

ABSTRACT

This document serves as the Final Report by the City of Oakland pursuant to its Agreement ARV-14-060 with the California Energy Commission under solicitation PON-14-607 for Zero-Emission Vehicle Readiness Plan Implementation.

The project had two main deliverables: plug-in electric vehicle infrastructure building code adoption in the City of Oakland, City of Fremont, and the City and County of San Francisco, and to improve and streamline the permitting and inspection process for electric vehicle charging in Oakland.

As a result of work conducted under this agreement, each partnering local government adopted new building codes that require a higher level of electric vehicle charging infrastructure at a greater number of parking spaces than required by the California Green Building Standards Code. These efforts will generate significant benefits.

The permitting/inspection streamlining and staff training carried out in Oakland through this grant was meant to decrease the rate of non-compliance, but this is an area that the project team recommends for further consideration and grant funding, as discussed in Chapter 5. In addition, some electric vehicle plug-in electric vehicle infrastructure would have been required under existing California Green Building Standards Codes, though in general the code does not require compliance with Title 24 Chapter 11B requirements.

Keywords: California Energy Commission, Plug-in Electric Vehicle, City of Oakland, California Green Building Standards Code

Please use the following citation for this report:

Pike, Ed, Jeffery Steuben, Shayna Hirshfield. 2020. *City of Oakland Plug-in Electric Vehicle Readiness Grant*. California Energy Commission. Publication Number: CEC-600-2020-025.

TABLE OF CONTENTS

	Page
Acknowledgements	i
Preface.....	ii
Abstract	iii
Table of Contents.....	v
Executive Summary.....	1
CHAPTER 1: Background	3
Purpose	3
California PEV Adoption Goals.....	3
Local Policy Goals	5
Building Code Opportunity.....	7
Permit and Inspection Streamlining.....	8
Chapter 2: Local Code Adoption Process.....	9
Agency Staff Engagement Process.....	9
Modeling Analysis	10
Stakeholder Engagement and Public Process	11
Specific Cost Comparisons	12
Transformer Upgrades.....	12
Adopted Local Codes	13
CHAPTER 3: Permitting and Inspection Streamlining	15
Purpose	15
Evaluation Process.....	15
Outcomes and Recommendations.....	15
Key Recommendations:	15
CHAPTER 4: Expected Benefits	17
CHAPTER 5: Potential Next Steps.....	20
Existing Buildings.....	20
Direct Current Fast Charging	21
Curbside Charging	21
Goods Movement Transportation Electrification	22
Electric Stand-By Transportation Refrigeration Unit Infrastructure	22
Forklift Electrification Infrastructure	22
Building Code Compliance	23
GLOSSARY.....	25
APPENDIX A: Modeling Details.....	A-1
PEV Infrastructure Cost-Effectiveness Model.....	A-1

Project Benefit Calculations	A-1
PEV Future Fleet Mix	A-1
PEV Electric Vehicle Miles Traveled and Efficiency.....	A-2
Emissions Rates	A-5
Petroleum Vehicle Fuel Efficiency	A-6
Parking Space Estimates	A-7
Environmental Benefit Calculations	A-8

LIST OF FIGURES

	Page
Figure 1: California and U.S. PEV Sales.....	4
Figure 2: Clean Vehicle Rebate Program Rebate Heat Map by ZIP Code	5
Figure 3: Bay Area PEV Ownership and EV Charger Proliferation	6
Figure 4: PEV Infrastructure Categorized Cost San Francisco Report Results	11
Figure 5: BEV eVMT vs Electric Range	A-4

LIST OF TABLES

	Page
Table 1: CALGreen Mandatory and Voluntary PEV Readiness Standards	8
Table 2: City of Oakland Cost-Effectiveness Report Scenario Summary	10
Table 3: City of Oakland Cost-Effectiveness Results per Parking Space	10
Table 4: PG&E-Funded City of San Francisco Cost-Effectiveness Report.....	11
Table 5: Oakland Estimated Cost of Compliance: Parking Spaces and Building	12
Table 6: Local Adopted Codes Compared to CALGreen Mandatory Codes.....	14
Table 7: Electric Vehicle Data	A-3
Table 8: Plug-in Electric Vehicle Measured and Calculated Annual eVMT	A-4
Table 9: Estimated New Multifamily Dwellings and Parking Spaces	A-7
Table 10: Estimated New Nonresidential Parking.....	A-8
Table 11: EV Parking and Environmental Benefits Increase by the Year 2025	A-9

EXECUTIVE SUMMARY

The CEC funded the City of Oakland (Oakland) to support plug-in electric vehicle (PEV) readiness under grant ARV-14-060 in 2015. The project had two main deliverables: PEV infrastructure building code adoption in Oakland, Fremont, and the City and County of San Francisco as well as improving and streamlining the permitting and inspection process for PEV charging in Oakland. These efforts will support [Zero-Emission Vehicle Action Plan](#) (ZEV Action Plan) goals, local climate and air quality goals, and lead to economic benefits for each community.

The project included several steps:

- Engage local staff and decision-makers, including stakeholders within the Cities and in the broader communities;
- Select target levels of PEV charging infrastructure in new construction and model scenarios to demonstrate that local building codes are cost-effective compared to later retrofit costs or other soft-costs of development.
- Develop an innovative model code package for each city to increase the amount of PEV charging electrical infrastructure included in new buildings, and to ensure that PEV parking subject to the Title 24 Chapter 11B accessibility requirements is designed for compliance.
- Conduct outreach to stakeholders and address feedback before following a formal public process for adopting codes.
- Examine the permitting and inspection process in Oakland and take additional steps to streamline these processes, including through staff training.

Each partnering local government adopted new building codes that require a higher level of PEV charging infrastructure at a greater number of parking spaces than required by the California Green Building Standards Code. These efforts will generate significant benefits. The project team estimates that this project will create over 11,000 additional PEV parking spaces with electric circuit infrastructure by 2025, facilitating adoption of at least 10,000 new PEVs. This will reduce at least 35,200 metric tons carbon dioxide equivalent of greenhouse gas (GHG) emissions, and avoid 3,520,000 million gallons of petroleum usage per year by 2025 along with significant improvements to air quality and public health.

The project team also identified potential future projects that can build on the successful adoption of these local codes. Implementing similar passenger vehicle local codes to additional jurisdictions is one opportunity. Others include electrical infrastructure solutions for curbside charging, accessibility guidelines, and guidelines for Direct Current Fast Charging. Building codes can also cover electric infrastructure for goods movement vehicles, such as forklifts at warehouses and stand-by emissions from transportation refrigeration units.

CHAPTER 1: Background

Purpose

This project was funded by an Energy Commission grant to the City of Oakland (Oakland) for two primary purposes. The first was to facilitate the adoption of local building code amendments to the 2016 California Green Building Standards Code (CALGreen) and provide related training and outreach to municipal staff and the public in the three participating cities. This effort was led by Oakland, City of Fremont (Fremont), and the City and County of San Francisco (San Francisco) with contractor support from Energy Solutions. The second, led by Oakland with support from Energy Solutions, was to benchmark Oakland's permitting approval and inspection process, recommend areas for improvement, and provide support to optimize implementation of the new code requirements. Oakland also provided project administration. These efforts will support state and local climate and PEV adoption goals described below.

California PEV Adoption Goals

California will most likely need to achieve a 12 percent statewide PEV market share of new vehicle sales by 2025 to meet the 2016 [ZEV Action Plan](#) target of 1.5 million zero emission vehicles on the road by 2025, based on the size of the State's current fleet and expected growth rates.¹ California is already ahead of California Air Resources Board's (ARB) expected trajectory to that goal; as of June 2019,² there were more than 595,000 PEVs on the road in the state, or nearly half of all electric vehicles in use nationally, which can be seen in figure 1.3 In the San Francisco Bay Area, two cities have the highest PEV sales rates in the country. San Francisco's PEV sales rate through the second quarter of 2019 is 23 percent, while San Jose's PEV sales rate is 21 percent for the same period.⁴ These market penetration rates are well above the ARB expected trajectory toward the 2025 goals, so 12 percent may represent a floor with actual PEV market share potentially much higher.⁵

1 ["Plug-in Electric Vehicle Infrastructure Cost-Effectiveness Report" July 20, 2016](#) (<https://energy-solution.com/wp-content/uploads/2016/08/PEV-Infrastructure-Cost-Effectiveness-Summary-Report-2016-07-20a.pdf>). Even higher adoption rates will be needed to meet the five million ZEV 2030 target in the [Governor's January 2018 Executive Order](#) (<https://www.gov.ca.gov/2018/01/26/governor-brown-takes-action-to-increase-zero-emission-vehicles-fund-new-climate-investments/>).

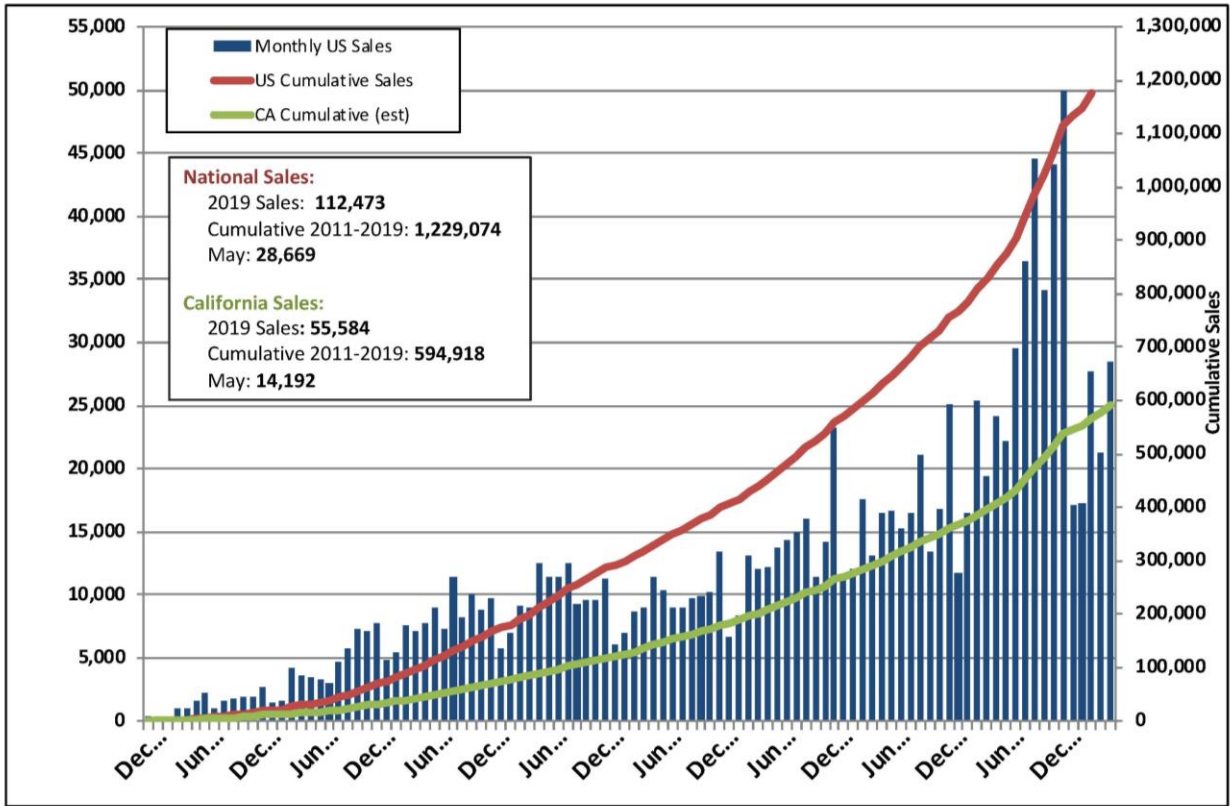
2 This Final Project Report was originally drafted in 2017. The 2017 data from Veloz showed 300,000 PEVs in California.

3 [California PEV Collaborative](http://bit.ly/capevcollabnov2016) (<http://bit.ly/capevcollabnov2016>).

4 International Council on Clean Transportation. *The Surge of Electric Vehicles in United States Cities*. ICCT Briefing. June 2019.

5 [ARB "Staff Report: Initial Statement of Reasons for Rulemaking"](#), September 2013 (<http://www.arb.ca.gov/regact/2013/zev2013/zev2013isor.pdf>), and the Plug in Electric Vehicle Collaborative [Plug in Electric Vehicle Collaborative "Detailed Monthly Sales Chart"](#), June 2017 (http://www.pevcollaborative.org/sites/all/themes/pev/files/4_april_2016_Dashboard_PEV_Sales.pdf)

Figure 1: California and U.S. PEV Sales



Note: Approximation assumes CA sales are 49% of national sales.
 Reference: www.hybridcars.com and www.insideevs.com

6/7/2019

Source: Veloz

To support the Zero-Emission Vehicle (ZEV) proliferation goal, the 2016 ZEV Action Plan notes that upwards of 1,000,000 charging locations will likely be needed at homes, workplaces, and public garages by 2020. There are about 40,000 public charging stations available in California currently.⁶ According to ARB’s [2016 Mobile Source Strategy](#), California will need 4.2 million electric vehicles on the road by 2030 and “the vast majority of the on-road fleet must be ZEVs and PHEVs by 2050 in order to meet GHG targets.” Thus, a dramatic increase in PEV charging infrastructure in new buildings is needed in the immediate term, and both infrastructure and policy mechanisms are needed to provide flexibility for additional growth in PEV charging over the life of each new building.

Multifamily buildings and workplaces are widely recognized priorities for increasing access to PEV charging. Increased PEV infrastructure in multifamily housing will also be needed to achieve equitable access to PEVs for disadvantaged communities as required by California SB-

6 Brecht, Patrick and Jacob Orenberg. 2019. *2019-2020 Investment Plan Update for the Clean Transportation Program*. California Energy Commission, Fuels and Transportation Division. Publication Number: CEC-600-2018-005-LCF-REV. See Table 11.

350 (*De León, Chapter 547, Statutes of 2015*) transportation electrification goals. California electric utilities have adopted pilot-level passenger vehicle PEV infrastructure pilots focused on multifamily buildings and workplaces and have been developing potentially broader programs as well that can complement building codes.

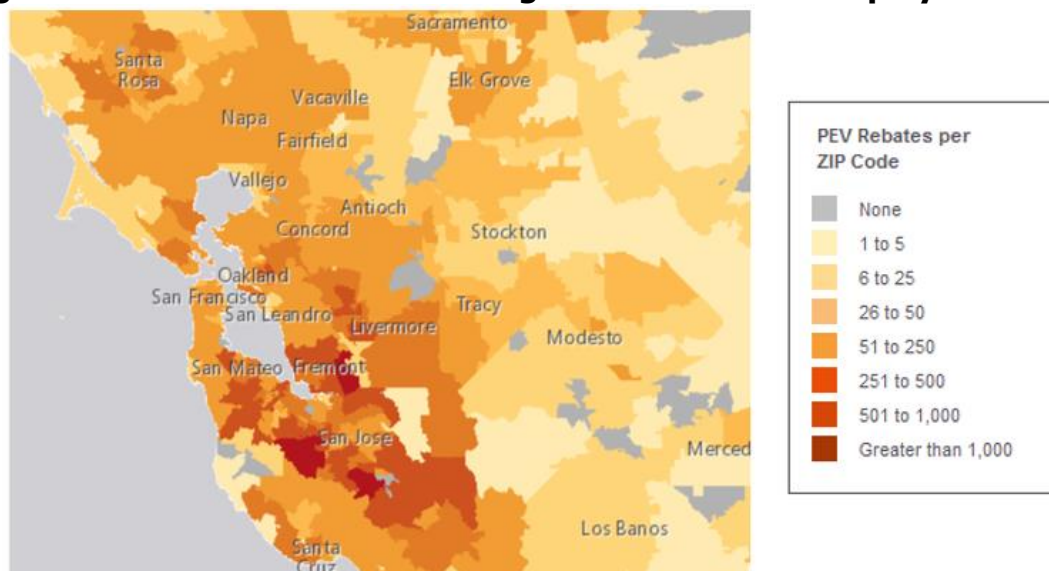
Local Policy Goals

Many local governments in the San Francisco Bay Area including Fremont, Oakland, and San Francisco have adopted progressive climate and energy goals that also include promoting PEV adoption. For instance, Oakland has adopted goals of reducing GHG emissions by 36 percent below 2005 levels by 2020 and 83 percent below 2005 levels by 2050. Oakland’s 2012 [Energy and Climate Action Plan](#) identifies PEV Infrastructure as a priority action toward achieving those goals. Similarly, San Francisco [Ordinance No. 81-08](#) sets goals of reducing greenhouse gas emissions citywide to 40 percent below 1990 levels by 2025 and 80 percent by 2050. The City of Fremont’s 2012 [Climate Action Plan](#) reflects the goal of a 25 percent reduction in GHGs by 2020, and notes the importance of PEV infrastructure in meeting this goal.

These three San Francisco Bay Area communities already have higher PEV adoption than statewide averages. Shows how the Bay Area forms a PEV adoption “hot spot” where adoption of Electric Vehicle (EV) is concentrated. Oakland’s per capita PEV adoption rate is about 50 percent higher than statewide averages based on analysis of 2015 vehicle registrations from the Department of Motor Vehicles. Fremont boasts the zip code with the highest PEV adoption in the country.

Figure 2 below shows a map representing the number of PEV rebates, provided by the Clean Vehicle Rebate Program, per ZIP Code in the San Francisco Bay Area.

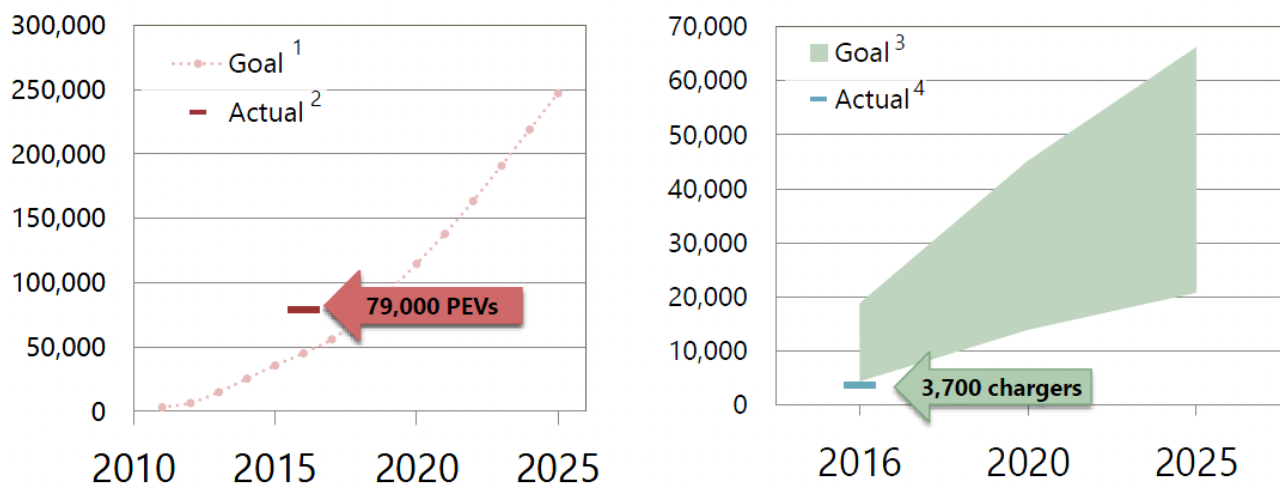
Figure 2: Clean Vehicle Rebate Program Rebate Heat Map by ZIP Code 7



Source: Center for Sustainable Energy

Industry experts agree that solving the current lack of widespread PEV charging infrastructure in multifamily housing, workplace, and other nonresidential buildings will unlock further demand for PEVs, both in areas with already high adoption levels and in those struggling to advance PEV ownership. However, significant barriers to installing residential charging in multifamily buildings continue to limit potential demand. In addition, unlike PEV ownership, public PEV charging infrastructure in the Bay Area lags behind estimates of the levels needed to support the PEV targets described above, as seen in figure 3. With PEV ownership ahead of projections but public charging infrastructure falling behind the low end of anticipated requirements, the region may soon approach the limits of what can be accommodated without significantly increasing that infrastructure.

Figure 3: Bay Area PEV Ownership and EV Charger Proliferation



Source: Bay Area Electric Vehicle Coordinating Council, September 2016

In Oakland, one of the nation’s most racially and economically diverse cities, equitable access to clean transportation is a critical goal. Oakland’s low-income neighborhoods tend to be along freeways and major transportation corridors where air pollution is most acute; residents there have emergency room visits and hospitalizations from asthma at twice the rate of the rest of the county. Facilitating PEV infrastructure in buildings that serve a wide range of customers, and in new multifamily housing that is expected to absorb a significant share of lower-income residents over the coming decades, is a key goal within Oakland’s climate equity strategy.⁸

⁸ Oakland has seen an average of 220 new affordable housing units per year, all within multifamily housing developments, for the eight years prior to 2017. This trend is expected to continue as new developments are constructed thanks to a range of City policies and adopted measures, including newly approved development impact fees, available Cap and Trade funding through the Affordable Housing and Sustainable Communities program, and the City’s Infrastructure Bond.

Building Code Opportunity

Building codes facilitate PEV infrastructure installation by reducing the total cost of installations, as discussed below, and avoiding non-cost barriers associated with retrofits.⁹ CALGreen is a primary source of building code guidance for PEV charging infrastructure in California. CALGreen was formally adopted by the California Building Standards Commission for residential and nonresidential buildings. The residential section was authored by the California Department of Housing and Community Development, while the nonresidential section was authored by the California Building Standards Commission.

Electric vehicle charging infrastructure is an amenity that can help both residential and commercial landlords attract tenants. In addition, California law (*AB 2565 enacted in 2014*) requires that building owners allow residential tenants in buildings with six or more parking spaces to install PEV charging equipment at their own expense. Building codes that set minimum requirements on PEV infrastructure can facilitate convenient and cost-effective access to electricity so that residents and commuters, as well as fleet managers and car sharing services, can benefit from the significant operating cost advantages and emission reductions that PEVs provide.

CALGreen requirements for PEV-ready parking spaces in new construction (described in Title 24, Part 11, sections 4.106 and 5.106) include sufficient electrical panel capacity and installation of raceways (conduit) to reduce the burden of preparing a building for installation of charging equipment after initial construction is complete. CALGreen also contains voluntary requirements for PEV charging infrastructure (Title 24, Part 11, sections A4.106 and A5.106). Local governments may choose to adopt the voluntary requirements (or “Tiers”) as-is, which then become mandatory in their jurisdiction, or adopt tailored local codes based on specific local findings. The CALGreen statewide minimum PEV charging electrical infrastructure requirements are summarized in

⁹ Non-cost barriers can include the need for HOA and/or landlord approvals, lack of information, and the time required to hire and manage a contractor.

Table 1.

Table 1: CALGreen Mandatory and Voluntary PEV Readiness Standards

	Nonresidential	Nonresidential	Nonresidential	Multifamily dwelling ¹⁰	Multifamily dwelling ¹¹
	Mandatory	Tier 1	Tier 2	Mandatory	Voluntary
Minimum threshold	10 parking spaces	10 parking spaces	One parking space	17 units	17 units
New parking spaces that must be EV Ready 11	~6%	~8%	~10%	3%	5%

Source: California Building Standards Commission

Adoption of local building “reach” codes for PEV readiness can provide significantly greater benefits than current CALGreen minimum standards. For instance, even the voluntary tiers of CALGreen exclude small to mid-sized multifamily housing. In addition, CALGreen minimums are not high enough to meet California PEV deployment goals and expected local demand, particularly in the San Francisco Bay Area. Finally, CALGreen does not address new Title 24 Chapter 11B accessibility codes that must be met at the time of PEV charging station installation. These standards may be impractical to meet when charger installation is desired if building codes do not impose similar requirements for slope, vertical clearance, etc. for a portion of parking spaces at the time of original construction.

Permit and Inspection Streamlining

Beyond updates to the building code, this project also placed an emphasis on improving the efficiency of local government permitting and inspection processes to reduce the soft costs (e.g. project staff time) associated with EV infrastructure installations and to increase compliance rates. The goal was to review and evaluate existing processes, and propose adoption of best practices. Direct education of city staff and the development of reference material complemented the process improvement.

10 The California Department of Housing and Community Development has proposed revisions that would become effective January 1, 2020 if finalized.

11 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.

Chapter 2: Local Code Adoption Process

Agency Staff Engagement Process

The project team, which consisted of one lead agency staff from each city and staff from consultant Energy Solutions, engaged local staff from multiple municipal departments in Fremont, Oakland, and San Francisco at the outset and maintained a collaborative approach among the partners. This process promoted the sharing of ideas and strategies over the duration of the project and facilitated the development of innovative approaches that are not contained in the CALGreen building codes. The project team pooled expertise and provided feedback to each other throughout, including:

- Guiding outreach to local policy-makers.
- Fine-tuning the scenarios and methodology for technical research led by Energy Solutions.
- Determining the level of enhancements to basic state codes.
- Exceeding the scope of CALGreen through the development of technical specifications that covered 3-16 unit multifamily buildings and require full circuits.
- Developing language to address accessibility, which became a priority after the adoption of Title 24 Chapter 11B accessibility requirements.
- Fine-tuning outreach messages and approaches for stakeholder engagement, particularly with the developer community.
- Communication with PG&E regarding transformer upgrade requirements.

Agency project leads met with local government internal stakeholders such as Planning and Building Department permitting & inspection staff, environmental or sustainability staff, internal code advisory committees, and staff of local elected officials. Agency staff and/or Energy Solutions presented background on the need for codes to facilitate PEV demand and support policy goals. The meetings gathered valuable feedback and achieved buy-in from staff across the local government agencies. This feedback was especially valuable as each agency chose to go beyond the original project scope and consider more progressive revisions. For instance, each agency proposal included (but was not limited to) full circuits for approximately 10 percent of parking spaces in multifamily and non-residential buildings.

This feedback also led the team to identify alterations and additions to existing buildings as a priority for future research and policy development, as most building permits are for modifications to existing buildings rather than new construction. Fremont and Oakland chose not to develop code language for these projects at the time due to the lack of existing guidelines to differentiate projects that should trigger this requirement from projects that should not. San Francisco's ordinance takes an initial step toward addressing existing buildings, relying on existing definitions in its municipal code to capture a limited scope of major renovations. It also contains new exemption language specific to PEV infrastructure so that projects unrelated to electrical infrastructure would not trigger electrical infrastructure upgrades. The project partners agreed that additional guidance on this topic would be beneficial. This is discussed further in Chapter 5.

Modeling Analysis

Energy Solutions prepared a cost-effectiveness model and summary report to document the expected cost-effectiveness of installing PEV charging infrastructure during new construction versus during a later building retrofit. The scenarios examined for the report are shown below in Table 2, and include large, small, indoor, and outdoor parking areas. The scenarios were modeled with both “PEV-ready” infrastructure and full circuits. “PEV-ready” provisions in the model include electrical service panel capacity sufficient to supply a Level 2 charger at 40 amps and space and all inaccessible raceway (raceway in areas that would become inaccessible after construction, such as that embedded in floors or concrete walls), similar to requirements included in the current CALGreen code for multifamily housing. A complete PEV circuit adds wire, circuit breakers, termination point, and surface conduit to the extent not provided by PEV-readiness standards.¹² The results from the June 2016 report prepared for the Fremont, Oakland, and San Francisco are summarized below in Table 3.

Table 2: City of Oakland Cost-Effectiveness Report Scenario Summary

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

Source: Plug-in Electric Vehicle Infrastructure Cost-Effectiveness Report, July 26, 2016

Table 3: City of Oakland Cost-Effectiveness Results per Parking Space

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

Source: Plug-in Electric Vehicle Infrastructure Cost-Effectiveness Report, July 26, 2016

¹² In Oakland’s code and public messaging, the term “PEV-ready” was changed to refer to spaces that are equipped with complete electrical circuits as described in the Cost-Effectiveness report, while “PEV-capable” denotes spaces that have sufficient electrical capacity and inaccessible (empty) conduit only. Thus, in the City of Oakland’s final adopted nomenclature, “PEV-ready” is the higher level of readiness.

Energy Solutions also prepared a related report on November 17, 2016 for the City of San Francisco, with funding from Pacific Gas and Electric (PG&E), as preparing a second report was outside the scope of the CEC grant. This report found that the costs of in-slab conduit installation during new construction, as recommended by industry experts during San Francisco building code stakeholder meetings, resulted in much lower installation costs, broken down in Table 4, and larger cost-savings when compared to later retrofits. Figure 4 details infrastructure cost results by cost category.

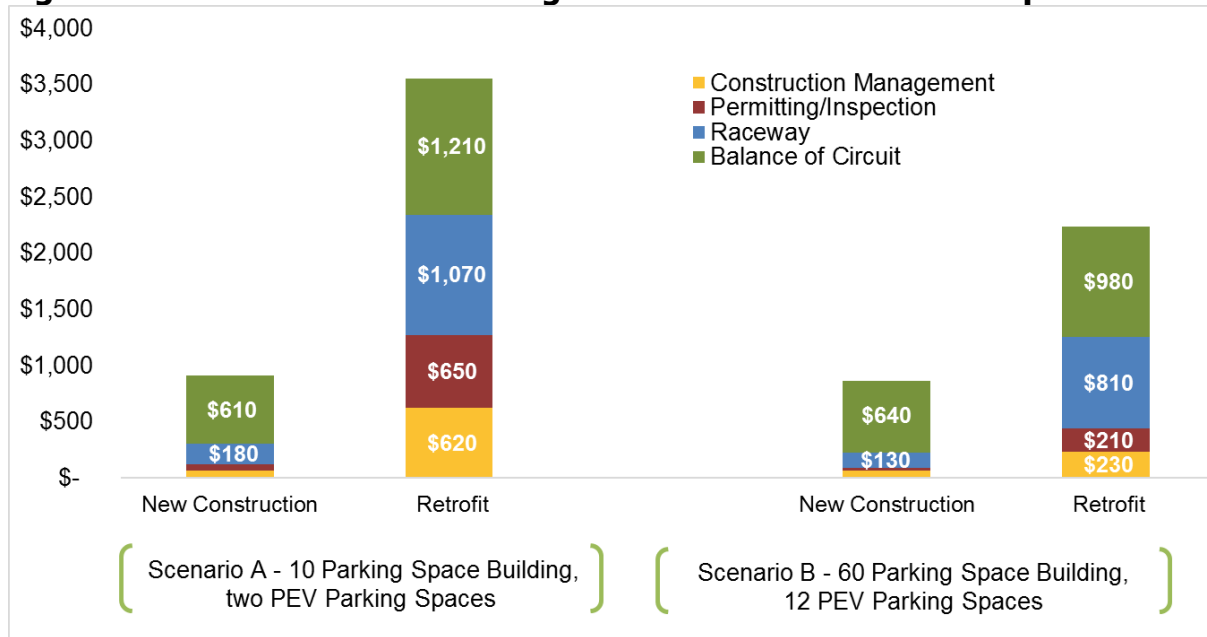
Examples of avoided costs from PEV infrastructure building codes include: breaking and repairing walls, upgrading electric service panels, additional permitting and inspections, and breaking and repairing parking surfaces and/or sidewalks (for the surface parking scenario). Additional details are contained in the Appendix of this report.

Table 4: PG&E-Funded City of San Francisco Cost-Effectiveness Report

	New	Retrofit	Cost Savings
Scenario A - 10 Parking Space Building, two PEV Parking Spaces	\$920	\$3,710	\$2,790
Scenario B - 60 Parking Space Building, 12 PEV Parking Spaces	\$860	\$2,370	\$1,510

Source: Plug-in Electric Vehicle Infrastructure Cost-Effectiveness Report for San Francisco, November 17, 2016

Figure 4: PEV Infrastructure Categorized Cost San Francisco Report Results



Source: PEV Infrastructure Cost-Effectiveness Report for San Francisco, November 17, 2016

Stakeholder Engagement and Public Process

Each agency provided formal and informal opportunities for stakeholder engagement and public comments. Informal outreach included discussions with developer and other stakeholders, including community members, installers, and market participants. Formal opportunities included stakeholder meetings and industry group presentations. Oakland and San Francisco provided additional feedback to stakeholders regarding potential utility

infrastructure costs, with information and funding for consulting services provided by PG&E based on stakeholder requests.

Each city also followed an advisory committee process to engage experts and key stakeholders. The codes were then reviewed by any sub-committee(s) required by local processes and subject to formal public comment periods.

Specific Cost Comparisons

In Oakland, the stakeholder engagement process revealed developer concerns about the costs of compliance. In response, staff developed a supplemental Council report that provided a more detailed analysis of cost comparisons, based largely on the San Francisco cost effectiveness report, as seen in Table 5. This cost analysis showed that for a scenario with a typical multifamily 60 parking space building, the total compliance cost was estimated to be \$8,580. This included an estimated cost for the spaces equipped with full circuits of \$800 per space, totaling \$4,800. The cost of creating electric panel capacity for an additional 10 percent of spaces (six spaces), plus installing inaccessible conduit for all remaining spaces, averaged \$70 per space across the 54 PEV-capable spaces, for a total of \$3,780. The total compliance cost for 60 spaces was \$142 per space, or \$71 per housing unit in a 120-unit building, and slightly lower per-space costs in a similarly sized nonresidential building.

Table 5: Oakland Estimated Cost of Compliance: Parking Spaces and Building

	CALGreen: Multifamily Mandatory	CALGreen: Nonresidential Mandatory	Oakland Ordinance: Multifamily	Oakland Ordinance: Non- residential
Estimated Total Cost of Compliance	\$1,300	\$3,100	\$8,580	\$8,300
Incremental Total Cost of Compliance with Proposed Ordinance Relative to CALGreen	-	-	\$7,280	\$5,200
Estimated Cost of Compliance per Parking Space	\$22	\$52	\$142	\$138
Estimated Cost of Compliance per Residential Unit	\$11	\$26	\$71	\$69

(Note: Actual site-specific costs in table 5 will vary based on factors such as parking area layout, conduit lengths and configuration, and availability of spare panel capacity)

Source: Plug-in Electric Vehicle Infrastructure Cost-Effectiveness Report for San Francisco, November 17, 2016

Transformer Upgrades

Some stakeholders expressed concern about the utility costs associated with proposed code compliance. The two cost effectiveness models do not include the cost of transformer upgrades because those upgrades are expected to be required only infrequently. California’s Investor Owned Utilities reported in 2016 “Of the 202,569 vehicles estimated to be currently on the road, only 387, or 0.19 percent, have required a service line or distribution system

upgrade solely to support the PEV load at their residential charging location.”¹³ Transformers are included in the California’s Investor Owned Utilities’ definition of “distribution system.” This report includes both single family and multifamily buildings, so the need for upgrades will vary based on building type and site-specific circumstances.

In the uncommon instances where a distribution system upgrade is needed, adding a stand-alone, low voltage (120 kilovolt Amp - 500 Amp, 240 volts) transformer with capacity to support a dozen charging circuits would cost approximately \$10,000, including labor. In a 60-parking space building subject to Oakland’s new PEV Readiness ordinance, the additional cost would equal \$83 per unit, or \$167 per parking space. The incremental cost of upsizing a transformer in new construction to provide this amount of capacity would be substantially less.

Adopted Local Codes

The Fremont City Council formally adopted local building codes via [Ordinance 21-2016](#) in November 2016. The Oakland City Council adopted building code [Ordinance 13419](#) in February 2017. The San Francisco Board of Supervisors adopted a building code ordinance ([File number 170202](#)) that was signed by Mayor Lee on April 27, 2017. All three adopted local codes exceed the original project goal of implementing CALGreen voluntary codes and are currently in effect.

To ensure that special circumstances would not generate an undue cost burden on new developments, all three new ordinances contain a compliance cost cap of \$400 per parking space, which a developer may need to pay for utility infrastructure upgrades at multifamily housing (including utility transformer upgrades). The codes also contain a similar exemption for nonresidential construction, both of which are based on existing CALGreen language.

Table 6 compares the number of spaces and level of infrastructure to the CALGreen mandatory and voluntary codes. The difference is most dramatic for multifamily housing, where the codes require full circuits at 10 percent of parking spaces, and Oakland and San Francisco potentially require certain types of infrastructure sufficient to serve an additional 10-90 percent of parking spaces. These local codes will result in significantly higher levels of nonresidential infrastructure.

¹³ [The California’s Investor Owned Utilities](http://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M171/K806/171806139.PDF) load research report (http://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M171/K806/171806139.PDF).

Table 6: Local Adopted Codes Compared to CALGreen Mandatory Codes

	Multifamily	Nonresidential
Fremont	Approximately 10% of spaces have full circuit	Approximately 10% of spaces have full circuit
Oakland	A minimum of 10 percent of spaces have full circuits ("PEV-ready"); additional 10% of spaces have panel capacity; inaccessible conduit required for all spaces without a full circuit. Tiered requirements for buildings with fewer than 20 spaces.	Depending on number of parking spaces, a minimum of 10% of spaces have full circuit; additional 10% of spaces have panel capacity & inaccessible conduit
San Francisco	Approximately 10% of spaces have full circuit; additional 10% of spaces have panel capacity; inaccessible conduit required for all spaces without a full circuit	Same as multifamily
Mandatory CALGreen	Buildings with 17 or more residential units must have panel capacity & installation of inaccessible raceways at 3% of parking spaces. No requirements for buildings with fewer than 17 units.	Panel capacity and conduit at approximately 6% of spaces required for buildings with 10 or more parking spaces
Voluntary CALGreen	Buildings with 17 or more units must have panel capacity & installation of inaccessible raceways required at 5% of parking spaces (plus conduit if only one space). No requirements for buildings with fewer than 17 units.	Two options: Panel capacity and conduit at 8%-10% of spaces at buildings with either 1 or more parking spaces; or 10 or more parking spaces.

Source: Energy Solutions

All three local codes also require design for accessibility. Title 24, Chapter 11B dictates state accessibility requirements for the installation of EV Charging Stations. Currently, Title 24 Chapter 11B requirements are triggered when EV Charging Stations are built, *not* at the time of new construction.¹⁴ Thus, buildings could be designed and constructed in a way that is incompatible with slope, vertical clearance, and other requirements that must be met when the EV Charging Stations are installed. If the required accessible EV Charging Stations are not installed, then no EV Charging Stations can be installed, creating a barrier to permitting and installation of the charging stations. Therefore, each partnering city adopted local codes that require designing new parking areas so that compliance with accessibility requirements will be practical when installing EV Charging Stations in the future.

Oakland’s code includes requirements that in large (more than 20 parking spaces) multifamily buildings, up to 100 percent of parking spaces may eventually be equipped with EV chargers. San Francisco’s code contains similar requirements for both multifamily and nonresidential housing. These provisions and electrical panel capacity requirements would allow electric vehicles in up to 100 percent of spaces to charge simultaneously (at a slower rate of 6 or more Amp instead of 30 Amp at 208/240 volts) through voluntary installation of load management technologies and additional conduit.

The benefits of these local codes are discussed further in Chapter 4.

¹⁴ CALGreen requires that one in 25 EV charging spaces in multifamily residential buildings with 17 or more units are designed to meet specific accessibility requirements.

CHAPTER 3: Permitting and Inspection Streamlining

Purpose

In addition to enhancement of local building codes, this project included review of Oakland's existing permitting and inspection processes to facilitate smooth installation of electric vehicle supply equipment (EVSE) and promote best practices.

Evaluation Process

The project team conducted a full evaluation of existing processes to establish a baseline and the foundation upon which recommendations for improvement could be built. The first step was conducting a literature review of documents published by California cities, the state, and other entities such as the Bay Area Air Quality Management District and the Association of Bay Area Governments. This review helped set the stage for the types of materials that have already been created by other cities, and the slate of recommended best practices offered. The evaluation also included a review of Oakland's materials, webpages, and documents. This review established that basic PEV infrastructure permitting and inspection are addressed by existing City processes. To fully understand how PEV charger installations were currently being handled, multiple interviews were conducted with Planning, Building, and Inspection staff.

Outcomes and Recommendations

After conducting all aspects of the evaluation, Energy Solutions prepared a summary report of the findings and recommendations to improve Oakland's permitting and inspection processes. The report found that the efficiency of the application process hinges on the City's ability to incorporate EVSE charger installations into existing processes and did not recommend a separate permitting process. It also found that the fee schedule is reasonable and consistent with comparable projects in Oakland and with EVSE installations in other jurisdictions.

Energy Solutions recommended that Oakland continue their existing EVSE approval process as part of existing City processes, rather than developing separate and unique approval processes, with the following recommendations and outcomes:

Key Recommendations:

- Train city planners, plan checkers, and inspectors about EVSE and code requirements.
- Provide these staff with training regarding Title 24 Chapter 11B accessibility requirements.
- Provide EVSE permitting checklists to staff and the public.
- Create EVSE inspection resources for city inspectors.
- Create a page on the City website dedicated to EV charging information and requirements.

The project team completed a series of actions to facilitate the above recommendations:

- Created new accessibility code requirements to facilitate implementation of Title 24 Chapter 11B accessibility requirements.
- Provided Oakland Building Division Inspection staff with training regarding Title 24 Chapter 11B accessibility requirements including applicability, technical requirements, and practical implications.
- Provided EVSE training for inspection and permitting staff.
- Revised local building code proposals based on permitting and inspection staff input.
- Created a new Condition of Approval for development applications based on the new code requirements (Conditions of Approval are handled by the Planning Division).
- Created guidelines and an online Fact Sheet detailing the new recommendations, now posted on the City's website.¹⁵
- Created an internal guidance document with frequently asked questions for City staff.

¹⁵ [City of Oakland " Electric Vehicle Infrastructure Requirements for New Multi-Family and Nonresidential Buildings"](http://www2.oaklandnet.com/oakca1/groups/pwa/documents/report/oak063669.pdf) (http://www2.oaklandnet.com/oakca1/groups/pwa/documents/report/oak063669.pdf)

CHAPTER 4: Expected Benefits

The project team estimated benefits expected by 2025, which is the deadline for adoption of 1.5 million zero emission vehicles (mainly PEVs) in California under the ZEV Action Plan. The project is expected to facilitate the deployment of an estimated 11,000 PEV charging spots and at least 10,000 additional PEVs on the road by 2025, based on the number of parking spaces served by either PEV-ready infrastructure (full circuits) or full circuits minus wiring (which can easily be converted to full circuits) anticipated to be constructed by 2025. The project will also result in almost 31,000 parking spaces with inaccessible conduit installed. Additional details for these calculations are located in the Appendix. One key assumption is that rates of parking construction would tend to be half of typical averages for multifamily housing and 40 percent for nonresidential construction for Oakland and San Francisco. These assumptions are based on progressive policies to promote alternative forms of transportation and constrain construction of new parking, as well as limits on available land for development.

In Fremont, these spaces will also have EVSE installed due to zoning code revisions passed concurrently with the above building code revisions. The San Francisco codes will also facilitate the addition of electric infrastructure and EVSE at facilities built prior to PEV infrastructure building codes.

Most of these spaces exceed what would have been required by CALGreen. While future PEV adoption rates are uncertain, the project team expects that the vast majority of infrastructure resulting from this project will be utilized given the state's ambitious PEV adoption goals, the high and growing levels of PEV adoption in the Bay Area, and continued advancements in PEV technologies and battery ranges by vehicle manufacturers.

In all three cities, new parking facilities will be designed to meet Title 24 Chapter 11B accessibility requirements. Facilities that fall within the scope of Title 24 Chapter 11B may not install any non-accessible EV charging stations unless the required number of accessible EV charging stations are also installed. Local codes will now ensure that facilities are designed to enable Title 24 Chapter 11B compliance.

In the immediate term, the project has provided municipal staff, building developers, and the public a better understanding of PEV infrastructure code requirements in all three jurisdictions. The project team estimates that 35,170 metric tons of carbon dioxide equivalent (CDE) emissions and 3.5 million gallons of petroleum will be avoided by 2025.

The project will also lead to significant reductions of carbon monoxide and other air pollutants, such as those leading to harmful levels of ozone and fine particulates. Assuming that about half of PEVs will be battery electric vehicle (BEV), the benefits from BEV will include about 240,000 kilogram of criteria pollutant benefits in 2025. These estimates are based on the following assumptions for annual per-vehicle benefits from PEVs that are purchased and driven as a result of this project (please see the Appendix for additional details of the scenario used to estimate these benefits):

- 3.5 metric tons of avoided CDE.¹⁶
- 350 gallons of avoided petroleum use.
- 48 kilogram of air pollutants per BEV (reductions for plug-in hybrids can vary based on duty cycles and were not included in the analysis).

Related benefits include social/economic equity benefits; one of the key barriers to EV ownership – lack of access to convenient vehicle charging – will be removed for those individuals living in new low-income or affordable housing. PEVs have lower lifetime operating costs and greater local public health benefits as compared to equivalent internal combustion engine vehicles.¹⁷ Oakland’s code focused on facilitating widespread charging in multifamily buildings for this reason. Fremont and San Francisco codes will also greatly expand access to EV charging infrastructure in multifamily buildings.

The project benefits are subject to several uncertainties. First, these estimates do not include new parking spaces that will be equipped with conduit in inaccessible areas, with the potential to support nearly 31,000 more PEV charging stations, nor charging infrastructure in renovated buildings in San Francisco.¹⁸ Second, these estimates do not account for improved permitting & inspection processes in Oakland, primarily through increased training, which is likely to improve code compliance. Third, the estimates do not account for new installations of EVSE in existing buildings due to building owners or managers wishing to “keep up” with industry standards, or higher customer expectations stimulated by the new ordinances. Fourth, Community Choice Aggregations launching in Alameda County (covering both Fremont and Oakland) and already operating in San Francisco include cleaner power mixes (reducing the lifecycle emissions of driving PEVs).¹⁹ These factors may significantly increase benefits beyond those reported above.

An additional uncertainty that could suppress benefits is the rate of non-compliance with the new requirements. The Permitting and Inspection Streamlining and staff training carried out in Oakland through this grant was meant to decrease the rate of non-compliance, but this is an area that the project team recommends for further consideration and grant funding, as

16 This number is likely low, resulting in an overall under-estimation of CDE reduction benefits, since all three participating cities will be part of Community Choice Aggregation (CCA) energy procurement by early 2018. The CCAs will provide much higher renewable energy mixes and lower emissions rates compared to PG&E’s current and projected electricity mix, resulting in significantly lower per-vehicle and per-mile emissions for PEVs charging within their boundaries. East Bay Community Energy, the CCA serving Oakland and Fremont, will launch in early 2018, and thus the exact power mix at program launch and in 2025 is not known. Exact reduction in CDE is beyond the scope of this project.

17 For instance, see [“Cost-Effectiveness of Electric Vehicle”](http://mjbradley.com/sites/default/files/MA_PEV_CB_Analysis_FINAL_17nov16.pdf) by M.J. Bradley (http://mjbradley.com/sites/default/files/MA_PEV_CB_Analysis_FINAL_17nov16.pdf). This 2016 report was prepared for the state of Massachusetts, which has adopted the California Zero Emission Vehicle mandate.

18 The project team did not attempt to quantify the number of spaces resulting from modifications due to uncertainty regarding the number of projects that would trigger these requirements.

19 [San Francisco Clean Power renewables percentages](https://sfwater.org/index.aspx?page=960) (https://sfwater.org/index.aspx?page=960) and [East Bay Community Energy potential renewables percentages](http://ebce.org/power-portfolio/) (http://ebce.org/power-portfolio/)

discussed in Chapter 5. In addition, some PEV infrastructure would have been required under existing CALGreen codes, though in general CALGreen does not require compliance with Title 24 Chapter 11B requirements.²⁰

²⁰ CALGreen does require the design of one in 25 potential multifamily EV charging spaces to allow for installation of a van accessible EV charging station.

CHAPTER 5: Potential Next Steps

Oakland staff, in discussion with other project partners, identified several opportunities to expand on the project's success through additional PEV readiness research and code adoption. One opportunity is to expand to other cities, leveraging lessons from this project, such as design for accessibility and installation of higher levels of PEV infrastructure than CALGreen voluntary codes. Oakland staff have already been approached by staff from other municipalities inquiring about the process of adopting the new codes, with the intention of replicating all or some of the requirements in their own jurisdictions. Additional opportunities for passenger vehicles include adding PEV charging requirements in existing buildings, evaluating curbside charging, and designing codes for direct current (DC) fast charging. Related opportunities for electrification of goods movement include PEV infrastructure for electric stand-by transportation units and warehouses. Finally, opportunities exist to enhance public awareness of the need for charging infrastructure and to increase rates of code compliance, which would improve EVSE infrastructure even in cities without reach codes. These opportunities are described in detail below.

Existing Buildings

Existing buildings are a top priority because they make up the majority of both building stock and building permit applications across the state. Moreover, a disproportionate number of low-income residents live in older buildings. The 2016 [California ZEV Action Plan](#) calls for the California Housing and Community Development Department to address this topic at the state level in 2017. Municipalities can complement or lead statewide efforts by developing innovative solutions at the local level. For instance, San Francisco's ordinance includes limited code language covering "gut" rehabs as an initial effort to address existing buildings.

Several major challenges include determining which types of renovations and additions should be covered under EV infrastructure building codes to maximize opportunity and promote equity (while minimizing undue burdens on property owners and tenants), showing technical feasibility and cost-effectiveness, and drafting the technical details of the code language. Future research topics for local governments to pursue could include:

- Evaluating the scope of existing requirements for renovations and additions, including state codes.
- Classifying types of renovations or additions that are most likely to provide cost-effective opportunities to install EV infrastructure, such as electrical upgrades, lighting or building system retrofits that create additional electrical capacity, or parking area expansions and/or repaving.
- Determining technical feasibility of adding EV infrastructure to existing buildings.
- Developing recommended building code language and related implementation guidance to capture opportunities to install EV infrastructure, while excluding unrelated modifications.

- Assessing levels of available unused electrical capacity in existing buildings that could be used for EV charging.
- Identifying how building codes can specifically protect affordable housing and low-income tenants, and prevent housing displacement, while simultaneously promoting expanded EV charging infrastructure in existing buildings.
- Identifying other potentially feasible policy mechanisms such as “retrofit on resale.”

Direct Current Fast Charging

DC fast charging of EVs is not addressed by state building codes. DC fast charging typically provides capacity of at least 25 kilowatt and commonly around 50 kilowatt higher. It more closely matches customer expectations of a “fill and go” experience like gas stations provide, and is particularly suited to short-term parking situations such as shopping centers. However, widespread DC fast charger installation is limited by cost and availability of electrical infrastructure. San Francisco code language allows DC fast charging in lieu of some of the required Level 2 (e.g. a 40-Amp 208/240-volt branch circuit) charging infrastructure. Oakland developed internal guidance to help Building permit and inspection staff evaluate “Alternative Means” requests to install infrastructure for DC fast chargers in place of a portion of required Level 2 spaces in appropriate developments on a case-by-case basis. Additional best practices would help local governments to encourage DC fast charging without excessive trade-offs of Level 2 charging infrastructure and to develop appropriate code language. Additional research funding for local governments could support tasks such as:

- Researching the cost-effectiveness of installing DC fast charging infrastructure during original construction compared to retrofits.
- Identifying potential grid impacts of widespread proliferation of DC fast charging, as well as best practices for mitigating high demand charges and utilizing the charging network for grid services.
- Identifying best practices regarding appropriate trade-offs between DC fast and Level 2 charging for various building types.
- Researching and developing building code options and related implementation guidance.

Curbside Charging

Curbside charging may help facilitate PEV ownership in neighborhoods or commercial districts where dedicated parking is limited and/or retrofitting PEV charging into existing buildings is difficult. This is particularly needed in older neighborhoods and areas with dense, existing multifamily housing. The number of local policies that limit off-street parking in new construction is growing, further increasing the potential value of curbside charging. Additional research funding for local governments could support tasks such as:

- Evaluating the potential to “piggy-back” onto installation or maintenance of other utility infrastructure such as underground conduits and streetlights.
- Evaluating the potential for energy-efficient street lighting to free-up capacity for curbside charging.

- Determining the feasibility of installing curbside charging during urban redevelopment projects, greenfield development, and retrofits.
- Evaluating technical feasibility and cost-effectiveness of curbside charging, including review of examples such as installations sponsored by the Los Angeles Department of Water and Power.
- Identifying safety concerns and mitigation measures for EVSE installed in the public right-of-way.
- Identifying policy overlap and best practices to integrate curbside charging with the dedicated car share spaces and local car share policies.
- Developing potential code language and/or other local policies to facilitate curbside charging.

Goods Movement Transportation Electrification

On July 17, 2015, Governor Brown issued [Executive Order B-32-15](#) directing the Energy Commission and other state agencies to improve freight efficiency, transition to zero-emission technologies, and increase competitiveness of California’s freight system. Two building code opportunities to support the goals of this Executive Order are listed below.

Electric Stand-By Transportation Refrigeration Unit Infrastructure

Goods movement is a vital and growing sector of the state economy but also contributes heavily to state, local, and global air quality issues. Transportation refrigeration units idling at warehouses emit half as much nitrogen oxides as all utility power plants in California, as well as GHG and toxic diesel particulates that frequently have negative impacts on disadvantaged communities. The [California Sustainable Freight Action Plan](#) developed by the CEC and other partners (July 2016) focuses on reduction of these emissions and identifies development of electric infrastructure for refrigerated truck parking areas as an important priority. Additional funding for local governments to help achieve these goals could support tasks such as:

- Surveying existing facilities with electric standby transportation refrigeration unit’s electric infrastructure and determining best practices.
- Evaluating cost-effectiveness for new construction and retrofits.
- Considering adoption of local codes and providing recommendations for statewide code adoption.
- Preparing a summary report that describes cost-effectiveness, code language options, and associated benefits.

Forklift Electrification Infrastructure

Forklifts are commonly used to transport goods into, out of, and around warehouses. Forklifts with internal combustion engine’s use diesel, compressed natural gas, or liquid propane as fuel sources. Electric forklifts typically use lead-acid batteries and utilize on-site battery charging stations (though advanced battery technologies are also available). Switching to electric forklifts will reduce overall energy use because electric units are more efficient than internal combustion engines and can use California’s increasingly clean grid. Switching to electric

forklifts will also improve the indoor air quality of the facilities, in turn reducing energy use associated with ventilation and potentially improving the health of warehouse workers.

Potential options for a PEV Readiness project to encourage greater use of electric forklifts include building code standards that would promote electric forklifts, and/or demonstration of controls so that battery charging is scheduled to minimize impact on the grid. A local government reach code requiring electric charging infrastructure for forklift batteries in new construction would ensure that new warehouses contain the electrical infrastructure necessary to accommodate electric forklift charging. Existing warehouses may not have sufficient electrical capacity and/or the infrastructure necessary to install a battery charging room without costly retrofits. The proposed standards for new warehouses could include elements such as electrical service type (type, such as three-phase, and total capacity), designated space and designs suitable for a battery charging room, and require any electrical conduit that runs under floors or through walls to avoid costly retrofits later.

Project tasks could include:

- Surveying existing facilities with electric infrastructure and reviewing reports by ARB, electric power research institute, and others to determine best practices.
- Evaluating technical options such as lithium and lead-acid batteries, and recycling practices for lead-acid batteries.
- Evaluating cost-effectiveness for new construction and retrofits using project-cost modeling.
- Evaluating mechanisms and best practices to implement demand response strategies to improve cost-effectiveness.
- Evaluating energy efficiency opportunities in existing facilities and associated capacity for electrification.
- Preparing a report summarizing opportunities, cost-effectiveness, and potential code options.
- Considering adoption of local policies and providing recommendations for statewide policies to encourage forklift infrastructure, especially in new construction.

Building Code Compliance

Promulgating local reach codes for PEV infrastructure is a critical component of realizing the California ZEV Action Plan, [statewide greenhouse gas reduction goals](#), and local climate action plans. However, building code non-compliance is a challenge for most municipalities, and resources (including funding for additional staff and for staff training) to support compliance and effective enforcement are lacking. Anecdotal evidence from building officials and industry experts suggests that a building code compliance rate of 100 percent is rarely if ever fully realized, and that code enforcement activities are lowest for requirements related to green building and energy efficiency, and higher for key life, health, and safety provisions.

Project tasks could include:

- Developing and piloting technology tools to standardize and automate the approval process for EVSE, potentially including tablet-based software such as CodeCycle, remote-video inspections (as offered via Accela), or similar.
- Integrating PEV component requirements into Title 24, Part 3 (Electrical Code) to ensure consistent design and consideration in the development and engineering of electrical systems in new buildings.
- Creating fact sheets and process guides for engineers and designers, to be distributed at Building Department counters and via websites, documenting the correct procedures for meeting PEV code requirements.

GLOSSARY

AMPERE (Amp) - The unit of measure that tells how much electricity flows through a conductor. It is like using cubic feet per second to measure the flow of water. For example, a 1,200 watt, 120-volt hair dryer pulls 10 amperes of electric current (watts divided by volts).

ASSOCIATION OF BAY AREA GOVERNMENTS (ABAG) - ABAG is part regional planning agency and part local government service provider. We accomplish our goals by providing planning services and cost-effective ABAG member services to local governments struggling with rising costs and diminishing incomes. ABAG stands for the Association of Bay Area Governments. Our mission is to strengthen cooperation and collaboration across local governments to build healthier, stronger communities.²¹

BATTERY ELECTRIC VEHICLE (BEV) -- Also known as an "All-electric" vehicle (AEV), BEVs utilize energy that is stored in rechargeable battery packs. BEVs sustain their power through the batteries and therefore must be plugged into an external electricity source in order to recharge.

CALIFORNIA AIR RESOURCES BOARD (ARB) -- The "clean air agency" in the government of California, whose main goals include attaining and maintaining healthy air quality; protecting the public from exposure to toxic air contaminants; and providing innovative approaches for complying with air pollution rules and regulations.

CALIFORNIA GREEN BUILDING STANDARDS CODE (CALGreen) - the first-in-the-nation mandatory green building standards code. In 2007, California Building Standards Commission developed green building standards in an effort to meet the goals of California's landmark initiative AB 32, which established a comprehensive program of cost-effective reductions of greenhouse gases (GHG) to 1990 levels by 2020. California Building Standards Commission has the authority to propose CALGreen standards for nonresidential structures that include, but are not limited to, new buildings or portions of new buildings, additions and alterations, and all occupancies where no other state agency has the authority to adopt green building standards applicable to those occupancies.²²

CARBON DIOXIDE EQUIVALENT (CDE). A metric measure used to compare the emissions from various greenhouse gases based upon their global warming potential (GWP). Carbon dioxide equivalents are commonly expressed as "million metric tons of carbon dioxide equivalents (MMTCDE)" or "million short tons of carbon dioxide equivalents (MSTCDE)" The carbon dioxide equivalent for a gas is derived by multiplying the tons of the gas by the associated GWP. $MMTCDE = (\text{million metric tons of a gas}) * (\text{GWP of the gas})$ (EPA)

DIRECT CURRENT (DC) – A charge of electricity that flows in one direction and is the type of power that comes from a battery.

²¹ [Association of Bay Area Governments](https://abag.ca.gov/) (https://abag.ca.gov/)

²² [California Department of General Services](https://www.dgs.ca.gov/BSC/Resources/Page-Content/Building-Standards-Commission-Resources-List-Folder/CALGreen). (https://www.dgs.ca.gov/BSC/Resources/Page-Content/Building-Standards-Commission-Resources-List-Folder/CALGreen)

DIRECT CURRENT FAST CHARGER - Direct-current (DC) fast charging equipment, sometimes called DC Level 2 (typically 208/480V AC three-phase input), enables rapid charging along heavy traffic corridors at installed stations. There are three types of DC fast charging systems, depending on the type of charge port on the vehicle: a J1772 combo, CHAdeMO, or Tesla.²³

ELECTRIC VEHICLE MILES TRAVELED (eVMT) - Refers to miles driven using electric power over a given period of time. The more general term, VMT, is a measure of overall miles driven over a period of time.²⁴

ELECTRIC VEHICLES (EV) – A broad category that includes all vehicles that are fully powered by electricity or an electric motor.

ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE) – Infrastructure designed to supply power to EVs. EVSE can charge a wide variety of EVs including battery electric vehicle (BEV) and PHEVs.

GREENHOUSE GASES (GHG) – Any gas that absorbs infrared radiation in the atmosphere. Greenhouse gases include water vapor, carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), halogenated fluorocarbons (HCFCs), ozone (O₃), perfluorinated carbons (PFCs), and hydrofluorocarbons (HFCs).

KILOWATT-HOUR (kWh) -- The most commonly-used unit of measure telling the amount of electricity consumed over time. It means one kilowatt of electricity supplied for one hour. In 1989, a typical California household consumes 534 kWh in an average month.

PACIFIC GAS AND ELECTRIC (PG&E) - The acronym for Pacific Gas and Electric Company an electric and natural gas utility serving the central and northern California region.

PLUG-IN ELECTRIC VEHICLE (PEV) – A general term for any car that runs at least partially on battery power and is recharged from the electricity grid. There are two different types of PEVs to choose from—pure battery electric and plug-in hybrid vehicles.

PM10 (PARTICULATE MATTER) -- A criteria air pollutant consisting of small particles with an aerodynamic diameter less than or equal to a nominal 10 microns (about 1/7 the diameter of a single human hair). Their small size allows them to make their way to the air sacs deep within the lungs where they may be deposited and result in adverse health effects. PM10 also causes visibility reduction.

ZERO-EMISSION VEHICLE (ZEV) -- Vehicles which produce no emissions from the on-board source of power (e.g., an electric vehicle).

ZERO-EMISSION VEHICLE ACTION PLAN (ZEV ACTION PLAN) - California's Zero Emission Vehicle Action Plans are a set of documents designed to organize state agency actions to grow the zero emission vehicle market. They reflect input from a broad stakeholder base and strive

²³ [U.S. Department of Energy, National Renewable Energy Laboratory, Alternative Fuels Data Center.](https://afdc.energy.gov/fuels/electricity_infrastructure.html)

(https://afdc.energy.gov/fuels/electricity_infrastructure.html)

²⁴ [U.C. Davis - International EV Policy Council](https://phev.ucdavis.edu/wp-content/uploads/Exploring-the-Role-of-Plug-In-Hybrid-Electric-Vehicles-in-Electrifying-Passenger-Transportation.pdf) (<https://phev.ucdavis.edu/wp-content/uploads/Exploring-the-Role-of-Plug-In-Hybrid-Electric-Vehicles-in-Electrifying-Passenger-Transportation.pdf>)

to increase transparency and accountability. Feedback and ideas for improvement are always welcome. In 2013, the first ZEV Action Plan was released, a roadmap designed to support the Governor's goal of 1.5 million ZEVs on the road by 2025 (Executive Order B-16-2012). It laid out progress to-date, challenges, and four high-level goals with a series of actions for state agencies to take that could accelerate ZEV adoption.²⁵

²⁵ [California Governor's Office of Business and Economic Development](http://www.business.ca.gov/ZEV-Action-Plan). (<http://www.business.ca.gov/ZEV-Action-Plan>)

APPENDIX A: Modeling Details

PEV Infrastructure Cost-Effectiveness Model

Each construction project scenario summarized in Chapter 2 was modeled for the following levels of infrastructure: “PEV-ready” (referred to in Oakland’s outreach as “PEV Capable”) and full electrical circuit. The “PEV-ready” provisions for each scenario include electrical service panel capacity and space, plans, and all inaccessible 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-ready” standards.

The modeling analysis *does not* include electrical infrastructure outside of the customer’s premises, nor any distribution transformer upgrade that may be required on-site (a related project funded by PG&E addressed these costs as noted in Chapter 2). The report does not address other costs that are related to installing EVSE rather than an electric circuit and thus does not include the cost of the EVSE, associated lighting, signage, bollards, etc.

The cost-effectiveness model was developed in Microsoft Excel and broke down each scenario and level of PEV infrastructure into individual tasks and quantities (e.g. 100 feet of one inch PVC or stainless steel conduit or 100 feet of 8-gauge copper wire). 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, such as permitting and inspection fees and contractor labor, are based on data from Oakland and other jurisdictions. Additional data sources used to capture different tasks required for each scenario included feedback from construction industry and utility experts, engineering estimates, and direct experience.

For additional details of the modeling analysis, please see the July 2016 [Plug-In Electric Vehicle Infrastructure Cost-Effectiveness Report](#) or the November 2016 [Plug-In Electric Vehicle Infrastructure Cost-Effectiveness Report for San Francisco](#), both prepared by Energy Solutions for the City of Oakland.

Project Benefit Calculations

The project benefits in Chapter 4 are based on a scenario developed using data and calculations summarized below. For a summary of the results of the project benefit calculations, please see Chapter 4.

PEV Future Fleet Mix

The project team generated a forecast of the 2022 PEV fleet as a proxy for the 2025 PEV fleet. The vehicle mix was projected out five years from 2017 to allow time for market uptake of longer-range vehicles that have been introduced recently or are expected soon. The project team did not attempt to make projections of the vehicle fleet mix beyond 2022 because projections beyond five years would rely largely on predicting future technology development and adoption.

The project team used a California Department of Motor Vehicles dataset for PEV registrations in 2015 (Table 7), as the starting point for deployments of existing vehicle models. The project team also added newer models based on available data. For instance, the project team assumed that the Tesla Model 3 would enter the market in 2018 at 80,000 units, with half deployed in California. (Note that if Tesla achieves reported Model S production targets of 500,000 and/or the Chevy Bolt achieves significant sales volume, the average vehicle miles traveled and environmental benefits will be larger). The project team also used 2016 and 2017 sales data to help estimate future sales. If sales data for a model were not readily available, the project team assumed that annual sales for that model were one-third of its 2015 California Department of Motor Vehicles registrations. This approximate rule of thumb allowed the project team to align overall PEV projected sales for 2017 to equal an annual sales rate of 99,500 units consistent with the June 2017 California sales of 8,296 units.²⁶ The team also assumed 25 percent growth in sales of each current PEV model beyond 2017 to represent a trajectory towards statewide 2030 adoption goals of 4.2 million PEVs. This estimate is not intended to represent a specific projection of the future PEV market but rather a potential trajectory to meet future goals.

PEV Electric Vehicle Miles Traveled and Efficiency

Electric vehicle miles traveled (eVMT) for each model were determined by plotting eVMT against electric range for battery electric and plug-in hybrid electric vehicles and determining an equation for each battery type. Idaho National Lab and California ARB eVMT data are available for nine PEV models listed in

²⁶ [Plug-in Electric Vehicle Collaborative.](http://www.pevcollaborative.org/sites/all/themes/pev/files/6_june_2017_Dashboard_PEV_Sales.pdf)

(http://www.pevcollaborative.org/sites/all/themes/pev/files/6_june_2017_Dashboard_PEV_Sales.pdf.)

Table 8. 27

Figure 5 shows the plot used to determine a correlation between electric range and eVMT for current battery electric models (eVMT = 7,956 + [20.9 times electric range]).

27 Carlson, "[Electric Vehicle Mile Traveled \(eVMT\): On-road Results and Analysis](http://energy.gov/sites/prod/files/2015/07/f24/vss171_carlson_2015_p.pdf)"
(http://energy.gov/sites/prod/files/2015/07/f24/vss171_carlson_2015_p.pdf);
[ARB Mid-Term Review Appendix G](https://www.arb.ca.gov/msprog/acc/mtr/appendix_g.pdf) (https://www.arb.ca.gov/msprog/acc/mtr/appendix_g.pdf)

Table 7: Electric Vehicle Data

Vehicle Model	Number of Department of Motor Vehicles registrations (2015, CA)	Electric Range (miles)	Calculated eVMT	kWh/100 miles
500e	12,642	87	9,774	30
Accord Plug-in Hybrid	647	13	3,336	29
B-Class Electric Drive	1,995	87	9,774	40
Bolt	-	238	12,930	28
C-MAX Energi	9,297	20	4,700	37
e-Golf	3,219	83	9,691	29
Fit EV	604	82	9,680	29
Focus Electric	3,149	76	9,544	32
ForTwo Electric Drive	2,176	68	9,377	32
Fusion Energi	12,316	20	4,700	37
i3	2,053	81	9,649	27
i3 REX	4,816	72	9,063	29
Leaf	29,221	84	9,712	30
Model 3	-	265	13,495	36
Model S	24,051	265	13,495	36
Model X	-	289	13,996	36
Prius Plug-in/Prime	25,146	11	2,585	29
Spark EV	3,260	82	9,670	28
Volt	32,596	53	12,455	31
x5 drive 40e	-	14	3,290	59

Source: City of Oakland

The calculated eVMT are within one percent of reported average eVMT for BEVs as shown in

Table 8. The calculated eVMT are within +/- eight percent of the measured value for PHEVs except that the calculated C-MAX Energi range is 16 percent higher than the measured range.

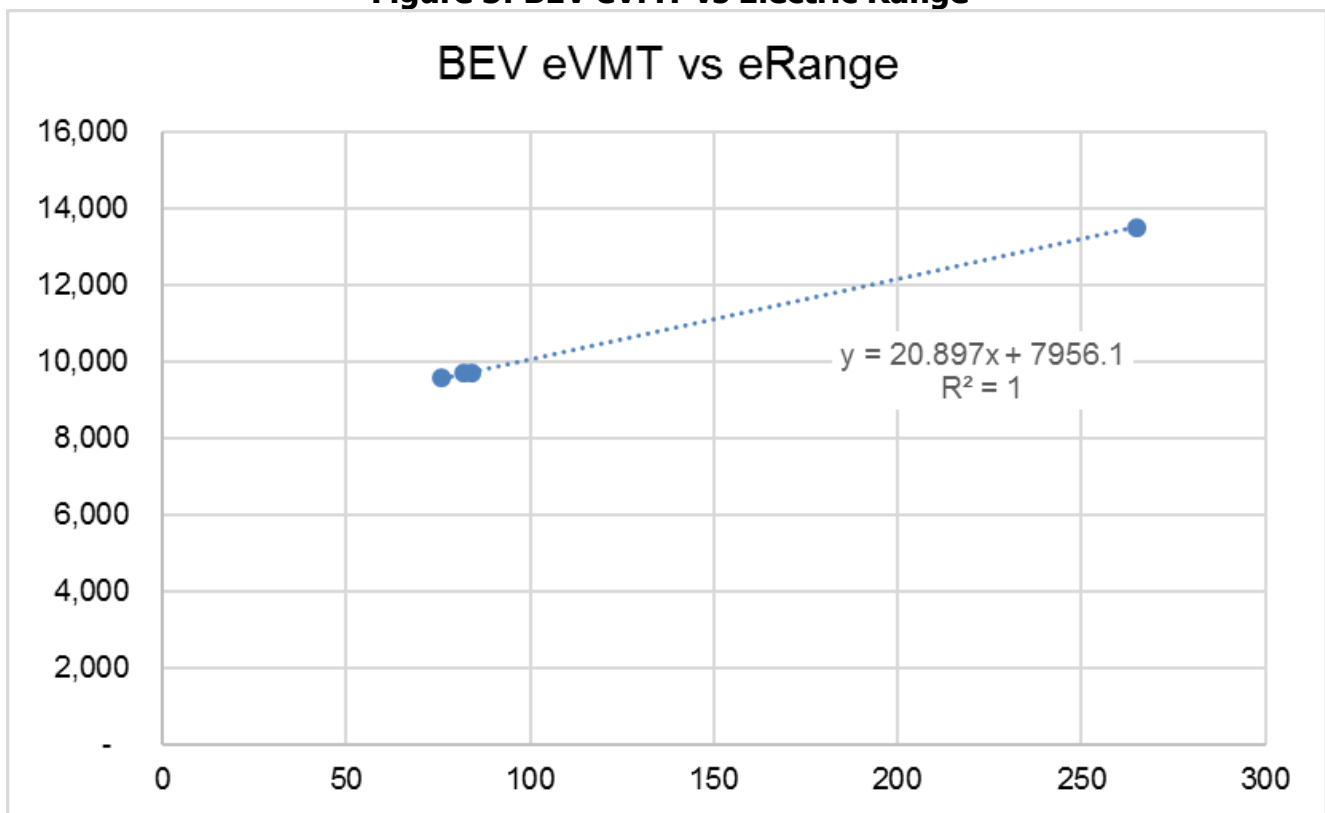
The project team projected a future annual eVMT rate of 11,500 miles per vehicle compared to 9,000 miles per vehicle in 2015. This difference seems reasonable given the introduction of the Chevy Bolt and Tesla Model 3 with electric ranges comparable to the Model S but much lower price points. The equations for BEVs and PHEVs appear to provide reasonable estimates for currently available PEVs, and though these equations would need to be reassessed prior to use with other vehicles.

Table 8: Plug-in Electric Vehicle Measured and Calculated Annual eVMT

	Vehicle Model	Electric Range	Reported eVMT	Calculated eVMT
BEVs	Tesla Model S	265	13,494	13,495
	Leaf	84	9,697	9,712
	Fit EV	82	9,680	9,670
	Focus Electric	76	9,548	9,544
PHEVs	Volt	38	9,112	8,930
	Fusion Energi	20	4,337	4,700
	C-MAX Energi	20	4,069	4,700
	Accord Plug-in Hybrid	13	3,336	3,055
	Prius Plug-in/Prime	11	2,484	2,585

Source: City of Oakland

Figure 5: BEV eVMT vs Electric Range



Source: City of Oakland

Average PEV efficiency was determined using the U.S. EPA fuel economy guide rating, including electric vehicle charging losses, and the following equation:

- Efficiency (kWh/mile) = efficiency of each vehicle model (kWh/mile) weighted by total eVMT for each model divided by total eVMT for all vehicles.²⁸

The weighted average efficiency does not appear highly sensitive to the projected fleet mix. The project team calculated a weighted average of 34.1 kWh/100 miles and an unweighted average of 33.2 kWh/100 miles.

Emissions Rates

Internal combustion engine tailpipe emission rate projections for 2025 came from the ARB vehicle emissions model [EMFAC2014](#). The project team downloaded data for passenger cars (category LDA) and light trucks with gross vehicle weight ratings less than 6000 pounds and equivalent test weight equal to or less than 5,750 pounds (categories LDT1 and LDT2).²⁹ The average gram per mile emissions are calculated as shown below. Per vehicle air pollution benefits for carbon monoxide, fine particulates (PM10), nitrogen oxides, sulfur oxides, and volatile organic compounds are calculated the same way:

- Vehicle tailpipe gram/mile = gram/mile for each vehicle category times share of each vehicle category (weighted based on vehicle miles traveled)

Net CDE benefits are based on vehicle tailpipe emissions and upstream electricity and GHG production. Upstream California gasoline CDE emissions are based on Pike, E., [Calculating Electric Drive Vehicle Greenhouse Gas Emissions](#), August 2012.³⁰ Electricity GHG intensity rates are based on PG&E reported values for 2020. Future GHG intensity rates will likely continue to decrease due to aggressive state-level renewable energy goals that apply to PG&E and the introduction of Community Choice Aggregation options with higher levels of renewable energy than current statewide averages.³¹

The equations used to determine project CDE benefits per vehicle are as follows:

- Total internal combustion engine CDE (gram/mile) = tailpipe (gram/mile CDE) plus upstream petroleum production CDE (gram/mile).

28 US EPA estimates include charging losses per personal communication, John Mikulin, US EPA May 19 2017.

29 EMFAC Start Exhaust Tailpipe carbon dioxide emissions are not included as no significant start-up emissions are expended, which could lead to a conservative estimate of per vehicle carbon dioxide emissions.

30 The ratio of 28% upstream emissions to tailpipe emissions was used to calculate upstream petroleum production CDE.

31 Note that by 2019, all three cities involved in this project will be served by Community Choice Aggregation (CCA) electricity provision. East Bay Community Energy (EBCE, serving most of Alameda County, including Oakland and Fremont) will launch in spring of 2018; the power mix at program launch is likely to be 50% renewable, reaching 80% by 2020. CleanPowerSF began delivering energy to San Francisco neighborhoods in phases in May 2016 and will enroll all eligible San Francisco electricity customers by the end of 2019, However, there remains too much uncertainty in these programs (e.g. the exact power mix for EBCE and the number of enrollees in San Francisco's "SuperGreen" 100% renewable energy option once full program rollout occurs) to accurately estimate the upstream emissions for the sake of this project.

- Total PEV CDE (gram/mile) = electricity carbon intensity (gram CDE/kWh) times kWh/mile.
- Net GHG saving (gram/mile) = Total internal combustion engine CDE (gram/mile) - Total PEV CDE (gram/mile).
- Annual GHG saving (metric tons) = Net GHG savings (gram/mile) times 1 kilogram/1000 gram times 1 metric ton/1000 kilogram.

Petroleum Vehicle Fuel Efficiency

The project team calculated per vehicle avoided annual petroleum benefits based on:

- Calculated average internal combustion engine fleet fuel economy of 34 miles/ gallon
- Expected annual electric range as noted earlier.

The project team selected an average internal combustion engine fleet fuel economy level roughly half-way between the National Highway Traffic Safety Administration 2017 (30 miles per gallon) and 2025 (40 miles per gallon) fuel economy standards (note that miles per gallon cannot be averaged directly)³². The project team used this halfway point as a rough estimate of the mix of newer and older cars that will be on the road in 2025. This value probably underestimates the fuel consumption of the average internal combustion engine vehicle in 2025 (and thus the project benefits) since many vehicles older than 2017 will still be on the road in 2025.

The project team used 2025 fuel economy levels reported by the [Detroit Times](#) in January 2017.³³ The project team adjusted those real world fuel economy levels backwards from 2025 to 2017 based on the average percent difference in NHSTA nominal standards for 2025 and 2017 for several example passenger vehicles and light trucks to get a 2017 nominal average of 30 miles per gallon.³⁴

32 Miles per gallon values cannot be averaged directly because fuel consumption is in the denominator of the miles/gallon ratio.

33 Real world fuel economy is less than nominal standards due to a variety of credits and other factors.

34 National Highway Traffic Safety Administration sets nominal fuel economy curves from 2017 to 2025 separately for light duty vehicles and trucks. The nominal standard for each model depends on the footprint of the vehicle, i.e. a vehicle with a larger footprint between the axles is allowed greater emissions than a smaller vehicle in the same category. The percent change in stringency between 2017 and 2025 varies in some cases based on the type and footprint of a vehicle model.

The project team selected the largest and smallest vehicle in the light duty vehicle and truck categories, i.e. rows A and B in Table A-1 of National Highway Traffic Safety Administration's memo "[2017-2025 Model Year Light-Duty Vehicle GHG Emissions and CAFE Standards: Supplemental Notice of Intent](#)".

(http://www.nhtsa.gov/staticfiles/rulemaking/pdf/cale/2017-2025_CAFE-GHG_Supplemental_NOI07292011.pdf).

The project team then averaged the difference in nominal National Highway Traffic Safety Administration CAFE standards between 2017 and 2025. Based on this data, standards will increase an estimated 35% in stringency from 2017 to 2025 from 30 miles per gallon for vehicles sold in model year 2017 to 40 miles per gallon for vehicles sold in 2025.

Parking Space Estimates

Parking space estimates were calculated separated for multifamily residential and nonresidential housing. These multifamily and nonresidential estimates were created solely to estimate expected project benefits and are not intended to represent targets or policies endorsed by any government agency.

The annual new multifamily housing construction estimates were based on Association of Bay Area Governments estimates of housing needs in each city from 2014 to 2022, where the results estimate that about 65 percent of those units will be multifamily housing.³⁵ The project team used the same estimated rate of multifamily housing construction for 2023 through 2025 as well.

A common rule of thumb is one parking space per bedroom for multifamily housing, i.e. 1.5 spaces per unit if the average multifamily unit has 1.5 bedrooms. However, the project team used a more conservative estimate that only 0.75 parking spaces would be built per multifamily housing unit for Oakland and San Francisco due to local policies that limit parking in new construction and encourage alternative forms of transportation.³⁶ The project team used an estimate of 1.5 for Fremont due to zoning codes that generally require between 1.5 and 2.0 parking spaces per unit, though in some cases these minimums can be reduced.³⁷ The actual ratio for any given building will vary on a project-to-project basis and may vary due to future economic trends and other factors. Estimated new multifamily parking spaces are shown below in table 9.

Table 9: Estimated New Multifamily Dwellings and Parking Spaces

	Annual new housing units	Annual new multifamily units	Total new multifamily units 2017-2025	New parking from 2017-2025
Fremont	682	440	3,520	5,280
Oakland	1,846	1,200	9,600	7,200
San Francisco	3,609	2,350	18,800	14,100
Total	6,136	3,990	31,920	23,940

Source: City of Oakland

The project team estimated the number of additional nonresidential parking spaces based on ARB statewide analysis for the 2015 CALGreen nonresidential building codes update and the

³⁵ [Association of Bay Area Governments - Regional Housing Need Plan](http://www.abag.ca.gov/files/ABAG_Final_RHNA_Publication.pdf)

(http://www.abag.ca.gov/files/ABAG_Final_RHNA_Publication.pdf).

³⁶ In 2016, Oakland revised its minimum parking requirements to reflect a shift away from onsite parking. The new requirements include no minimums (and parking maximums of 1.25 spaces per residential unit) in the downtown core, and reduced minimums along major transit corridors.

³⁷ [Fremont zoning code parking requirements](http://www.codepublishing.com/CA/Fremont/html/Fremont18/Fremont18183.html#18.183) lists out different use types, and potential exemptions.

(<http://www.codepublishing.com/CA/Fremont/html/Fremont18/Fremont18183.html#18.183>)

population of Fremont, Oakland and San Francisco compared to statewide population.³⁸ The project team then calculated the parking share for each city based on their share of California population, but discounted that estimate for Oakland and San Francisco by 60 percent to account for existing high development densities and local policies that constrain construction of new parking based on consultation with local staff experts. The project team did not discount this estimate for Fremont due to available land and expected potential new industrial developments.

Environmental Benefit Calculations

The project team used the estimated total number of parking spaces to calculate the number of parking spaces with full circuits plus the number of PEV-ready spaces, shown in

³⁸ ARB's estimates [Economic and Fiscal Impacts Statement](https://www.documents.dgs.ca.gov/bsc/2015TriCycle/CAC/GREEN/Exhibit-B-CARB-Cost-Analysis-and-Technical-Report.pdf) (<https://www.documents.dgs.ca.gov/bsc/2015TriCycle/CAC/GREEN/Exhibit-B-CARB-Cost-Analysis-and-Technical-Report.pdf>). ARB's low estimate of non-residential parking for retail (including groceries and restaurants), small and large commercial offices, and misc. (excluding warehouses) total 1,190,892 from 2017-2021, or 244,786 per year.

Table below.

The project team then assumed that vehicles will typically charge at home, or in some cases at their workplace, and will less frequently access a public charger resulting in a ratio of 1.1 PEV chargers per vehicle. We estimate that the current ratio of public chargers to PEV is about 0.1:1 based on the number of reported public chargers and PEV sales noted in Chapter 1. (This estimate is intended to represent current conditions, rather than an ideal public charging network that would provide widespread access to public charging). As noted in Chapter 4, these estimates are subject to some uncertainty and are likely conservative.

Table 10: Estimated New Nonresidential Parking Spaces

	Population (2015, U.S. Census)	Share of California population	New parking from 2017-2025
Fremont	232,206	0.6%	11,620
Oakland	419,267	1.1%	8,390
San Francisco	864,816	2.2%	17,310

Source: City of Oakland

The project team then calculated the increase in PEV adoption and the estimated environmental benefits per vehicle described earlier to calculate total project environmental benefits, which can be seen in table 11.

Table 10: EV Parking and Environmental Benefits Increase by the Year 2025

	Total New Parking Spaces	Spaces with full circuits	PEV-ready spaces	Total full circuits and PEV-ready spaces	Total PEVs served	Additional parking spaces with inaccessible conduit	2025 avoided metric tons CDE	2025 avoided petroleum (gallons)
Fremont								
Multifamily	5,280	530	-	530	480	-	1,670	168,000
Nonresidential	11,620	1,160	-	1,160	1,060	-	3,690	369,000
Total	16,900	1,690	-	1,690	1,540	-	5,360	537,000
Oakland								
Multifamily	7,200	720	720	1,440	1,310	5,760	4,570	457,000
Nonresidential	8,390	840	840	1,680	1,530	-	5,320	533,000
Total	15,590	1,560	1,560	3,120	2,840	5,760	9,890	990,000
San Francisco								
Multifamily	14,100	1,410	1,410	2,820	2,560	11,280	8,940	895,000
Nonresidential	17,310	1,730	1,730	3,460	3,150	13,850	10,980	1,099,000
Total	31,410	3,140	3,140	6,280	5,710	25,130	19,920	1,994,000
Overall Total	63,900	6,390	4,700	11,090	10,090	30,890	35,170	3,521,000

Source: City of Oakland