The termination point is assumed to consist of an outlet box with a face plate and no electric vehicle service equipment (i.e. the unit that connects to the vehicle) installed at the time of construction. No additional curbs or bollards are assumed. Local jurisdictions may wish to include anchor points for EVSE near the termination point. While this cost was not included in the model, it should be small.

Task Descriptions:

Task descriptions for each scenario are listed below in Table 9. The table lists tasks with a note to designate where the task applies to retrofits, new construction or both. Tasks are listed with a “0” quantity where they do not apply or are subsumed in cases where minimum job costs are assumed. A negative number indicates the avoidance of smaller electrical panel(s) due to installation of a larger panel.



Table 9. Task Descriptions and Quantities for Scenarios A and B

Task Description	Construction Type ¹	Work Type ²	Unit ³	Scenario A PEV Circuit	Scenario A PEV-Ready ⁴	Scenario B PEV Circuit	Scenario B PEV-Ready ⁴
Structural concrete, in place, minimum labor/equipment charge	R	P	Job	0	0	0	0
Chemical anchoring, for fastener 1-3/4" diameter x 12" embedment, includes epoxy cartridge, excludes layout, drilling & fastener	R	C	Ea.	2	2	12	12
Concrete sawing, concrete slabs, rod reinforced, up to 3" deep	R	D	L.F.	0	0	0	0
Concrete sawing, concrete, existing slab, rod reinforced, for each additional inch of depth over 3"	R	D	L.F.	0	0	0	0
Selective demolition, concrete slab cutting/sawing, minimum labor/equipment charge	R	D	Job	0	0	0	0
Concrete core drilling, core, reinforced concrete slab, 2" diameter, up to 6" thick slab, includes bit, layout and set up	R	D	Ea.	2	2	12	12
Branch meter devices, main circuit breaker, 400 A, electrical demolition, remove, includes circuit breaker	R	D	Ea.	0	0	0	0
Wire, copper, stranded, 600 volt, #8, type THW, in raceway	N	C	C.L.F.	1	0	2.7	0
Wire, copper, stranded, 600 volt, #8, type THW, in raceway	R	C	C.L.F.	1	0	5.4	0
Wire, minimum labor/equipment charge	R	C	Job	0	0	0	0
Outlet boxes, pressed steel, 4" square	R	C	Ea.	2	0	12	0
Outlet boxes, pressed steel, 4" square	N	C	Ea.	2	0	12	0
Outlet boxes, pressed steel, covers, blank, 4" square	R	C	Ea.	2	0	12	0
Outlet boxes, pressed steel, covers, blank, 4" square	N	C	Ea.	2	0	12	0
PVC conduit, schedule 40, 1-1/4" diameter, in concrete slab, includes terminations, fittings and supports	N	R	L.F.	40	0	180	0
PVC conduit, schedule 40, 1-1/4" diameter, in concrete slab, includes terminations, fittings and supports	R	R	L.F.	0	0	0	0
Rigid galvanized steel conduit, 2" diameter, in trench, includes terminations and fittings	R	R	L.F.	0	0	8	8
Rigid galvanized steel conduit, 2" diameter, in trench, includes terminations and fittings	N	R	L.F.	0	0	0	0
Rigid galvanized steel conduit, 1-1/4" diameter, to 15' H, includes 2 terminations, 2 elbows, 11 beam clamps, and 11 couplings per 100 LF	N	R	L.F.	0	0	0	0



Table 9. Task Descriptions and Quantities for Scenarios A and B

Task Description	Construction Type ¹	Work Type ²	Unit ³	Scenario A PEV Circuit	Scenario A PEV-Ready ⁴	Scenario B PEV Circuit	Scenario B PEV-Ready ⁴
Rigid galvanized steel conduit, 1" diameter, to 15' H, includes 2 terminations, 2 elbows, 11 beam clamps, and 11 couplings per 100 LF	N	R	L.F.	0	0	0	0
Intermediate metal conduit, 1-1/4" diameter, to 15' high, includes 2 terminations, 2 elbows, 11 beam clamps, and 11 couplings per 100 LF ⁵	R	R	L.F.	92	0	414	0
Intermediate metal conduit, 1" diameter, to 15' high, includes 2 terminations, 2 elbows, 11 beam clamps, and 11 couplings per 100 LF	R	R	L.F.	0	0	0	0
Conduit, to 15' high, minimum labor/equipment charge	R	R	job	0	0	0	0
Load interrupter switch, 2 position, 300 kVA & below w/CLF fuses, 4.8 kV, 600 amp, NEMA 1	B	I	Ea.	0	0	0	0
Cable lugs, for 2 feeders, 4.8 kV or 13.8 kV	B	I	Ea.	0	0	0	0
Transformer, dry-type, 3 phase 480 V primary 120/208 V secondary, 300 kVA	B	I	Ea.	0	0	0	0
Switchboards, distribution section, aluminum bus bars, 4 W, 120/208 or 277/480 V, 1200 amp, excludes breakers	N	I	Ea.	0	0	0	0
Load centers, 1 phase, 3 wire, main lugs, indoor, 120/240 V, 100 amp, 12 circuits, includes 20 A 1 pole plug-in breakers (additional to existing)	R	C	Ea.	1	1	0	0
Load centers, 1 phase, 3 wire, main lugs, indoor, 120/240 V, 200 amp, 16 circuits, includes 20 A 1 pole plug-in breakers	N	C	Ea.	1	1	0	0
Load centers, 1 phase, 3 wire, main lugs, indoor, 120/240 V, 100 amp, 12 circuits, includes 20 A 1 pole plug-in breakers (cost avoided by installing 200 amp panel at time of new construction)	N	C	Ea.	-1	-1	0	0
Circuit breakers, bolt-on, 10 k A I.C., 3 pole, 240 volt, 15 to 60 amp (commercial main breakers may have these pre-installed)	B	C	Ea.	2	0	0	0
Excavating, trench or continuous footing, common earth, 1/2 C.Y. excavator, 1' to 4' deep, excludes sheeting or dewatering	R	E	B.C.Y.	0	0	0	0



Table 9. Task Descriptions and Quantities for Scenarios A and B

Task Description	Construction Type ¹	Work Type ²	Unit ³	Scenario A PEV Circuit	Scenario A PEV-Ready ⁴	Scenario B PEV Circuit	Scenario B PEV-Ready ⁴
Excavating, trench backfill, 1 C.Y. bucket, minimal haul, front end loader, wheel mounted, excludes dewatering	R	E	L.C.Y.	0	0	0	0
Excavating, chain trencher, utility trench, common earth, 40 H.P., 16" wide, 24" deep, operator riding, includes backfill	B	E	L.F.	0	0	0	0
Excavating, chain trencher, utility trench, common earth, includes excavation and backfill, minimum labor/equipment charge	B	E	Job	0	0	0	0
Cycle hauling(wait, load, travel, unload or dump & return) time per cycle, excavated or borrow, loose cubic yards, 20 min load/wait/unload, 12 C.Y. truck, cycle 10 miles, 50 MPH, excludes loading equipment	R	P	L.C.Y.	0	0	0	0
Excavated or borrow, loose cubic yards, small excavation job, 8 C.Y. truck per hour, excludes loading equipment	R	D	Hr.	0	0	0	0
Asphaltic concrete paving, parking lots & driveways, 6" stone base, 2" binder course, 2" topping, no asphalt hauling included	R	P	S.F.	0	0	0	0
Painted pavement markings, acrylic waterborne, white or yellow, 4" wide, less than 3000 L.F.	R	C	L.F.	100	0	600	0
Painted pavement markings, acrylic waterborne, white or yellow, 4" wide, less than 3000 L.F.	N	C	L.F.	100	0	600	0
Add equipment minimum for concrete demo- assume labor minimum subsumed under saw cut minimum	R	D		0	0	0	0
Mobilization or demobilization, dozer, loader, backhoe or excavator, 70 H.P. to 150 H.P., up to 50 miles	R	D		0	0	0	0
Rent, asphalt distributor, trailer mounted, 38 HP diesel 2000 gallon, one day including 4 hours operating cost	R	D		0	0	0	0
Rent mixer power mortar & concrete gas 6 CF, 18 HP, one day including 4 hours operating cost	R	D		0	0	0	0
Rent core drill, electric, 2.5 H.P. 1" to 8" bit diameter, includes hourly operating cost	R	D		1	1	3	3
Rent backhoe-loader 40 to 45 HP 5/8 CY capacity, one day including 4 hours operating cost	R	D		0	0	0	0



Table 9. Task Descriptions and Quantities for Scenarios A and B

Task Description	Construction Type ¹	Work Type ²	Unit ³	Scenario A PEV Circuit	Scenario A PEV-Ready ⁴	Scenario B PEV Circuit	Scenario B PEV-Ready ⁴
Main Circuit breaker, 3 pole 3 wire 100 amp (a negative quantity indicates cost avoided by installing larger capacity unit)	N	C	Ea.	0	0	-2	-2
Main Circuit breaker, 3 pole 3 wire 100 amp	R	C	Ea.	0	0	0	0
Main Circuit breaker, 3 pole 3 wire 225 amp	N	C	Ea.	0	0	0	0
Main Circuit breaker, 3 pole 3 wire 225 amp	R	C	Ea.	0	0	0	0
Main Circuit breaker, 3 pole 3 wire 400 amp	N	C	Ea.	0	0	2	2
Main Circuit breaker, 3 pole 3 wire 400 amp	R	C	Ea.	0	0	2	2

1. Some codes that appear duplicative are retrofit in one case and new construction in another case.
2. Work Type Codes: Circuit including panel and paint (C), Demo (D), Excavate (E), Fee (F), Electric Infrastructure (I), Paving asphalt and concrete (P), Raceways (R).
3. Unit refers to quantity, such as linear foot (LF), hundredlinear foot (CFL), square yard (SY), cubic yard (CY).
4. PEV Ready refers to the level of infrastructure required by the CALGreen multi-family codes, and is included to facilitate comparison with the July 2016 PEV Infrastructure Cost-effectiveness report for the City of Oakland.
5. The distance is increased slightly based on cost factors that are not captured in the model.

