Pacific Gas and Electric Company

EPIC Final Report

Program	***Electric Program Investment Charge (EPIC)***
Project	***EPIC 1.25 – Develop a Tool to Map the Preferred Locations for DC Fast Charging, Based on Traffic Patterns and PG&E's Distribution System, to Address EV Drivers' Needs While Reducing the Impact on PG&E's Distribution Grid***
Reference Name	***Direct Current (DC) Fast Charging Mapping***
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List of Acronyms

BEV	Battery Electric Vehicle
DART	Distribution Asset Reconciliation Tool
DCFC	DC Fast Charger
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
FC	Fuel Cell
GIS	Geographic Information System
MPO	Metropolitan Planning Organization
PEV	Plug-in Electric Vehicles
VMT	Vehicle Miles Travelled
ZEV	Zero-emission Vehicle

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1 Executive Summary

Increased public Electric Vehicle (EV)[1] charging infrastructure is needed to accelerate EV adoption, reach California's ambitious Zero-Emission Vehicle (ZEV)[2] targets, leverage significant public spending on vehicle incentives, and realize the state's carbon reduction and clean air goals. Public EV fast charging allows more electric miles driven to be substituted for gasoline miles by increasing EV range and reducing "range anxiety" for both existing and potential EV drivers. Drivers strongly prefer Direct Current Fast Chargers (DCFCs)[3] over other public charging options available, which can charge many EV models to roughly 80% in 30 minutes or less. DC fast charging provides the on-the-road experience that most closely resembles the convenience of gas stations.

For DCFC networks to successfully promote EV adoption, individual chargers must be sited with care. Siting DCFCs in locations that offer safety, reliability, convenience, and comfort will provide the closest available experience to conventional vehicle refueling, boosting driver confidence in EV technology. Effective siting is also important for minimizing the significant costs involved in installing chargers, as well as spreading the economic and air quality benefits of EVs to disadvantaged communities.

Project Objectives

The objectives of EPIC Project 1.25 entitled, "Develop a Tool to Map the Preferred Locations for DC Fast Charging, Based on Traffic Patterns and PG&E's Distribution System, to Address EV Drivers' Needs While Reducing the Impact on PG&E's Distribution Grid", in short referred to as "Direct Current (DC) Fast Charging Mapping," are to:

- Develop best practices in siting public DC fast charging;
- Develop a transferable and repeatable method to identify potential host sites;
- Apply learnings to develop a tool to identify and order recommended potential host sites based on varying user preferences and certain non-exclusive factors[4], including driving patterns, distribution capacity, driving EV adoption, support for disadvantaged communities, etc.; and
- Apply learnings and develop an interactive map to identify and display potential prioritized DC Fast Charging locations that is based on projected unmet charger demand in PG&E's territory.[5]

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[1] In this report, EV refers to light-duty, plug-in electric vehicles (both pure battery electric vehicles and plug-in hybrid electric vehicles).

[2] Zero-emission vehicles (ZEVs) include both light-duty plug-in electric vehicles and light-duty fuel cell vehicles.

[3] See Tweed, K. November 17, 2013, "Fast Charging Key to Electric Vehicle Adoption, Study Finds,"
Kane, M. November 29, 2015, "NRG Analyzes 10 EVgo Freedom Sites: Fast Charging Preferred 12 to 1 Over L2,"

[4] The tool includes criteria for identifying and ranking potential host sites based on the PG&E specific territory. Other criteria may and should be included by users of this report based on current market and customer research and location-specific siting requirements.

[5] This map optimizes the non-exclusive factors included in the method as a means of screening potential DCFC sites before applying more direct analysis and evaluation using more detailed information and other potential siting factors. Actual DCFC siting analysis will involve more detailed evaluation and application of the factors included in the algorithm, as well as other quantitative and qualitative factors and market research not included in the algorithm.

Methods

Key contributors to the project included a range of expert perspectives on DC Fast Charger siting, including staff from the University of California, Davis Institute of Transportation Studies (UC Davis), Energy and Environmental Economics (E3), PlugShare, Ricardo[6], and PG&E.

To identify best practices for siting DCFCs, dozens of reports on past DCFC rollouts, as well as siting best practices were reviewed. Additionally, experts from twenty different organizations were interviewed to contribute to the recommendations for ideal siting locations. This approach validated a set of developed best practice guidelines for DCFC siting to minimize installation costs, maximize EV adoption, and support disadvantaged communities. Based on these guidelines, the team implemented a methodology for recommending DCFC sites in PG&E's territory. This involved the following key inputs and major tasks that led to two major deliverables:

Inputs

- Forecasts of California's EV adoption through 2025[7] using a cost-based and ZEV compliance method;
- Map of the current DCFC landscape;
- Expert interviews to develop key criteria for siting DCFCs; and
- Quantities of available distribution capacity.[8]

Major Tasks

- Develop EV adoption forecast scenarios;
- Assess the current landscape of installed DCFCs;
- Determine the areas in PG&E's territory with the highest future demand for charging;
- Determine the areas in PG&E's territory with available distribution capacity;
- Determine potential charger host sites at each of the 300 identified locations;
- Conduct industry expert interviews to identify key factors for DCFC siting;

Deliverables

- Developed an online, interactive map of the top 300 one-mile radius locations (i.e. "bubbles") in PG&E's territory predicted to have the highest unmet charger demand, as well as the potential host sites within each bubble. The map shows all potential hosting sites where a user can search using a specified address or by dragging and clicking on locations to see details. The following information is included in the map: Site ID Number, Priority Number based on unmet need (1-300), Site Type (e.g., bank, grocery store), Parking Dwell Time (Short, medium or long), business location (name, address), existing L2 and DCFCs chargers at site, new DCFCs that could be added with existing site capacity, and new DCFCs needed in the specific "bubble"[9] in 2025;
- Identified 14,416 potential charger host sites using proximity to available distribution capacity and other non-exclusive parameters and developed a Micro-Siting Tool[10] that can be leveraged

[6] Ricardo is a global engineering and strategic, technical and environmental consultancy business.

[7] The year 2025 was used to match Governor Brown's Executive Order B-16-2012 goal of 1.5 million zero-emission vehicles on California roads by 2025.

[8] Sites identified with sufficient distribution transformer capacity are static based on the time of study, and additional analysis of changes in electric grid infrastructure is required when pursuing installation to draw a final conclusion on secondary transformer capacity.

[9] The term used in this report to describe the one-mile radius area around locations of unmet need and represents the level of granularity of the map.

[10] The Excel tool will be available upon request

by utilities or DCFC installers to prioritize the 14,416 potential DCFC sites in PG&E's territory, where potential sites can be filtered based on a multitude of criteria and preferences including cost, available capacity and/or proximity to disadvantaged communities.

The siting tool developed as a result of this project only reviewed certain DCFC siting criteria as it relates to PG&E's service territory and priorities. In order to leverage the Micro-Siting Tool among other utilities and the wider industry, the user would need to identify the inputs and preferences relevant to the particular use case. Users of this report should investigate other criteria based on market and customer research and location-specific siting requirements.

Primary Lessons Learned

- The DC Fast Charger Micro-Siting Tool and best practices described can support the screening and siting process for DCFC installation plans for PG&E, California, and beyond.
- Thoughtful siting of EV charging infrastructure may support reduced installation costs, improved site host acceptance, and maximized use from drivers.
- For initial site screening purposes, 14,416 businesses, parking lots, and other locations match the DCFC use case[11] in PG&E's electric distribution territory.
- Of the 14,416 potential host sites identified, roughly 45% of these sites have available transformer capacity.
- Support for siting DCFCs to benefit disadvantaged communities can be provided by including three criteria among other siting criteria: placement of chargers within the community, proximity to multi-unit dwellings, and proximity to minority-owned businesses.
- Support for siting DCFCs to maximize EV adoption should focus on future capacity, as well as potential capability and availability of parking spots.
- Support for siting DCFCs to minimize cost should focus on finding available transformer capacity and include specific site criteria, such as installation distance to the transformer.

Best Practices in DC Fast Charger Siting

The literature review, expert interviews, and siting analysis performed for this project led to a number of conclusions that support the framework for developing best practice guidelines for siting DCFCs:

1. It is important to site DCFCs in areas of high unmet EV charging need (macro-siting) and also to choose individual sites that will meet criteria for three key stakeholder groups (micro-siting): drivers, charger hosts, and network developers.
2. To get DCFC projects off the ground and maximize driver willingness to use the public charging networks, the following criteria from the perspectives of three key stakeholder groups must be considered:
    - *Drivers:* EV Drivers seek safety, comfort, reliability, and convenience.
    - *Hosts:* Site hosts must advocate for site permitting and dedicate time to negotiations and contracting, but this can be challenging since there is not yet a clear business case

[11] The DCFC use case identifies favorable places to park while charging

for hosting DCFCs, even when equipment and installation is subsidized. Thus far, hosts have largely been driven by factors other than direct revenue from chargers, such as green public relations benefits, sustainability goals, LEED certifications, or a perceived future value of EV charging to building tenants, employees, or customers.

- *Network developers:* DCFC network developers must try to fit varied hosts into standardized contracts and leases to avoid prolonged negotiations.

3. Public cost data on DCFCs is limited and often fails to include the full range of costs involved in siting and installing chargers. Nonetheless, available studies reveal a number of key cost drivers for DCFC installations. One significant cost driver is the cost of any needed electrical transformer upgrades. Hard surface materials and the distance of trenching and boring can also increase costs significantly but can vary considerably by site. Despite the difficulty of predicting the exact costs involved in developing a specific DCFC site, there are a number of site selection filters that planners can apply to minimize costs for screening purposes. See Expert Siting Criteria, which outlines the filters used for DCFC siting.
4. Based on the outcomes from expert interviews, disadvantaged communities can be served by siting DCFCs according to three criteria, among others:
    - Placement of chargers within disadvantaged communities
    - Proximity to multiple-unit dwellings
    - Proximity to minority-owned businesses

Conclusion
In order to encourage the use of the developed siting methods, map and tool for initial site screening purposes, PG&E has several engagement efforts planned. PG&E has presented the report at two conferences with additional presentations planned. Upon the report's release, PG&E will be reaching out to potential end-users, such as the CEC, CPUC, EV service providers, installers, and automakers. PG&E supports the use of the tool for initial site screening, yet also recognizes that additional detailed analyses, as well as additional factors not included in the tool will be an essential part of actual optimal DCFC siting decisions.

In the end, this project successfully achieved all of its key objectives and, in doing so, has addressed multiple barriers related to electric vehicle adoption. The project executed a thoughtful DCFC siting approach of EV charging infrastructure, which can reduce installation costs and improve site host acceptance, taking into account the available transformer capacity for the sited locations. The best practices and siting methodology detailed in this report, along with the Micro-Siting Tool and Interactive Map, support thoughtful, data-driven DCFC deployment throughout the utility's territory, the state, and beyond. The results of this EPIC project are intended to guide all levels of DCFC stakeholders, and while tools developed focus on PG&E, methodology and best practices are applicable to efforts statewide, including the pursuit of a test case using recently CEC-funded DCFC installations, as referenced in Section 4.2.

2 Introduction

This report documents achievements, highlights key learnings that have industry-wide value, and identifies future opportunities for PG&E to leverage from the EPIC 1.25 project "Develop a Tool to Map The Preferred Locations for Siting DC Fast Charging Mapping, Based on Traffic Patterns and PG&E's Distribution System, to Address EV Drivers' Needs While Reducing the Impact on PG&E's Distribution Grid," referred to in short as "Direct Current (DC) Fast Charging Mapping".

The California Public Utilities Commission (CPUC) passed two decisions that established the basis for this pilot program. The CPUC initially issued D. 11-12-035, *Decision Establishing Interim Research, Development and Demonstrations and Renewables Program Funding Level*[12], which established the Electric Program Investment Charge (EPIC) on December 15, 2011. Subsequently, on May 24, 2012, the CPUC issued D. 12-05-037, *Phase 2 Decision Establishing Purposes and Governance for Electric Program Investment Charge and Establishing Funding Collections for 2013-2020*[13], which authorized funding in the areas of applied research and development, technology demonstration and deployment (TD&D), and market facilitation. In this later decision, CPUC defined TD&D as "the installation and operation of pre-commercial technologies or strategies at a scale sufficiently large and in conditions sufficiently reflective of anticipated actual operating environments to enable appraisal of the operational and performance characteristics and the financial risks associated with a given technology[14]."

The decision also required the EPIC Program Administrators[15] to submit Triennial Investment Plans to cover three-year funding cycles for 2012-2014, 2015-2017, and 2018-2020. On November 1, 2012, in A.12-11-003, PG&E filed its first triennial Electric Program Investment Charge (EPIC) Application at the CPUC, requesting $49,328,000 including funding for 26 Technology Demonstration and Deployment Projects. On November 14, 2013, in D.13-11-025, the CPUC approved PG&E's EPIC plan, including $49,328,000 for this program category. Pursuant to PG&E's approved EPIC triennial plan, PG&E initiated, planned, and implemented the EPIC Project 1.25 Direct Current (DC) Fast Charging Mapping. Through the annual reporting process, PG&E kept CPUC staff and stakeholder informed on the progress of the project. The following is PG&E's final report on this project.

3 Project Overview

This project ultimately created two key deliverables including an interactive map that prioritizes identified DCFC siting locations based on unmet need and also developed a Micro-Siting Tool[16] that can be leveraged by utilities or DCFC installers to prioritize potential DCFC sites in PG&E's territory based on a multitude of criteria and preferences, including cost, available capacity[17] and/or proximity to disadvantaged communities. The following section summarizes the need for such tools, and the inputs, tasks and methods that led to their development.

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[12] *Decision Establishing Interim Research, Development and Demonstrations and Renewables Program Funding Level*

[13] http://docs.cpuc.ca.gov/PublishedDocs/WORD_PDF/FINAL_DECISION/167664.PDF

[14] Decision 12-05-037 pg. 37

[15] Pacific Gas & Electric (PG&E), San Diego Gas & Electric (SDG&E), Southern California Edison (SCE), and the California Energy Commission (CEC)

[16] The Excel tool will be available upon request

[17] Sites identified with sufficient distribution transformer capacity are static based on the time of study, and additional analysis of changes in electric grid infrastructure is required when pursuing installation to draw a final conclusion on secondary transformer capacity.

3.1 Issue Addressed

Electric Vehicle (EV) adoption recently surpassed 100,000 units in PG&E's territory, and adoption of Battery Electric Vehicles (BEV) is outpacing PHEVs on a twofold scale. Research in the past has pointed to installing DC Fast Chargers (DCFCs) as one way to further increase and support BEV adoption.[18] DCFCs commonly have power ratings of 50kW or higher and can fully charge many EVs to 80% in 30 minutes or less. Compared to lower levels of charging, DCFCs approach the refueling time of a gas station, providing the most on-the-road experience that most closely resembles the convenience of gas stations. Recognizing this driver preference, private-sector charging companies, automakers, the California Energy Commission (CEC), and both individual cities and counties have begun installing networks of DC fast chargers around the state.

DCFCs are typically expensive to install and little research has been done on how to reduce this barrier. To ensure that the investment in higher power charging is impactful, it is imperative to find sites that can support high utilization and additional EV adoption, lower installation costs, or support other state policies, such as supporting Disadvantaged Communities (DACs). Due to their high power (typically 50 kW or greater), there are often significant upgrades to utility distribution infrastructure that can quickly increase DCFC installation costs. Furthermore, these DCFCs can be expensive to operate as they may incur significant demand charges (utility rate components based on peak kW usage) during a customer's billing cycle. Identifying locations where there is available upstream capacity for a DCFC can likely lower the installation cost. Further, identifying locations where there is substantial charger utilization can help spread the fixed demand charge portion of DCFC operating costs over a larger customer base.

Fast charging is needed to increase the utility of battery electric vehicles (BEVs), but is not restricted to one purpose or use case. It can be used to reach a destination beyond the vehicle's range, as a backup for a level 2 charger in case it is occupied, and when home charging is slow, unavailable, or the driver has simply forgotten to charge their car when at home or work. Addressing these factors increases range confidence while using the vehicle. Finally, the existence of fast chargers at destinations or along routes that are high-priority for a potential EV driver is important to reduce "range anxiety" sufficiently to support their EV purchase, irrespective of the actual utilization of these chargers once the EV has been purchased. Fast charging creates travel and charging flexibility that customers may value. Given DC Fast Chargers are often expensive to install, justification for the investment can be helped by identifying methods to either increase station utilization by intelligent siting or locating sites with available distribution capacity, thereby reducing installation cost.

3.2 Project Objective

A stronger network of public EV charging infrastructure is needed to reach the state's ZEV goals and leverage spending on vehicle incentives. By increasing EV range, public fast charging allows more electric miles to substitute gasoline miles. Public fast charging is also critical to reducing range anxiety. All else equal, drivers prefer faster public charging.[19]

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[18] Li et al., *The Market for Electric Vehicles: Indirect Network Effects and Policy Impacts*, Cornell University, February, 2015.
Plug-In Electric Vehicle Multi-State Market and Charging Survey. EPRI, Palo Alto, CA: 2016. 3002007495.
Charles Morris*, Given the choice, EV drivers prefer DC fast charging 12-to-1 over Level 2,* Charged EVs Magazine, November 12, 2015.

[19] See Tweed, K. November 17, 2013, "Fast Charging Key to Electric Vehicle Adoption, Study Finds," http://www.greentechmedia.com/articles/read/fast-charging-key-to-electric-vehicle-adoption-study-finds;

For DCFC networks to successfully promote EV adoption, individual chargers must be sited with care. The project had the following objectives:

- Develop best practices in siting public DC fast charging;
- Develop a transferable and repeatable method to identify potential host sites;
- Develop a tool to identify and order recommended host sites based on varying user preferences and certain non-exclusive factors[20], including driving patterns, distribution capacity, driving EV adoption, support for disadvantaged communities, etc.; and
- Develop an interactive map to identify and display potential prioritized DC Fast Charging locations that is based on projected unmet charger demand in PG&E's territory.[21]

The project team encompassed a range of expert perspectives on DC fast charger siting, comprising staff from the University of California, Davis Institute of Transportation Studies (UC Davis), Energy and Environmental Economics (E3), PlugShare, Ricardo, and PG&E.

3.3 Scope of Work

In order to reduce the cost of DCFC installation and increase vehicle miles travelled using electricity, PG&E identified high-value sites for drivers (based on unmet charger demand) and low-cost sites for installers (based on available distribution capacity). The research leveraged E3, PlugShare, Ricardo, UC Davis, and other industry experts to forecast future EV adoption, identify existing DCFC locations, develop best practices in siting DCFCs, and identify locations in PG&E's territory that may make optimal site hosts. PG&E's distribution planning engineers identified one-mile radius bubbles and linked them with publicly available data to identify addresses with enough three-phase capacity on the service transformer to install DCFCs based on the current network loading.

The project was divided into five overlapping work streams:

1. Develop EV adoption forecast scenarios;
2. Assess the current landscape of installed DCFCs in California and PG&E's territory;
3. Determine the areas in PG&E's territory with the highest future demand for charging;
4. Determine the areas in PG&E's territory with available distribution capacity; and
5. Conduct industry expert interviews to identify key factors for DCFC siting.[22]

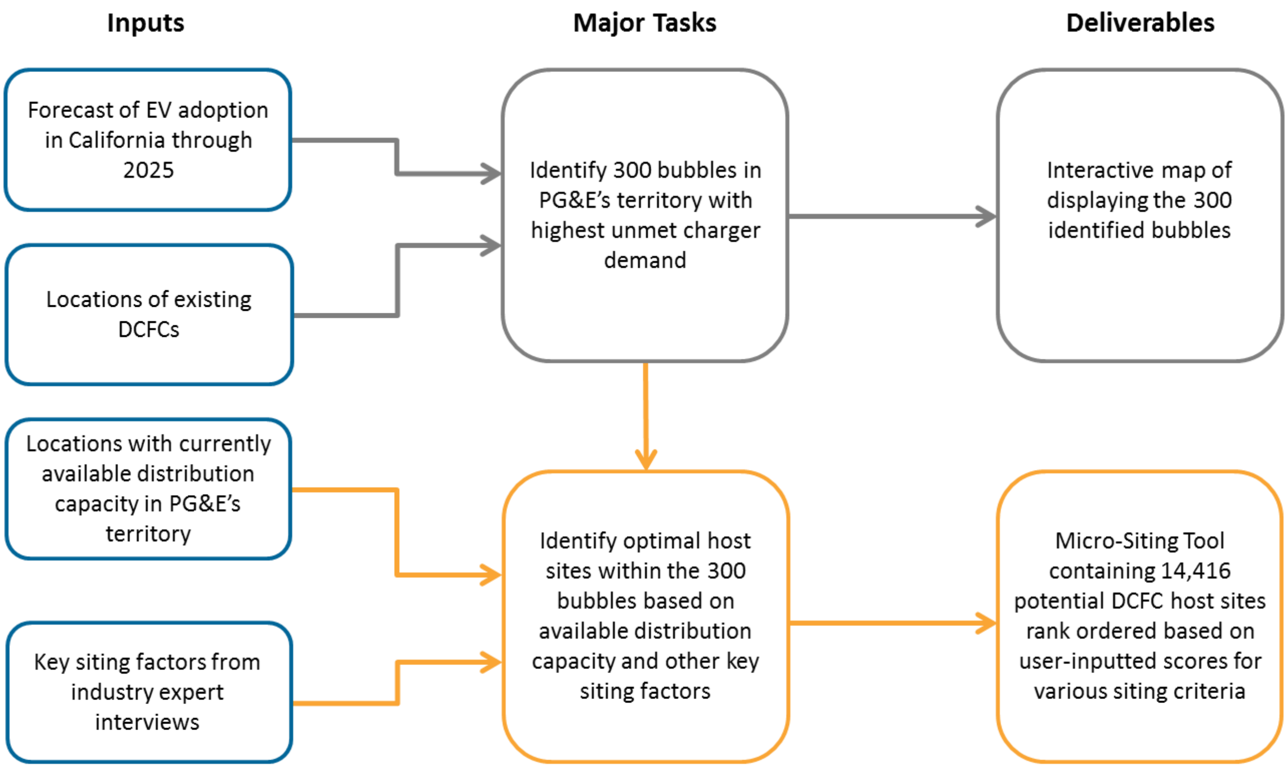
[20] The tool includes criteria for identifying and ranking potential host sites based on the PG&E specific territory. Other criteria may and should be included by users of this report based on current market and customer research and location-specific siting requirements.

[21] This map represents the output of the algorithm developed in this project to optimize the non-exclusive factors included in the method as a means of screening potential DCFC sites. This is a precursor to applying more direct analysis and evaluation using more detailed information and other potential siting factors. Actual DCFC siting analysis will involve more detailed evaluation and application of the factors included in the algorithm, as well as other quantitative and qualitative factors and market research not included in the algorithm.

[22] Sites identified with sufficient distribution transformer capacity are static based on the time of study, and additional analysis of changes in electric grid infrastructure is required when pursuing installation to draw a final conclusion on secondary transformer capacity.

Figure 3-1 shows how the results of the four work streams fed into each of the major tasks and deliverables.

Figure 3-1. Overview of Project Scope of Work



Ultimately, PG&E produced an interactive map displaying the 300 identified locations/bubbles and a micro-siting tool for potential installers to identify optimal sites within the identified locations based on a non-exhaustive list of customized inputs. While the siting results from both tools are specific to and applicable only to PG&E's territory, the methods for developing the map and Micro-Siting Tool, as well as the best practices in siting are transferrable to other utilities and states.

3.3.1 Major Tasks and Deliverables

The five work streams described in Section 3.3 naturally lead to the following eight project tasks, with their corresponding deliverables:

1. **Develop EV adoption forecast scenarios:** This task develops forecasts for EV adoption in California through 2025 to be used as a primary input to understand the amount of future unmet demand for EV charging stations. Ricardo's EV adoption forecasts were applied to two adoption scenarios:
    - Scenario 1: Compliance with the California ZEV Mandate — based on meeting the California Zero Emission Vehicle (ZEV) Mandate assuming the overall fleet behavior follows the requirements for PEV sales aimed at large volume manufacturers; and
    - Scenario 2: EV Affordability — based on modelling PEV affordability through time, compared to their internal combustion (IC) engine equivalents

Deliverable: Two sets of EV adoption forecasts through 2025 for California under the two scenarios described above. These are used as model inputs for determining the top 300 1-mile radius locations of highest future unmet charging demand in PG&E's service territory in 2025 (.

2. **Assess the current landscape of installed DCFCs:** This task uses PlugShare's database[23] to map existing DCFCs in California and in PG&E's territory. Since there are many fast chargers that are not supported by an electric vehicle service provider, PlugShare also collects fast charger data from automotive partners. This data is then supplemented by networked and non-networked fast charger data crowdsourced by PlugShare's more than 140,000 registered users on both web and mobile applications.

   Deliverable: Locations of existing DCFCs in PG&E's service territory, which are used as model inputs for determining the top 300 one-mile radius locations of highest unmet charging demand.

3. **Determine the areas in PG&E's territory with the highest future unmet demand for charging:** This task uses an existing transportation demand model created by UC Davis to identify the top 300 one-mile radius bubbles within PG&E's territory that have the highest predicted future unmet demand for charging stations. The model's inputs included the forecasts of EV adoption for 2025 and the locations of existing DCFCs.

   Deliverable: Longitude and latitude values for the top 300 locations of highest predicted unmet charger demand in PG&E's territory in 2025. These 300 locations were used to prioritize areas where potential charging host sites were identified (see Appendix D).

4. **Determine the areas in PG&E's territory with available distribution capacity:** This task identifies locations where there is available upstream capacity for a DCFC installation. PG&E's distribution engineers used the Distribution Asset Reconciliation Tool (DART) to identify areas with spare capacity on the secondary distribution transformer to support a minimum of two DCFCs charging at 65 kW from peak loading. This criteria is statically built into the micro-siting tool, and available capacity should be verified when planning installation projects.

   Deliverable: Method for identifying available capacity and determining locations within PG&E's territory with available distribution capacity to support potential DCFC installations. These were used in conjunction with the 300 locations of highest unmet charger demand to identify the potential host sites that are displayed in the interactive map and are ranked in the Micro-Siting Tool.

5. **Conduct industry expert interviews to identify key factors for DCFC siting:** This task uses feedback from industry experts to identify key factors for inputs to DCFC siting that drive three metrics: (1) minimizing installation costs; (2) maximizing EV adoption; and (3) supporting disadvantaged communities.

   Deliverable: Twenty industry expert interviews were conducted and the results were used to develop a non-exclusive list of siting criteria supporting each of the three metrics referenced above (see Appendix F - Guidelines for DCFC Siting from Industry Expert Interviews). The siting criteria, included in the Micro-Siting Tool, are factors that users of the tool could score based on preferences and particular use cases. The list of 14,416 identified potential host sites in PG&E's

[23] PlugShare provides the most complete charging infrastructure database in North America by combining fast charger data from multiple network partner sources.

territory could be re-ordered at the users discretion. The expert interviews were also used to identify best practices for DCFC siting.

6. **Determine potential charger host sites at each of the 300 identified locations:** This task uses the following process for identifying potential host sites at each of the 300 identified locations of highest unmet charger demand:
    - Determine the location of high potential unmet charger demand in 2025 (Task 3);
    - Expand the location to encompass a one-mile radius location/bubble;
    - Identify potential host sites that correspond to the three charger demand types (i.e., corridor, workplace, home); and
    - Determine whether sites are within a 300 foot radius of a distribution transformer with sufficient capacity for at least two DCFCs (Task 4)

    Deliverable: A list of 14,416 potential DCFC host sites. These sites are displayed within their respective one-mile radius locations/bubbles on the interactive map and can be ranked based on certain non-exclusive factors and user-inputted scores in the Micro-Siting Tool.

7. **Create an interactive map of unmet charger demand, including potential host sites:** This task visualizes the results of Task 3, allowing users to see all potential locations for high value DCFC installations in PG&E's service territory.

    Deliverable: An interactive map that displays all 300 one-mile radius locations (displayed as a bubbles on the map) that is rank ordered from 1–300 based on unmet charger demand. The following information is displayed in each bubble: Potential charger host site information, existing chargers at each site, new DCFCs that could be added and the number of estimated DCFCs that could be installed to satisfy unmet need in 2025. The map does not include the functionality to allow the user optimize and rank potential host sites based on minimizing installation costs, increasing EV adoption, or supporting disadvantaged communities.

8. **Develop a tool to rank potential host sites based on user input:** This task develops a tool that uses certain non-exclusive factors identified in Task 6 and user-inputted scores for those factors to optimally rank the 14,416 potential host site based on the user's preferences.

    Deliverable: The Micro-Siting Tool[24] that ranks the potential host sites based on user preferences in optimizing one or more of the following metrics: (1) minimizing installation costs; (2) maximizing EV adoption; and (3) supporting disadvantaged communities.

[24] The tool includes criteria for identifying and ranking potential host sites based on the PG&E specific territory. Other criteria may and should be included by users of this report based on current market and customer research and location-specific siting requirements.

4 Project Results and Key Findings

This section summarizes the project's technical results, key findings, and recommendations.

4.1 Forecasted EV Adoption

Ricardo's EV adoption forecasts were used to understand the degree of unmet demand for EV charging stations. There are two different EV adoption forecast scenarios considered:

Scenario 1: Compliance with the California ZEV Mandate — based on meeting the California Zero Emission Vehicle (ZEV) Mandate assuming the overall fleet behavior follows the requirements for PEV sales aimed at large volume manufacturers

Scenario 2: EV Affordability — based on modelling PEV affordability through time, compared to their internal combustion (IC) engine equivalents

4.1.1 There are significant differences in the predictions of EV adoption under the two scenarios

As shown in Figure 4-1 and Figure 4-2, the scenarios have significantly different predictions for the amount of PEVs estimated to be driven in California in 2025.

Figure 4-1. EV Adoption Forecast for Scenario 1

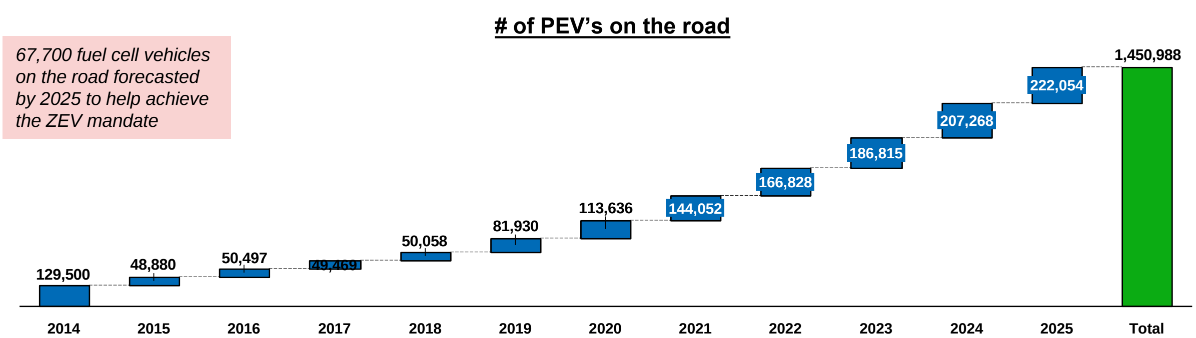
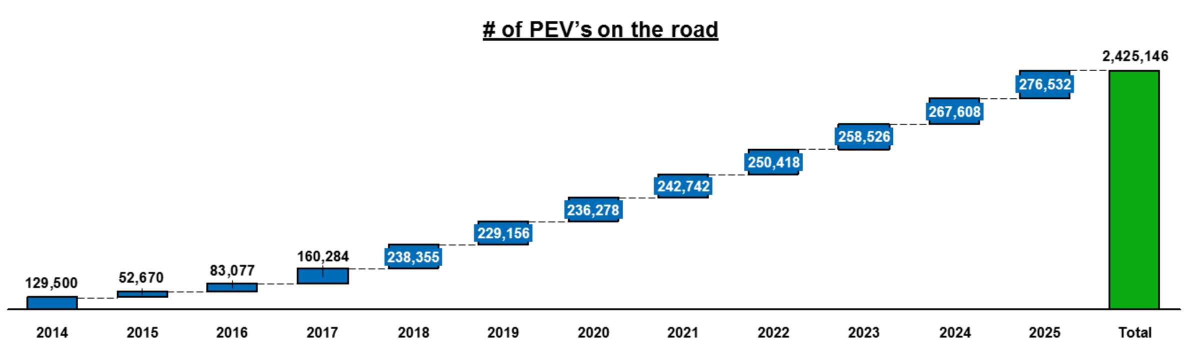


Figure 4-2. EV Adoption Forecast for Scenario 2



Some of the key differences between the two scenarios are:

- In 2025, far lower BEV-200 sales are predicted in 2025 for Scenario 2 (28,265) than for Scenario 1 (53,096)
- In 2025, far higher PHEV sales are predicted for Scenario 2 (150,000) than for Scenario 1 (89,310)
- Meeting the ZEV mandate involves little growth (2.4%) in PEV sales from actual 2015 sales to 2018 sales. However, based on affordability, there is large growth from actual 2015 sales to projected 2018 sales (453%)
- Meeting the ZEV mandate involves large growth in PEV sales from 2018 to 2025 (444%), in-line with the 489% increase in the "Total ZEV percent requirement." However, based on affordability, only very modest growth is seen from 2018 to 2025 (16%), as the federal incentive becomes limited
- In 2025, total PEV sales are 250,000 ± around 10% for both scenarios

Each scenario was calculated separately to provide the most insight for tool users. A detailed explanation of the differences between the two scenarios is provided in Appendix C. The forecasts from Ricardo were used as a model input to identify the areas of highest unmet charger demand in PG&E's territory. A comparison of DCFC demand by location is provided in Appendix D.

4.2 Identification of Existing DCFC Locations

PlugShare's database[25] was used to map existing DCFCs in California and in PG&E's territory. Since there are many fast chargers that are not supported by an electric vehicle service provider, PlugShare also collects fast charger data from automotive partners. This data is then supplemented by networked and non-networked fast charger data crowdsourced by PlugShare's more than 140,000 registered users on both web and mobile applications.

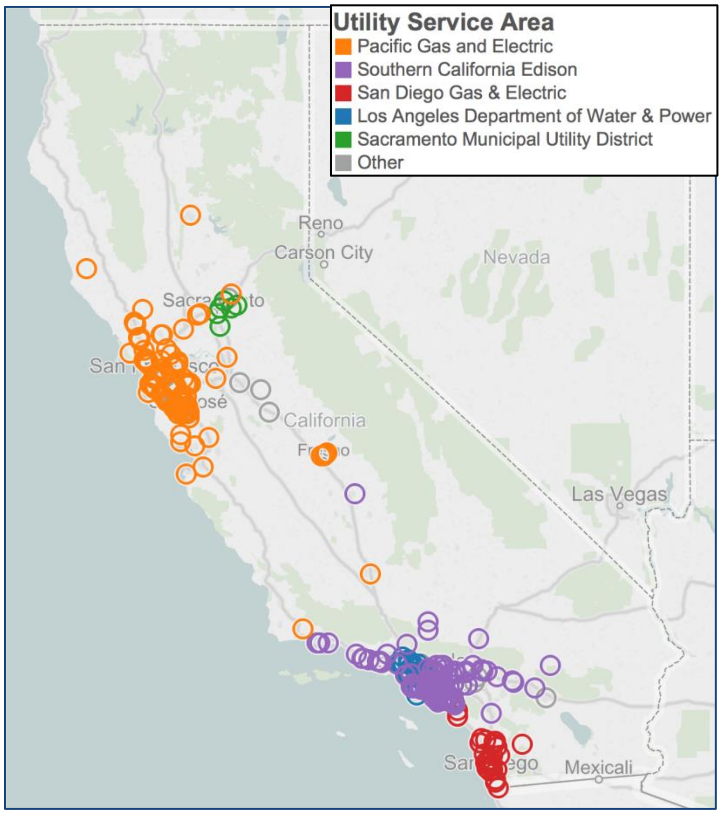
As of October 2015, PlugShare had identified over 400 existing DCFCs in California, and of those, 157 are located within PG&E's territory — 80% of which are in the San Francisco Bay Area. PlugShare also helped UC Davis augment their identified locations to exclude existing reliable DCFCs. Both publicly available and restricted access fast chargers are included in the map shown in Figure 4-3. Tesla Superchargers were filtered out of the database because they belong to a closed network that is inaccessible to drivers of other vehicle makes. Both non-proprietary major North American fast charger standards, CHAdeMO and CCS (SAE Combo), were included. Once collected, charger data was processed for quality using PlugShare's data integrity processes, which include site validation through user comments and photos, as well as latitude and longitude adjustments using aerial and satellite imagery.

The installations are colored according to the electric utility service territory in which they reside. Note that this map does not include proposed DCFC installations along Interstate 5 and State Route 99 from the CEC-funded project that was awarded after the majority of this project's completion in February

[25] PlugShare provides the most complete charging infrastructure database in North America by combining fast charger data from multiple network partner sources.

2016.[26] DCFCs spanned across five different utility networks, including over 70 non-utility networked fast chargers.

Figure 4-3. DCFC Installations in California by Utility Service Area (as of October 2015)[27]



Source: PlugShare

4.3 Identification of 300 Locations in PG&E's Territory with Highest Unmet Charger Demand

The top 300 locations were identified that corresponded to the highest amount of future unmet charging demand predicted for 2025. Researchers at UC Davis used the forecasts for EV adoption and the locations of existing DCFCs as inputs in their existing transportation demand model. For each location, the UC Davis researchers estimated the number of charging events, as well as the number of chargers needed near each location. The total number of chargers at these 300 general locations varied from 574 chargers to 916 chargers depending on Ricardo's vehicle scenario. PG&E used the "GIS EV Planning Toolbox for MPOs"[28] to estimate the spatial distribution of BEV drivers and their charging

[26] California Energy Commission, February 16, 2016, "Alternative and Renewable Fuel and Vehicle Technology Program Grant Solicitation GFO-15-601 DC Fast Chargers for California's North-South Corridors," http://www.energy.ca.gov/contracts/GFO-15-601_NOPA.pdf

[27] There were more DCFC planned for deployment during the development of this report, but this map captures the existing and confirmed installed DCFC locations as of October 2015.

[28] PH&EV Center (2015). "UC Davis GIS EV Planning Toolbox for MPOs" from http://phev.ucdavis.edu/project/uc-davis-gis-ev-planning-toolbox-for-mpos/.

demand. This data was used to determine both the location of DCFCs and the number of charging events at each location.

The spatial distribution of PEV drivers was predicted using the “Market Tool” of the EV Toolbox. As described in Section 3.3.1 and furthermore in Appendix C, Ricardo created two forecast scenarios describing the California PEV Market in 2025. Accounting for vehicle attrition, the vehicle volumes were used to estimate demand for DCFCs in 2025 (shown in Table 4-1).

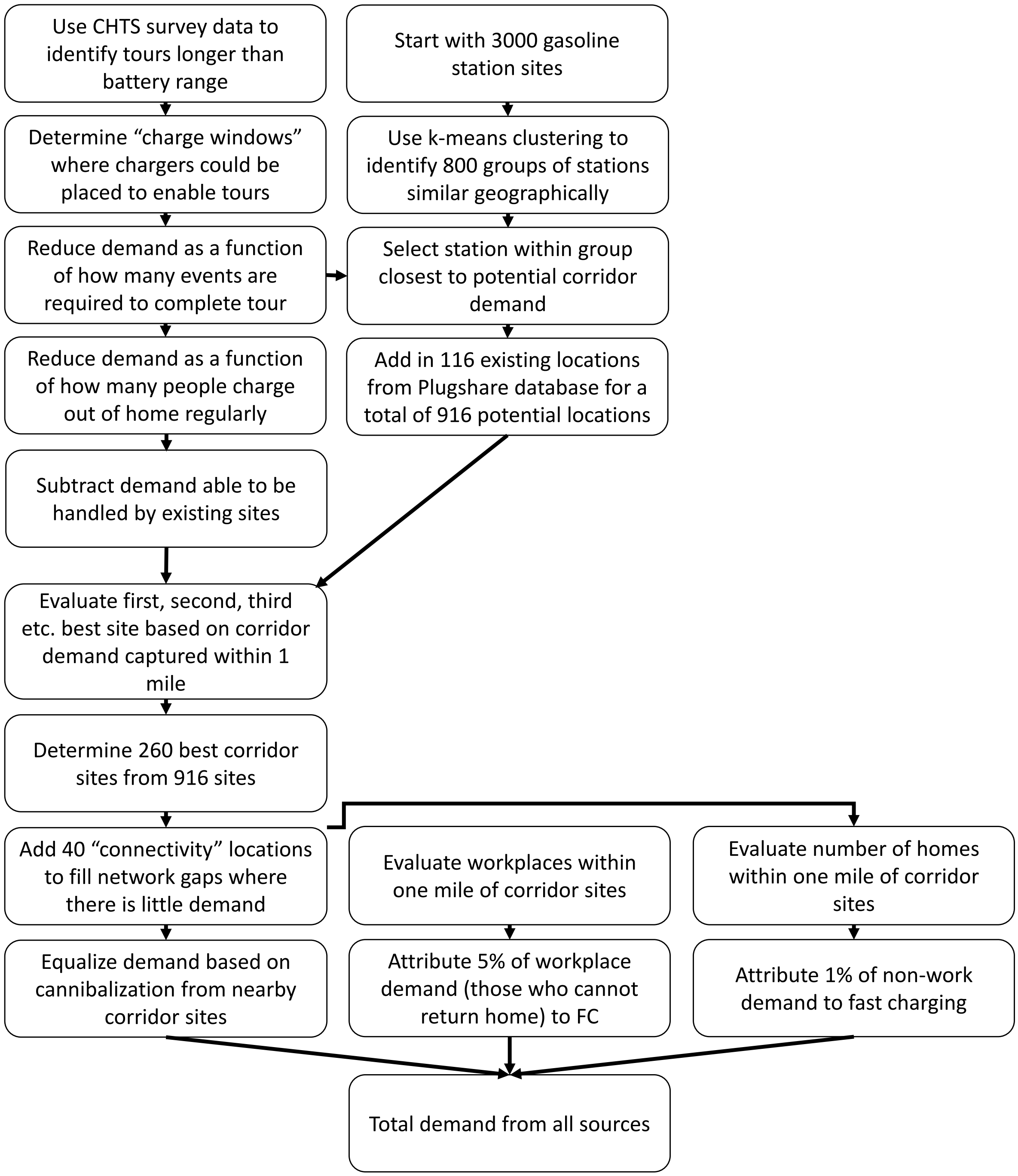
Table 4-1. Vehicle Volumes Used in DCFC Demand Analysis

	PHEV 40	BEV 100	BEV 200	Total
ZEV Mandate Scenario	514,222	537,302	269,964	1,321,488
Affordability Scenario	1,150,918	980,117	164,609	2,295,644

These vehicles were assigned proportionally across socio-demographic data and commute distance of local residents. For simplification, these few categories are meant to approximate the variety of vehicle ranges that are distinct from a use perspective. They do not reflect all of the actual vehicle ranges in the future. This analysis assumes that only BEV drivers will use a DCFC.

The decision process for identifying all 300 locations using the conditions above and estimating their charging demand is outlined in Figure 4-4 below.

Figure 4-4. Decision Process Flow Chart for Identifying Locations and Estimating Charging Demand



A full printed list of the 300 identified locations is available in Appendix D. This includes latitude, longitude, number of new chargers needed in 2025 under each forecast scenario, and the total number of charger sites in each bubble.

4.4 Expert Interviews

PG&E interviewed expert stakeholders from over 20 organizations from multiple industries, including academic research institutions, car manufacturers, environmental non-profits, utilities, etc.

Interviews and published works reveal that stakeholders have been broadly aiming to choose DCFC sites that will:

1. Best support EV adoption
2. Keep installation costs low
3. Spread the benefits of EVs amongst all groups

These objectives do not always align, and stakeholder opinions vary as to the optimal weighting and acceptable tradeoffs between the three outcomes. The interviews revealed that in order for DCFCs to be installed and utilized by drivers, it is important to consider the perspectives of drivers, charger hosts, and network developers. Given a choice, EV drivers strongly prefer DC fast charging over Level 2 chargers due to the DCFCs' fast charging time. Interviews also revealed it is important to site DCFCs in areas of high unmet charger need, and to choose individual sites that will be agreeable to all three of these key stakeholder groups.

Appendix F - Guidelines for DCFC Siting from Industry Expert Interviews, summarizes the available literature, and includes a list of interviewees and their expert opinions to guide planners, policymakers, and those on the ground in achieving each of the three aims.

4.5 Identification of Potential Host Sites with Available Distribution Capacity[29]

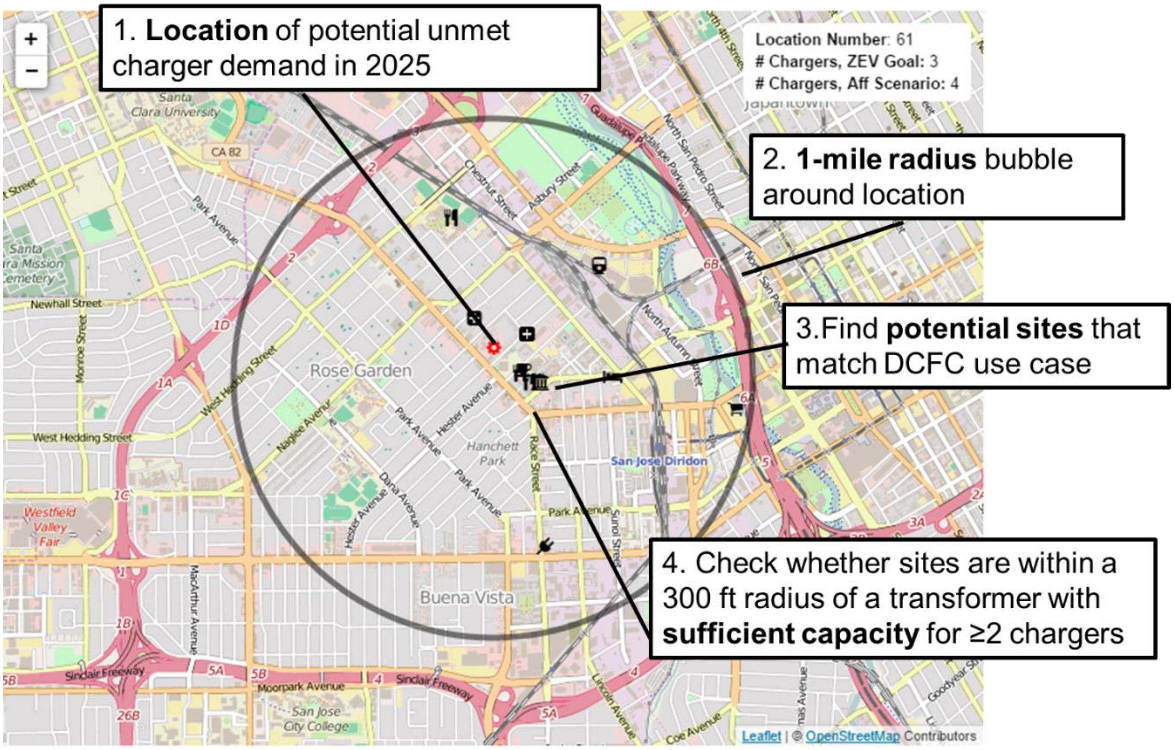
Three factors were considered when identifying potential sites within each one-mile radius location/bubble:

1. Existing 480V, three-phase service transformers with DCFC hosting capacity;
2. Site type sites (e.g., businesses, parking lots, public places, etc.); and
3. Existing charger sites.

From the 300 one-mile radius locations identified, the team worked with distribution planning to identify potential host sites with available distribution capacity. Service transformer upgrades are a major cost driver for DCFC installation, so identifying locations that may have existing capacity can remove this installation barrier. However, of the 300 one-mile radius locations/bubbles identified in the map, only about 45% of locations had available capacity. In the instances where no sites with available capacity could be found, PG&E listed all potential business addresses that may make good DCFC sites. Installers of DCFC should work with PG&E directly to help identify lower distribution cost sites. Figure 4-5 describes the process for identifying potential host sites within each bubble.

[29] Sites identified with sufficient distribution transformer capacity are static based on the time of study, and additional analysis of changes in electric grid infrastructure is required when pursuing installation to draw a final conclusion on secondary transformer capacity.

Figure 4-5. Process for Identifying Suitable Sites Based on Service Transformer Capacity[30]



It was determined that sufficient capacity for at least two DCFCs was a realistic threshold. The reasoning is twofold. First, the tool is currently static and the distribution system is changing constantly, so allowing for a buffer makes the results more resilient. Second, in many areas, site hosts are deciding to install either two DCFCs or a DCFC and a Level 2 (L2) EVSE, so allowing for an easy increase in the number of EVSEs becomes important for siting.

Installing a new 480V, three-phase transformer is a significant cost driver for DCFC installation, and leveraging existing transformers is therefore extremely valuable.[31] Due to this uncertainty, a site was deemed co-located with an existing transformer only if a minimum of 2 DCFCs were supportable with the existing capacity. A follow-up study could include analyzing the grid impact of aggregated DCFCs, and the expected load impact at each of the sites. This was considered out of scope for this project.

A third-party database of sites was used for analysis of site types. Specifically, site types were included that most aligned with the DCFC demand types (i.e., corridor, workplace, home) and were most likely to include factors attractive to drivers (see Table A-1. Driver Priorities for DCFC Micro-siting).

[30] While this project identified sites with sufficient distribution transformer capacity, other distribution upgrades may be required based on existing conditions and size of DCFC deployment.
[31] It is important to note that electric grid infrastructure is constantly changing and that a detailed study of each site would be required to draw a final conclusion on secondary transformer capacity.

Three different types of charger demand was assessed:

1. **Corridor Demand:** This could be from travelers with a driving distance that exceeds their vehicle's battery range;
2. **Workplace Demand:** This could be from commuters who use fast charging stations near their workplace as an alternative to workplace chargers; and
3. **Home Demand:** From BEV drivers who use fast charging stations near their home as an occasional supplement to home chargers or when they need to charge their BEVs in a short period of time.

A "corridor-first" strategy was adopted by the project, meaning that all sites were required to have some function for long trips. This allows all sites to be evaluated on their ability to extend vehicle range on trips that are farther than battery range (e.g., a trip is 80 miles and battery range is 60).

Additionally, site types listed in Table 4-2 below were included due to their historical willingingness to be charger hosts. Finally, the team added existing Level 2 charger and DCFC sites from PlugShare's database[32] that did not appear in the third-party database of business listings because existing hosts may be amenable to hosting additional chargers. Providing multiple DCFCs at one site creates reliability benefits to drivers by providing redundancy and can help reduce congestion. This is discussed in more detail in - Expert Siting Criteria.

Table 4-2. Site Types Included as Potential DCFC Sites Based on Estimated Location Dwell Times

Short Dwell Time	**Medium Dwell time**	
Bakery	Clothing store	Medical office
Bank	Court	Movie theater
Drug store	Department store	Museum, performing arts, or art gallery
Gas station	Electronics store	Parking lot
Grocery or convenience store	Environmental agency	Restaurant or café
Health food store	Furniture, home appliances	Retail store
Post office	Government building	Sports field or stadium
Long Dwell Time	Gym or health club	Supermarket
Airport	Hospital	Tourist attraction or recreation site
Botanical garden, zoo, or aquarium	Library	Utility regulator
College or university	**Not Classified**	
Lodging	Existing DCFC, not elsewhere classified	
Railway station	Existing Level 2, not elsewhere classified	

Note: Medical offices were limited to SIC codes describing medical centers, internal medicine, and primary care physicians.

The process began by keeping only sites within each bubble that matched the site types identified in Table 4-2. Then, each site was flagged with the number of co-located existing EVSEs (Level 2 or DCFC) if PlugShare's database showed an EVSE within 300 feet of the site. This data was deemed useful as an

[32] See Section 4.2 for a description of PlugShare's database.

indicator that the site is attractive for additional EVSE development (e.g., by having adequate parking spaces or a supportive owner). Tesla Superchargers were included in this count, since these locations are natural indicators that are attractive for ESVE development.

After performing this analysis on the 300 one-mile radius locations/bubbles, the team attempted to reduce the number of sites identified to the most likely candidates for installation, while not being overly restrictive. Therefore, if more than five sites within a bubble had existing transformer hosting capacity, only sites with existing capacity were reported in the Tool. Otherwise, all the businesses in the bubble were reported. Where EVSE installations within a bubble were found in PlugShare's database, but were not able to be matched with a site in the third-party database, these were added in the Tool with Site Type 'Existing Level 2' or 'Existing Level DCFC.' Tesla Superchargers were excluded for this purpose since they are only compatible with Tesla vehicles.

A diagram of the decision process for including or excluding host sites can be found in Appendix E- Algorithm Implemented for Potential Host Site Identification. The third-party database used describes sites using Standard Industrial Classification (SIC-8) code.[33]

4.5.1 Leveraging existing distribution transformers can help reduce DCFC installation costs

Each of the resulting sites was then analyzed for co-location with existing 480V, three-phase service transformers with available capacity and tagged with the number of new DCFCs that could be supported by the service transformer. Transformers were deemed to be co-located with the site if they were within 300 feet. To determine how many DCFCs could be supported by the service transformer, total available capacity was divided by 65kW (based on the CHAdeMO power rating of 62.5kW[34]). However, of the approximately 14,000 sites that were investigated, only 45% of them had available distribution capacity. The existing service transformer information was obtained from PG&E databases.

Installing a new 480V, three-phase service transformer is a significant cost driver for DCFC installation, and leveraging existing service transformers is therefore extremely valuable. Providing information on PG&E's distribution network capacity in the Micro-Siting Tool should therefore prove incredibly useful to DCFC network developers. It is important to note, however, that electric grid infrastructure is constantly changing and that a detailed study of each site would be required to draw a final conclusion on secondary transformer capacity. Due to this uncertainty, a site was deemed co-located with an existing service transformer only if a minimum of 2 DCFCs were supportable with the existing capacity. A follow-up study could include analyzing the grid impact of aggregated DCFCs, and the expected load impact at each of the sites. This was considered out of scope for this project.

4.6 Final List of Potential Host Sites

The process described in Section 4.4 resulted in 14,416 potential EV charger installation sites within a one-mile radius bubble of the 300 highest unmet charging demand locations generated by UC Davis. Because some of the one-mile locations/bubbles overlap, some of the sites are repeated in multiple bubbles: the number of resulting unique sites[35] was 13,249.

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[33] Standard Industrial Classification (SIC) is a system for classifying industry areas/type by a code

[34] What Are The Actual Power Limits of Available DC Quick Charging Standards? http://insideevs.com/what-are-the-power-limits-of-available-dc-quick-charging-standards/

[35] A unique site is defined as a unique combination of name, address, longitude and latitude

Though 14,416 is a large total number of potential sites, the number of sites per bubble varies widely. Thirty-eight out of 300 bubbles (13%) show greater than 100 sites resulting from the analysis (bubbles in San Francisco, for example, show upward of 300 sites), whereas 65 out of 300 bubbles (22%) have ten sites or fewer. Of the 14,416 sites that were identified, only 45% of them had available distribution capacity based on the analysis completed by PG&E (see Section 4.5 Identification of Potential Host Sites with Available Distribution Capacity).

To further filter these sites, the team identified three main sets of weightings for installing DCFCs that may be important to installers or funding resources to further sort by:

1. Increase EV adoption – focused on making sites the most comfortable for customers. Criteria include: access to food, shelter, shopping, Wifi, extra parking capacity, and the ability to expand the number of sites.
2. Minimize costs – siting with a focus on minimizing cost included: proximity to a transformer with available capacity, and ease of installation.
3. Support disadvantaged communities – High CalEnviro Screen score, CARE top quartile, near a non-luxury MUD, a minority owned business.

It is important to note that this report does not represent PG&E's recommendation or endorsement of particular locations or regions for siting DCFCs, and factors other than those included in this report will be relevant to siting decisions. This report only reviews certain criteria to be used for siting DCFC. Other criteria may and should be used by users of the report based on market and customer research and siting requirements.

4.7 Interactive Map of 300 Identified One-Mile Radius Locations and Potential Host Sites

The results of the model ultimately identified 300 one-mile radius locations (displayed as a bubble) within PG&E's territory, rank-ordered by need, focusing first on high traffic corridor locations and second on coverage across the territory.

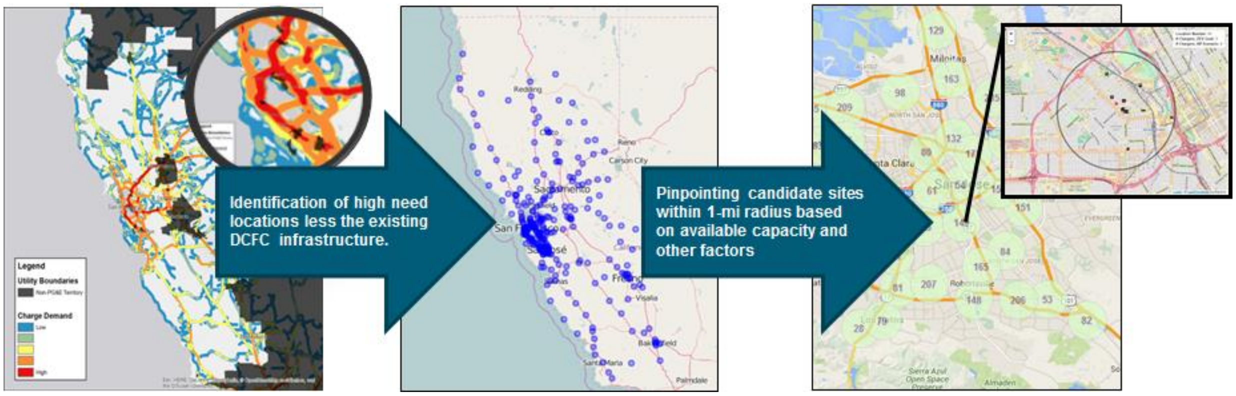
Three different types of charger demand were assessed:

1. **Corridor Demand:** This could be from travelers with a driving distance that exceeds their vehicle's battery range;
2. **Workplace Demand:** This could be from commuters who use fast charging stations near their workplace as an alternative to workplace chargers; and
3. **Home Demand:** From BEV drivers who use fast charging stations near their home as an occasional supplement to home chargers or when they need to charge their BEVs in a short period of time.

The project adopted a "corridor-first" strategy, meaning that all sites were required to have some function for long trips. This allows all sites to be evaluated on their ability to extend vehicle range on trips that are farther than battery range (e.g., a trip is 80 miles and battery range is 60).

The team then identified business locations (through publicly available data) within the 300 locations and subsequently based on available distribution capacity. Figure 4-6 is a visual flow chart of the results:

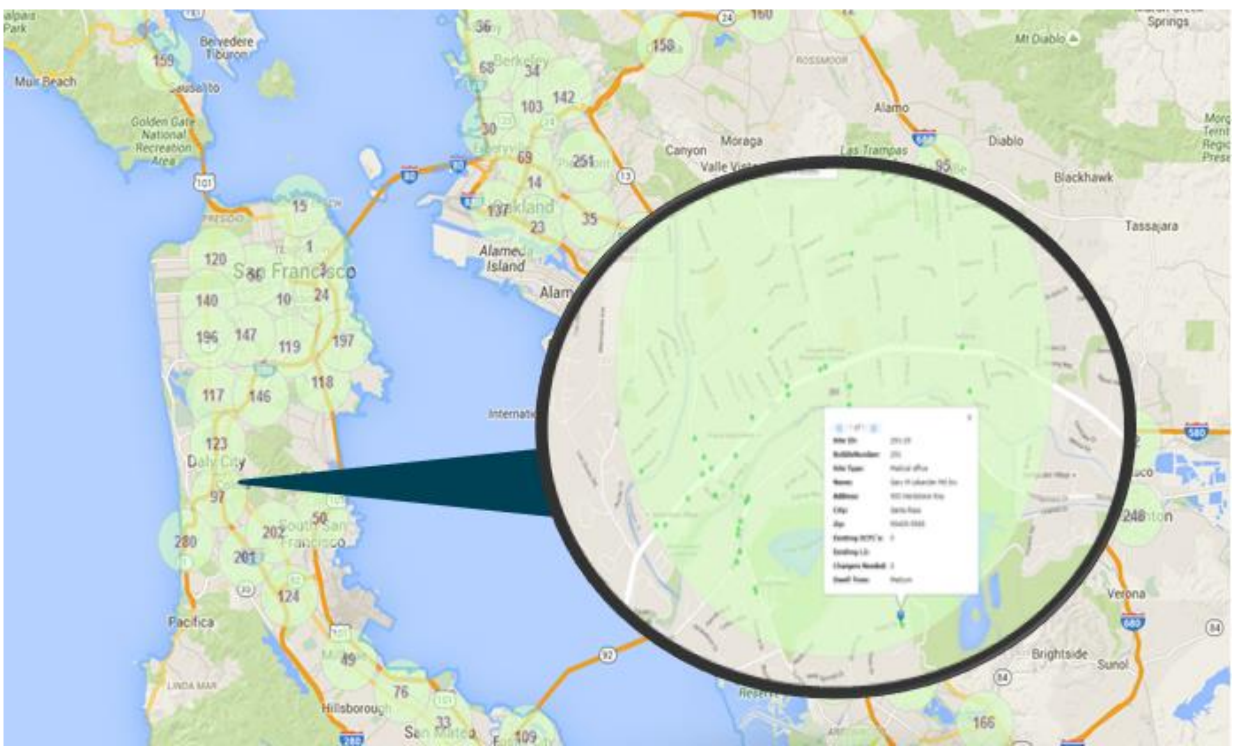
Figure 4-6. Flow Chart for Identifying Site Hosts



The results are displayed in an interactive map on www.pge.com/epic-project-dcfastcharging.

The map allows DCFC installers to see the top 300 identified bubbles of highest future unmet charging demand, as well as the potential host sites within each bubble. The map does not provide the user with the ability to rank or optimize the sites displayed based on minimizing installation costs, increasing EV adoption, or supporting disadvantaged communities, which is an available functionality in the Micro-Siting Tool. Figure 4-7 shows a screenshot of the map in the San Francisco Bay Area. The bubbles are located across PG&E's territory, which includes a minimum of one bubble per Division[36].

Figure 4-7. Screenshot of Interactive Map Showing Identified Potential DCFC Site Hosts



[36] Divisions represent distinct geographic regions in PG&E's service territory.

If a user clicks on a bubble, they will see the addresses and relevant siting information, including DCFC capacity that a site can support, the business address, and whether or not there is available distribution capacity to support 2 or more DCFCs. While there are 300 bubbles, the resulting addresses, or potential site hosts, amounted to a total of 14,416 sites, of which only 45% had available capacity.

For each location, the following information is included in the interactive map:

- Site ID Number: each site within the bubble is numbered
- Bubble Priority Number (1-300)
- Site Type (i.e. bank, grocery store)
- Parking Dwell Time: Short, medium or long
- Business Name
- Address
- City
- Zip Code
- Existing L2 chargers at site
- Existing DCFCs at site
- New DCFCs that could be added with existing site capacity
- New DCFCs needed in the bubble in 2025

The interactive map developed by PG&E went through extensive usability and accessibility testing both internally and by a third party vendor. PG&E team members first interviewed three target end users: an automaker, an EV Service Provider, and a CPUC staff member. Input focused primarily on how best to communicate the results to end users. One particular recommendation identified the need to communicate the limitations of the tool, since locations and information are not updated after publishing the map. PG&E also worked with an external consultant to complete user testing to identify usability issues, collect user feedback, and prioritize opportunities for improvement for the tool. The interactive map was assessed based on the following categories: User control, navigation and feedback, communication and relevance, simplicity and ability to scan, consistency, help and forgiveness, and aesthetic integrity. The consultant identified fourteen findings ranging from high severity that could have a high potential for user confusion, errors or abandonment to low severity that could lead to minor confusion to the user. PG&E incorporated the majority of the feedback from the usability testing into the interactive map prior to its release.

There are no plans to expand or update the map or tool as of August 2016, and a developer or installer will still need to contact PG&E to confirm available capacity and upstream impacts due to the static nature of the tool and analysis. Due to the nature of DCFC siting, much of the final siting work must be a “boots on the ground” operation. The micro-siting tool described in the next section is meant to support that effort.

4.8 Micro-Siting Tool of Potential DCFC Hosts

E3 and PlugShare interviewed over 20 industry experts, including site hosts, automotive manufacturers, and charging station manufacturers, to identify best practices and optimal types of sites, especially as it relates to three metrics: (1) minimizing installation costs; (2) increasing EV adoption; and (3) supporting disadvantaged communities. The final Micro-Siting Tool allows users to input scores over a variety of factors under each metric and outputs an optimal ranking of the 14,416 potential host sites. The tool includes 26 weighting criteria options, including minimum site conditions (i.e. sufficient spaces, ADA-compliance, 24/7 access, restrooms), siting options that may increase EV adoption (i.e. food, shopping, parking capacity, Wi-Fi, etc.), siting options to minimize cost (i.e. transformer capacity, distance and surface) and siting criteria for disadvantaged communities (near non-luxury multi-dwelling units, near minority owned businesses, etc.). Certain factors can be weighted by inputting 1 – 5 in the user input score, while other factors include a Yes or No response. If the user enters No for any of the minimum conditions, the site received a 0 for the final weighted score. While the siting tool is specific to PG&E's territory and the parameters assessed during this project, the guidelines and weightings may be useful to others.

After identifying potential host sites within each of the 300 one-mile radius locations/bubbles, PG&E attempted to reduce the number of sites identified to the most likely candidates for installation, while not being overly restrictive. Therefore, if more than five sites within a bubble had existing transformer hosting capacity, only these sites were reported in the tool. Otherwise, all the businesses in the bubble were reported. More information on the Micro-Siting Tool is available in Appendix B - Overview of the Micro-Siting Tool, which includes a description of the pre-filled fields in the tool, as well as the criteria definitions and user-inputted fields.

4.9 Recommendations

While the interactive map and the Micro-Siting Tool are specific to PG&E's territory and provides useful information for local installers, perhaps the most useful industry finding is the overall methodology developed in this report for identifying potential charging host sites. The overall recommendation from this project is to use the method developed as best practice guidelines for developing a repeatable process to identify potential host sites for DCFCs.

Additionally, PG&E created a set a best practices guideline for siting DCFCs based on the project's scope of work with input from 20 industry experts. Interviews and published works reveal that stakeholders have been broadly aiming to choose DCFC sites that will:

1. Minimize installation costs;
2. Support EV adoption; and
3. Spread the benefits of EVs amongst all groups (captured in the Micro-Siting Tool as Supporting Disadvantaged Communities)

These objectives do not always align, and stakeholder opinions vary as to the optimal weighting and acceptable tradeoffs between the three outcomes. The remainder of this section summarizes the available literature, as well as expert opinions to guide planners, policymakers, and those on the ground in achieving each of the three aims.

A complete description of the best practices guidelines for siting DCFCs, driven by the industry expert interviews, can be found in Appendix F - Guidelines for DCFC Siting from Industry Expert Interviews.

4.10 Special or Unique Technology Implementation Issues

It is PG&E's intent that the interactive map and Micro-Siting Tool are useful to DCFC installers; however, there are some caveats to the analysis:

- **Changing distribution capacity:** PG&E's distribution capacity is constantly changing, and the results presented within the map and tool is static. Before finalizing a DCFC location, it is recommended to investigate the transformer capacity.

- **Modeled results:** The results are based off of modeled transportation data and estimated DCFC need in 2025. Similar to any projection, circumstances, policy, or technologies, true outcomes may vary from the model.
- **Customer Hosting:** The business information used here is from a public database, and was current as of December 2015. PG&E does not guarantee that these businesses are interested in hosting a DCFC.

4.11 Data Access

Upon request, PG&E will provide access to data collected that is consistent with the CPUC's data access requirements for EPIC data and results. The interactive map is posted online at www.pge.com/epic-project-dcfastcharging. The Excel-based Micro-Siting Tool as discussed in this report is available upon request.

4.12 Value proposition

4.12.1 Mandatory Guiding Principles of EPIC

The mandatory guiding principle of EPIC is to invest in clean energy technologies and approaches that provide benefits to electricity ratepayers by promoting greater reliability, lower costs, and increased safety. This project advances all of the following primary principles:

1. **Affordability:** The report identifies distribution upgrades as a major cost driver for DCFC installers. By identifying site hosts with and without distribution capacity, PG&E can assist in saving the time and money from future potential installers by identifying site hosts that have available capacity.
2. **Reliability:** By providing recommended site locations based on available transformer capacity, PG&E guides developers to install DCFCs in locations that would mitigate capacity overload or upgrades.
3. **Safety:** The DC fast charger Micro-Siting Tool includes a number of safety-related inputs in the prioritization of the DCFC locations including the following: adequate lighting for charging during night time hours, site is free of contamination of hazardous waste, location is highly visible and there is sufficient available parking to avoid congestion of drivers.

4.12.2 Secondary Principles of EPIC

EPIC also has a set of complementary secondary principles that include: Societal benefits; Greenhouse gas (GHG) emissions reduction and adaptation in the electricity sector at the lowest possible cost; The loading order; Low-emission vehicles/transmission; Economic development; and Efficient use of ratepayer funds. This project advances four of the secondary principles of EPIC:

1. **Greenhouse gas (GHG) emissions reduction and adaptation in the electricity sector at the lowest possible cost:** Increased electric miles driven would provide direct environmental benefits, as the electricity that PG&E provides for use in electric vehicles as transportation fuel is much cleaner than using fossil fuels as a transportation fuel.
2. **Low-emission vehicles:** This project supports the accelerated adoption of EVs in California.
3. **Economic development:** This project supports job growth in California with EV network developers and partnered with Greenling Institute to identify ways in which siting DCFCs could improve EV adoption in disadvantaged communities. PG&E identified three ways in which siting DCFCs could support disadvantaged communities: placement of chargers within disadvantaged

communities, proximity of DCFCs to non-luxury multi-unit dwellings, and proximity to minority owned businesses. Additional methodology behind these conclusions is in Appendix F- Guidelines for DCFC Siting from Industry Expert Interviews.

4. **Efficient use of ratepayer funds:** Pending approval of PG&E's EV infrastructure program (A.15-02-009), PG&E will use the siting rubric and interactive map to guide its own infrastructure deployment.

4.13 Technology Transfer Plan

4.13.1 IOU's technology transfer plans

A primary benefit of the EPIC program is the technology and knowledge sharing that occurs both internally within PG&E and across other IOUs, the CEC, and industry. In order to facilitate this knowledge sharing, PG&E will share the results of this project in industry workshops and through public reports published on the PG&E website. Industry outreach will be directed towards DCFC hardware and network developers with previous experience building infrastructure in California, as well as automakers. Table 4-3 below identifies the information-sharing forums where the results and lessons learned from this EPIC project were presented or are planned to be presented.

Table 4-3. Conferences and Convening Groups

Name	Description	Timing/Location
Electric Vehicle Symposium 29 (EVS29)	International EV Symposium featuring both technical and policy-focused presentations and discussion	June 2016, Montreal
Behavior, Energy, and Climate Change Conference (BECC)	National conference focused on decision-making to accelerate low-carbon economy growth	October 2016, Baltimore
EPRI Electric Vehicle Infrastructure Working Council	Convening group of utilities and EV infrastructure providers	November 2016, San Francisco
2016 CEC EPIC Symposium	Statewide symposium discussing annual EPIC program highlights	December 2016, Sacramento
PEV Collaborative	Convening stakeholder group of leaders in California EV sphere (state policymakers, automakers, charging providers, NGOs, and more)	Q4 2016
SAE Plug-in Symposium	Technical conference for engineers from automakers and charging providers	February 2017, San Diego
CEC & UC Davis Workshops	Workshops for interested parties applying for CEC-funded grant infrastructure and UC Davis STEPS program	TBD

4.13.2 Adaptability to Other Utilities / Industry

The following deliverables of this project are relevant and adaptable to other utilities and the industry:

- **Siting Map:** Exclusive to the PG&E territory and useful for installers, or potential installers of DCFCs. Such parties could be, but are not limited to:

- ○ CEC Infrastructure Grants
- ○ NRG CPUC Settlement
- ○ Automakers funding or developing charging infrastructure
- ○ Other DCFC Installers

- **Micro-Siting Tool:** Gives weighting criteria and “watch points” for site hosts and installers.

5 Metrics

The following metrics, as identified in Decision 13-11-025, Attachment 4 have been captured in the project and described in the associated sections noted in the report.

List of Proposed Metrics and Potential Areas of Measurement	See Section
3. Economic benefits	
a. Maintain / Reduce operations and maintenance costs	4.5
d. Number of operations of various existing equipment types (such as voltage regulation) before and after adoption of a new smart grid component, as an indicator of possible equipment life extensions from reduced wear and tear	4.5
4. Environmental benefits	
a. GHG emissions reductions (MMTCO2e)	3.1
5. Safety, Power Quality, and Reliability (Equipment, Electricity System)	
c. Forecast accuracy improvement	4.1
d. Public safety improvement and hazard exposure reduction	3.1
7. Identification of barriers or issues resolved that prevented widespread deployment of technology or strategy	
b. Increased use of cost-effective digital information and control technology to improve reliability, security, and efficiency of the electric grid (PU Code § 8360)	4.7 and 4.8
l. Identification and lowering of unreasonable or unnecessary barriers to adoption of smart grid technologies, practices, and services (PU Code § 8360)	4.4
8. Effectiveness of information dissemination	
d. Number of information sharing forums held	4.13.1
f. Technology transfer	4.13
9. Adoption of EPIC technology, strategy, and research data/results by others	
d. Successful project outcomes ready for use in California IOU grid (Path to market)	4.13.2

6 Conclusion

The results of this EPIC project led to a number of key findings and recommendations that can help increase EV adoption and support California's ambitious zero-emission vehicle targets. The outcome of this project can guide PG&E and Direct Current Fast Charging installers to identify DCFC locations more optimally based on factors such as cost, available service transformer capacity[37], traffic patterns, as well as site host and driver preference. The results are made available via an interactive map at www.pge.com/epic-project-dcfastcharging.

Prior to this project, no one entity had evaluated where to site DCFCs by considering the input of three perspectives: the site host, the installer, and the driver. This project identified 300 high need locations based on travel demand, future forecasted unmet need in 2025, and then provided ways for installers to site DCFC based on three methods: minimizing installation cost, maximizing EV adoption, and supporting disadvantaged communities. To identify the most optimal DCFC installation locations, PG&E conducted multiple stakeholder interviews, developed a transferable, repeatable algorithm to identify and order sites, and created an interactive map and tool to for PG&E and DCFC installers to leverage the results.

Through multiple stakeholder interviews, PG&E captured key insights with the intention of maximizing EV adoption, dispersing benefits to all EV driver stakeholders, and minimizing the cost of installation. The interviews revealed that in order for DCFCs to be installed and utilized by drivers, it is important to consider the perspectives of drivers, charger hosts, and network developers. Given a choice, EV drivers strongly prefer DC fast charging over Level 2 chargers due to the DCFCs' fast charging time. Interviews also revealed it is important to site DCFCs in areas of high unmet charger need (macro-siting), and to choose individual sites that will be agreeable to all three of these groups (micro-siting). Based on the information conducted within the interviews and the average estimated dwell time at each location type, over 30 location types, like airports, banks, parking lots and universities, were identified as potential DFCF location sites.

To disperse benefits to all EV driver stakeholders, the project also prioritized siting DCFCs to be accessible to EV drivers from all communities within California. Given the majority of current EV charging stations are close to high-income households, DCFCs can be sited with the intention of promoting higher EV adoption within disadvantaged communities, defined by areas with high health and environmental hazards, as well as low income households. Interviews showed that siting DCFC locations to support disadvantaged communities can be best accomplished by installing DCFCs directly within disadvantaged communities, as well as in close proximity to non-luxury multiple-unit dwellings and minority-owned businesses. Additionally, the project used interviews to identify a number of cost drivers for DCFC installations. While costs can vary considerably by each site, the most significant costs are associated to any needed electrical transformer upgrades, as well as trenching and boring at a large distance or with hard surface materials.

To develop the prioritized DCFC site locations based on highest unmet EV charging need (i.e. macro-siting), the UC Davis' GIS EV Planning Toolbox for Metropolitan Planning Organizations (MPOs) was

[37] Sites identified with sufficient distribution transformer capacity are static based on the time of study, and additional analysis of changes in electric grid infrastructure is required when pursuing installation to draw a final conclusion on secondary transformer capacity.

augmented to include PlugShare data on the existing charging network and Ricardo's EV adoption estimates, which resulted in the identification of 300 locations of highest predicted unmet charging need in 2025 in PG&E's service territory.

The project found that much of the UC Davis analysis is dependent upon EV adoption scenarios and actual charging demand and DCFC utilization will vary as adoption and the market mature. PG&E completed an analysis of one-mile radius bubbles around these locations, filtering for on-site 480V, three-phase service transformer capacity, which resulted in 14,416 businesses, parking lots, and other locations that match the DCFC use case. The *DC Fast Charger Micro-Siting Tool* (available upon request) provides pre-filled data on estimated excess service transformer capacity, disadvantaged community status, and existing charging infrastructure at each site. The criteria included in the Micro-Siting Tool were specific to the PG&E territory that was conducted during this project, and does not represent an exhaustive list of criteria needed to conduct a full siting assessment. Users of this report may and should include other criteria based on market and customer research and location-specific siting requirements.

Upon identification of these locations and creating the Micro-Siting Tool, PG&E developed an online, interactive map and incorporated feedback after extensive user testing, which provides an easy-to-use tool for stakeholders to leverage the results of the results of the project. This tool and interactive map, along with the best practices detailed in this report, can help guide network developers as they pursue installations of DCFCs in PG&E's territory and beyond. Since the analysis performed for this report is only for areas served by PG&E's electric distribution system, areas served by other utilities or municipalities are not included. To note, while the report's detailed guidelines for identifying sites could be utilized by service planning organizations in other utilities to identify sites using similar analysis, the process for locating available capacity must be determined on a case-by-case basis.

If PG&E receives approval of its proposed infrastructure program (A.15-02-009), PG&E will use the results of this EPIC Project 1.25 to guide our own DCFC siting and deployment. While the results from the interactive map are specific to and applicable to PG&E's territory, the methods for developing the map and Micro-Siting Tool, as well as the best practices in siting are transferrable to other utilities and states.

This EPIC project successfully achieved all of its key objectives and, in doing so, has addressed multiple barriers related to electric vehicle adoption. The project executed a thoughtful DCFC siting approach of EV charging infrastructure, which can reduce installation costs and improve site host acceptance, taking into account the available transformer capacity for the sited locations.

This report presents a framework for collecting the on-the-ground data needed to prioritize potential DCFC installation sites (shown in Section 3.3.1 – Major Tasks and Deliverables), as well as industry-wide best practices for siting DCFCs (see Section 4.9 – Recommendations). The results of this EPIC project are intended to guide all levels of DCFC stakeholders, and while tools developed focus on PG&E, methodology and best practices are applicable to efforts statewide, including the pursuit of a test case using recently CEC-funded DCFC installations, as referenced in Section 4.2.

Appendix A - Expert Siting Criteria

Public cost data on DCFCs is limited and often fails to include the full range of costs involved in siting and installing chargers. Nonetheless, available studies reveal a number of key cost drivers for DCFC installations. The most significant of these is the cost of any needed electrical service transformer upgrades, hard surface materials, and the distance of trenching and boring, which can also increase costs significantly but can vary considerably by site. Despite the difficulty of predicting the exact costs involved in developing a specific DCFC site, there are a number of site selection filters that planners can apply to minimize costs, outlined in Table A-1 below.

Table A-1. Driver Priorities for DCFC Micro-siting

[Note: These do not represent the opinions of PG&E, but are rather taken from the sources listed in the table below]

Minimum conditions (in no particular order)	Details	Sources
Proximity to a major traffic thoroughfare	Drivers seeking DC fast charging should not be required to go far out of their way to charge. A number of sources suggested targeting freeway intersections, as is typical for gas stations.	Interviews, (ODOT), (DuBois & King 2013), (NRG EVgo 2015)
Publicly accessible during extended hours	Sites should be open to the public for extended hours, preferably 24 hours a day, and never locked or gated.	Interviews, (DuBois & King 2013), (CEA 2013)
Safe space for drivers and passersby, with adequate lighting	Lighting should be adequate to allow drivers to comfortably operate equipment and feel safe, and to discourage vandalism. CEA (2013) suggests employing principles of Crime Prevention through Environmental Design. Staffing at site or nearby can also increase safety. In addition, sites that allow parking perpendicular or angled to the curb are safest. EV manufacturers have not standardized which side of the vehicle has the recharging inlet, so parallel parking can expose standing drivers and cables to oncoming traffic or put passing cyclists at risk.	Interviews, (CEA 2013), (ETEC 2010), (Drive Electric Florida 2012), (Sustainable Transportation Strategies 2012), (Ready, Set, Charge California! 2011)
Highly visible *or* ability to install clear directional signage	Charging sites should be visible from the street, or else there should be the ability to install clear wayfinding signs.	Interviews, (DuBois & King 2013), (CEA 2013), (Powers 2014), (Drive Electric Florida 2012), (City of Mt Shasta et al. 2014), (Redwood Coast Energy Authority et al. 2014)

Easy ingress/egress from traffic	Charging sites should allow easy access from traffic and easy return to the direction of travel. DuBois and King (2013) suggest that charging sites should be installed on both sides of the highway in order to serve traffic in both directions.	Interviews, (ODOT n.d.), (DuBois & King 2013), (CEA 2013)
Sufficient available parking to install enough chargers for current and near-term demand	Planners should choose locations with enough parking spaces to support current and short-term increases in unmet charging demand. Tesla identified real-time charger availability as “the single most critical factor” for driver satisfaction. The company generally builds 4 to 12 charging posts at any one site in order to guard against congestion. Siting multiple chargers at one location can also reduce reliability concerns, and therefore range anxiety, by providing redundancy.	Interviews, (Nigro, Ye and Frades 2014)
ADA-compliant parking	The Americans with Disabilities Act requires one accessible parking space, plus adjacent access space of 60 inches, per 25 marked spaces. Draft guidelines issued in California in 2013 (see State of California Governor’s Office of Planning and Research 2013) suggest this same standard should apply to the provision of EV charging spaces. These guidelines only currently apply to state-owned and state-leased buildings, but indicate that it is possible they “will eventually become regulations” within the California Building Code.	(DuBois & King 2013), (ETEC 2010), (Drive Electric Florida 2012), (Ready, Set, Charge California! 2011), (NRG EVgo 2015), (City of Mt Shasta et al. 2014), (Redwood Coast Energy Authority et al. 2014)
Restrooms & drinking water	These should be regularly monitored to ensure cleanliness.	Interviews, (ODOT n.d.)
Paved site with level topography	Sites should not be on a hill (this creates rolling risk) and should provide proper drainage so as not to gather rainwater or snow.	(DuBois & King 2013), (CEA 2013), (ETEC 2010), (Drive Electric Florida 2012)
Food/snacks for purchase	This is particularly important for charger sites intended to allow longer trips, as it allows drivers to fulfill two needs in one stop.	Interviews
On-site signage	In addition to the wayfinding signage referenced above, signage is needed to reserve spaces for EVs, to set charging etiquette expectations, and to ensure proper use of charging equipment. Caperello (2013) states “almost every initial encounter with a public charger was described in terms of uncertainty about the etiquette for using the chargers.” Drivers face uncertainty about what to do or what is appropriate when an unoccupied vehicle is using the charger. Drivers are also unsure about how long they can park or charge for. Signs at EV charger spaces should explicitly state the rules for using the charger and parking.	Interviews, (ETEC 2010), (Caperello et al. 2013)

	Interviewees suggested that local enforcement structures are needed in order for signage to be effective. This can be an issue particularly at sites with significant competition for parking spaces. The California Vehicle Code gives local jurisdictions the ability to cite or remove vehicles that are in violation of posted signs designating parking spaces exclusively for EV charging.[38]	
Shelter	Shelter should provide sufficient protection against inclement weather. In cold climates, access to a nearby indoor location with climate control is preferable.	Interviews, (CEA 2013), (ETEC 2010), (Sustainable Transportation Strategies 2012)
Adjacent space available for *future* chargers	Planners should consider whether additional parking spaces at the same site will be available for use as EV charging in the future.	Interviews, (CEA 2013), (City of Mt Shasta et al. 2014), (Redwood Coast Energy Authority et al. 2014)
Ability to stage a second vehicle while another is charging	The short charge times required by DC fast charging may lead some drivers to wait if a charger is occupied. The ability to temporarily park a vehicle while waiting is therefore a benefit.	Interviews
Nearby wireless internet	Wi-Fi allows a diversion for drivers while waiting for charging.	Interviews
Nearby shopping and/or lodging	Tesla indicated that these conveniences are desirable in their siting. Los Angeles Department of Water and Power, on the other hand, sites their fast chargers at locations without these amenities (often near substations and customer service centers) and has found that their charging network continues to attract customers despite the lack of facilities.	Interviews
Premium / preferred parking spaces	These are of significant interest to EV drivers, and are also valuable in maximizing the visibility of EV charging to non-EV drivers.	(ETEC 2010), (Sustainable Transportation Strategies 2012)

[38] California Vehicle Code, Section 25511, http://law.onecle.com/california/vehicle/22511.html

Table A-2. Driver Priorities for DCFC Hardware

Driver priorities (in no particular order)	Notes	Sources
Service reliability and networking	Charger reliability is central to driver confidence in the public charging network. Planners should select chargers based on their reliability record, and ensure that responsibility for timely repairs is allocated and incentivized. Chargers should also be networked using web- or mobile-based communication. This will allow drivers to obtain real-time operational status for each charger, and allow for remote diagnosis of service issues. Networking will also allow for a wide range of payment options (e.g. credit card, mobile, and electronic payments).	Interviews, (Ready, Set, Charge California! 2011)
Dual connector compatibility	Chargers are only useful to a given driver if they provide a connector compatible with their vehicle. This has been a challenge for DC fast charging networks, since there is no universal standard connector. At present: Nissan, Kia, and Mitsubishi EVs use CHAdeMO connectors; Tesla vehicles can use CHAdeMO or Tesla; and Audi, BMW, Daimler, Ford, GM, Porsche, Volkswagen, and Volvo EVs use the SAE J1772 Combo. Planners seeking to maximize EV adoption should provide dual SAE Combo and CHAdeMO chargers.	Interviews, (NRG EVgo 2015)
Ability to pay without memberships, without incurring additional fees	DC fast charger installations are less valuable to EV adoption efforts if they only serve the subset of the driver population that holds a specific membership. Chargers should include methods to access the charger using a credit card, whether via an app or directly on the charger.	Interviews, (NRG EVgo 2015)

Appendix B - Overview of the Micro-Siting Tool

PG&E aimed to provide a list of potential charger sites (individual businesses, government agencies, parking lots, etc.) that network developers could target at 300 locations of highest unmet need. This section describes the approach taken to identify potential charger sites, and also includes the pre-filled fields in the DC Fast Charge Micro-Siting Tool, as well as the Micro Siting Tool Criteria Definions.

To retain the criteria of identifying 300 locations of highest projected unmet charger need, the analysis was limited to identifying sites within a one-mile radius "bubble" centered at each of the 300 locations. A one-mile bubble was chosen to ensure all sites were close to major roads (this was an important factor for drivers, as identified in Section 1.1), and to bound the analysis to some reasonable geographic area. However, it should be noted that in many cases a site close to the one-mile boundary would work just as well in meeting the unmet charger demand estimated by UC Davis.

B.1 Resulting Sites

This process resulted in 14,416 potential EV charger installation sites within a one-mile bubble of the 300 highest unmet charging demand locations generated by UC Davis. Because some of the one-mile bubbles overlap, some of the sites are repeated in multiple bubbles: the number of resulting unique sites[39] was 13,249.

Though 14,416 is a large total number of potential sites, the number of sites per bubble varies widely. Thirty-eight out of 300 bubbles (13%) show greater than 100 sites resulting from the analysis (bubbles in San Francisco, for example, show upward of 300 sites), whereas 65 out of 300 bubbles (22%) have ten sites or fewer. As discussed previously, it can be difficult to find sites that meet all the minimum conditions (listed in Table A-1. Driver Priorities for DCFC Micro-siting) a*nd* belong to a willing and eager charger host. It can therefore be useful to have a long list of options.

[39] A unique site is defined as a unique combination of name, address, longitude and latitude

Table B-1. DC Fast Charger Micro-Siting Tool Criteria Definitions

Criteria	Description	Default weight for criteria (note that these are only valid within each group of criteria)	Data format	USER INPUT SCORE 1	2	3	4	5
MINIMUM SITING CONDITIONS								
(NOTE: All of the Minimum Conditions must be marked 'Y' for a site to receivea non-zero Final Weighted Score in Column BM. Therefore, as soon as the user enters 'N' for one of these Minimum Conditions, the site receives a zero Final Weighted Score, and the user need not bother filling the remainder of the data fields for that site.)								
1. **Sufficient spaces**	Sufficient available parking spaces to install planned # of chargers shown in Instructions tab Step 2	Minimum Conditions (ie. Total Weighted Score = 0 if ANY of these conditions is 'N')	Y/N	Y = Sufficient available parking spaces to install number of EV chargers planned (as defined by user in Instructions tab Step 2)				
2. **ADA**	Proposed parking space is ADA-compliant, or adjacent space is available for conversion		Y/N	Y = Proposed EV charger parking space is ADA-compliant (one accessible parking space, plus adjacent access space of 60 inches, per 25 marked spaces), or one adjacent parking space per every 18 proposed charger spaces can be converted for ADA compliance				
3. **Paved & level**	Parkings space/s are paved and level		Y/N	Y = Available parkings space/s are paved and level (<2.5% grade)				
4. **24/7 access**	Charger accessible 24 hrs/day, 7 days/week (no locks or gates)		Y/N	Y = Charger is accessible 24 hrs/day, 7 days/week, and not behind locked gates				
5. **Ingress/ egress**	Easy ingress/egress from traffic		Y/N	Y = Site is accessible via a route that can safely and conveniently accommodate electric vehicles entering and leaving the facility, returning to the highway, and continuing in the original direction of travel				
6. **Safe**	Safe space for drivers, with adequate lighting		Y/N	Y = Area feels safe during nighttime hours. General lighting of the area is sufficient for drivers to feel safe approaching and operating charging equipment. Answer 'Y' even if site would require additional lighting at specific parking space to facilitate reading instructions and use of charging station.				
7. **Visible**	Highly visible, or ability to install clear directional signage from main road/thoroughfare		Y/N	Y = Site is on or visible from a main road or freeway, or ability to install wayfinding signs to clearly show a simple route from a main road or freeway				
8. **Restrooms**	Restrooms and drinking water available		Y/N	Y = Water and restrooms available at potential site, or within two-minute walk via safe path				
9. **Willing host**	Willing site host with authority to sign lease (or agreement of owner)		Y/N	Y = Host is interested in hosting a charging station in one parking space and has authority to sign a lease for the parking space (or, alternatively, the owner of the parking space is willing to sign)				
10. **Hazard**	On additional screen, free of contamination with hazardous waste		Y/N	The relevant threshold for hazardous waste will depend on permitting laws and funding sources for each individual network developer. One definition garnered from expert interviews is as follows: Site is not directly listed on, or adjacent to a property listed on, one of the databases that constitute the California Environmental Protection Agency's "Cortese list" of hazardous sites in the state (available here: http://www.calepa.ca.gov/SiteCleanup/CorteseList/). Property does not host nor has recently hosted business that use the land for hazardous waste intensive activities, including but not limited to airport tarmacs, dry cleaning, waste management or storage, landfill services, chemical processing or storage, or wood processing. If site is a gas station, owner has been consulted to ensure any hazardous materials issues can be resolved with minimal costs and delays.				

Criteria	Description	Default weight for criteria (note that these are only valid within each group of criteria)	Data format	USER INPUT SCORE 1	2	3	4	5
SITING TO INCREASE EV ADOPTION								
11. **Food**	Food for purchase	5	1 - 5	Food is not available at potential site, nor within a 2-minute walk via safe path	Food is available at potential site, or within a 2-minute walk via safe path, at least 8 hours/day, 7 days/week	Food is available at potential site, or within a 2-minute walk via safe path, at least 12 hours/day, 7 days/week	Food is available at potential site, or within a 2-minute walk via safe path, at least 16 hours/day, 7 days/week	Food is available at potential site, or within a 2-minute walk via safe path, 24 hours/day, 7 days/week
12. **Parking capacity**	Sufficient non-EV parking on site (to avoid customer complaints over EV conversion, and to provide space for EVs to wait if charger is occupied)	5	1 - 5	Highly constrained parking	Constrained parking, high utilization of non-EV parking space/s	Plenty of non-EV parking, but high utilization of non-EV parking space/s		Plenty of unused parking area
13. **Enforcement**	Parking time limits, with enforcement	4	1 - 5	Poor or zero time limits and/or parking enforcement	Parking time limit, not enforced	4 hour time limit exists, signs present, enforced	2 hour time limits exist, signs present, enforced	24/7 parking enforcement exists
14. **Shelter**	Shelter from inclement whether, or nearby indoor location very	4	Y/N	Y = Existing shelter that can cover a charging station, or indoor/overhang shelter available 24/7 within short distance of charger				
15. **Premium space**	Ability to offer premium/preferred spaces for EV	3	Y/N	Y = Site host willing and able to offer premium / preferred spaces for EV drivers				
16. **Shop / lodge**	Nearby shopping and/or lodging	3	1 - 5	No shopping or lodging within a five-minute walk	At least 2 shopping/lodging outlets (not including food outlets) within a 5-minute walk	At least 4 shopping/lodging outlets (not including food outlets) within a 5-minute walk	At least 6 shopping/lodging outlets (not including food outlets) within a 5-minute walk	At least 8 shopping/lodging outlets (or 1 deparment store or supermarket) within
17. **Future spaces**	Adjacent space available to install future chargers beyond planned # of chargers shown in Instructions tab Step 2	3	1 - 5	No adjacent spaces available for conversion to EV charging	1 adjacent space available for conversion to EV charging	2 adjacent space available for conversion to EV charging	3 adjacent space available for conversion to EV charging	4 or more adjacent spaces available for conversion to EV charging
18. **Future capacity**	Excess transformer capacity for at least two additional chargers beyond planned # of DCFC EVSEs shown in Instructions tab Step 2	2	Y/N	Y = Sufficient capacity available on a secondary transformer within 300 ft of potential site to fit at least two additional DCFC EVSEs beyond the minimum number to be installed at site (shown in Instructions tab Step 2).				
19. **Wifi**	Wireless internet available	1	Y/N	Y = Reliable public Wifi is available at site at no or nominal cost				

Criteria	Description	Default weight for criteria (note that these are only valid within each group of criteria)	Data format	USER INPUT SCORE				
				1	2	3	4	5
SITING TO MINIMIZE COST								
20. **Transformer Capacity**	Sufficient available capacity on a 480V, three phase transformer to install planned # of new chargers shown in Instructions tab Step 2	5	Y/N	Data is pre-filled. Y = Sufficient available transformer capacity to install planned # of new chargers shown in Instructions tab Step 2. This is calculated by comparing a) the no. of DCFCs that can be served by excess capacity on a 480V, three-phase transformer within 300 ft of the site (column U) with b) the planned # of new chargers to be installed at each chosen site in this bubble (column H, hidden). If a) > b), the entry in this column is Y.				
21. **Distance**	Distance from transformer to furthest proposed EV space at site	1	1 - 5	Proposed EV parking space is greater than 150 feet from 480V, three-phase transformer	Proposed EV parking space is 101 - 150 feet from 480V, three-phase transformer	Proposed EV parking space is 51 - 100 feet from480V, three-phase transformer	Proposed EV parking space is 21 - 50 feet from 480V, three-phase transformer	Proposed EV parking space is within 20 feet of 480V, three-phase transformer
22. **Surface**	Surface material b/w transformer and furthest proposed EV space	1	1 - 5	Path to furthest proposed EV parking space from transformer is fully concrete or asphalt. 480V, three-phase transformer is > 20 feet from EV space	Path to furthest proposed EV parking space from transformer is mostly concrete/asphalt and some dirt/grass. 480V, three-phase transformer is > 20 feet from EV space	Path to furthest proposed EV space is mostly dirt/grass and some concrete/asphalt. 480V, three-phase transformer is > 20 feet from EV space	Path to furthest proposed EV parking space is fully dirt or grass. 480V, three-phase transformer is > 20 feet from EV space	480V, three-phase transformer is within 20 feet of furthest proposed EV parking space.
SITING FOR DISADVANTAGED COMMUNITIES								
23. **CalEnviroScreen top PG&E quartile**	Top quartile of Cal EnviroScreen2.0 Score within PG&E's territory	Min. Condition for Disad. Comm. Score (24 or 25 must be Y, otherwise Disad. Comm. Score = 0)	Y/N	Data is pre-filled. Potential site's census tract is in the top quartile of Cal EnviroScreen2.0 scores within PG&E's territory				
24. **CARE top quartile**	Top quartile of PG&E's CARE rate eligibility		Y/N	Data is pre-filled. Potential site's census tracts is in the top quartile of CARE-eligible census tracts, established by ranking census tracts by number of CARE eligible customers, and taking the top 25% of the ranked census tracts				
25. **Near non-luxury MUD**	Near non-luxury multi-unit dwelling/s	5	Y/N	Within 2 minutes' drive of at least one non-luxury multi-unit dwelling. Note: the user need only fill this field for a give site if at least one of fields 23. or 24. above are 'Y'				
26 **Minority-owned**	Minority-owned business	5	Y/N	Data is pre-filled. Site is a minority-owned business.				

Table B-2. Pre-filled Fields in the DC Fast Charger Micro-Siting Tool

Column	Field	Description	Source
Location of unmet need in 2025			
B	Bubble number	Unique identifier for each of the 300 one-mile radius bubbles centered at the locations of unmet need identified by UC Davis. These are sorted by highest predicted unmet charger need in 2025 (columns F and G)	UC Davis. See Section 4.3
C	Longitude of bubble center	Longitude of location of unmet need, as identified by UC Davis	
D	Latitude of bubble center	Latitude of location of unmet need, as identified by UC Davis	
Existing infrastructure at location			
E	Number of existing DCFCs within bubble	The number of existing, public DCFCs installed within a one-mile-radius bubble of the Location, excluding Tesla Superchargers	PlugShare. See Section 4.2
Number of new chargers needed at location in 2025			
F	Under ZEV Goal adoption scenario	Number of new chargers needed to meet unmet charging need at the Location in 2025, under Ricardo's ZEV Goal Adoption Scenario	See Sections 4.1 – 4.3
G	Under Affordability adoption scenario	Number of new chargers needed to meet unmet charging need at the Location in 2025, under Ricardo's Affordability Adoption Scenario	
J	Bubbles, if any, that overlap with this bubble	Bubble number (from column B) of any bubble/s with a center within 2 miles of the current bubble's center, i.e. which has some geographic overlap and may therefore contain overlapping sites.	
Site data			
K	Site ID	Unique identifier for each potential bubble-site combination. Site ID consists of the bubble number and a counter for each potential site	
L	Bubble number – unformatted	This field repeats data in column B, but shows the bubble number on each row. It is useful if doing any manual filtering of sites (see Filter 1 on the Instructions tab).	Column B
M	Site type	Categorization of site type. The subset of SIC-8 codes mapped to Site Types for site selection is included in a third party database.	See Table 4-2
N	Name		Third-party list of places, plus PlugShare database. See Section 4.2
O	Address		
P	City		
Q	Zip code		
R	Site longitude		
S	Site latitude		
Existing infrastructure at site			
T	# existing L2 chargers at site	Number of existing, public Level 2 chargers located at site	PlugShare database. See Sections 4.2
U	Network for existing L2 chargers	Network/s for existing Level 2 chargers at site, where available	
V	# existing DC fast chargers at site	Number of existing, public DCFCs located at site. This count includes Tesla Superchargers.	
W	Network for existing DCFC chargers	Network/s for existing DCFCs at site, where available	
X	No. of new DCFCs that could be served by excess transformer capacity	Number of new DCFCs (65kW) that could be served by excess capacity on a 480V, 3-phase transformer within 300 feet of site latitude-longitude.	PG&E. See Section 4.5
AX	Sufficient available transformer capacity to install planned # of chargers in Instructions Tab Step 2	This field contains a formula that returns a 'Y' if there is sufficient transformer capacity (column X) to accommodate the minimum number of new chargers planned by the user to be installed at each successful site in the bubble (See Instructions tab Step 2).	Columns H (user input) and X.
Disadvantaged Communities Score Criteria			
BC	Census tract is in top quartile of Cal EnviroScreen2.0 scores within PG&E's territory	Site is within a census tract that has a Cal EnviroScreen 2.0 score in the top quartile of Cal EnviroScreen2.0 scores in PG&E's territory	PG&E. See discussion of Disadvantaged Communities Score in Appendix F.3.
BD	Census tract is in top quartile of PG&E's CARE rate eligibility	Site is within a census tract in the top quartile of census tracts, established by ranking census tracts by number of CARE-eligible customers, and taking the top 25% of the ranked census tracts	

B.2 References Used

The following are references used for identifying potential charging site:

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Appendix C - Ricardo's EV Adoption Scenario

Disclaimer: This information is not necessarily representative of PG&E-specific service territory forecasts.

This appendix summarizes two plug-in electric vehicle (PEV) adoption scenarios, described succinctly as:

- **Scenario 1:** Compliance with the California ZEV mandate - based on meeting the California Zero Emission Vehicle (ZEV) mandate assuming the overall fleet behavior follows the requirements for PEV sales aimed at large volume manufacturers
- **Scenario 2:** Affordability - based on modelling PEV affordability through time, compared to their internal combustion (IC) engine equivalents

This appendix is structured to provide:

- A summary of the California ZEV mandate and the requirements that have to be met to 2025
- An analysis of battery electric vehicle (BEV) and plug-in hybrid electric vehicle (PHEV) sales in the past year in the context of the ZEV mandate requirements
- A description of Scenario 1, compliance with the Californian ZEV mandate, based on the current sales as a starting point
- The approach used to develop the affordability model
- A description of Scenario 2, based on the results of the affordability model
- Some concluding comments

C.1 Adoption Scenario 1: California ZEV Mandate

C.1.1 California ZEV mandate and implications

This Section contains:

- A summary of the California ZEV mandate requirements
- Current BEV and PHEV sales in the context of the ZEV mandate
- An adoption forecast for BEV, and PHEV sales and fleet composition based on compliance with the California ZEV mandate

C.1.2 California ZEV mandate

An overview of the whole Zero-emission vehicle legal and regulatory activities and background is available from the California Air Resources Board web-site.[40] There are three key California Code of Regulations (CCR) that contain requirements for the California ZEV regulation. These are:

1. CCR Section 1962.1: 2009 – 2017 Model Year Requirements
2. CCR Section 1962.2: 2018 and Subsequent Model Year Requirements
3. CCR Section 1962.3: Electric Vehicle Charger Requirements

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[40] http://www.arb.ca.gov/msprog/zevprog/zevregs/zevregs.htm

This study is specifically interested in the 10-year window 2015 – 2025. Scenario 1 assumes:

- In 2015 the BEV and PHEV sales = 1.5x the actual sales for the first 8 months of the year
- For 2018 – 2025 the California ZEV mandate is met and no credits are brought forward from previous years
- For 2016 & 2017 sales are an interpolation between 2015 actual sales and the 2018 ZEV mandate requirement

Therefore, the key document is CCR Section 1962.2: "2018 and Subsequent Model Year Requirements."[41]

C.2 Overall requirements for 2018 - 2025

From the document: "California exhaust emission standards and test procedures for 2018 and subsequent model zero-emission vehicles and hybrid electric vehicles in the passenger car, light-duty truck and medium-duty vehicles classes", which was adopted March 22, 2012 and amended December 6, 2012. Page C-1 gives the "total percentage ZEV requirement" for each manufacturer. This covers requirements for large volume manufacturers, intermediate volume manufacturers, small volume manufacturers, and independent low volume manufacturers.

Scenario 1 is based on the assumption that California vehicle sales of ZEV and PHEV during the 2018-2025 period is well represented by the percentage ZEV requirement for large volume manufacturers. The requirements given in the relevant Section C "Zero-emissions vehicle standards" are reproduced in the below section: C.2.1 Excerpts from Section C of the California ZEV Mandate.

The implication of these assumptions for Scenario 1 is the assumption that state sales must produce the Total ZEV Percentage Requirement of credits. These can be met with qualifying BEVs or a mixture of BEVs and PHEVs which qualify as Transitional Zero Emission Vehicle provided that the BEV credits reach the Minimum ZEV Floor requirement.

The excerpt above specifies **linear growth between 2018 and 2025**, with the "total ZEV percent requirement" growing by 2.5% p.a. (linearly) and the "minimum ZEV floor" growing by 2.0% p.a. (linearly). This requirement is that at least 80% of the "total ZEV percent requirement" must be met by ZEVs rather than TZEVs. In 2018, the minimum ZEV floor, 2%, is 44.4% of the total ZEV percent requirement, 4.5% (that is 55.5% TZEVs are permitted). By 2025, the minimum ZEV floor has increased to 72.7% of the total ZEV percent requirement (27.3% TZEVs permitted).

C.2.1 Excerpts from Section C of the California ZEV Mandate

Part of "California exhaust emissions standards and test procedures for 2018 and subsequent model zero-emission vehicles and hybrid electric vehicles, in the passenger car, light-duty truck and medium-duty vehicle classes" describing requirements for large volume manufacturers. (Section C, Zero-emission vehicle standards).

[41] See http://www.arb.ca.gov/msprog/levprog/cleandoc/2018+%20my%20hevtps_clean%20complete_12-12.pdf

3.3 Allowances for TZEVs
a) Zero Emission Vehicle Miles Traveled TZEV Allowance Calculation. A vehicle that meets the requirements of subdivision C.3.2 and has zero-emission vehicle miles traveled (VMT), as defined by and calculated by this test procedure and measured as equivalent all electric range (EAER) capability will generate allowance according to the following equation;

4.5 Credits for 2018 and Subsequent Model Years.
(a) ZEV Credit Calculations. Credits from a ZEV delivered for sale are based on the ZEV's UDDS all electric range, determined in accordance with these test procedures using the following equation:

*ZEV Credit = (0.01) * (UDDS range) + 0.50*

[1] A ZEV with less than 50 miles UDDS range will receive zero credits.
[2] Credits earned under this provision C.4.5 (a) are capped at 4 credits per ZEV.
[3] Provisions for 2018 through 2025 Model Years. Large volume manufacturers and intermediate volume manufacturers with credits earned from hydrogen fuel cell vehicles that are certified to the California ZEV standards applicable for the ZEV's model year, delivered for sale and placed in service in California or in a section 177 state, may be counted towards compliance in California and in all section 177 states with the percentage ZEV requirements in subdivision C.2

2.2 Requirements for Large Volume Manufacturers.
The requirements for large volume manufacturers (LVM) in 2018 and through 2025 Model Years. LVMs must produce credits from ZEVs equal to minimum ZEV floor percentage requirement, as enumerated below. Manufacturers may fulfil the remaining ZEV requirement with credits from TZEVs, as enumerated below.

C.3 Impact of This Understanding on Scenario 1

The allowances for ZEV and TZEV given above means that the "Total ZEV percent requirement" in Section C.2.1, e.g. 22.0% in 2025, **are for the weighted allowances, not vehicle sales.** Therefore, if all qualifying vehicles had a ZEV allowance at the cap of 4.00 ZEV credits per vehicle, only 5.5% of vehicle sales would need to be ZEVs.

Conversely, if all the qualifying ZEVs had a range of 50 miles, then, using the equation for determining the value of ZEV credits, each ZEV would receive a ZEV allowance of 1.00 (calculated from 50 x 0.01 + 0.50). Therefore, if all qualifying vehicles had a ZEV allowance at this lower limit of 50 miles then 22.0% of vehicle sales would need to be ZEVs.

C.3.1 Value of ZEV credits for electric vehicles

From Section 4.5 of CCR Section 1962.2, reproduced in C.2.1, the equation for determining the value of ZEV credits for a ZEV is:

ZEV Credit = (0.01) * (UDDS range) + 0.50 Credit cap = 4.0 credits

The value for a TZEV is:

TZEV Credit = (0.01) * (EAER range) + 0.30 Credit cap = 1.1 credits.

Hence, in 2025 for new sales, the "Total ZEV percent requirement" is less than or equal to the "Number of ZEVs" which is itself less than or equal to a quarter of the "Total ZEV percent requirement."

C.3.2 Value of ZEV credits for fuel cell vehicles

This too is described in Section 4.5 of CCR Section 1962.2, shown in the final paragraph in C.2.1. The equation for determining the value of ZEV credits for a hydrogen fuel vehicle is:

ZEV Credit = (0.01) * (UDDS range) + 0.50 Credit cap = 4.0 credits

This is applicable only if the vehicle has been certified to the California ZEV standards.

C.3.3 Current BEV and PHEV sales in the context of the California ZEV mandate

The methodology used to determine the BEV and PHEV sales in California in 2015 was:

1. To use a database from Argonne National Laboratory on sales of BEVs and PHEVs in the US in the first eight months of 2015, and to scale up to a full year;
2. To use EPA BEV labels to provide the electric range for each vehicle;
3. To calculate the sales weighted number of California ZEV credits anticipated for 2015;
4. To express the sales weighted average ZEV credit score in terms of BEV-100 and BEV-200 mile range only;
5. To estimate the fraction of the US BEV and PHEV sales that occurred in California;
6. To estimate the percentage of BEV and PHEV sales in California as a fraction of total light vehicle sales;
7. To use these data to calculate the California ZEV credits as a "total ZEV percent achieved".

The sales of BEV and PHEV during the first 8 months in 2015 were taken from the Argonne National Laboratory "Light duty electric drive vehicles monthly sales updates" for sales recorded to the end of August 2015.[42] This gives number of sales identified by vehicle model for the whole of the US. The data for the first eight months of 2015, extracted from this database is given in the first three columns of Table C-1.

[42] Argonne National Laboratory "Light duty electric drive vehicles monthly sales updates" taken from: http://www.anl.gov/energy-systems/project/light-duty-electric-drive-vehicles-monthly-sales-updates

Table C-1. Argonne National Lab data on sales of BEV and PHEV models: first eight months of 2015

	Vehicle	Sales in first eight months of 2015	Total electric range from economy label
Electric Vehicles	Leaf	12,383	75
	Smart ED	861	68
	Mitsubishi I EV	90	62
	BMW Active E	0	94
	Ford Focus	1,122	76
	Honda Fit EV	1	82
	Tesla Model S*	15,100	208
	RAV4 EV	17	103
	Chevrolet Spark	1,977	82
	Fiat 500E	2,455	87
	BMW i3	6,183	81
	Mercedes B-Class	1,540	87
	VW e-Golf	2,212	83
	Kia Soul EV	622	93
	Total for all EVs	44,563	
Plug-in Hybrid Electric vehicles	Volt	8,315	38
	Prius PHEV	3,818	11
	Ford C-Max Energi	4,959	21
	Honda Accord	62	13
	Ford Fusion Energi	6,091	21
	Panamera S E-Hybrid	289	16
	Cadillac ELR	704	37
	BMW i8	1,160	15
	Porsche Cayenne S E-hybrid	709	14
	Mercedes S550 Plug	20	19
	Volvo-XC90 Plug In	4	25
	Total for all PHEVs	26,131	

C.3.4 Electric Range of BEVs

The values of the ZEV credits are given by Section 4.7 of CCR Section 1962.2 as:

ZEV Credit = (0.01) * (UDDS range) + 0.50 Credit cap = 4.0 credits

The EPA provides data for each BEV (and PHEV) model via obligatory fuel economy labels designed to display key information to the consumer. Figure C-1 is the fuel economy label for an illustrative BEV.[43] It contains data on the energy required to travel 100 miles (both as kWh and also as a miles per gallon gasoline equivalent) for both the combined city and highway cycle (107 MPGe) and for the separate cycles. It also contains the total electric range for the vehicle (68 miles).

It is possible to disaggregate the information within the fuel economy label to obtain a UDDS range, which will often differ slightly from the fuel economy label range due to variations in the city, highway and combined cycles. For the development of Scenario 1, however, it was assumed that the EPA total electric range can be taken as the UDDS range in the equation to calculate the ZEV credits. These values, from the EPA fuel economy labels, are given in the fourth column of Table C-2. Therefore, for the 2015

[43] Taken from https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=35859

Smart Fortwo electric drive coupé, its total electric range of 68 miles means each sale generates 1.18 ZEV credits (from 0.01 x 68 + 0.5), using the ZEV credit formula outlined above.

Figure C-1. Fuel Economy Label for Illustrative Electric Vehicle

C.3.5 Equivalence of BEVs Sold Expressed as 100 and 200 Mile Range BEVs

The matrix of model, sales, and UDDS range displayed in Table C-2 was analyzed using the ZEV credit equation to give the sales-weighted average California ZEV credits per electric vehicle sold of 1.727.

Table C-2. California ZEV credits for the three largest volume selling electric vehicles

Model	Sales in first 8 months of 2015	Range	Number of California ZEV credits per vehicle sold
Nissan LEAF	12,383	75 miles	1.25
Tesla S	15,100	208 miles	2.58
BMW i3	6,183	81 miles	1.31

These three vehicles represent slightly over 75% of all electric vehicles sold. Their sales weighted average California ZEV credits is 1.858, but overall the average is reduced because the remaining vehicle models have a range < 100 miles.

It is convenient to express the sales weighted average ZEV credit value in terms of a ratio of generic BEV-100 and BEV-200 mile range vehicles only rather than consider the range of individual models, which keep changing. This is the nomenclature adopted by the US Energy Information Administration as a descriptor for BEVs in its Annual Energy Outlooks. Each BEV-100 mile range vehicle sale would generate a 1.50 ZEV credit, and each BEV-200 mile range vehicle sale would generate a 2.50 ZEV credit. If the BEV sales comprised X% BEV-200 vehicles and (100-X)% BEV-100 vehicles, then the combined sales weighted average California ZEV credits per vehicle sold would be 1.50 + 0.01X. Given that the actual sales weighted average California ZEV credits per vehicle sold is 1.727, then X = 22.7%. In other words, the number of California ZEV credits from the actual US BEV sales is equivalent to 77.3% BEVs with 100-mile range, and 22.7% BEVs with 200 mile range.

C.3.6 Numbers of PHEVs Sold and Their Number Relative to BEVs

A similar analysis for PHEVs indicated that sales-weighted average California ZEV credits per PHEV vehicle sold = 0.554 ZEV credits per vehicle. The BEV and PHEV data are combined and summarized in Table C-3 below.

Table C-3. BEV and PHEV Vehicle Sales in US Showing Respective Contribution to ZEV Credits

Type of vehicle	Number sold in first 8 months of 2015	Average ZEV credit/vehicle	Total credits
BEV	44,563	1.727	76,960.3
PHEV	26,131	0.548	14,319.8
All vehicles			91,280.1

From the above it is seen that 84.31% of all the credits are from the sales of BEVs, and 15.69% are from the sales of PHEVs. From Section C.2.1 it is seen that in 2018 the "minimum ZEV floor" requires a minimum of 44.4% of credits to be from BEVs, whilst by 2025 the requirement is that a minimum of 72.7% of credits are from BEVs. The sales pattern in 2015 meets both of these future ZEV PHEV/PEV mandate requirements.

C.3.7 Estimate Number That Were Sold in California

An article in Electric Vehicle News in November 2014 gives BEV and PHEV sales in California for the first 9 months of 2014.[44] These sales were compared with sales of BEV and PHEV in the whole US for the same period (the first 9 months in 2014) as published by the Argonne National Lab data and noted below in Table C-4.

Table C-4. BEV and PHEV Vehicle Sales in US Showing their Relative Contribution to ZEV Credits

	BEV	PHEV
California sales in first 9 months of 2014 (from Electric Vehicle News)	20,516 (1.5% Of all sales)	23,648 (1.7% of sales)
Total US sales from ANL data	44,003	44,146
California proportion	46.6%	53.6%

A later article, published by Ecomento in March 2015 considered sales in California during the whole of 2014.[45] This article reports BEV sales in California 29,536 in the year (ANL says 63,525 across US), i.e. the Californian contribution is 46.5%. It also reports PHEV sales in California 29,936 in year (ANL says 55,357 across US) (i.e. 54.1% contribution). These figures closely match those above and support the data from Electric Vehicle News. Based on the above, a slightly conservative figure has been assumed, such that 45% of both total BEVs and PHEVs sold in the US are sold in California.

[44] "Electric vehicles account for almost 10% of Californian new car sales" article, available from http://www.electric-vehiclenews.com/2014/11/electric-vehicles-account-for-almost-10.html

[45] "California bought more electric cars than China in 2014" article, available from http://ecomento.com/2015/03/24/california-electric-car-sales-2014/

C.3.8 Projection of Current US Sales Numbers Onto the 2021 Requirement

The data derived above from the sales pattern for 2015 can be applied to future sales, within the context of the requirement of the California ZEV mandate. For example, in 2021 the ZEV mandate requires:

Total ZEV percent requirement = 12.0%
Minimum ZEV floor = 8.0%
Maximum number of TZEVs = 4%

From the section above, 84.31% of all the credits are from the sales of BEVs, and 15.69% are from the sales of PHEVs. If this proportion were maintained, then in 2021 the "Total ZEV percent requirement" of 12% would comprise 10.12% from BEVs and 1.88% from PHEVs.

To generate 10.12% of credits overall, then for BEVs with the average credit of 1.727 per vehicle, BEV sales of 5.86% of all light duty vehicle sold would meet this requirement. A similar calculation can be done for the PHEVs. Overall the current sales pattern, scaled to the 2021 requirement would give results, as shown in Figure C-2. Figure C-3 shows the 2015 BEV and PHEV sales in the context of all light duty vehicle sales.

Figure C-2. Projection of 2015 Sales Pattern of BEV and PHEV Vehicles to the 2021 California ZEV Target

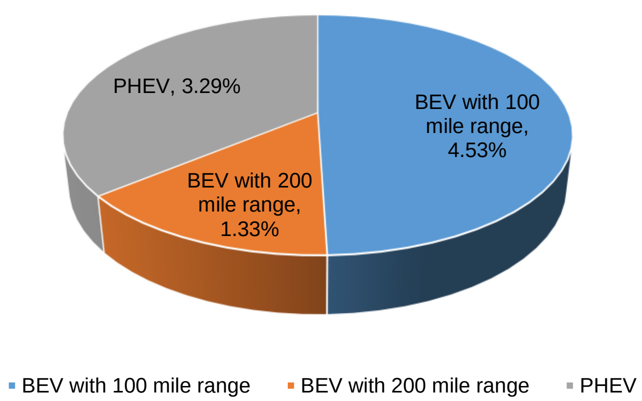
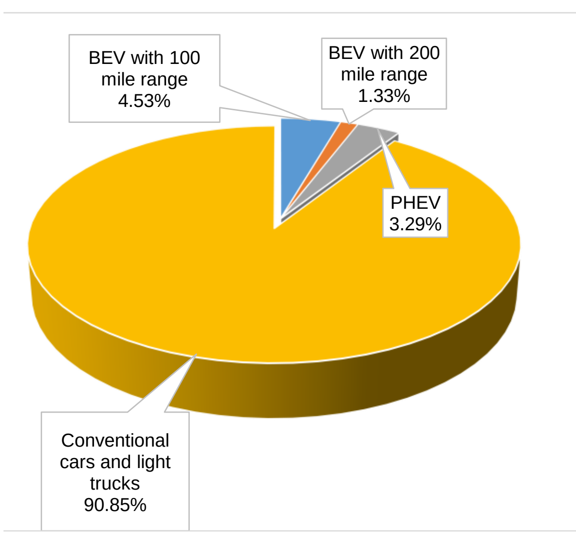


Figure C-3. Projection of 2015 Sales Pattern of BEV and PHEV Vehicles to the 2021 California ZEV Target Also Showing Importance of Conventional ICE Vehicles



C.3.9 Key Assumptions That Form the Foundation for Scenario 1

- The California ZEV mandate is met.
- The data for 2015 is obtained from US sales of BEV & PHEV in the first 8 months of 2015 scaled up to the full year, and the California/Whole of America ratio of 45%.
- The value of California ZEV credits is based on EPA total electric range and the formula given in the regulation.
- BEV sales can be represented by X% BEV-200 mile range plus (100-X)% BEV-100 mile range such that the average number of California ZEV credits per vehicle from this representation is the same as the average number of California ZEV credits per vehicle from actual sales.
- The ratio of the contribution to the California Total ZEV percent requirement contributed by BEV-100 and BEV-200 mile range vehicles assumes the BEV-200 fraction of the whole increases from the 2015 actual sales figure of 22.7% to 28% by 2019, and then to 40% by 2025.
- For PHEVs their range increases between 2015 and 2025 from 25 miles to 40 miles, but sales are given as the numbers of PHEV 40 vehicles that give the observed number of ZEV credits.
- The ratio of the contribution to the California Total ZEV percent requirement contributed by BEV-100 and BEV-200 mile range vehicles and PHEV vehicles remains constant at the 2015 actual sales figure for the period up to 2025.
- For this first BEV sales Scenario, no fuel cell vehicles are included.

Vehicle Forecasting Assumptions

This analysis is based on the assumption that the BEV purchasing patterns of the California market are reflected by the sales for the whole US. However, if Californians purchased more or less than the 45% predicted share of total US Tesla sales (or of other vehicle models), then the assumptions made here would require some modification.

Current sales data are an interesting snapshot for 2015. An important question is: “How are vehicle characteristics likely to evolve?” Some thoughts are provided below.

BEV 100-Mile Range: BEV 200-Mile Range Ratio

Looking to the future it is to be expected that:

- Batteries (per kWh) will become cheaper, and therefore vehicle range could increase for the same battery cost;
- BEV vehicle manufacturers will look to make their vehicles behave more like conventional gasoline vehicles, i.e. further pressure for range to increase;
- There are likely to be pressures to reduce BEV price, which could occur with cheaper batteries if vehicles’ range remained constant.

Overall it is expected that the average range for each model will increase. In part this will occur as the number of available models increases. The ANL sales data currently contains 14 BEV models, with only one (the Tesla model S) having a range >110 miles. The average range for the other 13 models is 88 miles, and there are two models that have a range between 100 and 110 miles. However, despite being only one of 14 models (or 7.1% of all the BEV models), Tesla sales are more than a third of all BEV sales (33.9% of electric vehicle sales).

So currently there is a distorted market, with low overall BEV sales as a percentage of all new LDV sales, and a single BEV model with a longer range selling very well. As BEVs become more main-stream whilst the number of models whose range is >150 miles is expected to increase, the average range is likely to increase and the BEV-200/all-BEV ratio is likely to increase. Combining these predicted trends, the BEV-200/All BEV ratio was assumed to follow the trend:

2015	22.7%	The ratio that applies to 2015 BEV sales observed today;
2019	28.0%	Modest increase relative to 2015 ratio (average increase of 1.06% p.a.);
2025	40.0%	More rapid increase relative to 2019 ratio (ratio increases at 2.0% p.a.).

PHEV Electric-Only Range

Current sales in 2015 indicate that PHEV sales comprise 36.96% of the PEV sold by number, but contribute only 15.69% of the ZEV credits. The analysis of sales also gives the sales weighted average electric range of PHEVs as 24.8 miles, and consequently the number of ZEV credits per sale as 0.548. The best-selling model is the Volt, which in 2015 has a 38 mile electric range. However, reports indicate the 2016 model has a 53 mile range.[46] Another high sales volume model is the Toyota PHEV Prius. The current model has an electric only range of 11 miles, but speculation is that the next version will have an electric only range of around triple this.[47] These two changes would increase the average electric range of PHEVs from 24.8 miles to around 33 miles.

However, given that the improvement in range for different PHEV models is likely to progress across all manufacturers and that new models are likely to come to market with increased range, we can expect the average range to increase beyond the 33 miles that would be achieved through the introduction of the new Volt and Prius models only. As such the average range for PHEVs in 2025 is assumed to be 40 miles. For consistency, the PHEV sales are expressed as a revised number of PHEV-40 equivalent vehicles that generate the same number of ZEV credits.

PHEV to PEV Sales Ratio

The California ZEV mandate has as a theme the reduction in the proportion of ZEV credits that come from PHEVs sales relative to the total ZEV credits from PEV (i.e. BEV + PHEV) sales.

It was noted earlier that in terms of **ZEV credits,** the California ZEV mandate requirements represent linear growth between 2018 and 2025, with the total ZEV percent requirement growing by 2.5% p.a. (linearly) and the minimum ZEV floor growing by 2.0% p.a. (linearly). In 2018, the minimum ZEV floor is 44.4% of the total ZEV percent requirement (**55.5% TZEVs permitted**). By 2025, this has increased to 72.7% of the total ZEV percent requirement (**only 27.3% TZEVs permitted**).

For the 2015 actual sales figures, the PHEVs generate 15.69% of the ZEV credits. From the data for the final scenario sales, in 2025 the PHEVs generate 16.2% of the ZEV credits, a slightly higher figure that is a consequence of the increasing range of PHEVs, meaning that each sale contributes a higher number of credits. However, this is well within the 27.3% permitted in 2025, being around 60% of this limit. Consequently, again the numbers suggested from the current sales are compliant with the California ZEV mandate.

C.3.10 Interim Result: Vehicle Sales Required to Meet ZEV Mandate

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[46] CNET website, article entitled: “Chevrolet 2016 Volt’s EPA label boasts 53-mile EV range”, taken from http://www.cnet.com/uk/news/the-2016-chevrolet-volt-gets-53-mile-electric-range-estimate/

[47] Speculation published in Car and Driver blog, article entitled: “Next Toyota Prius Plug-in allegedly could provide 30 – 35 miles of electric range”, taken from: http://blog.caranddriver.com/next-toyota-prius-plug-in-allegedly-could-provide-30-to-35-miles-of-electric-range/

Vehicle Sales Required as a Percentage of Californian Sales

The relative vehicle sales required to achieve the California ZEV mandate in different years can be calculated as a percentage of new LDV sales in California, based on the assumptions and methodology described at the end of Section C.3.9 Key Assumptions That Form the Foundation for Scenario 1. The data in Table C-5 is shown as a stacked column chart in Figure C-4.

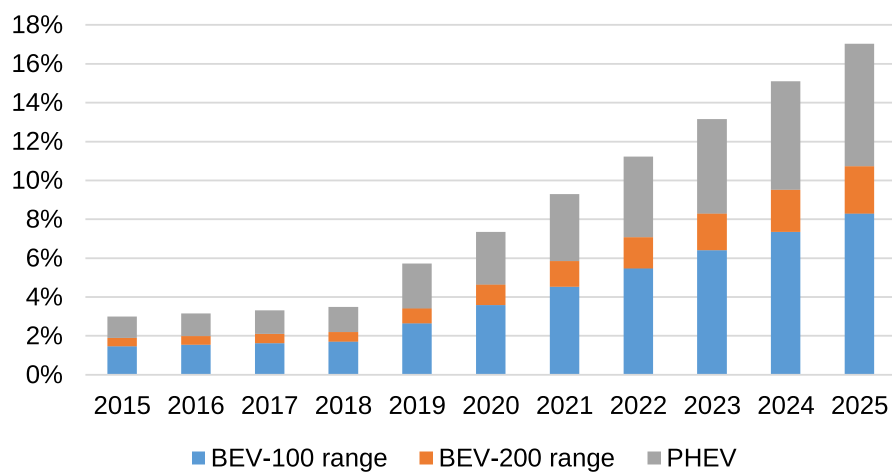
Table C-5. Percentage of BEVs and PHEVs of New Vehicle Sales in California for 2015 to 2025 Based on 2015 Sales Pattern

(Before Impact of FCs and Greater BEV-200 Sales Are Included)

Year	BEV-100 range	BEV-200 range	PHEV	Conventional vehicles
2015	1.462%	0.429%	1.108%	97.00%
2016	1.541%	0.453%	1.168%	96.84%
2017	1.619%	0.476%	1.228%	96.68%
2018	1.697%	0.499%	1.288%	96.52%
2019	2.640%	0.776%	2.30%	94.28%
2020	3.583%	1.054%	2.719%	92.64%
2021	4.526%	1.331%	3.434%	90.71%
2022	5.469%	1.608%	4.150%	88.77%
2023	6.412%	1.886%	4.865%	86.84%
2024	7.355%	2.163%	5.581%	84.90%
2025	8.298%	2.440%	6.296%	82.97%

Figure C-4. Projected ZEV Sales Pattern of BEV and PHEV Vehicles through 2025

(Before impact of fuel cell vehicles and greater BEV-200 sales are included: see next section)



The BEV-100 and BEV-200 mile range and PHEV vehicles sales required to meet the California ZEV mandate are shown in the light blue shaded cells in Table C-5 (i.e. for 2018 – 2025). The data for 2016 and 2017 are obtained by linear interpolation between the 2015 actual sales and the 2018 required sales that meet the Total ZEV percent requirement (the orange highlighted cells).

Vehicle Sales Required as Numbers of Vehicles Sold

The data in Table C-5 and Figure C-4 are the percentage of all Californian light duty vehicle sales required to meet the ZEV mandate before the impact of fuel cell (FC) vehicles and a higher ratio of BEV-200 sales (as a fraction of all BEV sales) are taken into account. To convert these into actual numbers of vehicles sold, projections of light duty vehicle sales in California are required. Projected vehicle sales in

California were taken from the CARB Vision Scenario Planning tool, using the model for light duty vehicles.[48] Vehicle sales are taken from the "Vehicle_Sales_(EMFAC)" worksheet. These are categorized into cars and light trucks. Sales data for years 2012 to 2025 are given in Table C-6.

Table C-6. Light Duty Vehicle Sales in California for 2012 to 2025 Based on CARB California Version of ANL's Vision Model

Year	Car sales	Light truck sales	Total LDV Sales
2012	1,009,834.08	546,563.59	1,556,397.67
2013	1,002,965.35	564,716.96	1,567,682.31
2014	1,000,950.48	589,412.02	1,590,362.50
2015	1,010,976.51	618,060.29	1,629,036.80
2016	1,016,590.70	633,620.25	1,650,210.95
2017	1,023,112.04	647,487.54	1,670,599.58
2018	1,029,837.71	655,890.23	1,685,727.94
2019	1,036,690.79	663,764.04	1,700,454.83
2020	1,037,480.98	669,693.40	1,707,174.38
2021	1,020,757.11	674,307.76	1,695,064.87
2022	1,030,918.54	679,736.42	1,710,654.96
2023	1,043,703.14	683,025.16	1,726,728.30
2024	1,061,563.50	689,985.88	1,751,549.38
2025	1,069,381.76	692,110.86	1,761,492.62

The total LDV sales given in the table above are multiplied by the percentages of BEVs and PHEVs of new vehicle sales given in Table C-5, to give the vehicle sales data in Table C-7.

Table C-7. Number of BEV and PHEV New Vehicle Sales in California for 2015 to 2025

(Before Impact of FCs and Greater BEV-200 Sales Are Included)

Year	BEV-100 range	BEV-200 range	PHEV-40	Total LDV sales
2015	23,823	6,996	18,055	1,629,036.8
2016	25,425	7,470	19,278	1,650,211.0
2017	27,046	7,950	20,516	1,670,599.6
2018	28,611	8,414	21,710	1,685,727.9
2019	44,894	13,202	34,067	1,700,454.8
2020	61,169	17,988	46,416	1,707,174.4
2021	76,718	22,560	58,215	1,695,064.9
2022	93,553	27,511	70,990	1,710,655.0
2023	110,714	32,558	84,012	1,726,728.3
2024	128,821	37,882	97,752	1,751,549.4
2025	146,161	42,982	110,910	1,761,492.6

C.3.11 Adding Fuel Cell Vehicle Sales and Increasing EV-200 Mile Range Sales

Fuel Cell Sales

A few years ago Ricardo Strategic Consulting developed a forecast for fuel cell (FC) fleet numbers. This can be converted into the year on year sales of fuel cell vehicles — this is unpublished information. With the benefit of hindsight, this has proved to be optimistic, because in October 2015 the first FC vehicles are only just becoming available, and 2015 sales realistically will be near to zero. The rate of growth assumed following fuel cell vehicles becoming available has been retained, i.e. the deployment rates

[48] CARB Vision Scenario Planning tool is available from: http://www.arb.ca.gov/planning/vision/docs/arb_vision_ldv_model.xlsx

have been shifted in time, but remain unchanged from the previous forecast. The annual sales of fuel cell vehicles from the modest growth scenario of this unpublished study are given in Table C-8.

From the characteristics of the first two commercially available fuel cell vehicles (the Hyundai IX 35 fuel cell vehicle (range 371 miles), and the Toyota Mirai (range 312 miles) application of the equation for the number of ZEV credits for ZEVs (from Section 4.5 in Box 1) gives these 4.00 and 3.62 ZEV credits, respectively. It is assumed that future fuel cell vehicles receive the capped limit of 4.00 California ZEV credits.

It is noted that in 2019 the 2,900 sales (11,600 ZEV credits) represents 0.68% ZEV credits for the 1.7 million light duty vehicle sales in California, out of the target 7.0%. This is around 10% of the ZEV credits required. By 2025 the projected 21,600 FC sales generate 86,400 ZEV credits. This represents 4.90% ZEV credits for the 1.761 million light duty vehicle sales in California, out of the target 22.0%, i.e. 22.2% of the ZEV credits required. This is a major perturbation to the PEV sales figures required to meet the California ZEV mandate.

Some assumptions used to adjust the number of BEV and PHEV new vehicle sales in California for 2015 to 2025, given in Table C-8, are:

- First, assume FC vehicle sales are to buyers who otherwise would be PHEV purchasers, replacing one vehicle with an extended range (a range substantially longer than the average BEV) with a FC vehicle with its extended range.
- Each FC vehicle sale generates 4 ZEV credits.
- The numbers of EVs are then adjusted to bring the ZEV credits from the total sales of BEVs, PHEVs and FC vehicles back in line with the California ZEV mandate requirements.

Readjustment of BEV-100 to BEV-200 Sales Ratio

The ratio taken for 2015, based on modelling actual sales, was 22.7% of BEV sales were BEV-100. This is quite low. It has been assumed that with increasing sales, reductions in battery prices etc., the fraction of BEV-200 vehicles increases, reaching 26% in 2018, and then increasing linearly at 2% p.a. to 40% in 2025. The numbers of BEVs sold, was recalculated on this basis, whilst the number of PHEV sales and FC vehicle sales were as described above. Again the numbers of EVs are then adjusted to bring the ZEV credits from the total sales of BEVs, PHEVs, and FC vehicles back in line with the California ZEV mandate requirements.

C.3.12 Final Scenario 1 Results: Vehicle Sales Required to Meet California ZEV Mandate

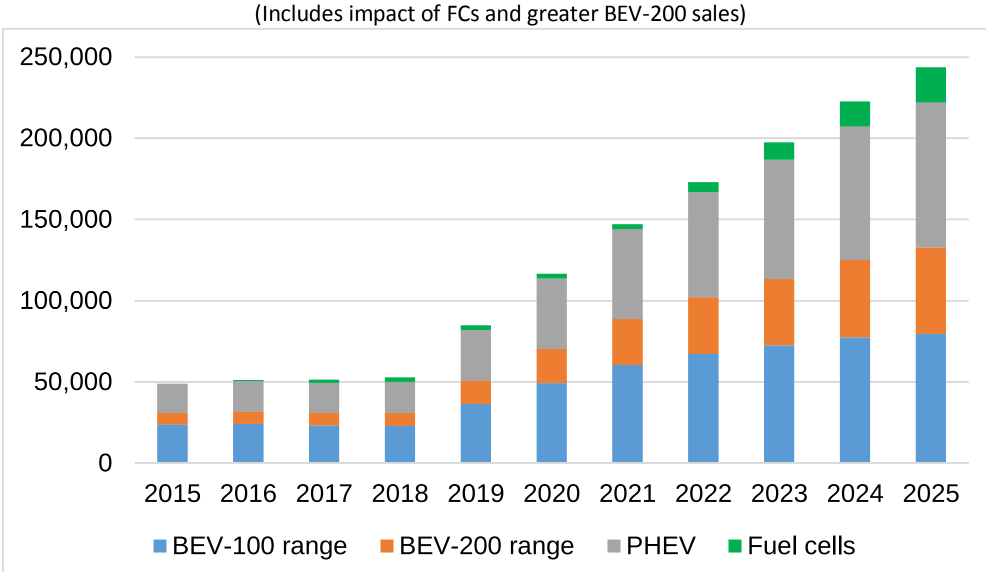
Applying the adjustments to the vehicle sales data of Table C-7 caused by the FC vehicle sales, and increased BEV-200 sales leads to a final Scenario 1 composition as shown in Table C-8. These data are shown as a stacked column graph in Figure C-5.

Table C-8. Number of BEVs, PHEVs, and FC new vehicle sales in California for 2015 to 2025

Year	BEV-100 range	BEV-200 range	PHEV-40	Fuel cells	Total vehicles
2015	23,828	6,997	18,055	0	1,629,037
2016	24,202	7,517	18,778	500	1,650,211
2017	23,232	7,621	18,616	1,900	1,670,600
2018	22,976	8,072	19,010	2,700	1,685,728
2019	36,549	14,214	31,167	2,900	1,700,455
2020	49,154	21,066	43,416	3,000	1,707,174
2021	60,341	28,396	55,315	2,900	1,695,065
2022	67,345	34,693	64,790	6,200	1,710,655
2023	72,578	40,825	73,412	10,600	1,726,728
2024	77,449	47,467	82,352	15,400	1,751,549
2025	79,648	53,096	89,310	21,600	1,761,493

Figure C-5. Projected ZEV sales pattern of BEV, PHEV and FC vehicles to 2025

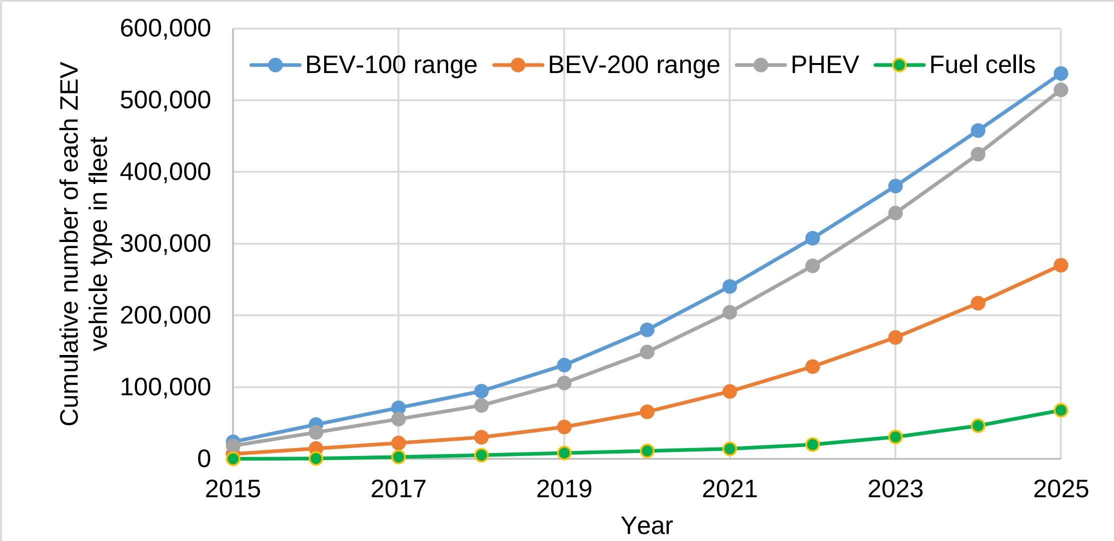
(Includes impact of FCs and greater BEV-200 sales)



The expected lifetime for US light duty vehicles has been increasing. A recent study indicated for vehicles sold in 1999 the expected lifetime is 14 years.[49] Therefore, the simple assumption was made that over the ten years being considered the vehicles sold, as shown in Table C-8 accumulate in the fleet, with no significant scrappage occurring. This gives projected ZEV fleet numbers to 2025 as shown in Figure C-6.

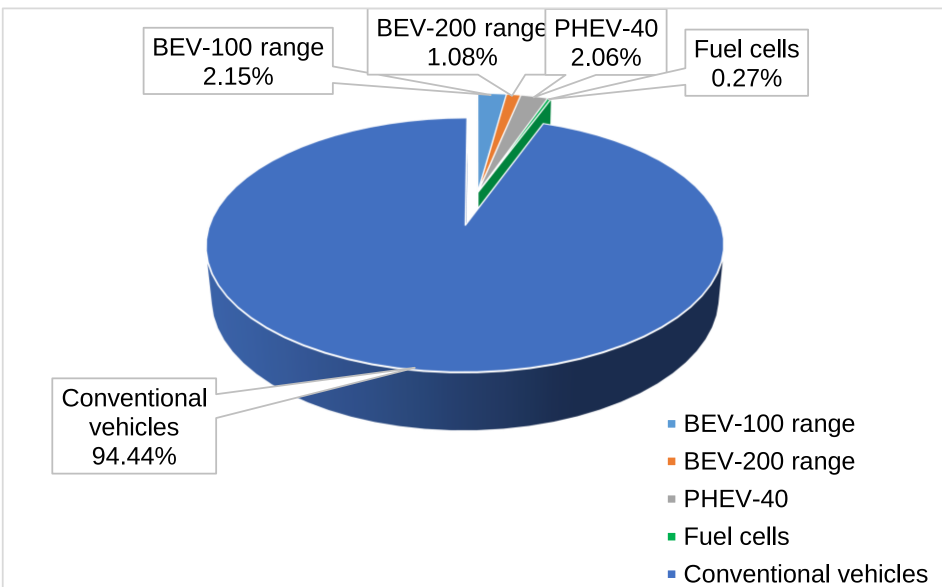
[49] AM Bento, KD Roth, Y Zui, "Vehicle lifetime trends and scrappage behavior in the US used car market", May 2013). Available at SSRN: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2262593

Figure C-6. Projected ZEV fleet numbers from 2025



The composition of the fleet in 2025 for Scenario 1 is shown as a pie chart in Figure C-7, which demonstrates importance of conventional ICE vehicles.

Figure C-7. Projected Numbers of BEV, PHEV and Fuel Cell Vehicles in the Californian Fleet in 2025



C.4 Affordability Model

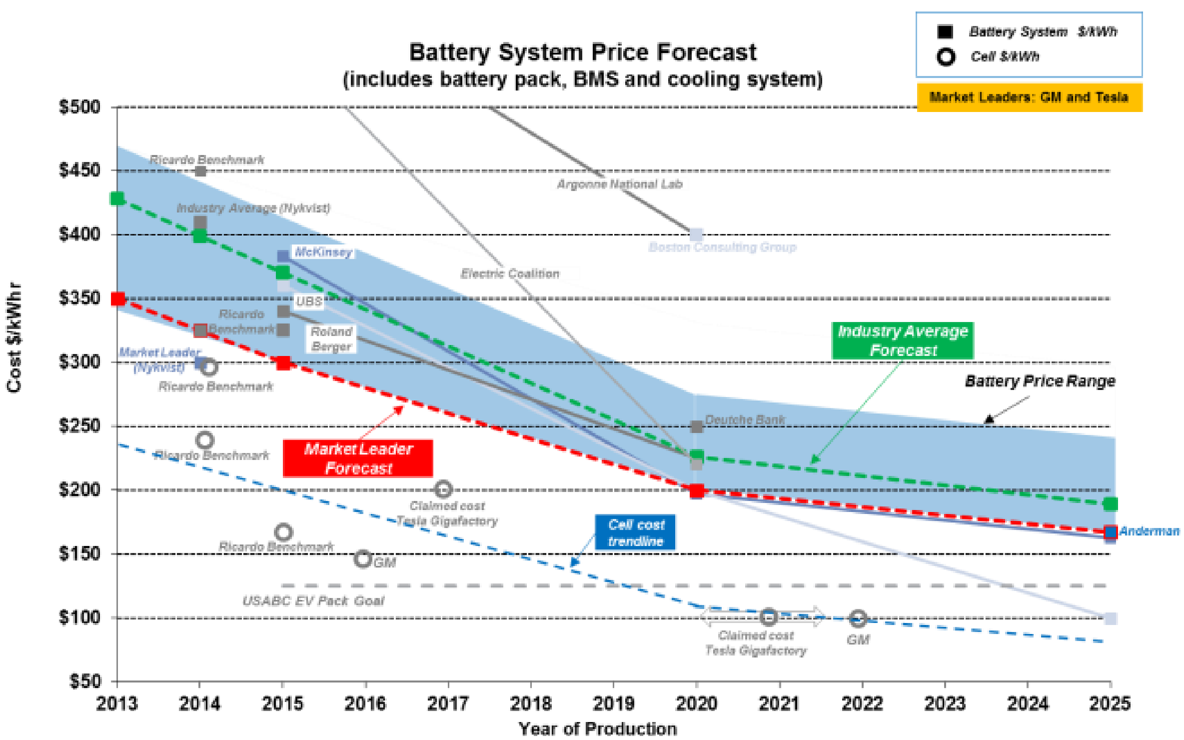
Affordability is a key consideration for consumers in their purchase decision for plug-in electric vehicles. Today, there is a price premium associated with BEVs and PHEVs. The federal government and state of California are offering economic incentives to boost PEV sales in the early stages of commercialization. While there are limitations to the number of such incentives, it is expected that sticker prices of PEVs will decline due to reductions in the cost of battery packs and the balance of plant. To estimate the impact of the above factors on future PEV sales, Ricardo has developed an affordability model which forecasts annual PEV sales through 2025 based on anticipated incremental costs to consumer. The methodology consists of 4 key steps:

- Develop a price forecast of plug-in electric powertrain components
- Use this data to estimate incremental PEV price with respect to comparable IC engine vehicle from 2015 through 2025
- Estimate the cost to the consumer after applying economic incentives through 2025
- Develop an adoption rate model and apply to light-duty vehicle sales projections

C.5 PEV Component Cost Forecast

Ricardo has developed cost roadmaps of electric powertrain components including the battery pack, motor, inverter etc. to predict future cost of plug-in electric vehicles. The roadmap of battery system price is shown below as an example (Figure C-8). The roadmap consists of an "industry average" price forecast which applies to the battery market in general and a "market leader" forecast based on anticipated costs for leading PEV OEMs such as Tesla Motors and General Motors. The projections are based on data points from a variety of studies, OEM announcements, industry inputs and Ricardo's benchmark data on cell and pack level costs. The "market leader" battery projections have been used in this study.

Figure C-8. Price Forecast through 2025



C.5.1 PV Incremental Price

Three variations of plug-in electric vehicles have been considered in this study:

- BEV 100: Pure electric vehicle with 100-mile range based on EPA combined cycle
- BEV 200: Pure electric vehicle with 200-mile range based on EPA combined cycle
- PHEV 40: Plug-in hybrid electric vehicle with 40 mile of battery only range based on EPA combined cycle

Currently most of the in-production EVs have 70 to 90 mile range while others like the Tesla Model S and anticipated Chevy Bolt are designed for 200+ mile range. BEV 100 and 200 are selected to represent these two evolving variations in the EV market. PHEV 40 reflects the average electric only range of the existing in-production PHEVs. At the low end of the spectrum, the Prius plug-in has a 10-mile electric range while the BMW i3 range extender with its 72 mile all electric range is the maximum offered by any in-production vehicle in the US.

C.5.2 PEV specifications

The incremental price of a plug-in electric vehicle depends on the size of battery and the rest of the electric powertrain components. The powertrain specifications vary greatly depending on whether the vehicle is smaller (e.g. a sub-compact segment vehicle) or larger (e.g. a SUV). To capture this variation, the analysis has been carried out for 7 different vehicle segments. For each segment, the electric energy requirement (kWh/mile) is determined based on energy consumption data on EPA combined cycle for in-production EVs as well as gasoline vehicles. The battery kWh is calculated based on the desired range. Motor/Inverter power rating is determined from the specs of in-production EVs and typical specifications of gasoline vehicles in each of the 7 segments. Table C-9 below highlights the powertrain specifications for each of the light-duty segments.

Table C-9. Powertrain Specifications for Different Light-duty Vehicle Segments for BEV 100, BEV 200, and PHEV 40

BEV 100	**Subcompact**	**Compact**	**Mid-Size**	**Full-size**	**Small SUV**	**Standard SUV**	**Pickup Truck**
kWh/mile	0.28	0.305	0.30	0.35	0.40	0.48	0.51
Battery Capacity (kWh)	28	30.5	30	35	40	48	51
Motor Power Rating (kW)	100	100	165	225	140	240	250
BEV 200	**Subcompact**	**Compact**	**Mid-Size**	**Full-size**	**Small SUV**	**Standard SUV**	**Pickup Truck**
kWh/mile	0.30	0.32	0.32	0.37	0.43	0.52	0.54
Battery Capacity (kWh)	60	64	64	75	86	103	108
Motor Power Rating (kW)	100	100	165	225	140	240	250
PHEV 40	**Subcompact**	**Compact**	**Mid-Size**	**Full-size**	**Small SUV**	**Standard SUV**	**Pickup Truck**
kWh/mile	0.28	0.30	0.30	0.35	0.40	0.48	0.51
Battery Capacity (kWh)	11	12	12	14	16	19	20
Motor Power Rating (kW)	100	100	165	225	140	240	250

Example Incremental Price Calculation

The cost of electric powertrain consists of the battery pack including battery management system (BMS) and cooling system, electric motor, inverter, converter, gearbox, control unit, on-board charger, high voltage cables, pumps, battery heater and other ancillaries. Ricardo has developed cost roadmaps for each of the electric components through 2025. Based on the determined PEV specifications, the cost of the powertrain is calculated for each PEV type and vehicle segment through 2025. The incremental PEV price is calculated by subtracting the cost of ICE powertrain from PEV powertrain and applying 10% margin and 7.5% California sales tax to the difference through CY 2025 (Figure C-9). It is assumed that besides the drivetrain, the rest of the vehicle remains unchanged. Also, the ICE powertrain cost includes the cost of compliance as determined by EPA for cars and light trucks through 2025.

Figure C-9. Steps in Calculation of PEV Incremental Price – Example of a 2015 Compact BEV 100

Determination of PEV specs

BEV 100 Specifications	
kWh/mile	0.3
Battery Capacity (kWh)	30
Power Rating (kW)	100

Calculation of EV Powertrain Cost

EV Powertrain Cost (in 2015)	
Battery	$ 9,219
Motor	$ 906
Inverter	$ 1,119
DC/DC Converter	$ 330
EV Transmission	$ 297
Control Unit	$ 160
On-board Charger	$ 396
HV Cable	$ 250
Pumps & Battery/cabin heater	$ 400
Misc. (alternator/starter)	$ 550
Total PEV Powertrain Cost	**$ 13,626**

ICE pwt cost

Subcompact ICE Powertrain Cost	$ 4,150

Incremental PEV price includes margin & sales tax

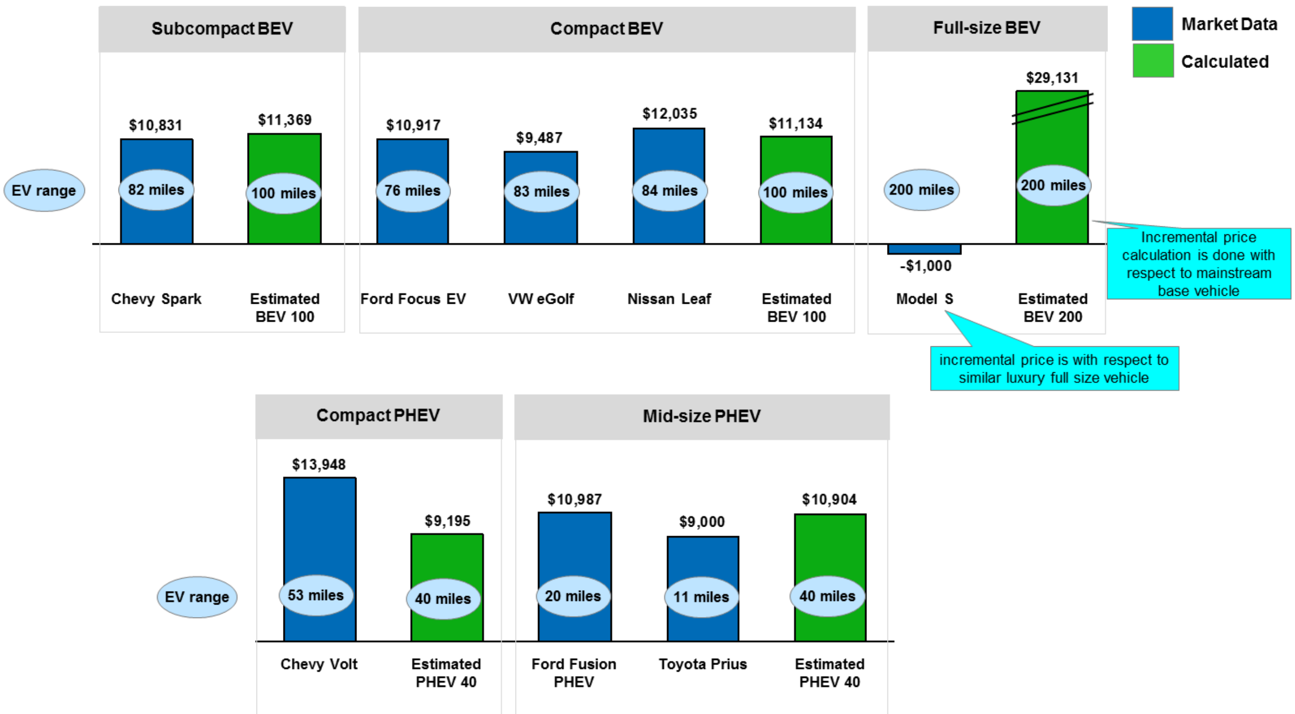
Incremental Pwt Cost	**$ 9,476**
Margin	**10%**
CA Sales Tax	**7.5%**

PEV Incremental Price (USD) ***[market leader battery forecast]***

Vehicle Segments	*PEV variant*	CY 2015	CY 2020	CY 2025
Subcompact (Base cost: $15,000)	PHEV 40	$ 8,913	$ 6,111	$ 3,864
	BEV 100	$ 11,369	$ 6,523	$ 3,582
	BEV 200	$ 22,621	$ 14,024	$ 9,846
Compact (Base cost: $20,000)	PHEV 40	$ 9,195	$ 6,299	$ 4,021
	BEV 100	$ 11,134	$ 6,053	$ 3,035
	BEV 200	$ 23,190	$ 14,090	$ 9,746
Mid-size (Base cost: $24,000)	PHEV 40	$ 10,904	$ 7,749	$ 5,324
	BEV 100	$ 12,725	$ 7,385	$ 4,221
	BEV 200	$ 24,781	$ 15,422	$ 10,931
Full-size (Base cost: $29,000)	PHEV 40	$ 13,187	$ 9,558	$ 6,919
	BEV 100	$ 15,067	$ 8,900	$ 5,406
	BEV 200	$ 29,131	$ 18,276	$ 13,235
Compact SUV (Base cost: $29,000)	PHEV 40	$ 12,594	$ 8,923	$ 6,319
	BEV 100	$ 15,557	$ 8,987	$ 5,408
	BEV 200	$ 31,678	$ 19,735	$ 14,382
Standard SUV (Base cost: $40,000)	PHEV 40	$ 15,434	$ 11,689	$ 7,824
	BEV 100	$ 18,214	$ 11,004	$ 5,978
	BEV 200	$ 37,560	$ 23,902	$ 16,747
Pickup Truck (Base cost: 30,000)	PHEV 40	$ 16,054	$ 12,151	$ 8,223
	BEV 100	$ 19,370	$ 11,823	$ 6,676
	BEV 200	$ 39,734	$ 25,399	$ 18,012

The calculated incremental prices of BEV and PHEVs are in line with the range of price premiums observed in the market today (Figure C-10). Estimated premiums for subcompact and compact BEVs are higher than the market data in general due to higher electric range and hence larger battery packs. The discrepancy in the Full-size BEV comparison is due to the fact that the Tesla Model S is a luxury vehicle and does not cost more than its IC engine counterpart (e.g. Audi S6) while the calculated price is based on mainstream full-size vehicles such as the Ford Taurus.

Figure C-10. Comparison of Incremental Prices in 2015 Based on Calculations and Market Data for BEVs and PHEVs



Incremental Cost to the Consumer

The incremental cost to the consumer includes economic incentives offered by the Federal Government and State of California.

The Federal Government is providing tax credits as part of the American Recovery and Reinvestment Act to buyers of plug-in hybrids and electric cars subject to meeting certain eligibility criteria. The amount of credit varies from $2,500 to $7,500, depending on the size of the battery in the car. On the low end of the spectrum, cars with 4 kWh battery packs will qualify for a $2,500 tax credit. The credit maxes out at $7,500 for cars with a 16 kWh battery pack. The incentive begins phasing out after an automaker sells 200,000 vehicles that are eligible for the credit. [1]

Assuming that PEVs will be offered by 18 automakers in the US and each automaker is allowed 200,000 vehicles + 20,000 vehicles sold during the phase-out period, it is estimated that approximately 4 million federal tax rebates will be available to consumers. Since, PEV sales in California makes up 45% of total US sales, the study assumes that 1.8 million federal tax rebates will be available in the state of California through 2025.

In the state of California, the Clean Vehicle Rebate Project (CVRP) offers rebates for the purchase or lease of qualified vehicles. The rebates include a subsidy of $2,500 for light-duty BEVs and $1,500 for light-duty PHEVs that are approved or certified by the California Air Resources Board (ARB).[50] In this

[50] http://plugincars.com/federal-and-local-incentives-plug-hybrids-and-electric-cars.html

analysis, the rebates have been assumed to decline linearly to zero in 2020 due to the reduction in PEV prices.

Based on the incentives described above, the incremental costs to the consumer are significantly reduced. Costs are estimated to decline in future, driven by reduction in battery and powertrain component costs. These cost reductions are taken into account in Ricardo's forecasts, which show that subsidized BEV-100 vehicles in the subcompact and compact segments will not cost more than a conventional vehicle to the consumer in 2020 and beyond. Base costs shown in Table C-10 are the price of conventional IC engine vehicle in each segment.

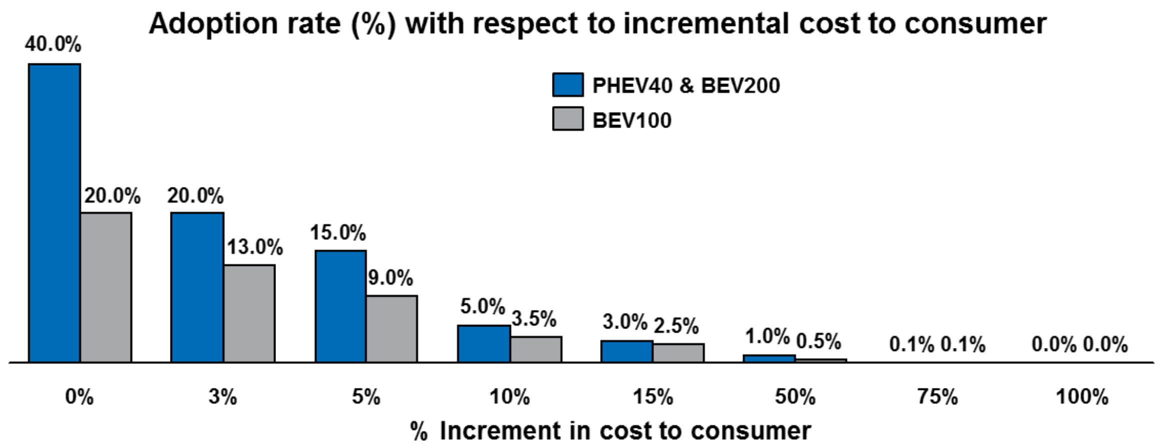
Table C-10. Projected Incremental Cost to Consumer for PHEV 40, BEV 100, and BEV 200 by Vehicle Segment

Vehicle Segments	*PEV Variant*	CY 2015	CY 2020	CY 2025
Subcompact (Base cost: $15,000)	PHEV 40	$ 1,911	$ 1,422	$ 574
	BEV 100	$ 1,369	$ -	$ -
	BEV 200	$ 12,621	$ 7,337	$ 4,558
Compact (Base cost: $20,000)	PHEV 40	$ 1,859	$ 1,276	$ 397
	BEV 100	$ 1,134	$ -	$ -
	BEV 200	$ 13,190	$ 7,403	$ 4,458
Mid-size (Base cost: $24,000)	PHEV 40	$ 3,568	$ 2,726	$ 1,700
	BEV 100	$ 2,725	$ 698	$ -
	BEV 200	$ 14,781	$ 8,735	$ 5,644
Full-size (Base cost: $29,000)	PHEV 40	$ 5,017	$ 3,701	$ 2,462
	BEV 100	$ 5,067	$ 2,213	$ 118
	BEV 200	$ 19,131	$ 11,589	$ 7,948
Compact SUV (Base cost: $29,000)	PHEV 40	$ 3,594	$ 2,237	$ 1,031
	BEV 100	$ 5,557	$ 2,300	$ 120
	BEV 200	$ 21,678	$ 13,048	$ 9,095
Standard SUV (Base cost: $40,000)	PHEV 40	$ 6,434	$ 4,441	$ 2,964
	BEV 100	$ 8,214	$ 3,756	$ 1,118
	BEV 200	$ 27,560	$ 16,653	$ 11,887
Pickup Truck (Base cost: $30,000)	PHEV 40	$ 7,054	$ 4,902	$ 3,363
	BEV 100	$ 9,370	$ 4,574	$ 1,816
	BEV 200	$ 29,734	$ 18,151	$ 13,152

C.5.3 Adoption Rate Model

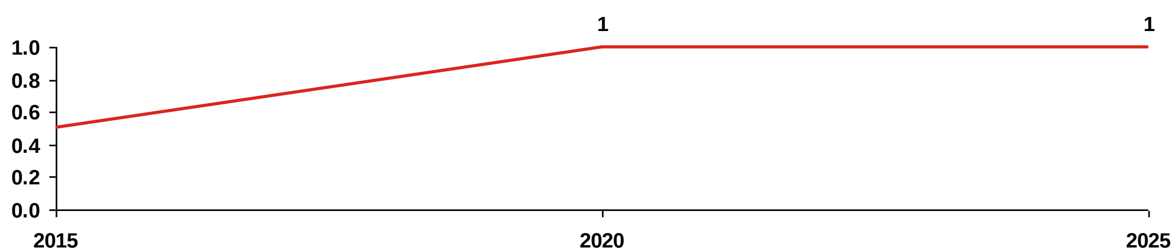
The adoption rate of PEVs is modeled based on consumer acceptance for percentage increments in vehicle costs. The $ increment in cost to the consumer is converted to a percentage increment in cost with respect to conventional IC engine vehicles. This is because a $2000 incremental cost for a full-size vehicle is more acceptable than the same incremental cost in the sub-compact vehicle segment, due to the higher base cost of the vehicle. The model assumes that customers will prefer to buy PEVs if they do not cost more than conventional IC engine vehicles. BEV-200 and PHEV-40 are assumed to be more attractive than BEV-100 due to lower range anxiety. The adoption rates in Figure C-11. shows the % of customers who would elect to buy a plug-in electric vehicle depending on the % increment in cost. This adoption rate model is applied to the projected sales in each vehicle segment based on the % incremental cost in subsequent years.

Figure C-11. Adoption Rate of Plug-In Electric Vehicles Based on Incremental Cost to Consumer



An adjustment factor is applied to the resulting projected BEV and PHEV sales to account for the fact that there are a limited number of plug-in electric models offered in the different vehicle segments. The adjustment factor increases from 0.5 in the year 2015 to 1 in 2020 (Figure C-12). It is assumed that by 2020, a number of OEMs will offer BEVs and PHEVs in all the vehicle segments.

Figure C-12. Adjustment Factor Due to Limited Plug-In Electric Vehicles Offered by OEMs in Different Vehicle Segments



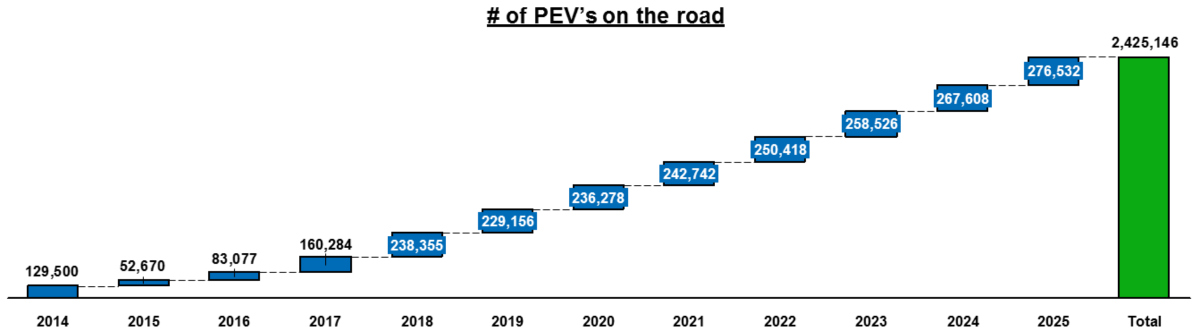
C.5.4 Final Scenario 2 Results: Adoption under the Affordability Model

The plug-in electric vehicle volume forecast in Scenario 2 is based on the affordability model described earlier. Key assumptions for this scenario are:

- Market-leader battery price forecasts, from the Ricardo roadmap of battery system prices
- Limited federal incentives (1.8 million tax rebates in the state of California)
- Gradual reduction in rebates offered by the state of California to $0 in the year 2020

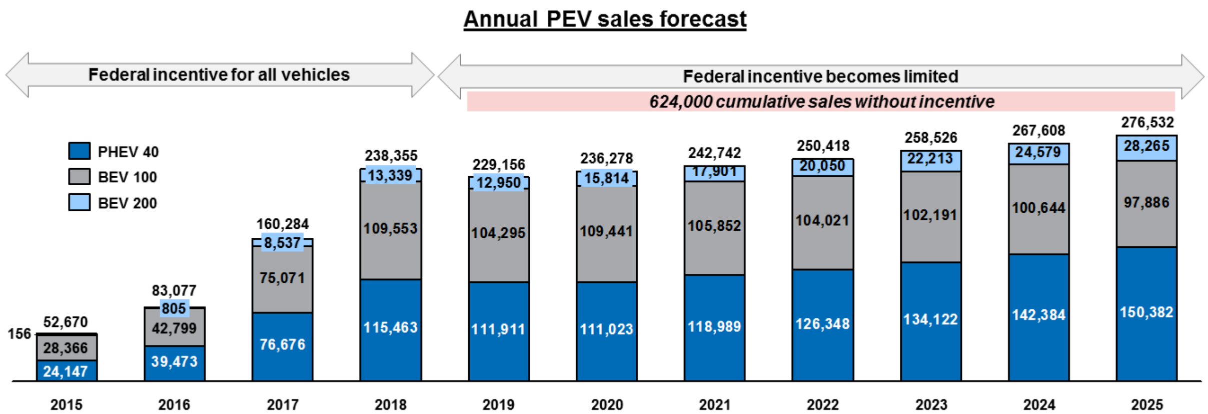
Based on the affordability modelling outputs, the PEV fleet is estimated to reach 2.4 million by 2025 in the state of California (see Figure C-13).

Figure C-13. Cumulative number of plug-in electric vehicles on the road through 2025 in California



In this scenario, the adoption of plug-in electric vehicle is estimated to raise from ~52k/year in 2015 to over 238k/year in 2018 due to the decline in electric powertrain costs. It has been assumed that federal incentives will be available for all eligible PEV purchases during this time period. However, beyond 2018 leading automakers will start to run out of their quota of federal tax rebates. For sustained sales through 2025, it is assumed that federal incentives will be limited beyond 2018 and completely used up by 2025. As a result, it is estimated that a total of 624k vehicles will be sold without any incentives through 2025. The forecast also shows that the sales of PHEVs will be higher than BEV 100 and 200. This is because of the limited range of BEV 100 vehicles even though they are estimated to cost less than PHEV40 vehicles in most of the vehicle segments. Figure C-14 below depicts the annual plug-in vehicle forecast in California, accounting for Federal incentives for EVs.

Figure C-14. Annual plug-in electric vehicle sales forecast in California



Most of the early penetration of PEVs is estimated in the subcompact to full-size segments. But the adoption is expected to pick up in the SUV and pick-up truck segments with the reduction in electric powertrain costs and increasing cost of compliance for conventional powertrains.

C.6 Concluding summary

Annual sales of plug-in electric vehicles (PEVs), comprising both battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) have been estimated for 2015 to 2025 for two scenarios:

- **Scenario 1**: Based on meeting the California ZEV mandate assuming the overall fleet behavior follows the requirements for PEV sales aimed at large volume manufacturers.

- **Scenario 2**: Based on modelling PEV affordability through time, compared to their internal combustion (IC) engine equivalents.

Scenario 1 includes the introduction of fuel cell (FC) vehicle sales starting in 2016 at a relatively modest rate. These sales partially meet the ZEV mandate, and reduce the number of PEV sales required to achieve compliance. The numbers of PEVs on the road predicted from Scenarios 1 and 2 are Figure C-15 and Figure C-16.

Figure C-15. Cumulative number of plug-in electric vehicles on the road through 2025 in California: Scenario 1

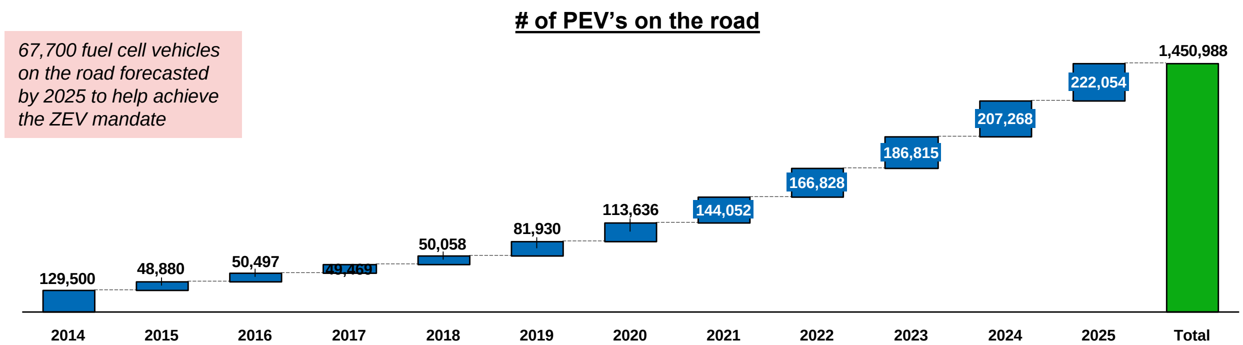
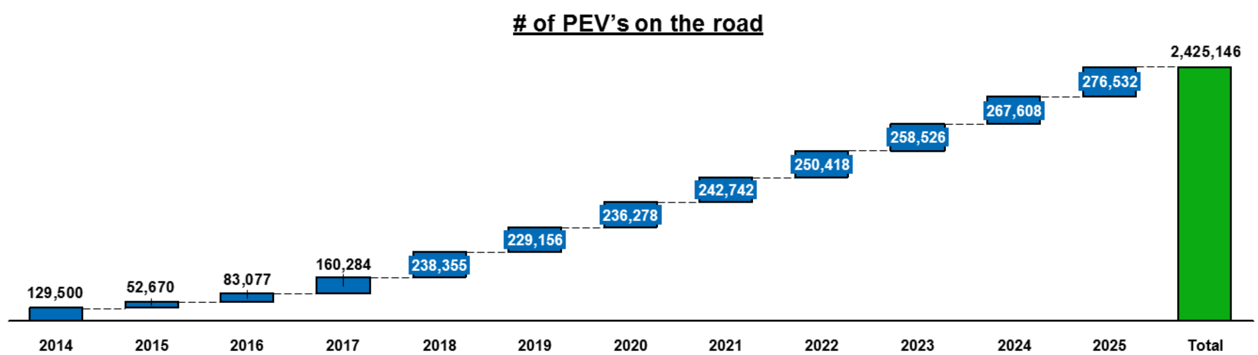
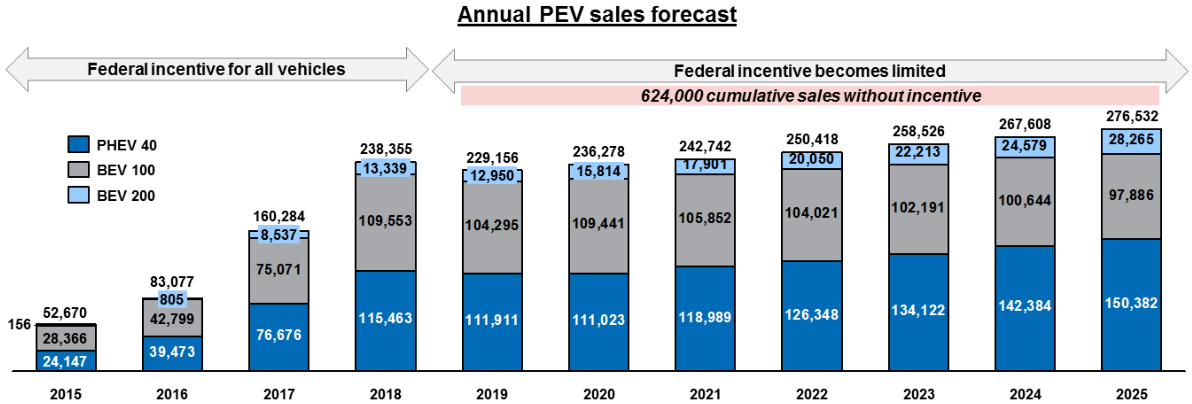


Figure C-16. Cumulative number of plug-in electric vehicles on the road through 2025 in California: Scenario 2



The key and striking difference between the two scenarios are how Scenario 1 projects the PEV fleet size in 2025 to be just below 1.5 million vehicles, whereas Scenario 2 projects the PEV fleet size in 2025 to be 167% of this, around 2.5 million vehicles. The detailed explanation regarding the principal causes are given below. The annual sales of the different types of PEVs are shown in Figure C-17. These detail sales of BEVs with 100- and 200-mile range, and PHEVs with an electric range of 40 miles in each year from 2015 through 2025. When added to the PEV fleet of 129,500 vehicles that are already present on California's roads by the end of 2014, these give the cumulative numbers of PEVs in the two figures above.

Figure C-17. Annual Plug-In Electric Vehicle Sales Forecast in California



For Scenario 2 annual sales numbers are estimated to rise from ~52k/year in 2015 to over 238k/year in 2018. The principal drivers for this are the predicted decline in electric powertrain costs and federal incentives. It has been assumed that federal incentives will be available for all eligible PEV purchases during this time period. However, beyond 2018 leading automakers will start to run out of their quota of federal tax rebates. For sustained sales through 2025, it is assumed that federal incentives will be limited beyond 2018 and completely used up by 2025. As a result, it is estimated that a total of 624k vehicles will be sold without any incentives through 2025. This leads to the initial rapid predicted growth followed by little further growth after 2018. This, in turn, generates the differences in fleet numbers between the two scenarios.

Some of the key differences between the two scenarios are:

- Meeting the ZEV mandate involves little growth in PEV sales from actual 2015 sales to 2018 sales (2.4%) whereas based on affordability, large growth from actual 2015 sales to projected 2018 sales (453%), for reasons summarized above.
- Meeting the ZEV mandate involves large growth in PEV sales from 2018 to 2025 (444%), in-line with the 489% increase in the "Total ZEV percent requirement" whereas based on affordability, only very modest growth is seen from 2018 to 2025 (16%), as the federal incentive becomes limited.
- In 2025 total PEV sales are 250,000 ± around 10% for the two scenarios.
- However, when based on affordability, in 2025 far higher PHEV sales are predicted (150,000) than for Scenario 1 (89,310).
- Also, when based on affordability, in 2025 far lower BEV-200 sales are predicted (28,265) than for Scenario 1 (53,096).

Appendix D - 300 Locations of Highest Predicted Unmet Charging Need in PG&E's Service Territory in 2025

The following table is a list of the 300 identified locations of highest predicted unmet charging need in PG&E's service territory in 2025. Each location represents a 1-mile circular bubble around the specified latitude/longitude. The table is sorted and prioritized by maximum number of new chargers needed in 2025 at each location.

Table D-1. 300 Locations of Highest Predicted Unmet Charging Need in PG&E's Service Territory in 2025

Location number (of 300 total)	Location Longitude	Location Latitude	Number of new chargers needed in 2025 at location: Under ZEV Goal adoption scenario (1.45M EVs by 2025)	Number of new chargers needed in 2025 at location: Under Affordability adoption scenario (2.4M EVs by 2025)	Number of charger sites in location bubble (see Section 4.6)
1	-122.409821	37.786539	10	17	357
2	-121.955856	38.366661	8	14	34
3	-122.401344	37.782007	8	14	389
4	-122.049987	38.258226	7	13	16
5	-121.986224	38.353505	7	13	168
6	-122.135242	38.217811	7	13	23
7	-119.043575	35.353863	7	12	96
8	-121.740285	38.547076	7	11	25
9	-121.547365	38.576899	6	11	15
10	-122.427109	37.768318	5	9	110
11	-121.650111	37.125055	5	9	8
12	-122.061584	37.895393	5	8	174
13	-121.714546	37.699474	5	8	15
14	-122.264313	37.81599	4	7	218
15	-122.417122	37.804733	4	7	170
16	-121.927368	37.694584	4	7	141
17	-122.006935	37.062634	4	7	30
18	-121.273279	38.219749	4	7	4
19	-120.668684	35.275198	4	7	34
20	-122.726513	38.456327	4	7	20
21	-120.381792	37.980796	4	7	21
22	-121.459088	37.754337	4	7	127
23	-122.262863	37.795422	4	6	287
24	-122.402725	37.76408	3	6	190
25	-122.059397	37.933155	3	6	50
26	-118.93158	35.353976	3	6	15
27	-118.9431943	34.98858619	3	6	11
28	-121.982474	37.229589	3	6	49
29	-122.321693	37.985577	3	5	10
30	-122.293818	37.840191	3	5	110
31	-122.545082	38.005322	3	5	22
32	-121.876625	37.696987	3	5	59
33	-122.323738	37.567463	3	5	86
34	-122.266099	37.866787	3	5	96
35	-122.229188	37.798993	3	5	156
36	-122.297758	37.88746	3	5	22
37	-122.04555	37.969978	3	5	102
38	-122.318446	37.911392	3	5	11
39	-122.331847	37.963097	3	5	9
40	-121.971098	37.768586	3	5	49
41	-121.071836	38.653565	3	5	12
42	-119.79452	36.73984	3	5	126

Location number (of 300 total)	Location Longitude	Location Latitude	Number of new chargers needed in 2025 at location		Number of charger sites in location bubble (see Section 4.6)
			Under ZEV Goal adoption scenario (1.45M EVs by 2025)	Under Affordability adoption scenario (2.4M EVs by 2025)	
43	-119.789699	36.832878	3	5	16
44	-122.531547	37.971564	3	5	59
45	-121.076595	38.904557	3	5	10
46	-120.676873	39.2911465	3	5	1
47	-121.360551	38.021337	3	5	39
48	-120.8055612	38.72730897	3	5	73
49	-122.385178	37.596329	3	5	40
50	-122.403811	37.661387	3	5	37
51	-120.435866	34.955579	3	5	37
52	-121.580247	37.013537	3	5	9
53	-121.805501	37.251363	3	5	14
54	-121.887778	37.337722	3	5	211
55	-122.035652	36.972305	3	5	86
56	-122.445651	37.77307	3	5	109
57	-122.32404	37.932245	3	4	13
58	-121.061976	39.215103	3	4	104
59	-121.390334	38.114138	3	4	11
60	-121.241641	37.954122	3	4	24
61	-121.91479	37.333549	3	4	20
62	-121.826553	38.445914	3	4	58
63	-122.255583	38.123368	3	4	210
64	-120.622897	35.121563	3	4	98
65	-122.566238	38.10577	2	4	38
66	-121.204584	38.79976	2	4	43
67	-119.774793	36.807342	2	4	11
68	-122.295432	37.868382	2	4	30
69	-122.271029	37.827381	2	4	97
70	-120.968823	38.6607	2	4	11
71	-122.040502	37.955101	2	4	11
72	-122.2452	38.1421	2	4	20
73	-122.367239	38.406761	2	4	57
74	-121.204317	37.797637	2	4	8
75	-121.320828	37.986883	2	4	199
76	-122.350934	37.581868	2	4	64
77	-122.220916	37.481118	2	4	100
78	-122.307378	37.545403	2	4	82
79	-121.962	37.2353	2	4	23
80	-121.920147	37.362292	2	4	55
81	-121.946827	37.260074	2	4	22
82	-121.768197	37.235362	2	4	11
83	-122.023004	37.367194	2	4	25
84	-121.845191	37.287715	2	4	100
85	-121.772613	36.916569	2	4	14
86	-121.661222	39.281805	2	4	26
87	-121.643385	39.127437	2	4	85
88	-122.19739	39.901668	2	4	5
89	-121.756034	38.677455	2	4	15
90	-122.895533	38.473737	2	4	20
91	-122.58027	38.575162	2	4	13
92	-120.649447	35.462287	2	4	47
93	-121.690181	38.160831	2	4	39
94	-121.758975	38.561044	2	4	74

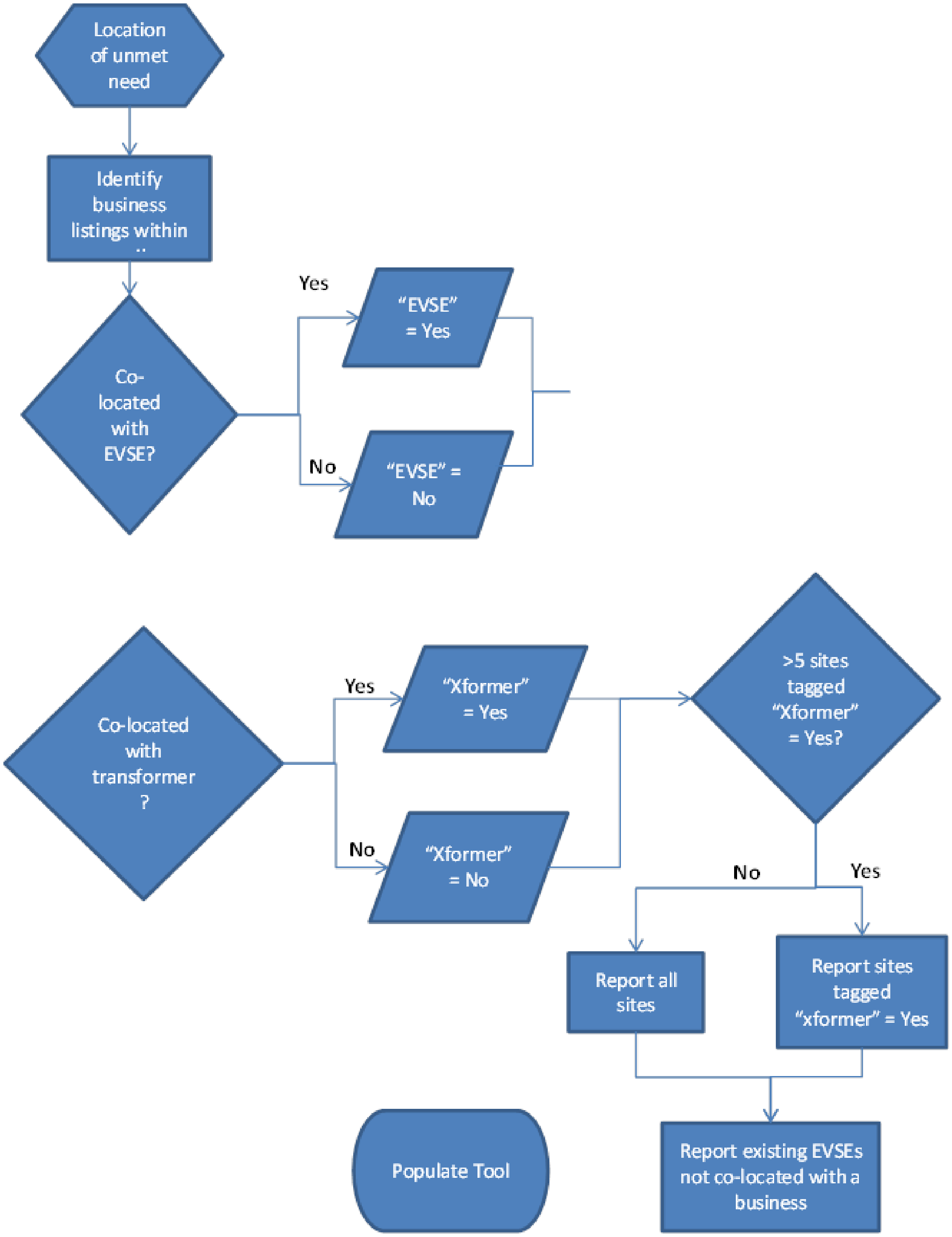
Location number (of 300 total)	Location Longitude	Location Latitude	Number of new chargers needed in 2025 at location		Number of charger sites in location bubble (see Section 4.6)
			Under ZEV Goal adoption scenario (1.45M EVs by 2025)	Under Affordability adoption scenario (2.4M EVs by 2025)	
95	-121.9994553	37.82331779	2	3	9
96	-122.634758	38.236774	2	3	37
97	-122.469696	37.671413	2	3	30
98	-121.945001	37.407237	2	3	30
99	-121.94707	37.542309	2	3	67
100	-122.08453	37.661595	2	3	39
101	-122.089326	37.631443	2	3	92
102	-121.771115	37.68099	2	3	15
103	-122.261408	37.850512	2	3	47
104	-122.195435	37.787517	2	3	94
105	-122.268651	37.527936	2	3	40
106	-122.090559	37.691985	2	3	11
107	-120.778808	38.352915	2	3	62
108	-120.3112695	38.76982401	2	3	2
109	-122.269884	37.560901	2	3	46
110	-122.06897	37.378303	2	3	35
111	-120.068153	36.968669	2	3	8
112	-121.052168	37.058094	2	3	1
113	-121.015727	37.103326	2	3	30
114	-121.882545	36.599963	2	3	40
115	-121.664704	36.799578	2	3	11
116	-122.300301	38.322512	2	3	22
117	-122.472572	37.718163	2	3	64
118	-122.402144	37.724109	2	3	12
119	-122.42316	37.740249	2	3	47
120	-122.471171	37.780788	2	3	69
121	-121.273051	37.960148	2	3	51
122	-120.686716	35.625388	2	3	14
123	-122.470264	37.695751	2	3	24
124	-122.4238	37.6257	2	3	19
125	-122.2535	37.5013	2	3	12
126	-122.250749	37.429137	2	3	21
127	-121.949827	37.284493	2	3	29
128	-122.032603	37.335245	2	3	33
129	-121.91064	37.454108	2	3	5
130	-122.09738	37.40346	2	3	38
131	-122.088994	37.388303	2	3	49
132	-121.894017	37.372926	2	3	31
133	-121.922317	37.30612	2	3	31
134	-121.995159	37.28896	2	3	32
135	-122.028893	37.395153	2	3	31
136	-121.964827	36.973141	2	3	22
137	-122.288152	37.802639	2	3	202
138	-119.016467	35.380245	2	3	74
139	-122.109662	37.692035	2	3	73
140	-122.476906	37.76148	2	3	334
141	-120.57487	38.76351001	2	3	23
142	-122.245111	37.858137	2	2	22
143	-122.062336	37.689422	2	2	6
144	-119.628681	36.560714	2	2	34
145	-119.794171	36.998182	2	2	1
146	-122.442444	37.717599	2	2	8

Location number (of 300 total)	Location Longitude	Location Latitude	Number of new chargers needed in 2025 at location		Number of charger sites in location bubble (see Section 4.6)
			Under ZEV Goal adoption scenario (1.45M EVs by 2025)	Under Affordability adoption scenario (2.4M EVs by 2025)	
147	-122.451427	37.7456	2	2	10
148	-121.875102	37.251017	2	2	68
149	-121.886823	37.309282	2	2	168
150	-121.9753	37.3163	2	2	14
151	-121.82834	37.320762	2	2	144
152	-121.851844	37.334302	2	2	147
153	-119.718629	36.765137	1	3	7
154	-120.3877015	39.3264867	1	2	5
155	-121.5683	40.36100001	1	2	1
156	-120.951172	39.09757	1	2	26
157	-122.144561	38.053351	1	2	73
158	-122.1805956	37.87882314	1	2	11
159	-122.5051837	37.87153958	1	2	16
160	-122.116974	37.893173	1	2	20
161	-121.27504	38.021606	1	2	7
162	-122.807259	38.067894	1	2	28
163	-121.896348	37.417349	1	2	77
164	-122.127186	37.624448	1	2	10
165	-121.868184	37.27584	1	2	68
166	-121.972834	37.56746	1	2	17
167	-122.013582	37.54385	1	2	99
168	-122.053164	37.552071	1	2	99
169	-122.107	37.666579	1	2	22
170	-121.988774	37.521926	1	2	44
171	-121.875716	37.361263	1	2	16
172	-122.032672	37.303021	1	2	8
173	-121.829982	37.354501	1	2	124
174	-120.550376	38.077276	1	2	44
175	-122.140016	37.70029	1	2	14
176	-122.160893	37.723369	1	2	45
177	-122.070472	37.590061	1	2	114
178	-121.807377	39.726763	1	2	10
179	-121.85142	39.725997	1	2	159
180	-121.83879	38.002301	1	2	37
181	-122.119396	37.997697	1	2	121
182	-121.889073	38.017454	1	2	15
183	-119.844773	36.793475	1	2	40
184	-119.735912	36.728659	1	2	85
185	-120.385031	36.75933	1	2	34
186	-124.157759	40.802901	1	2	161
187	-122.211451	37.773915	1	2	25
188	-119.038872	35.324658	1	2	94
189	-119.074441	35.441345	1	2	19
190	-122.044905	37.382684	1	2	46
191	-122.5325	37.9379	1	2	14
192	-122.528537	37.900154	1	2	146
193	-119.970047	37.489292	1	2	41
194	-120.836206	37.056627	1	2	5
195	-121.792402	36.684321	1	2	7
196	-122.475855	37.744536	1	2	10
197	-122.388173	37.743048	1	2	40
198	-121.15306	38.159863	1	2	23

Location number (of 300 total)	Location Longitude	Location Latitude	Number of new chargers needed in 2025 at location: Under ZEV Goal adoption scenario (1.45M EVs by 2025)	Under Affordability adoption scenario (2.4M EVs by 2025)	Number of charger sites in location bubble (see Section 4.6)
199	-122.141761	37.462969	1	2	20
200	-122.17735	37.450385	1	2	55
201	-122.451875	37.64341	1	2	9
202	-122.4338	37.655	1	2	10
203	-122.052126	37.322605	1	2	82
204	-122.0664	37.405676	1	2	13
205	-121.843388	37.369863	1	2	36
206	-121.8332	37.251	1	2	6
207	-121.917207	37.263034	1	2	108
208	-121.99414	37.309637	1	2	115
209	-121.997203	37.396037	1	2	29
210	-121.947606	38.417337	1	2	4
211	-122.702352	38.446505	1	2	138
212	-122.6956	38.3473	1	2	7
213	-121.586848	39.14856301	1	2	11
214	-120.528935	38.447699	1	1	8
215	-123.795126	40.100423	1	1	40
216	-120.2776	34.7427	1	1	7
217	-122.321677	40.733596	1	1	2
218	-120.2521	37.8261	1	1	2
219	-120.8295178	39.56017952	1	1	14
220	-120.6305282	39.56684171	1	1	3
221	-120.914339	39.93433701	1	1	14
222	-121.315987	39.93359	1	1	1
223	-121.224915	40.312046	1	1	23
224	-121.657564	40.88507301	1	1	30
225	-124.0779705	41.28345166	1	1	12
226	-123.048349	38.334951	1	1	31
227	-123.399303	38.651639	1	1	1
228	-123.692715	38.908707	1	1	13
229	-120.250302	36.253948	1	1	16
230	-121.335137	36.430109	1	1	39
231	-121.801807	36.26488112	1	1	7
232	-121.4457121	35.87653192	1	1	1
233	-121.082746	35.563733	1	1	63
234	-119.6546643	37.33208338	1	1	79
235	-119.5830291	37.74632958	1	1	4
236	-119.9391615	37.81607364	1	1	3
237	-122.8931047	40.35985596	1	1	4
238	-123.6068172	40.49263155	1	1	2
239	-122.429373	37.46441	1	1	83
240	-120.626661	36.638229	1	1	8
241	-123.7151601	39.86501199	1	1	9
242	-119.9591115	35.98764796	1	1	6
243	-120.861962	35.95254135	1	1	2
244	-123.211594	39.16928316	1	1	42
245	-122.1434389	38.73540415	1	1	3
246	-121.70215	37.936901	1	1	109
247	-122.06664	37.63271	1	1	86
248	-121.874985	37.66292	1	1	148
249	-122.177848	37.765808	1	1	92
250	-122.021475	37.587241	1	1	6

Location number (of 300 total)	Location Longitude	Location Latitude	Number of new chargers needed in 2025 at location		Number of charger sites in location bubble (see Section 4.6)
			Under ZEV Goal adoption scenario (1.45M EVs by 2025)	Under Affordability adoption scenario (2.4M EVs by 2025)	
251	-122.232289	37.825332	1	1	51
252	-121.876363	39.772932	1	1	31
253	-121.5714945	39.52042561	1	1	32
254	-120.8284	38.1911	1	1	27
255	-122.161007	39.156345	1	1	21
256	-121.968854	37.955894	1	1	7
257	-122.041456	37.99033	1	1	24
258	-122.024863	37.938592	1	1	22
259	-119.922382	36.837602	1	1	11
260	-119.869057	36.820614	1	1	10
261	-119.454542	36.596563	1	1	12
262	-122.212519	39.524337	1	1	36
263	-124.154313	40.578439	1	1	40
264	-119.075267	35.383437	1	1	21
265	-119.654242	35.616163	1	1	14
266	-119.229168	35.681637	1	1	31
267	-119.34913	35.587062	1	1	40
268	-119.780018	36.302063	1	1	86
269	-122.6246	38.9506	1	1	49
270	-122.7209	38.8353	1	1	1
271	-120.259029	37.123271	1	1	46
272	-123.8057099	39.44231	1	1	121
273	-123.351746	39.404276	1	1	71
274	-121.130334	36.210497	1	1	14
275	-121.669922	36.682599	1	1	15
276	-121.2866853	38.81411484	1	1	37
277	-121.225788	38.743837	1	1	103
278	-121.3933	36.84226	1	1	15
279	-121.425502	38.22843129	1	1	2
280	-122.490769	37.650767	1	1	41
281	-122.241047	37.465237	1	1	84
282	-122.336905	37.517829	1	1	30
283	-120.191	34.6124	1	1	9
284	-119.679	34.9457	1	1	2
285	-121.8576	37.4033	1	1	34
286	-121.996828	37.370975	1	1	22
287	-122.05192	37.351937	1	1	6
288	-121.382427	36.986294	1	1	8
289	-122.08848	37.353861	1	1	65
290	-122.297546	40.454151	1	1	62
291	-122.664019	38.463924	1	1	60
292	-123.016982	38.788898	1	1	32
293	-122.461	38.2356	1	1	6
294	-122.468982	38.29312	1	1	10
295	-122.10002	40.028878	1	1	15
296	-122.240275	40.176277	1	1	88
297	-119.396326	36.545563	1	1	9
298	-121.974	38.8816	1	1	3
299	-121.559165	39.127737	1	1	33
300	-120.698357	35.695642	1	1	3

Appendix E - Algorithm Implemented for Potential Host Site Identification



Appendix F - Guidelines for DCFC Siting from Industry Expert Interviews

While the interactive map and the Micro-Siting Tool are specific to PG&E's territory and provides useful information for local installers, perhaps the most useful industry finding is the best practices guide, outlined below.

The following stakeholders from over 20 organizations were interviewed:

- Anand Gopal, Scientist, and Colin Sheppard, Research Associate, *Lawrence Berkeley National Laboratory* [Interview]
- Alex Keros, Manager and Senior Project Engineer, *General Motors* [Survey]
- Ashley Horvat, Vice President Strategic Initiatives, *PlugShare,* formerly State of Oregon Chief EV Officer, *Oregon Department of Transportation* [Interview]
- Bahram Fazeli, Director of Research and Policy, *Communities for a Better Environment* [Interview]
- Bill Boyce, Manager, Electric Transportation, *Sacramento Municipal Utility District* [Survey]
- Charlie Botsford, Business Development, *AeroVironment* [Survey]
- Chris Walt, Program Manager – EV Infrastructure, *Tesla Motors* [Survey]
- Daniel Schmidlkofer, Maintenance Manager, *Fred Meyer (host site for AeroVironment & Blink chargers)* [Survey]
- David Carter, Senior Research Engineer, and Jerome Carman, Research Engineer, *Schatz Energy Research Center* [Interview]
- Jim Francfort, Lead Advanced Vehicle Researcher, *Idaho National Laboratory* [Interview]
- Joel Espino, Environmental Equity Legal Counsel, *The Greenlining Institute* [Interview]
- John Halliwell, Senior Project Manager, *Electric Power Research Institute* [Interview]
- Josh Boone, Deputy Executive Director, *California Plug-in Electric Vehicle Collaborative* [Interview]
- Ian Thompson, SVP Global Solutions Consultancy and Debbie Miggins, Vice President, Location Services, *Kalibrate* [Interview]
- Marc Melaina, Senior Engineer, *National Renewable Energy Laboratory* [Interview]
- Marvin Moon, Director of Engineering and EV Program Manager, *Los Angeles Department of Water and Power (LADWP)* [Survey]
- Mike Tinskey, Director of Vehicle Electrification and Infrastructure, *Ford Motor Company* [Survey]
- Stephen Kosowski, Manager, Long Range Planning and Strategy, *Kia Motors America* [Survey]
- Terry O'Day, Vice President, California, *NRG EVgo* [Survey]
- Thomas Garetson, Director, *Electric Transportation Engineering Corp* and Director, *Ecotality North America* [Interview]

Interviews and published works reveal that stakeholders have been broadly aiming to choose DCFC sites that will:

1. Minimize installation costs;
2. Support EV adoption; and
3. Spread the benefits of EVs amongst all groups (captured in the Micro-Siting Tool as Supporting Disadvantaged Communities)

These objectives do not always align, and stakeholder opinions vary as to the optimal weighting and acceptable tradeoffs between the three outcomes. The remainder of this section summarizes the available literature, as well as expert opinions to guide planners, policymakers, and those on the ground in achieving each of the three aims.

F.1 Siting DCFCs to Maximize EV Adoption

Maximizing EV adoption is defined here broadly to include both maximizing EV sales and maximizing electric vehicle miles travelled (VMT) that are substituted for gasoline-powered VMT. Neither the literature nor interviewees tended to differentiate between the two adoption goals when it came to discussing DC fast charger siting.

Narrowing down the best sites for individual chargers has posed challenges for planners and on-the-ground installers, but recent pilots and rollouts have provided valuable insights. Written and verbal accounts of such rollouts reveal three important perspectives for siting public chargers in order to maximize EV adoption: drivers, charger site hosts, and charging network developers. Written literature and expert interviews revealed that considering all three of these points of view is critical to building a DCFC network that will be used regularly, relied upon by drivers, and capable of being built in a timely manner.

The Driver Perspective

Interviewees indicated that planners aiming to install DCFCs to maximize EV adoption should focus broadly on geographic areas that face, or are predicted to face, unmet demand for public charging. Unmet demand can be caused by either insufficient EV charging capacity in areas that see (or will see) high numbers of EV drivers, or ‘gaps’ in the charging network, i.e. a lack of charging infrastructure along travel corridors. Focusing on the former will alleviate congestion in areas of high charging need, while focusing on the latter can alleviate consumer range anxiety and allow for longer-range EV trips.

Interviewees considered it important to fill both forms of unmet demand. Interviewees also suggested that the chicken-and-egg relationship between charger availability and electric vehicle purchases made it important to plan for *future* EV adoption scenarios, rather than focusing only on *current* unmet need. This process of choosing charger locations at the regional level to meet unmet demand and fill gaps in a network can be referred to as ‘macro-siting[51].’

After pinpointing areas of high unmet charging demand, planners should choose specific parking sites (i.e. businesses, parking lots, recreation locations, etc.) within these areas that offer the highest level of comfort, safety, accessibility, amenity and visibility to drivers. By selecting these specific parking sites, l driver confidence and comfort in using the charging network will be improved. This process of narrowing in on individual parking sites for EV charging within a region where charging is generally needed can be referred to as ‘micro-siting.’[52]

[51] This term is used, for example, in the North Coast Plug-in Electric Vehicle Readiness Plan, funded by the California Energy Commission and authored by the Schatz Energy Research Center, the Redwood Coast Energy Authority, GHD, and PG&E (2014).
[52] *Ibid.*

The Charger Site Host Perspective

A number of interviewees insisted that a dedicated and supportive host site is critical to support the permitting, design, installation, and ongoing operations of an EV charger. Finding motivated host sites has been a significant challenge in charger rollouts thus far. Interviews revealed that the benefits that accrue to host sites rely heavily on future EV adoption and are difficult to quantify. These uncertain benefits combined with significant installation and other costs make it a challenge for prospective hosts to assess a concrete business case.

In an analysis of profitability from the site host perspective, UCLA's Luskin School[53] find that "site owners have little control over revenues and costs with respect to EVSEs, and unfortunately, site owners do not benefit financially from the current value chain." To make a profit from EV charging infrastructure, the Luskin Center found, site hosts would need to see a significant increase in driver turnover, charger utilization and/or driver willingness to pay a mark-up on electricity. Low EV adoption rates and the prevalence of home charging and free public charging today make this growth difficult to rely on. Demand charges can also negatively impact the business case for charger hosts if they are required to pay for the electricity. In 2012, the State of Hawaii facilitated the installation of six DCFCs by partnering with private entities like gas stations and EVSE provider AeroVironment. Most of the EV charging rollout case studies found in the literature were installed with the assistance of grant money, and were installed without an expectation that the chargers would generate profits from electricity sales. However, as private investment begins to install DCFCs, this will likely change.

Interviewees suggested a number of potential locations which are discussed in depth in the report. These locations ranged from office buildings, government buildings, ski resorts, parking garages, wineries, and hotels. Several interviewees also recommended banks as good targets for EV charging, especially in rural areas. This is because they often have parking spaces with low congestion, due to decreasing foot traffic since the age of internet and mobile banking. Gas stations, while obvious as good, visible locations for drivers, have apparently been less willing to host chargers thanks to the very high value they place on each available 'pump space.' Interviewees were hopeful that this would change over time, with increases in EV adoption leading to more reliable EV charging revenue. NYSERDA (n.d.) provides a final siting success story: doctors' offices and medical campuses. Doctors' appointments match well with DCFC charging duration, and doctors have been found to be sympathetic to the need for EV adoption as a way to improve air quality and therefore reduce illness.

Despite this list of successful targets, interviewees indicated that potential host sites have many concerns about installing an EV charger. Many of these concerns stem from unfamiliarity with the business case and the risks involved in hosting a charger. Potential hosts often communicate a lack of clarity on charger ownership, and on their responsibility for installation costs, electricity costs, and future maintenance costs. The EV Project, a program funded by the US Department of Energy that installed approximately 14,000 Level 2 chargers and 300 DCFCs between 2010 and 2013, identified the lack of knowledge about operating costs and revenue opportunities as a significant issue when attempting to execute a contract with a site owner.[54] Potential hosts have also expressed concern about liability in the case of driver injury or equipment malfunction. According to interviewees, clear and

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[53] Chang, D. et al. (2012) *Financial Viability of Non-Residential Electric Vehicle Charging Stations.* Luskin Center for Innovation.

[54] Francfort, J. (2013) *Plug-in 2013 - EV Project Charging Infrastructure Deployment Costs, Cost Drivers and Use,* Idaho National Laboratory.

straight-forward contracting between a host site and an EV charging network service provider can help alleviate these concerns. Education and ongoing engagement with site hosts by charging network service providers is also essential.[55]

Interviewees revealed that potential hosts have also been concerned with the loss of parking spaces involved with hosting a charger. The charging infrastructure projects reviewed indicate that unlike gasoline infrastructure for conventional vehicles, EV charging has not been located in purpose-built spaces. Instead, EV charging generally relies on re-purposing existing parking. Interviewees reported encountering potential site hosts that were concerned about backlash or loss of patronage from conventional vehicle drivers that cannot find parking or feel mistreated when parking spots are reserved for EVs.

The Charging Network Developer Perspective

In this discussion, a charging network developer is defined as any entity responsible for the rollout of multiple chargers at multiple sites. These can include private-sector charging networks, cities and counties, utilities, automakers, and others. The network developer must manage their relationships with site hosts, EV drivers, utilities, and governments to successfully develop their network of chargers. Broadly, charging network developers are responsible for:

- Finding willing site hosts
- Negotiating site leases and site access
- Site design and permitting
- Coordinating (or performing) interconnection to the electric grid
- Installation and Commissioning

Depending on the arrangement with charger host sites, network developers may also be responsible for ongoing operations and maintenance of chargers.

Published works and interviews suggest that the most difficult hurdle for a network provider is finding willing hosts and contracting with charger sites. The insights provided give some guidance to planners trying to narrow in on sites that may be willing to host chargers. However, it is clear from interviews that network developers need to do significant work ‘on the ground’ to narrow in on sites that will be willing to champion EV charger development on their property.

Even after a willing host is found, leasing the site can be a challenge. One of the lessons learned from the DC fast charger installations for the West Coast Electric Highway (WCEH) in Oregon and Washington was that “lease negotiation was by far the most time-consuming, tenuous, and difficult part of the process to site and build a WCEH fast charge station.” During the build-out of the WCEH, the property owner legal review of the lease agreement typically required an average of 6 months to secure. For one site located on U.S .Forest Service land, lease negotiations took two years.[56]

Network providers must also consider customer engagement and management. Enforcement of parking signage is also an issue for network developers, since it affects EV charger availability and makes

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[55] Larson, M. (2012) *Lessons Learned: The Early Adoption of Electric Vehicle Charging Stations from the Perspective of Oahu’s Commercial Properties.* Honolulu Clean Cities.

[56] Botsford C. (2014) *The West Coast Electric Highway.* EnergyCentral.com. Available at: http://www.energycentral.com/enduse/electricvehicles/articles/3017/The-West-Coast-Electric-Highwa

charging more attractive to potential hosts worried about conflicts between EV drivers and drivers of conventional vehicles.

F.2 Siting DCFCs to Minimize Cost

In addition to promoting EV adoption, network developers and site hosts must be incentivized by minimizing DCFC installation costs. The following discussion aims to summarize available literature and interviews related to DCFC installation costs and cost drivers. The discussion covers three key aspects of DCFC costs:

1. Steps involved in the installation process
2. DCFC cost estimates in the literature
3. Major cost drivers and recommendations for minimizing costs

Steps Involved in the Installation Process

In order to assess the total cost of a DCFC installation, it is crucial to understand the steps that occur during the installation process that create project costs. The following steps are involved in the installation process, which is based on a compilation of interviews and the steps were taken from a 2013 report authored by the Community Energy Association for BC Hydro (CEA 2013):

1. **Comply with funding requirements:** The first step is driven by how the project is funded. If the project has any federal, state or local government funding, chances are there are several grant requirements to adhere to, all of which entail a certain cost to compliance. This includes prevailing wage, but also some other not as widely known costs such as environmental assessments, hazardous material avoidance, and soil testing to comply with environmental clearances and safety rules and regulations.
2. **Review other permitting authority requirements:** Even if the project isn't publically funded, a project proponent may still be required by other governing authorities to adhere to standards and processes. Thus, public planning, public siting locations, traffic patterns, street signage and other permitting authority requirements should be reviewed in advance.
3. **Evaluate the utility costs:** Utility costs of a particular site should be considered, including the utility rate structure, availability of power, metering, total load management, conduit size and length, power pole upgrades, and overhead or underground requirements for extending power in a particular locality.
4. **Collect feedback from local EV drivers:** If available, include input from drivers and potential adopters on location, usage, etc.
5. **Conduct a needs assessment:** Work with charger providers to conduct a needs assessment by considering factors such as charger make and model, charger quantity based on current and future EV needs, electrical loads, and the desired user payment mechanisms.
6. **Conduct a detailed site evaluation: C**ollect information including the location of parking areas to host the charger, ADA compliance, flood zone risks, available electric power and infrastructure, and other important considerations. Interviewees stressed the importance of evaluating ADA considerations as soon as possible in order to determine the cost of extending power to an area that can accommodate the requirements of ADA parking spaces. Also, when evaluating sites, interviewees strongly recommend taking the time necessary to assess the ownership conditions, so as to plan for how many easements may be needed to maintain site control.
7. **Consult with surrounding local business owners and property owner of site**s: Consider cost sharing, maintenance, vandalism, lighting, shelter and other owner concerns.

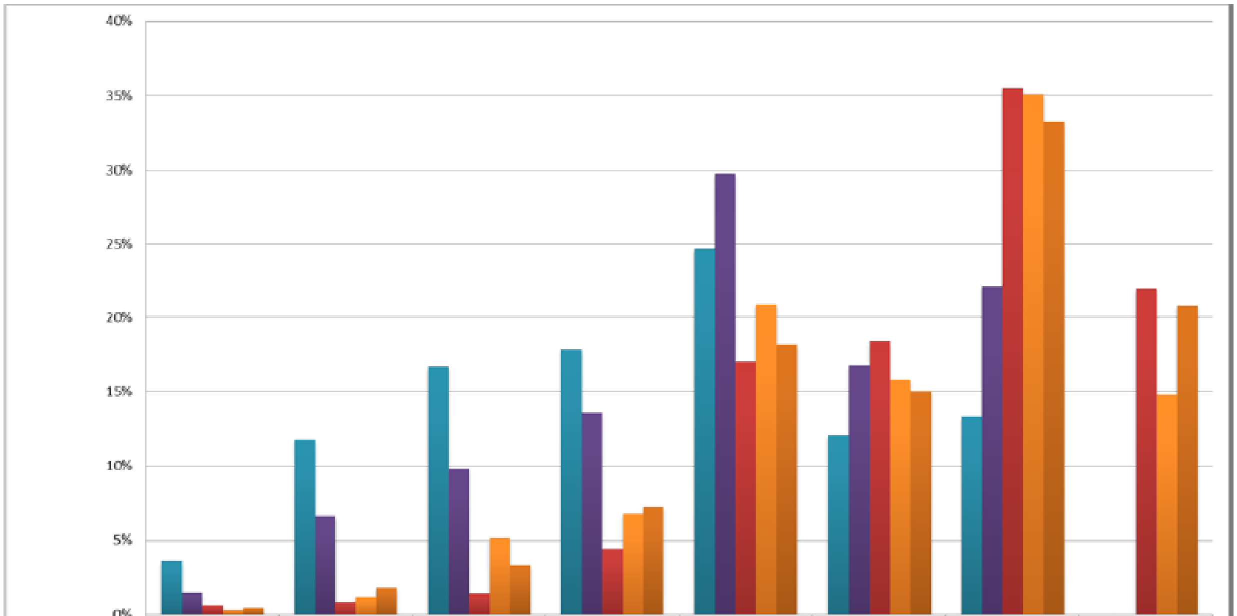
8. **Determine electric contractor costs:** Assess items such as accessibility considerations, proximity to utility panel, building code requirements, and boring and trenching needs.
9. **Synthesize these results into a recommendation to the host site owner:** After coming to consensus on aforementioned elements, develop a site plan, including charger location drawing, electrical plan, meter requirements, surface area improvements like cutting into concrete, trenching under pavement (how deep to trench based on local water levels and avoidance requirements), and contractor cost estimate.
10. **Obtain permits:** Attain necessary permits from the approving authority with your certified contractor, ensuring all building codes are satisfied.
11. **Conduct installation by Electrical Contractor:** An electrical contractor should conduct the installation, including setting the template for the concrete pad, digging through surface area to extend power to charger location, completing the utility upgrade with the pad mounted or pole mounted transformer in place, pouring the concrete pad, setting up the charger, turning on power to the site, and commissioning the station.
12. **Complete installation:** Complete installation, including final inspection and approvals.

F.3 Siting DCFCs for Disadvantaged Communities

High-income households have represented the majority of EV purchasers thus far. A study by UC Davis[57] combined data from the Caltrans 2012 Travel Survey with surveys of those receiving the California Air Resources Board's Clean Vehicle Rebate to investigate income differences between purchasers of traditional internal combustion engine (ICE) vehicles and EVs. The study showed that purchasers of new 2012-model-year EVs were likely to have higher incomes than purchasers of new ICE vehicles: 51% of new ICE car buyers (or leasers) reported an annual income less than $100,000, compared with only 32% of hybrid owners and 11% of PEV owners. On the high end of the income spectrum, only 13% of ICE buyers reported an income higher than $200,000 per year, versus 34% of PEV owners. Twenty percent of PEV owners declined to state their income, meaning this difference could be even starker. provides additional detail.

[57] Tal, G. and M. Nicholas (2013) *Studying the PEV Market in California: Comparing the PEV, PHEV and Hybrid Markets.* Available at http://pevcollaborative.org/sites/all/themes/pev/files/EVS27_Gil%20Tal%20Mike_11_14_final.pdf

Figure F-1. Annual Household Income for Purchasers of New Vehicles, 2012 Model Year

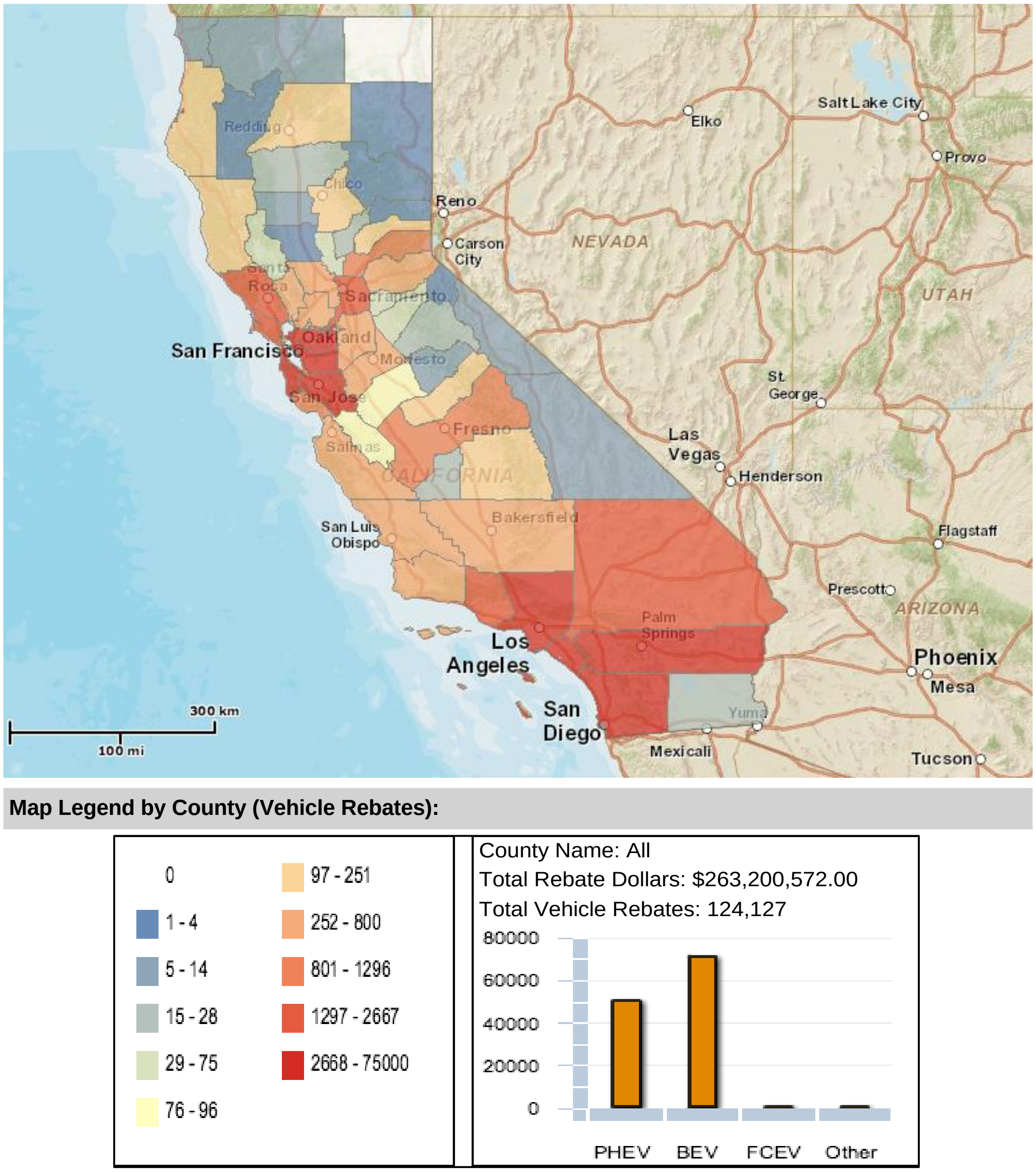


	Less than $24,999	$25,000 to $49,999	$50,000 to $74,999	$75,000 to $99,999	$100,000 to $149,999	$150,000 to $199,999	$200,000 or more	No Answer
ICE	4%	12%	17%	18%	25%	12%	13%	0%
Hybrid	1%	7%	10%	14%	30%	17%	22%	0%
PRIUS PLUG-IN	1%	1%	1%	4%	17%	18%	36%	22%
VOLT	0%	1%	5%	7%	21%	16%	35%	15%
LEAF	0%	2%	3%	7%	18%	15%	33%	21%

Source: Tal and Nicholas (2013)

Further, the majority of electric vehicles (represented in by CARB vehicle rebates) sold in California have been purchased in and around the San Francisco Bay Area, Los Angeles, and San Diego.

Figure F-2. Total CARB Clean Vehicle Rebates by California County[58]



In addition, switching out a conventional gasoline vehicle for an electric vehicle can have a disproportionately large positive impact in those communities living with the worst levels of air pollution. These communities tend to be home to a disproportionately high number of low-income and minority residents. A 2011 study, for example, found that U.S. counties in the lowest quantile of air quality had a higher fraction of non-Hispanic blacks and persons in poverty than counties in the highest quantile of air quality for $PM_{2.5}$[59] and ozone (Miranda 2011).

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[58] Source: Center for Sustainable Energy (2015). *California Air Resources Board Clean Vehicle Rebate Project Rebate Map*. Retrieved 10/28/15 from http://cleanvehiclerebate.org/survey-dashboard.

[59] Particulate matter with aerodynamic diameter.

This non-uniform distribution of EV ownership and air quality has led to significant interest amongst stakeholders in ensuring future clean air benefits from electric vehicles are distributed more widely. There has been particular focus in California on "disadvantaged communities," defined by the California Environmental Protection Agency as including (but not limited to) areas "disproportionately affected by environmental pollution and other hazards that can lead to negative public health effects, exposure, or environmental degradation" and "areas with concentrations of people that are of low income, high unemployment, low levels of home ownership, high rent burden, sensitive populations, or low levels of educational attainment."[60]

California's Senate Bill 1275, approved by Governor Jerry Brown in September 2014, established the Charge Ahead California Initiative to "increase access for disadvantaged, low-income, and moderate-income communities and consumers to zero-emission and near-zero-emission vehicles." E3 interviewed representatives from the Greenlining Institute and Communities for a Better Environment (CBE) (two of the five steering committee members of the Charge Ahead California Campaign) to determine their priorities for DC fast charger siting. These interviewees emphasized three screening criteria for potential DC fast charger sites:

1. **Placement of chargers within disadvantaged communities**: Greenlining and CBE are hopeful that in addition to providing charging for local residents, chargers located in disadvantaged communities will generate economic activity from drivers who are passing through on longer trips. Neither interviewees nor written literature have so far been able to provide concrete evidence on the effectiveness of this strategy. This is not surprising given the early stage of public EV charging in disadvantaged communities, and represents an area in which additional data would be valuable.

   Greenlining and CBE also indicated that placing chargers in disadvantaged communities could generate exposure and interest in EVs and contribute to more widespread EV adoption in these neighborhoods. This could be especially valuable if combined with information on CARB and/or other programs that provide funds for drivers to purchase EVs or provide EV car-sharing.[61]

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[60] See California Environmental Protection Agency (2014) "Designation of Disadvantaged Communities Pursuant to Senate Bill 535 (De León)," http://www.calepa.ca.gov/EnvJustice/GHGinvest/Documents/SB535DesCom.pdf

[61] For example:

- CARB's Clean Vehicle Rebate Project (CVRP) currently provides rebates of up to $2,500 per vehicle for the purchase or lease of new EVs for applicants with annual income less than $250,000 for single tax filers, less than $340,000 for head-of-household filers and less than $500,000 for joint filers. Applicants eligible as low- or moderate-income can receive up to $4,000 for an EV.
- CARB's Vehicle Retirement and Replacement Plus-Up Pilot Project in the Greater Los Angeles area and San Joaquin Valley provides an incentive to low- and moderate-income individuals who scrap old, dirty vehicles and replace them with new or used EVs. The incentives offered are up to $9,500 per vehicle (depending on income level) and $2,000 for a home charging unit, and are in addition to the CVRP. (See http://www.arb.ca.gov/msprog/aqip/ldv_pilots/efmp_plus_up_faq.pdf)
- CARB's Public Fleet Pilot Project replaces standard CVRP rebates with incentives of up to $10,000 per vehicle for public agencies operating in disadvantaged communities. (See https://cleanvehiclerebate.org/eng/pfp#block-views-pfp-faqs-block-1)
- CARB has selected the Community Housing Development Corporation (CHDC) as administrator of a low-income financing assistance program in disadvantaged communities. CHDC launched the program in January 2016 to provide low-interest loans of $4,000-8,000 to residents of disadvantaged neighborhoods in Alameda, Contra Costa, Santa Clara, Santa Cruz, Solano and San Francisco Counties. Additionally, the program offers grants of up to $2,000 to buy and install

2. **Proximity to non-luxury multiple-unit dwellings (MUDs):** Interviewees indicated that low- and moderate-income residents are more likely than the general population to live in multiple-unit housing, and less likely to have access to EV charging at home. Siting reliable public charging close to non-luxury MUDs would provide increased access to EV ownership to this unserved segment, especially as EV prices continue to fall and the second-hand market for EVs grows.

3. **Proximity to minority-owned businesses:** Chargers placed within disadvantaged communities would ideally be placed close to minority-owned businesses, so that the economic benefits mentioned above flow to minority groups.

Interviewees also suggested that siting public charging infrastructure nearby EV car-sharing programs targeted at disadvantaged communities could be valuable, to the extent that such infrastructure is not already included in these programs.

Finally, interviewees from Greenlining and CBE encouraged network developers to ensure consultation with and representation of community-based organizations (CBOs) throughout the siting process. They suggested that the familiarity of these groups with their local area and local priorities could be of significant benefit to charging network developers as they narrow in on the most appropriate sites for EV charging.

EV charging equipment in single-family homes or multiunit dwellings. See chdcnr.com for more information. (See http://www.arb.ca.gov/msprog/aqip/ldv_pilots/efmp_plus_up_faq.pdf)

- CARB recently awarded $1.6 million to the City of Los Angeles to set up a pilot EV car-sharing program in disadvantaged communities. The project is in the planning stages, but hopes to provide approximately 100 EVs to serve around 7,000 residents, as well as the infrastructure needed to support charging. See http://www.arb.ca.gov/msprog/aqip/ldv_pilots/car_sharing_faq_072315.pdf.