Plug-In Electric Vehicle Infrastructure Cost-Effectiveness Report

July 20, 2016

Prepared for:

Shayna Hirshfield-Gold
Energy Policy Analyst
City of Oakland
250 Frank Ogawa Plaza, Suite 5301
Oakland, CA 94612

Prepared by:

Ed Pike, PE
Jeffrey Steuben
Energy Solutions
449 15th Street
Oakland, CA 94612

Contents

Acknowledgements

The California Energy Commission provided grant funding for this report under PON-14-603.

The PEV Infrastructure cost-effectiveness model used for this report leverages prior experience from research funded by Pacific Gas & Electric.

The authors wish to express appreciation to the following reviewers. Any errors are the responsibility of the authors:

Rachel DiFranco, City of Fremont

Shayna Hirschfield-Gold, City of Oakland

Barry Hooper, City and County of San Francisco

List of Tables

List of Figures

1. EXECUTIVE SUMMARY

This report describes the costs associated with including Plug-in Electric Vehicle (PEV) charging infrastructure during initial construction for multifamily and nonresidential projects compared to retrofitting this infrastructure. The report finds that installing infrastructure during initial construction is much more cost-effective.

The cost of installing PEV charging infrastructure during new construction ranges from $200 to $1,400 per PEV parking space depending on the building type and completeness of the electrical circuit installed to support PEV charging. Installing a complete circuit with a rating of 240 volts and 40 amps during new construction saves approximately $1,000-$1,600 per PEV parking space for the three *parking garage* scenarios that were evaluated. Additional, approximately $5,000 per PEV parking space can be saved for the *surface parking lot* scenario.

The cost calculations in this report are based on costs from industry reference materials and are not intended to represent the costs of any specific installation. Examples of avoided costs include breaking and repairing walls, upgrading electric service panels, additional permitting and inspections, and breaking and repairing parking surfaces and/or sidewalks (for the surface parking scenario). The report does not discuss costs outside of code compliance, such as the cost of the Electric Vehicle Service Equipment that plugs into the PEV, associated lighting, signage, any required bollards, etc.

2. PURPOSE

The purpose of the cost-effectiveness model and this summary report is to document the expected cost-effectiveness of installing PEV charging electric circuit infrastructure during new construction and major alterations of multifamily and nonresidential buildings. This documentation will assist local governments such as the City of Fremont, the City of Oakland, and the City and County of San Francisco in determining local building code requirements that support PEV infrastructure installation and facilitate PEV adoption to reduce greenhouse gases and other pollutants as well as reducing petroleum dependence.[1]

CALGreen building codes are formally adopted state-wide by the California Building Standards Commission (BSC) for residential and nonresidential buildings. The residential section is authored by the California Department of Housing and Community Development (HCD) and the nonresidential section is authored by the BSC. The current CALGreen building codes contain minimum statewide requirements for PEV-ready parking spaces in new construction (Title 24 Part 11 sections 4.106 and 5.106) including sufficient electrical panel capacity and conduit capacity as well as plans for the installation of the balance of the circuit. CALGreen also contains voluntary requirements that can serve as a model for local governments that wish to adopt them (Title 24 Part 11 sections A4.106 and A5.106). Table 1 summarizes the current code adopted in 2014 as well as the new nonresidential codes that take effect January 1, 2017. Local governments may

---

[1] Avoided emissions from displacing a typical vehicles' 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 generation and oil production and refining. Annual mileage is from "Factors Influencing Vehicle Miles Traveled in California: Measurement and Analysis", Kent M. Hymel, 2014. Emissions rates for a baseline conventional vehicle and 2012 Nissan Leaf powered on California electricity are from Calculating Electric Drive Vehicle Greenhouse Gas Emissions, Ed Pike, 2012.

choose to adopt voluntary codes, which then become mandatory in their jurisdiction, or tailored local codes.

A lack of PEV charging infrastructure is a key challenge for meeting California PEV adoption goals as noted in the draft 2015 ZEV Action Plan.[2] Local governments can exceed state-wide CALGreen minimums by adopting CALGreen voluntary targets or adopting more aggressive local codes tailored to local circumstances to help achieve PEV adoption goals.

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

	Non-Residential				Multifamily	
	Mandatory		Voluntary			
			Tier 1	Tier 2		
	Current	Effective January 1, 2017	Effective January 1, 2017		Current Mandatory	Current Voluntary
Minimum threshold for standards to be effective	51 parking spaces	10 parking spaces	10 parking spaces	One parking space	17 units	17 units
Percent of new parking spaces that must be PEV-ready	3%	~6%[3]	~8%	~10%	3%	5%

The CALGreen minimum state-wide standards are not high enough to meet California PEV deployment goals and expected local demand. California will need to achieve a 12% state-wide 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.[4] California is already ahead of CARB's expected trajectory to that goal. 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, according to the 2015 draft ZEV Action Plan, "The State has completed an initial analysis of the number of electric vehicle charging stations needed to meet the Executive Order goals, which suggest upwards of 900,000 charge points may be needed by 2020." Thus, a dramatic increase in available PEV charging infrastructure needs to begin during implementation of the upcoming CALGreen code cycle.

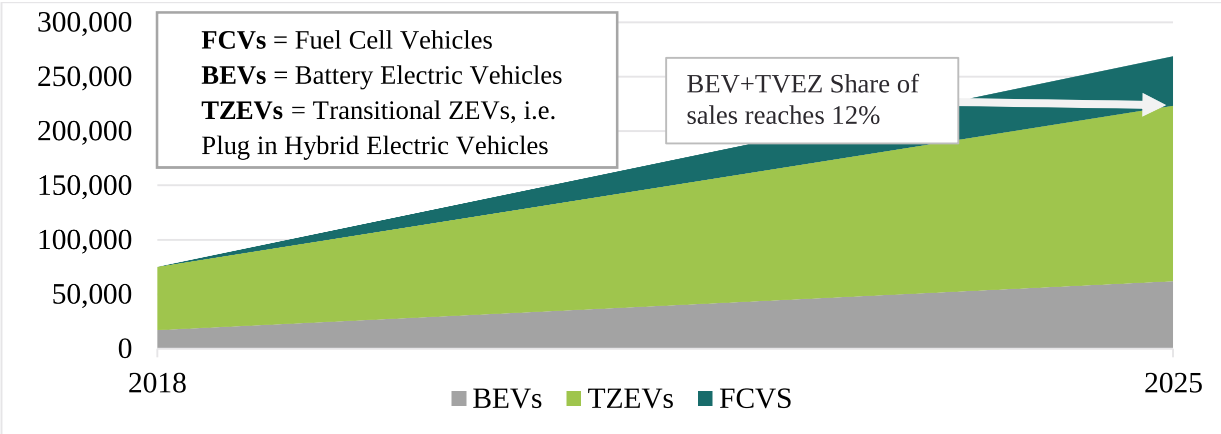
[2] Draft 2015 ZEV Action Plan, April 2015, Governor's Interagency Working Group on Zero-Emission Vehicles.

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

[4] 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.

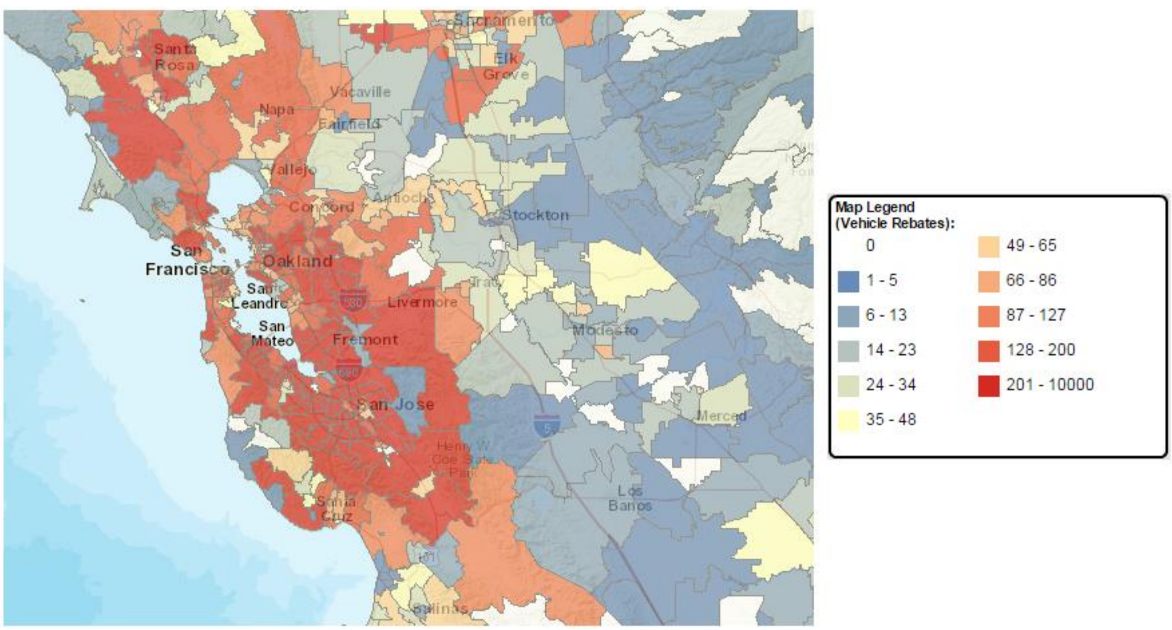
[5] See CARB "Staff Report: Initial Statement of Reasons for Rulemaking" September 2013 page 2 http://www.arb.ca.gov/regact/2013/zev2013/zev2013isor.pdf and the Plug in Electric Vehicle Collaborative "Detailed Monthly Sales Chart", April 2016 http://www.pevcollaborative.org/sites/all/themes/pev/files/4_april_2016_Dashboard_PEV_Sales.pdf

Figure 1. Annual Electric Vehicle Sales Under CARB Most Likely Compliance Pathway[6]



Bay Area communities such as Fremont, Oakland, and San Francisco currently have much higher PEV demand than statewide averages despite challenges such as very limited PEV charging infrastructure in multifamily housing. Figure 2 below shows that these communities and others form a regional PEV adoption "hot spot." This figure is based on PEV rebates per zip code. Since the number of households per zip code may vary this metric is a proxy for per capita adoption rates rather than an exact metric.

Figure 2. Number of California PEV Rebates per ZIP Code in California's Clean Vehicle Rebate Project[7]



[6] This figure is based on CARB's "Staff Report: Initial Statement of Reasons Advance Clean Cars 2012 Proposed Amendments to the California Zero Emission Vehicle Program Regulations" December 7, 2011.
[7] Downloaded June 3, 2016 from California Clean Vehicle Rebate Program https://cleanvehiclerebate.org/eng/cvrp-rebate-map. 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. Also, although the Chevrolet Volt was commercially available in California as of December 2010, it was not eligible for CVRP until February 2012. At least 1,861 Volts were sold in California prior to Feb. 2012.Note that 219 of the 150,529 total state-wide rebates included in CVRP graphics include fuel cell electric vehicle rebates as of June 14, 2016.

3. SCENARIOS

Four different installation scenarios were evaluated in this report.

> Each scenario was modeled for two levels of infrastructure: "PEV-ready" and a full electrical circuit. The "PEV-ready" provisions for each scenario include electrical service panel capacity, plans, and all underground conduits similar to the requirements included in the current CALGreen code. A complete PEV circuit adds wire, circuit breakers, termination point and surface conduit to the extent not provided by PEV-readiness standards.

The first two scenarios represent potential cost-savings from plugging the gap in the current CALGreen requirements for multifamily housing with between 3 and 16 dwelling units. The third scenario represents the cost-effectiveness of requiring that 10% of parking spaces in a representative 60-space parking facility are PEV spaces, as this percentage is similar to the CALGreen voluntary nonresidential code that was adopted January 2016. The final scenario represents a higher goal of requiring 20% PEV spaces in a facility of the same size.

The scenarios in this report include a greater focus on enclosed parking as compared to surface parking because new construction for Fremont, Oakland, and San Francisco is likely to focus on in-fill development with enclosed parking. All four scenarios are summarized in Table 2.

Table 2. Scenario Summary

	Scenario One	Scenario Two	Scenario Three	Scenario Four
Parking Type	Surface	Enclosed	Enclosed	Enclosed
PEV Parking Spaces	Two		Six	12
Base Case Panel	100-amp		225-amp	100-amp (two)
PEV-readiness Panel	200-amp		400-amp	400-amp (two)
Conduit Length (feet)	55	50	170	330
Trenching Required	Yes	No	No	No

Scenario One and Scenario Two assume a 24-vehicle surface parking lot with two PEV parking spaces[8] in either a surface parking area (Scenario One) or an enclosed garage (Scenario Two). This size of parking area is intended to represent multifamily developments with fewer than 16 dwelling units, which are currently exempt from CALGreen requirements for PEV-ready parking spaces (the results would likely also represent similar sized nonresidential parking areas). Twenty-one percent of new multifamily dwelling units are projected to be located at developments of this size or smaller based on research by Pacific Gas & Electric.[9] The number of PEV parking spaces is based on the current CALGreen multifamily voluntary Tier of 5% rounded up to two spaces.

---

[8] We use "PEV parking space" to mean a space that is either PEV-ready or is served by a full electrical circuit to support PEV charging.

[9] Pacific Gas & Electric December 2, 2013 letter to Mia Marvelli, Building Standards Commission and Emily Withers, California Department of Housing and Community Development.

To achieve PEV-readiness, the electric service panel would be upgraded from 100-amp to 200-amp. Additional PEV-readiness costs would also include breaking and repairing hardscape for 50 linear feet of conduit installation in Scenario One and installing a single underground conduit sufficient to accommodate two PEV charging spaces along with five feet of surface mounted conduit. A full circuit would add wire, breakers, and an outlet box; and for Scenario Two also surface mounted conduit.

Scenario Three assumes a two level, 60-space enclosed parking area with six PEV parking spaces, which could serve either a multifamily building or nonresidential parking area. This number of PEV parking spaces is equal to the CALGreen nonresidential voluntary Tier 2 code. A 225-amp main circuit breaker (3 wire, 3 pole) serving both floors to support elevator, lighting, and other loads would be required in the base case and would be upgraded to 400-amp to achieve PEV-readiness. Electrical circuits would pass through a six-inch-thick concrete wall on each floor, resulting in significant costs if installed as a retrofit. Installing a full circuit would also include circuit breakers and two sets of surface-mounted conduit and wire from an electrical room running 30 feet vertically between floors and 70 feet horizontally on each floor.

Scenario Four represents a two level, 60-space enclosed parking area with 12 PEV parking spaces, which exceeds current CALGreen requirements but could be selected by a local jurisdiction to match policy goals and expected local PEV demand. Two 100-amp main circuit breakers (3 wire, 3 pole) to support lighting and other loads would be required in the base case and would be upgraded to two 400-amp panels to achieve PEV-readiness. Electrical circuits would pass through a six-inch-thick wall, again resulting in significant costs if installed as a retrofit. A full circuit would include circuit breakers and two sets of surface-mounted conduit and wire from an electrical room running 30 feet vertically between floors and 150 feet inside each floor.

The components for each scenario will support 40-amp “Level 2,” 110 V Level 1 charging, or a mix of both.[10] Appendix C lists the specific components included in each scenario. 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.

4. RESULTS

The results of the cost-effectiveness analysis show that installing a complete electric circuit for PEV charging at time of construction provides the largest cost savings compared to retrofit costs. Including key elements of PEV-ready parking spaces such as underground conduit and sufficient electrical panel capacity in new construction provides large cost savings while minimizing upfront costs, which may be helpful for spaces that are expected to be needed in the longer term but not in the immediate future. This section focuses on Scenario Three and Scenario Four because they represent the highest levels of PEV-readiness in enclosed garages most common for urban in-fill development. Detailed results of all four scenarios are included in the Appendix.

This study estimates that retrofitting installation of full electric circuit infrastructure at an existing building costs about $1,900-$3,000 per parking space for the three enclosed parking scenarios (Scenarios Two, Three, and Four) and $6,300 per surface parking space for the surface parking scenario (Scenario One). The same

[10] The HCD considered requiring complete circuits (at a January 23, 2014 workshop) but ultimately did not adopt this higher level of PEV charging infrastructure in their final code language. However, this could be considered by local governments. If a significant amount of Level 1 charging is expected then including at least some PEV-ready spaces without a complete circuit may be desirable to allow flexibility to install either Level 1 or Level 2 in the future.

infrastructure costs about $1,300 per space for all four scenarios if installed during new construction for a significant savings. Alternatively, new buildings can include only components such as any underground conduit and upgraded panel capacity to be PEV-ready without installing the full circuit if the spaces won't be immediately used for PEV charging. PEV-ready spaces can be installed for an initial cost of about $300-$500 per space for parking garages as shown below, with an additional cost of about $900-$1,100 per space to complete them (additional details are shown in the Appendix). This later scenario results in slightly higher total costs than installing a complete circuit when a new building is constructed, but still results in overall significant savings per space compared to the retrofitting a circuit in a facility that is not PEV-ready.

Table 3. Cost Results per Parking Space (Oakland, California)

	New	Retrofit	Savings
Scenario One, Two PEV Circuits	$1,280	$6,260	$4,980
Scenario One, Two PEV-ready Spaces	$810	$5,420	$4,610
Scenario Two, Two PEV Circuits	$1,330	$2,980	$1,650
Scenario Two, Two PEV-ready Spaces	$200	$1,860	$1,660
Scenario Three, Six PEV Circuits	$1,160	$2,060	$900
Scenario Three, Six PEV-ready Spaces	$300	$1,190	$890
Scenario Four, 12 PEV Circuits	$1,380	$1,870	$490
Scenario Four, 12 PEV-ready Spaces	$540	$1,010	$470

The results for enclosed parking areas are illustrated in Figure 3 and Figure 4. The first provides an overview of total costs. The later summarizes the major categories of costs, which can 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 inspections are a common expense for all building types, though higher for retrofits as explained in the Appendix. Excavating, trenching, and repairing parking lot pavement and sidewalks is likely to be a common expense for outdoor surface parking retrofits due to the unavailability of walls or ceilings on which to mount conduit as shown by the detailed results for Scenario One (which are shown along with the other scenarios in the Appendix). 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.[11]

[11] We also note that PEV-readiness standards can reduce or avoid non-cost barriers such as coordinating between building owners/operators and tenants and a lack of education.

Figure 3. Cost Difference for Retrofit and New Construction (2016 dollars per PEV charging space)

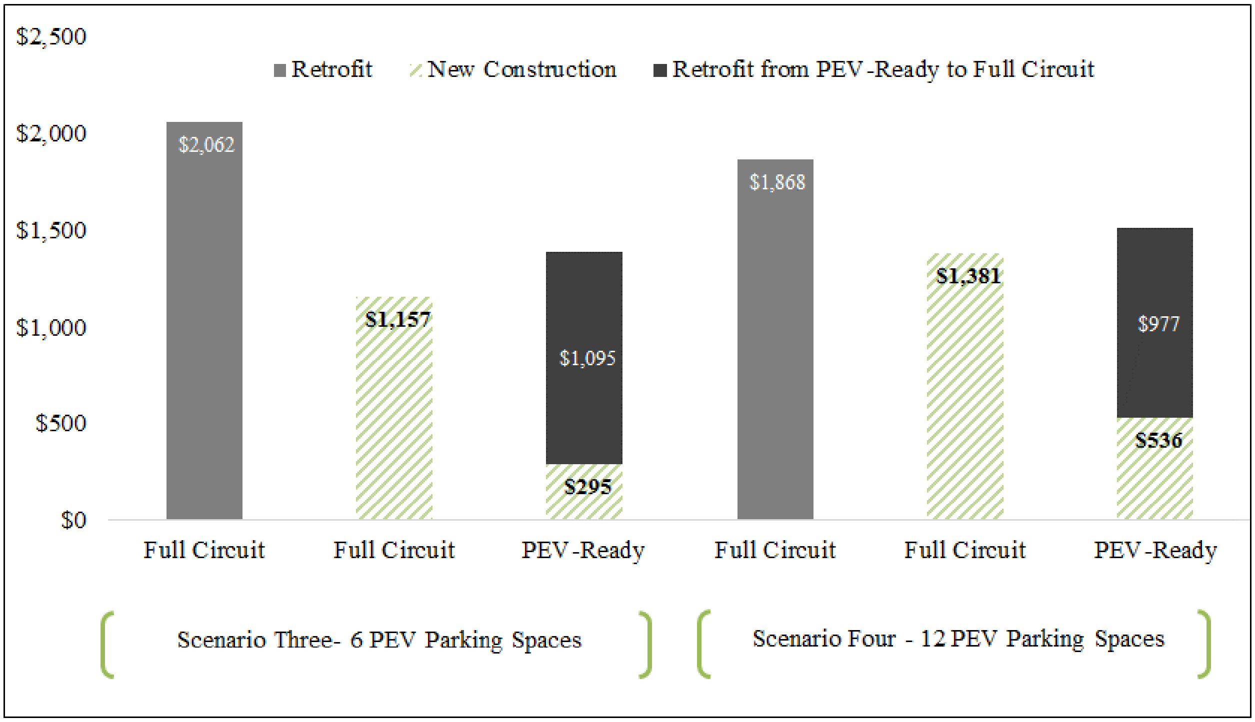
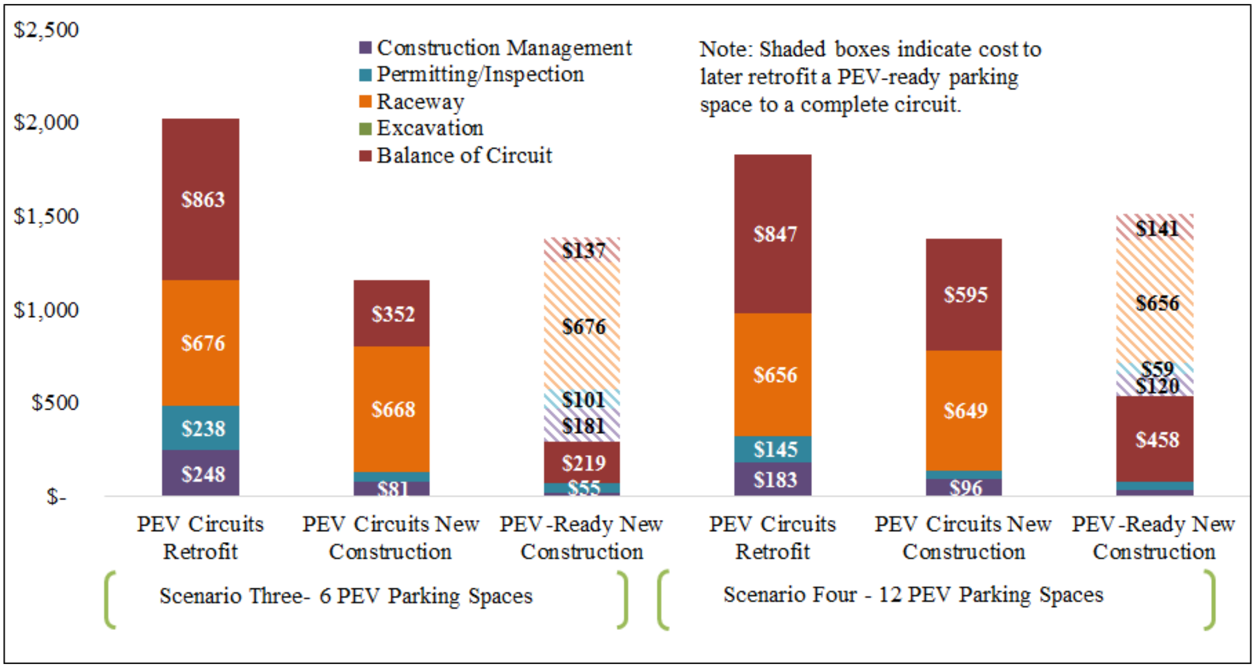


Figure 4. Cost by Work Type of New Construction vs. Retrofit (2016 dollars per PEV charging space)



The results indicate that applying PEV-readiness building codes to building alterations would also provide potential cost savings. For instance, installing underground conduits during parking area expansion or renovation could achieve much or all of the cost savings for demolition, excavation, and concrete and paving work shown for Scenario One in the Appendix. Requiring that new electrical service panels contain capacity for PEV charging could similarly avoid the cost of retrofitting expanded electrical service later for all of the scenarios evaluated in this report. 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.[12]

Costs shown earlier are based on construction cost estimates for Oakland, California. Table 4 shows examples of cost adjustment factors for several Bay Area cities. Table 5 shows that regional variations are modest compared to the overall benefits of installing PEV electric circuit infrastructure at the time of new construction. Cost factors are not available for the city of Fremont, so nearby Oakland and San Jose will likely provide a reasonable indicator of costs for Fremont.

Table 4. Regional Factors Compared to National Average[13]

	Oakland		**San Francisco**		**San Jose**	
	Labor	Materials	Labor	Materials	Labor	Materials
Cost Multiplier	1.260	1.085	1.404	1.107	1.313	1.058

Table 5. Regionally Adjusted Results per Parking Space for Two Enclosed Parking Scenarios

	Oakland		**San Francisco**		**San Jose**	
	New	Retrofit	New	Retrofit	New	Retrofit
Scenario 3 Six PEV Circuits	$1,160	$2,060	$1,261	$2,247	$1,185	$2,113
Scenario 3 Six PEV-ready Spaces	$300	$1,190	$322	$1,292	$302	$1,215
Scenario 4 12 PEV Circuits	$1,380	$1,870	$1,504	$2,034	$1,414	$1,913
Scenario 4 12 PEV-ready Spaces	$540	$1,010	$583	$1,098	$549	$1,033

5. METHODOLOGY

The cost-effectiveness model was developed in Microsoft Excel and utilizes spreadsheets that break each scenario and level of PEV infrastructure into individual tasks and quantities as shown in the Appendix. 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 hardware and related installation costs. Additional costs are based on a City of Oakland cost sheet and data from other jurisdictions on permitting and inspection fees and staff estimates for contractor labor for obtaining permitting and inspection. Additional data sources included 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-readiness elements,

[12] "Non-Residential Building Permits By Month", http://www.mychf.org/uploads/5/1/5/0/51506457/non-residential_cbia_website_04-2016.pdf, accessed 6-15-2016 and "Residential Building Permits By Month" http://www.mychf.org/uploads/5/1/5/0/51506457/residential_cbia_website_04-2016.pdf, accessed 6-15-2016.

[13] Sourced from RS Means Electrical Cost Data 2010 p482, national average =1.0

please see Appendix C.

The cost-effectiveness model includes four hypothetical installation scenarios to allow easy comparison of costs between different levels of PEV-readiness for both new construction and retrofit projects. Actual project costs and configurations will likely vary from these cases, which are intended to provide representative examples for comparison purposes rather than estimate site-specific costs. The modeled costs exclude design work and other project-specific costs outside the scope of CALGreen building codes such as signage, lighting, pedestal mounting, bollards, wheel stops, longer conduit runs, and contingencies.[14] 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.[15] The scenarios also do not include a separate utility sub-meter.[16]

6. Comparison to California PEVC Case Studies

The Plug-in Electric Vehicle Collaborative (PEVC) workplace charging study, "Amping up California Workplaces" (2013) reports a range of retrofit installation costs per charger for workplace charging, including both private and public parking. The costs for the enclosed parking PEV circuit retrofit case in the Plug-In Electric Vehicle Infrastructure Cost-Effectiveness Report tend to be closest to the low end of examples listed by the PEVC project ($2,300). This is likely because this report is intended to address common costs for certain scenarios and not a complete set of potential site-specific costs as noted earlier.[17] Thus, it may be conservative and the cost savings that would be achieved by PEV-readiness CALGreen standards may be greater than the figures presented in this report. The types of cost savings shown in this summary due to building codes are consistent with a PEVC document noting categories of significant expense for retrofitting PEV infrastructure in multi-unit housing.[18]

The surface parking costs in this Plug-in Electric Vehicle Infrastructure Cost-Effectiveness Report fall roughly in the middle of the cost estimates reported by the PEVC project. The PEVC report finds that "… if the installation entails trenching or asphalt and cement excavation, costs will increase. The cost of such work

---

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

[15] We note that 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. We note that a report prepared by HCD – "Report on Electric Vehicle Readiness" dated November 2013 provides some data on transformer costs.

[16] 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.

[17] California Plug-In Electric Vehicle Collaborative. 2013. "Amping up California Workplaces: 20 case studies on plug-in electric vehicle charging at work". November. http://www.evcollaborative.org/sites/all/themes/pev/files/WPC_Report4web.pdf.

[18] California Plug-In Electric Vehicle Collaborative. 2013. "Plug-in Electric Vehicle Charging Infrastructure Guidelines for Multi-unit Dwellings". November. http://www.evcollaborative.org/sites/all/themes/pev/files/MUD_Guidelines4web.pdf . This report notes that drilling through walls and parking decks at multifamily parking garages can be expensive.

can easily exceed the cost of the EVSE unit itself." This finding is consistent with the results of the PEV-Readiness Cost-Effectiveness Report finding that asphalt and concrete removal and repair for the surface parking examples are a major expense.

APPENDIX A: PEV PARKING SPACE COST DETAILS

The tables below summarize model results. See Appendix B and Appendix C for more details on the individual tasks included in each of the categories below.

Table 6. Scenario One Surface Parking

	PEV Circuits Retrofit	PEV Circuits New Construction	PEV-Ready Retrofit	PEV-Ready New Construction	Retrofit PEV-Ready to Full Circuit
Construction Management	$751	$90	$692	$56	$391
Permitting/Inspection	$610	$89	$610	$89	$254
Raceway	$432	$433	$432	$433	$0
Excavation	$114	$114	$114	$114	$0
Concrete/Paving	$977	$0	$977	$0	$0
Demolition	$2,284	$0	$1,965	$0	$0
Balance of Circuit	$1,095	$558	$630	$114	$465
Total	**$6,262**	**$1,284**	**$5,420**	**$807**	**$1,111**

Total cost for PEV-ready new construction plus retrofit PEV-ready to full circuit later is **$1,918.**

Table 7. Scenario Two Enclosed Parking

	PEV Circuits Retrofit	PEV Circuits New Construction	PEV-Ready Retrofit	PEV-Ready New Construction	Retrofit PEV-Ready to Full Circuit
Construction Management	$522	$93	$443	$14	$435
Permitting/Inspection	$640	$89	$640	$89	$254
Raceway	$581	$590	$0	$0	$581
Excavation	$0	$0	$0	$0	$0
Concrete/Paving	$0	$0	$0	$0	$0
Demolition	$145	$0	$145	$0	$0
Balance of Circuit	$1,095	$558	$630	$97	$465
Total	**$2,983**	**$1,330**	**$1,858**	**$201**	**$1,736**

Total cost for PEV-ready new construction plus retrofit PEV-ready to full circuit later is **$1,937.**

Table 8. Scenario Three Surface Parking

	PEV Circuits Retrofit	PEV Circuits New Construction	PEV-Ready Retrofit	PEV-Ready New Construction	Retrofit PEV-Ready to Full Circuit
Construction Management	$248	$81	$187	$21	$181
Permitting/Inspection	$238	$55	$238	$55	$101
Raceway	$676	$668	$0	$0	$676
Excavation	$0	$0	$0	$0	$0
Concrete/Paving	$0	$0	$0	$0	$0
Demolition	$35	$0	$35	$0	$0
Balance of Circuit	$863	$352	$727	$219	$137
Total	**$2,062**	**$1,157**	**$1,188**	**$295**	**$1,095**

Total cost for PEV-ready new construction plus retrofit PEV-ready to full circuit later is **$1,391.**

Table 9. Scenario Four Surface Parking

	PEV Circuits Retrofit	PEV Circuits New Construction	PEV-Ready Retrofit	PEV-Ready New Construction	Retrofit PEV-Ready to Full Circuit
Construction Management	$183	$96	$123	$37	$120
Permitting/Inspection	$145	$41	$145	$41	$59
Raceway	$656	$649	$0	$0	$656
Excavation	$0	$0	$0	$0	$0
Concrete/Paving	$0	$0	$0	$0	$0
Demolition	$37	$0	$37	$0	$0
Balance of Circuit	$847	$595	$706	$458	$141
Total	**$1,868**	**$1,381**	**$1,011**	**$536**	**$977**

Total cost for PEV-ready new construction plus retrofit PEV-ready to full circuit later is **$1,531.**

APPENDIX B: PERMITTING AND INSPECTION COSTS

The tables below summarize electrical and building permit and inspection costs. Additional information on data sources is described under the calculation methodology description in Appendix C.

Table 10. Electrical Permit and Inspection Cost Data

	Fees		
$110	Minimum inspection fee, which covers from 1 to 3 inspections		
$70	Application fee		
$8	Per circuit, including junction box		
$151	Basic electric service panel fee		
$50	Incremental fee per 100-amp increase in panel size		
15%	Records/Technology fee add-on		
$207	Total minimum electrical permit fee		
	source: City of Oakland fees as of June 1, 2016		
	Builder Staff Costs		
Retrofit PEV Circuit or PEV Ready	PEV Ready, New	Incremental Cost, New	
$100	$50	$25	Builder staff time to obtain new permit
$100	$50	$25	Builder staff time per inspection
$150	$0	$0	Electrical engineer staff time for load calculations

Table 11. Building Permit and Inspection Cost Data

	Fees	
$50	Basic fee	
$1.50	Per hundred dollars of project value up to $2000	
$0.75	Per hundred dollars of project value from $2000 up to $50,000	
	source: Estimates based on review of several jurisdiction's fee schedules	
	Builder Staff Costs	
Retrofit	Incremental Cost, New	
$100	$25	Builder staff time to obtain new permit
$100	$0	Builder staff time per inspection

Table 12. Total Permit and Inspection Cost Summary

		Retrofit			New (Incremental Costs)			Retrofit PEV Space to Circuit		
Scenario	**# of Circuits**	**Fee**	**Builder Staff Time**	**Total**	**Fee**	**Builder Staff Time**	**Total**	**Fee**	**Builder Staff Time**	**Total**
One	2	$489	$650	$1,139	$94	$75	$169	$284	$200	$484
Two	2	$436	$750	$1,186	$94	$75	$169	$284	$200	$484
Three	6	$587	$750	$1,337	$220	$100	$320	$325	$250	$575
Four	12	$779	$850	$1,629	$346	$125	$471	$370	$300	$670

APPENDIX C: CALCULATION METHODOLOGY

Data Sources

Estimates of retrofit and new construction costs were based on data from RS Means Quarter 3 2013, a construction cost reference handbook, for hardware and related installation costs; City of Oakland cost sheet for permitting fees; and staff estimates for contractor labor for obtaining permitting and inspection. Costs were escalated to 2016 using US Bureau of Labor Statistics Producer Price Index statistics for materials[19] and California Director of Industrial Relations labor costs for Oakland from 2013 to 2016.[20] 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 13 and Table 14 contain a list of all tasks included in the analysis.

General Assumptions

We made the following general assumptions:

- Cost estimates include a fixed general overhead and profit factor.[21] Overhead cost for smaller retrofit projects will likely be higher than PEV-readiness tasks bundled with new development. We added an estimated cost for project initiation and cost-estimation, assuming that most of this cost would be passed on to the customer and a portion would be absorbed by the contractor.
- Labor costs are based on union labor. The use of union labor can vary from project to project.
- Geographic adjustments are based on 2010 RS Means Electrical Cost Data page 465.
- In a number of cases RS Means contains minimum retrofit task costs.[22] 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 also perform a related task, we applied only one minimum labor charge.[23]

Permit and Inspection Fees

Permitting costs for breaking concrete and/or pavement in addition to electrical work are based on City of Oakland fees of $70 per application and a minimum of $110 per inspection plus a technology and records

[19] Material cost adjustment 2013 to 2016 are based on Producer Price Index category 1175 "Switchgrear, switchboard and industrial controls" relative index from Nov 2013 to March 2016 which shows virtually no change. http://www.bls.gov/ppi/ppidr201311.pdf

[20] See http://www.dir.ca.gov/OPRL/main.htm prevailing wage and superseded prevailing wage determinations for electrical job categories.

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

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

[23] For instance, we assume that a concrete sawing and demolition crew deployed for a day for a retrofit project could also drill concrete walls if concrete sawing required less than 8 hours (some additional equipment would be required).

fee.[24] Electrical inspection fees can exceed the minimum depending on the capacity and quantity of electric panels and number of circuits. The total estimated costs include rough and final building and electrical permit fees where applicable. Building permits are generally not required for converting PEV-ready spaces to full circuits, and the cost for adding work in new construction is assumed to be relatively low. Builder staff time for permit filing and inspections are included at $100/hour. Permit and inspection costs may vary between regions.

We assume a small additional amount of labor to accommodate an inspection of PEV-specific elements in new construction. Please see Appendix B for more details.

Paving and Conduit

Sidewalks are assumed to be four-inch-thick and made of concrete, and asphalt pavement is assumed to be a six-inch aggregate base and three-inch pavement.[25] Trenching is included for both new construction and retrofit surface parking. Conduits are assumed to serve two circuits each, whether below grade or surface mounted. No additional curbs or bollards are assumed.

Termination Point

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 termination point is included for the PEV-ready spaces.

Equipment Rentals

We assume one day of equipment rental for a backhoe, concrete mixer and asphalt spreader for surface parking retrofits. We assume a half-day of operating cost (labor and fuel) based on the expectation that this equipment may not be continuously utilized, and that workers could perform other tasks when that equipment was not in use.[26] A 40-horsepower backhoe was assumed to be sufficient for loading of excavated asphalt and concrete in the retrofit case.[27]

Task Descriptions

Task descriptions for each scenario are listed below in Table 13 and Table 14. The tables list 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 due to installation of a larger panel.

---

[24] http://www2.oaklandnet.com/Government/o/PBN/OurOrganization/BuildingServices/s/Permits/index.htm

[25] "Sidewalk Repair Manual". 2013. City of Portland Bureau of Transportation April. http://www.portlandoregon.gov/transportation/article/443054; Asphalt Paving Association of Idaho design guide: http://www.apai.net/cmdocs/apai/designguide/Chapter_5B.pdf.

[26] We assume that even if this equipment was needed for less than 8 hrs, it could not be demobilized and transportation to another job site in time for use on that alternate job site on the same day thus a full days cost would be incurred.

[27] A 40 hp backhoe with 3,300 lb lift capacity was assumed sufficient (Coyote C14 LB from www.specguideonline.com) which falls into the smallest bin listed in RS Means. Total mass of asphalt to be excavated was calculated at 14.5 tons at the National Asphalt Pavement Association: http://www.asphaltpavement.org/ and 40 hp backhoe lift capacity was assumed sufficient to economically excavate and lift both asphalt as well as additional concrete material to be removed in the retrofit case.

Table 13. Task Descriptions and Quantities for Scenario One and Scenario Two

Note: Construction type determines whether the task description and quantity applies to new construction (N), retrofit (R), or both (B) and the work type code denotes whether the work type corresponds to a circuit including panel and paint (C), demolition (D), excavation (E), fee (F), electric infrastructure (I), paving asphalt and concrete (P), or raceway (R).

Task Description	Construction Type[1]	Work Type	Unit[2]	Scenario 1 PEV Circuit	Scenario 1 PEV-Ready	Scenario 1 PEV-Ready to Circuit	Scenario 2 PEV Circuit	Scenario 2 PEV-Ready	Scenario 2 PEV-Ready to Circuit
				Quantity for Each Scenario					
Demolish, remove pavement & curb, remove bituminous pavement, 4" to 6" thick, excludes hauling and disposal fees	R	D	S.Y.	0	0	0	0	0	0
Demolish, remove pavement & curb, remove concrete curbs, plain, excludes hauling and disposal fees	R	D	L.F.	0	0	0	0	0	0
Demolish, remove pavement & curb, curbs, excludes hauling, minimum labor/equipment charge	R	D	Job	1	1	0	0	0	0
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.	R	D	Week	1	1	0	0	0	0
Deconstruction of concrete, floors, concrete slab on grade, plain, 4" thick, up to 2 stories, excludes handling, packaging or disposal costs	R	D	S.F.	50	50	0	0	0	0
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	R	D	C.Y.	0.27	0.27	0	0	0	0
Selective concrete demolition, minimum labor/equipment charge	R	D	Job	0	0	0	0	0	0
C.I.P. concrete forms, slab on grade, bulkhead with keyway, wood, 6" high, 1 use, includes erecting, bracing, stripping and cleaning	R	C	L.F.	0	0	0	0	0	0
C.I.P. concrete forms, slab on grade, edge, wood, 7" to 12" high, 4 use, includes erecting, bracing, stripping and cleaning	R	C	SFCA	0	0	0	0	0	0

Task Description	Construction Type[1]	Work Type	Unit[2]	Scenario 1 PEV Circuit	Scenario 1 PEV-Ready	Scenario 1 PEV-Ready to Circuit	Scenario 2 PEV Circuit	Scenario 2 PEV-Ready	Scenario 2 PEV-Ready to Circuit
Reinforcing steel, in place, dowels, smooth, 12" long, 1/4" or 3/8" diameter, A615, grade 60	R	C	Ea.	0	0	0	0	0	0
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	R	C	S.F.	0	0	0	0	0	0
Structural concrete, in place, minimum labor/equipment charge	R	P	Job	1	1	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	0	2	2	0
Concrete sawing, concrete slabs, rod reinforced, up to 3" deep	R	D	L.F.	0	0	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	0	0
Selective demolition, concrete slab cutting/sawing, minimum labor/equipment charge	R	D	Job	1	1	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.	0	0	0	2	2	0
Branch meter devices, main circuit breaker, 400 A, electrical demolition, remove, includes circuit breaker	R	D	Ea.	0	0	0	0	0	0
Wire, copper, stranded, 600 volt, #8, type THW, in raceway	N	C	C.L.F.	1	0	1	1	0	1
Wire, copper, stranded, 600 volt, #8, type THW, in raceway	R	C	C.L.F.	1	0	1	1	0	1
Wire, minimum labor/equipment charge	R	C	Job	0	0	0	0	0	0
Outlet boxes, pressed steel, 4" square	R	C	Ea.	2	0	2	2	0	2
Outlet boxes, pressed steel, 4" square	N	C	Ea.	2	0	2	2	0	2
Outlet boxes, pressed steel, covers, blank, 4" square	R	C	Ea.	2	0	2	2	0	2
Outlet boxes, pressed steel, covers, blank, 4" square	N	C	Ea.	2	0	2	2	0	2

Task Description	Construction Type[1]	Work Type	Unit[2]	Scenario 1 PEV Circuit	Scenario 1 PEV-Ready	Scenario 1 PEV-Ready to Circuit	Scenario 2 PEV Circuit	Scenario 2 PEV-Ready	Scenario 2 PEV-Ready to Circuit
PVC conduit, schedule 40, 1-1/4" diameter, in concrete slab, includes terminations, fittings and supports	N	R	L.F.	0	0	0	0	0	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	0	0
Rigid galvanized steel conduit, 2" diameter, in trench, includes terminations and fittings	R	R	L.F.	50	50	0	0	0	0
Rigid galvanized steel conduit, 2" diameter, in trench, includes terminations and fittings	N	R	L.F.	50	50	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.	5	5	0	50	0	50
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	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	R	R	L.F.	5	5	0	56	0	56
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	0	0
Conduit, to 15' high, minimum labor/equipment charge	R	R	job	0	0	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	0	0
Cable lugs, for 2 feeders, 4.8 kV or 13.8 kV	B	I	Ea.	0	0	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	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	0	0

Task Description	Construction Type[1]	Work Type	Unit[2]	Scenario 1 PEV Circuit	Scenario 1 PEV-Ready	Scenario 1 PEV-Ready to Circuit	Scenario 2 PEV Circuit	Scenario 2 PEV-Ready	Scenario 2 PEV-Ready to Circuit
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	1	1	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	1	1	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	-1	-1	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	2	2	0	2
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	0	0
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	0	0
Excavating, chain trencher, utility trench, common earth, 40 H.P., 16" wide, 24" deep, operator riding, includes backfill	B	E	L.F.	50	50	0	0	0	0
Excavating, chain trencher, utility trench, common earth, includes excavation and backfill, minimum labor/equipment charge	B	E	Job	1	1	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.	1	1	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	0	0

Task Description	Construction Type[1]	Work Type	Unit[2]	Scenario 1 PEV Circuit	Scenario 1 PEV-Ready	Scenario 1 PEV-Ready to Circuit	Scenario 2 PEV Circuit	Scenario 2 PEV-Ready	Scenario 2 PEV-Ready to Circuit
Asphaltic concrete paving, parking lots & driveways, 6" stone base, 2" binder course, 2" topping, no asphalt hauling included	R	P	S.F.	80	80	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	100	100	0	100
Painted pavement markings, acrylic waterborne, white or yellow, 4" wide, less than 3000 L.F.	N	C	L.F.	100	0	100	100	0	100
Add equipment minimum for concrete demo- assume labor minimum subsumed under saw cut minimum	R	D		1	1	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		2	2	0	0	0	0
Rent, asphalt distributor, trailer mounted, 38 HP diesel 2000 gallon, one day including 4 hours operating cost	R	d		1	1	0	0	0	0
Rent mixer power mortar & concrete gas 6 CF, 18 HP, one day including 4 hours operating cost	R	d		1	1	0	0	0	0
Rent core drill, electric, 2.5 H.P. 1" to 8" bit diameter, including hourly operating cost	R	d		0	0	0	1	1	0
Rent backhoe-loader 40 to 45 HP 5/8 CY capacity, one day including 4 hours operating cost	R	d		1	1	0	0	0	0
Main Circuit breaker, 3 pole 3 wire 100 amp	R	C	Ea.	0	0	0	0	0	0
Main Circuit breaker, 3 pole 3 wire 225 amp	N	C	Ea.	0	0	0	0	0	0
Main Circuit breaker, 3 pole 3 wire 225 amp	R	C	Ea.	0	0	0	0	0	0
Main Circuit breaker, 3 pole 3 wire 400 amp	N	C	Ea.	0	0	0	0	0	0
Main Circuit breaker, 3 pole 3 wire 400 amp	R	C	Ea.	0	0	0	0	0	0

1. Some codes that appear duplicative are retrofit in one case and new construction in another case.
2. Unit refers to quantity, such as linear foot (LF), hundred linear foot (CFL), square yard (SY), cubic yard (CY).

Table 14. Task Descriptions and Quantities for Scenario Three and Scenario Four

Note: Construction type determines whether the task description and quantity applies to new construction (N), retrofit (R), or both (B) and the work type code denotes whether the work type corresponds to a circuit including panel and paint (C), demolition (D), excavation (E), fee (F), electric infrastructure (I), paving asphalt and concrete (P), or raceway (R).

Task Description	Construction Type[1]	Work Type	Unit[2]	Scenario 3 Six PEV Circuits	Scenario 3 Six PEV-Ready Spaces	Scenario 3 Six PEV-Ready Spaces to Circuits	Scenario 4 Twelve PEV Circuits	Scenario 4 Twelve PEV-Ready Spaces	Scenario 4 Twelve PEV-Ready Spaces to Circuits
				Quantity for Each Scenario					
Demolish, remove pavement & curb, remove bituminous pavement, 4" to 6" thick, excludes hauling and disposal fees	R	D	S.Y.	0	0	0	0	0	0
Demolish, remove pavement & curb, remove concrete curbs, plain, excludes hauling and disposal fees	R	D	L.F.	0	0	0	0	0	0
Demolish, remove pavement & curb, curbs, excludes hauling, minimum labor/equipment charge	R	D	Job	0	0	0	0	0	0
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.	R	D	Week	0	0	0	0	0	0
Deconstruction of concrete, floors, concrete slab on grade, plain, 4" thick, up to 2 stories, excludes handling, packaging or disposal costs	R	D	S.F.	0	0	0	0	0	0
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	R	D	C.Y.	0	0	0	0	0	0
Selective concrete demolition, minimum labor/equipment charge	R	D	Job	0	0	0	0	0	0

Task Description	Construction Type[1]	Work Type	Unit[2]	Scenario 3 Six PEV Circuits	Scenario 3 Six PEV-Ready Spaces	Scenario 3 Six PEV-Ready Spaces to Circuits	Scenario 4 Twelve PEV Circuits	Scenario 4 Twelve PEV-Ready Spaces	Scenario 4 Twelve PEV-Ready Spaces to Circuits
C.I.P. concrete forms, slab on grade, bulkhead with keyway, wood, 6" high, 1 use, includes erecting, bracing, stripping and cleaning	R	C	L.F.	0	0	0	0	0	0
C.I.P. concrete forms, slab on grade, edge, wood, 7" to 12" high, 4 use, includes erecting, bracing, stripping and cleaning	R	C	SFCA	0	0	0	0	0	0
Reinforcing steel, in place, dowels, smooth, 12" long, 1/4" or 3/8" diameter, A615, grade 60	R	C	Ea.	0	0	0	0	0	0
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	R	C	S.F.	0	0	0	0	0	0
Structural concrete, in place, minimum labor/equipment charge	R	P	Job	0	0	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.	4	4	0	4	4	0
Concrete sawing, concrete slabs, rod reinforced, up to 3" deep	R	D	L.F.	0	0	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	0	0
Selective demolition, concrete slab cutting/sawing, minimum labor/equipment charge	R	D	Job	0	0	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	0	2	2	0
Branch meter devices, main circuit breaker, 400 A, electrical demolition, remove, includes circuit breaker	R	D	Ea.	0	0	0	0	0	0
Wire, copper, stranded, 600 volt, #8, type THW, in raceway	N	C	C.L.F.	1.7	0	1.7	3.3	0	3.3
Wire, copper, stranded, 600 volt, #8, type THW, in raceway	R	C	C.L.F.	1.7	0	1.7	3.3	0	3.3
Wire, minimum labor/equipment charge	R	C	Job	0	0	0	0	0	0

Task Description	Construction Type[1]	Work Type	Unit[2]	Scenario 3 Six PEV Circuits	Scenario 3 Six PEV-Ready Spaces	Scenario 3 Six PEV-Ready Spaces to Circuits	Scenario 4 Twelve PEV Circuits	Scenario 4 Twelve PEV-Ready Spaces	Scenario 4 Twelve PEV-Ready Spaces to Circuits
Outlet boxes, pressed steel, 4" square	R	C	Ea.	6	0	6	12	0	12
Outlet boxes, pressed steel, 4" square	N	C	Ea.	6	0	6	12	0	12
Outlet boxes, pressed steel, covers, blank, 4" square	R	C	Ea.	6	0	6	12	0	12
Outlet boxes, pressed steel, covers, blank, 4" square	N	C	Ea.	6	0	6	12	0	12
PVC conduit, schedule 40, 1-1/4" diameter, in concrete slab, includes terminations, fittings and supports	N	R	L.F.	0	0	0	0	0	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	0	0
Rigid galvanized steel conduit, 2" diameter, in trench, includes terminations and fittings	R	R	L.F.	0	0	0	0	0	0
Rigid galvanized steel conduit, 2" diameter, in trench, includes terminations and fittings	N	R	L.F.	0	0	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.	170	0	170	330	0	330
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	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	R	R	L.F.	195.5	0	195.5	379.5	0	379.5
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	0	0
Conduit, to 15' high, minimum labor/equipment charge	R	R	job	0	0	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	0	0

Task Description	Construction Type[1]	Work Type	Unit[2]	Scenario 3 Six PEV Circuits	Scenario 3 Six PEV-Ready Spaces	Scenario 3 Six PEV-Ready Spaces to Circuits	Scenario 4 Twelve PEV Circuits	Scenario 4 Twelve PEV-Ready Spaces	Scenario 4 Twelve PEV-Ready Spaces to Circuits
Cable lugs, for 2 feeders, 4.8 kV or 13.8 kV	B	I	Ea.	0	0	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	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	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.	0	0	0	0	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.	0	0	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 (cost avoided by installing 200 amp panel at time of new construction)	N	C	Ea.	0	0	0	0	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.	0	0	0	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	0	0
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	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	0	0
Excavating, chain trencher, utility trench, common earth, includes excavation and backfill, minimum labor/equipment charge	B	E	Job	0	0	0	0	0	0

Task Description	Construction Type[1]	Work Type	Unit[2]	Scenario 3 Six PEV Circuits	Scenario 3 Six PEV-Ready Spaces	Scenario 3 Six PEV-Ready Spaces to Circuits	Scenario 4 Twelve PEV Circuits	Scenario 4 Twelve PEV-Ready Spaces	Scenario 4 Twelve PEV-Ready Spaces to Circuits
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	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	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	0	0
Painted pavement markings, acrylic waterborne, white or yellow, 4" wide, less than 3000 L.F.	R	C	L.F.	200	0	200	600	0	600
Painted pavement markings, acrylic waterborne, white or yellow, 4" wide, less than 3000 L.F.	N	C	L.F.	200	0	200	600	0	600
Add equipment minimum for concrete demo- assume labor minimum subsumed under saw cut minimum	R	D		0	0	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	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	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	0	0
Rent core drill, electric, 2.5 H.P. 1" to 8" bit diameter, including hourly operating cost	R	d		1	1	0	3	3	0
Rent backhoe-loader 40 to 45 HP 5/8 CY capacity, one day including 4 hours operating cost	R	d		0	0	0	0	0	0
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	0	-2	-2	0

Task Description	Construction Type[1]	Work Type	Unit[2]	Scenario 3 Six PEV Circuits	Scenario 3 Six PEV-Ready Spaces	Scenario 3 Six PEV-Ready Spaces to Circuits	Scenario 4 Twelve PEV Circuits	Scenario 4 Twelve PEV-Ready Spaces	Scenario 4 Twelve PEV-Ready Spaces to Circuits
Main Circuit breaker, 3 pole 3 wire 100 amp	R	C	Ea.	0	0	0	0	0	0
Main Circuit breaker, 3 pole 3 wire 225 amp	N	C	Ea.	-1	-1	0	0	0	0
Main Circuit breaker, 3 pole 3 wire 225 amp	R	C	Ea.	0	0	0	0	0	0
Main Circuit breaker, 3 pole 3 wire 400 amp	N	C	Ea.	1	1	0	2	2	0
Main Circuit breaker, 3 pole 3 wire 400 amp	R	C	Ea.	1	1	0	2	2	0

1. Some codes that appear duplicative are retrofit in one case and new construction in another case.
2. Unit refers to quantity, such as linear foot (LF), hundred linear foot (CFL), square yard (SY), cubic yard (CY).