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Merging Expert Perspectives to Site DC Fast Charging

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Summary

The authors amassed their significant and varied expertise in plug-in electric vehicle (PEV) charging infrastructure to undertake a study of optimal DC fast charger siting within Pacific Gas and Electric's (PG&E's) utility service territory. The study combined EV adoption forecasts from Ricardo, PlugShare data on California's existing EV charging infrastructure, and a detailed model from UC Davis, in order to forecast likely unmet charging demand in 2025. The authors further utilized existing literature, expert interviews, and PG&E's distribution network data to formulate an algorithm, which outputs driver- and cost-friendly potential charger sites within areas of greatest unmet demand. Finally, the team created a micro-siting rubric to enable charging network developers on the ground to score, weight and sort DC fast charger sites to offer maximum support to EV adoption at least cost.

Keywords: DC Fast Charging, Siting, EV Adoption, Distribution Planning, Utility, Best Practices

1 Introduction

Electric Vehicle adoption surpassed 200,000 units in California recently, and battery electric vehicles make up over half of the total. Research in the past has pointed to installing DC Fast Chargers (DCFCs) as one way to further increase and support BEV adoption[1][2][3]. DCFCs provide EVs such as the Nissan LEAF the ability to recharge to 80% in 20 minutes or less. These DCFCs are as close to the refueling time of a "gas station" as anything on the market.

However, DCFCs are typically expensive to install and little research has been done on how to reduce this barrier. 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, but ultimately identifying locations where there is substantial charging demand can insure that both a) the DCFC is highly utilized and b) installation costs are kept low.

This project utilized an existing transportation demand model created by UC Davis to identify 300 locations within PG&E's territory that were along popular transportation corridors and met minimal coverage requirements across PG&E's 70,000 square mile territory. These 300 locations were then ranked

based upon their modeled driver demand. Each of the 300 locations was modeled to have a 1-mile radius, and specific sites were located within the 1-mile radius that had available transformer capacity and were publicly accessible. This resulted in over 14,000 businesses, restaurants, etc. that can be investigated to host a DCFC.

A Best Practices Guide and micro-siting tool were developed for a “boots-on-the-ground” approach – helping DCFC installers to identify ideal locations that will meet customer needs and preferences, and minimize other installation costs.

2 Best Practices in DC Fast Charger Siting

The project team interviewed and surveyed over 20 industry experts and reviewed a range of published works on installing DCFCs in order to identify best practices.

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

1. will best support EV **adoption**,
2. will keep **installation costs** low, and/or
3. will **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 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.

2.1 Siting DCFCs to maximize EV Adoption

Maximizing EV adoption is defined here broadly to include both a) maximizing EV sales, and b) 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 in on 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: a) drivers, b) charger site hosts, and c) 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 and relied upon by drivers, and which is capable of being built in a timely manner.

2.1.1 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 a) insufficient EV charging capacity in areas that see (or will see) high numbers of EV drivers, or b) ‘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.’¹

¹ 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).

After pinpointing areas of high unmet charging demand, planners should choose specific parking sites (businesses, parking lots, recreation locations, etc.) within these areas that offer the highest level of comfort, safety, accessibility, amenity and visibility to drivers. Doing so will boost driver confidence and comfort in using the charging network. 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.’²

2.1.2 The Charger 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 [4] 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; because they often have parking spaces with low congestion (banks have seen lower foot traffic since the age of internet and phone 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 [5]. Potential hosts have also expressed concern about liability in the case of driver injury or equipment malfunction. According to interviewees, clear and 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 [6].

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

² *Ibid.*

conventional vehicle drivers that cannot find parking or feel mistreated when parking spots are reserved for EVs.

2.1.3 The Charging Network Developer's Perspective

In this discussion, a charging network developer describes 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 [7].

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

3 Selecting Potential DCFC Sites in PG&E's Territory

The best practices discussed above, and in more detail in the publicly available report, informed the project team's selection of 14,471 potential charger sites (i.e. individual businesses, agencies, etc.) at the 300 locations³ of highest predicted unmet charging need in PG&E's territory in 2025. The year 2025 was used to match California Governor Edmund G. Brown's Executive Order B-16-2012, which sets goal of 1.5 million zero-emission vehicles on California roads by 2025.⁴

PG&E's service territory is shown in Figure 1. PG&E provides energy to nearly 16 million Californians – representing roughly 1 in 20 Americans.⁵ PG&E boasts the highest EV adoption of any service territory in the country: the utility's customers own over 80,000 PEVs, representing roughly 20% of US PEV sales.⁶

³ Studies by the Electric Power Research Institute (EPRI) [8] and the National Renewable Energy Laboratory (NREL) [9] have estimated that chargers are needed at 200 - 500 locations in Northern California in order to meet a goal of 1 million ZEVs deployed by 2023 – 2024. The project team used 300 as a reasonable mid-point.

⁴ See <https://www.gov.ca.gov/news.php?id=17472>.

⁵ See PG&E's 2015 Corporate Responsibility and Sustainability Report, Available at: <https://www.gov.ca.gov/news.php?id=17472>.

⁶ R.L. Polk Data, via EPRI, December 2015.



Figure 1 Map of California's Electric Investor-Owned Utilities

Source: California Energy Commission, <http://www.energy.ca.gov/maps/serviceareas/>

An overview of the team's analytical approach to selecting potential DCFC sites is provided in Figure 2.

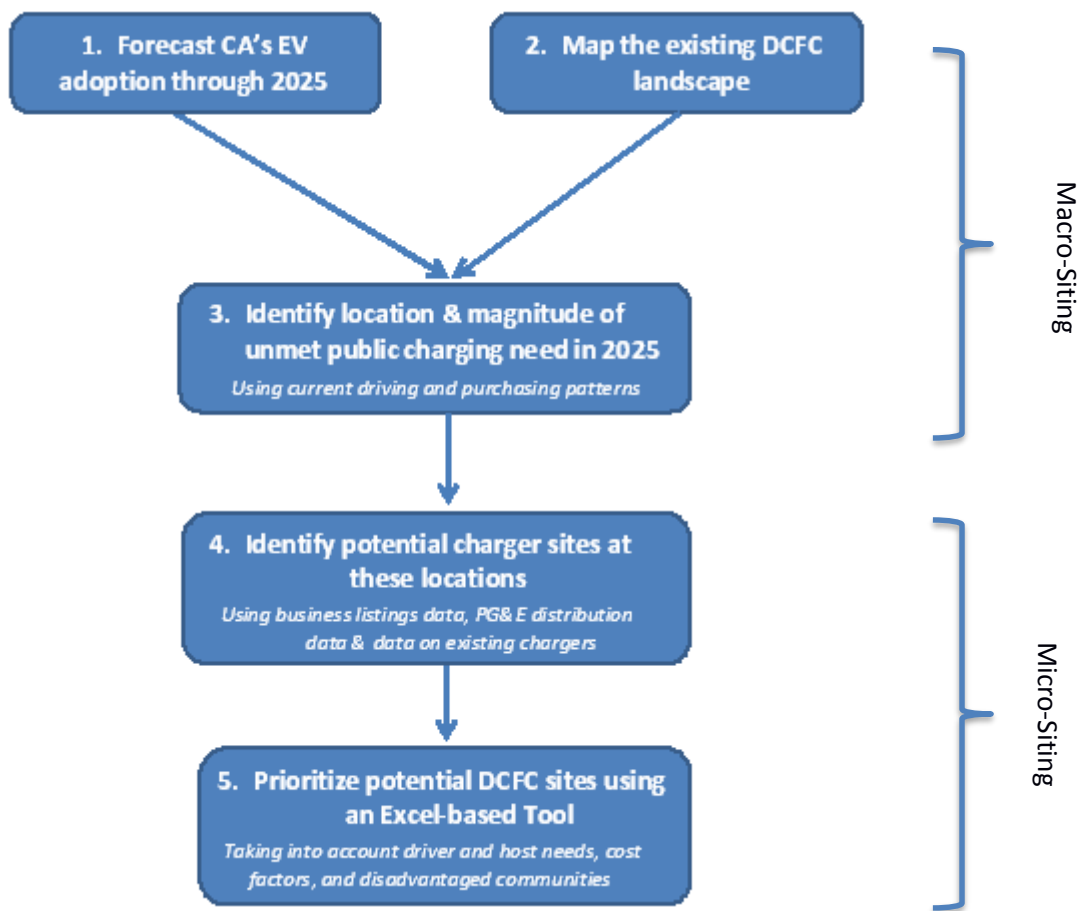


Figure 2 Overview of the team's approach to DCFC site selection

3.1 Forecasting EV Adoption in 2025

Estimating the level of public charging needed in 2025 requires an estimate of EV adoption. Ricardo produced two EV adoption scenarios for California, resulting in forecasts of both the number and types of EVs sold in 2025.

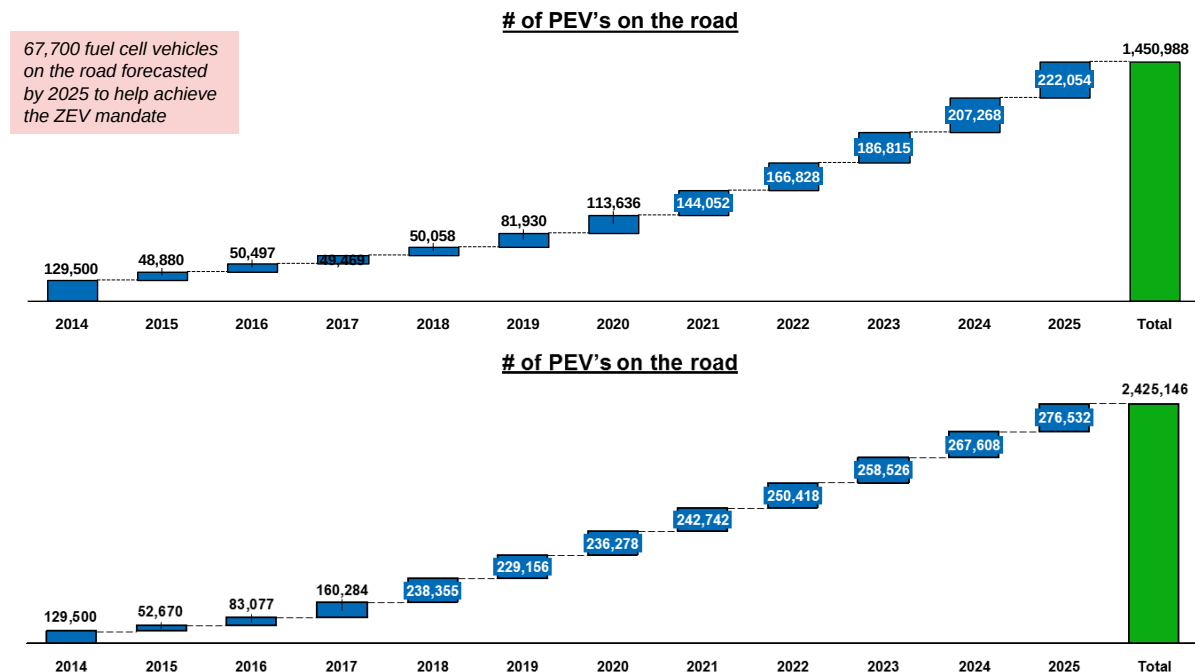
The first scenario estimates EV adoption based on California's Zero-Emission Vehicle (ZEV) Mandate. The California ZEV mandate specifies for large-volume manufacturers their obligations in terms of the percentage of credits they have to earn in 2018 and through 2025 model years.⁷ Eligible vehicles generate credits, and the mandate requires that the total number of credits (as a percentage of the total light-duty vehicle sales figures) is at least the specified "total ZEV percent requirement".

The second scenario is based on EV affordability. Affordability is a key consideration for consumers in their purchase decision for plug-in electric vehicles. Today, there is a price premium associated with both BEVs and plug-in hybrid EVs (PHEVs) over conventional gasoline vehicles. The federal government and state of California offer economic incentives to boost PEV sales in the early stages of commercialization.⁸ While there are limitations to the number of such incentives, it is expected that consumer prices of PEVs will decline over time due to reductions in the cost of battery packs and as economies of scale grow. To estimate the impact of the above factors on future PEV sales, Ricardo developed an affordability model that forecasts annual PEV sales through 2025 based on anticipated incremental vehicle price to consumers compared to alternative conventional vehicles. Results of the two adoption scenarios are shown in Figure 3.

⁷ See http://www.arb.ca.gov/msprog/zevprog/factsheets/general_zev_2_2012.pdf

⁸ See, for example, federal tax incentive information here: <https://www.fueleconomy.gov/feg/taxcenter.shtml>, and the California Clean Vehicle Rebate Project: <https://cleanvehiclerebate.org/eng>.

Figure 3 Ricardo EV Adoption Forecasts. Cumulative through 2025. ZEV Mandate (top) Affordability Scenario (bottom)



3.2 Mapping the Existing Public Charging Landscape

The project partners worked with publicly available data through PlugShare to map the existing DCFC data in California, and identified 157 non-Tesla SuperCharger Fast Chargers in PG&E's territory as of October 2, 2015.

3.3 Macro-Siting of DCFCs: Identifying Locations of Unmet Charger Need

UC Davis performed an analysis to select 300 general locations (1-mile radius) in PG&E's territory predicted to face the most unmet charging need in 2025 (hereafter referred to as 'locations'), as well as the predicted magnitude of unmet fast charger demand at each. The remainder of this section describes UC Davis' approach and results.

For each location, UC Davis estimated the number of charging events and subsequently, the number of chargers needed near each location. The total number of chargers needed at these 300 locations in 2025 varied from 574 chargers to 916 chargers, depending upon which of the two EV adoption scenarios was used. The team used the "GIS EV Planning Toolbox for MPOs" (the 'EV Toolbox')⁹ to estimate the spatial distribution of BEV drivers and their charging demand. This data were used both to determine the optimal location of DCFCs and to predict the number of charging events at each location.

3.3.1 Fast Charging Demand Types

There are three types of charging demand that might appear at fast charging locations:

1. **Corridor Demand:** this could be from travelers with a driving distance that exceeds the battery range;
2. **Workplace Demand:** this could be from commuters who use fast chargers near their workplace as an alternative of workplace chargers; and

⁹ See UC Davis Plug-in Hybrid and Electric Vehicle Research Center (2015). UC Davis GIS EV Planning Toolbox for MPOs, Available at: <http://phev.ucdavis.edu/project/uc-davis-gis-ev-planning-toolbox-for-mpos/>.

3. **Home Demand:** from BEV drivers who use fast chargers 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 team adopted a “corridor-first” strategy, meaning that all locations were required to have some function for long trips. This allows all locations to be evaluated on their ability to extend vehicle range on tours that are farther than battery range (i.e. a trip is 100 miles and range is 80). If the proposed location had little or no corridor demand based on travel survey data, it was not selected as a location. However, once the location was selected as one of the top 300 corridor locations, all demand that may occur as a result of its location, either from corridor, home, or work-based demand, was incorporated in the demand profile. In some cases, a location that had a low corridor score, scored high on a workplace or home demand score.

3.3.2 Corridor Demand

Corridor demand was calculated using travel diary data from the 2010-2012 California Household Travel Survey (CHTS) used to simulate travel behavior [10] Stretches of road, called charge windows, where a BEV must charge in order to continue his or her journey were identified based on travel distance. By overlapping all charge windows with weights representing demand, a heat map was created that displays an overview of the distribution of total fast charging demand. The weight of each charge window was calculated based on the estimated spatial distribution of BEV drivers. Each charge window represents a length of highway that could possibly work for a DCFC location. UC Davis determined the size and estimated demand of each charge window by considering research from two surveys. First, the total tour length – tour lengths beyond a certain distance become less likely to be covered by BEVs – and second, demand was scaled by 60% to adjust for BEV drivers who report rarely charging out-of-home.

3.3.3 Workplace Demand

Workplace charging demand was calculated based on employees’ commute distance, BEV range, and charging behavior. The weight of each origin-destination (OD) pair was calculated based on the spatial distribution of BEV drivers¹⁰.

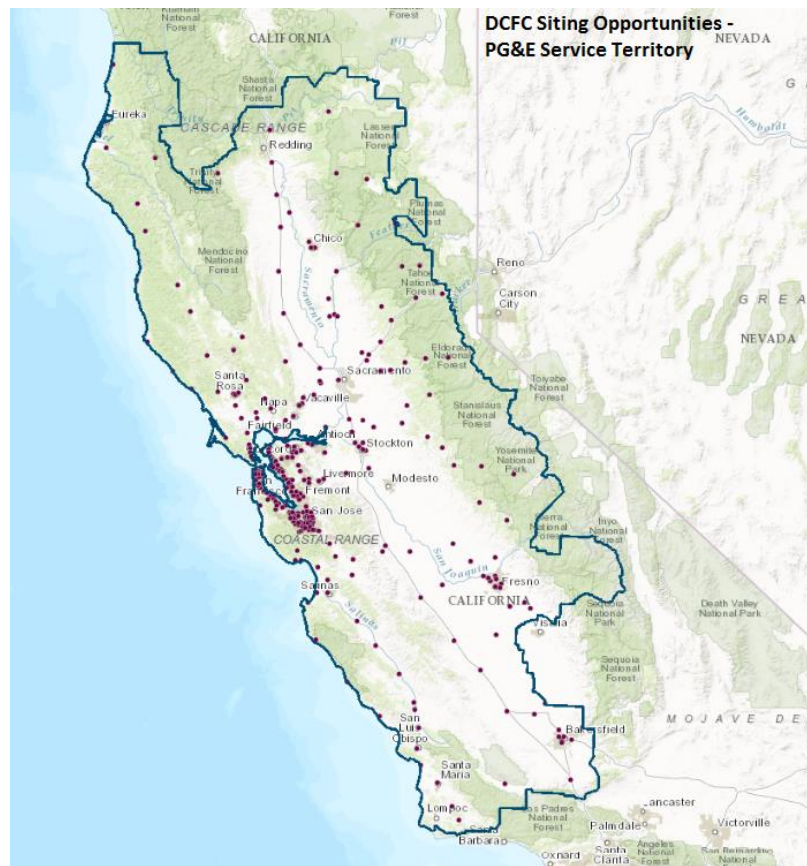
Previous studies on workplace charging have shown that roughly 40% of EV drivers are unable to charge every day due to charger congestion, meaning that DCFCs may be one potential solution to this problem. We estimate 5% of those who cannot complete their commute travel without charging will use fast charging.

3.3.4 Home-Based Demand

Lastly, there can be fast charging demand near the home. Most all BEV drivers charge at home, using either Level 1 or Level 2 charging. This model assumes that if there are fast chargers near a BEV driver’s home, those fast chargers can be substitutes for residential charging or provide additional support when they need to charge their BEVs in a short period of time. To avoid double counting work tour charging demand, only 1% of non-work tour charging demand was considered as potential fast charging demand near a driver’s home although this initial estimate needs to be verified with data. Figure 4 shows the final identified location of 300 DCFC sites.

¹⁰ Version 7 of LEHD Origin-Destination Employment Statistics (LODES) data were used to analyse commute distance.

Figure 4 Identified DCFC Siting Opportunities



3.4 Micro-Siting DCFCs: Identifying Potential Sites

The project team aimed to provide a list of potential charger sites (individual businesses, government agencies, parking lots, etc.) that network developers could target at these 300 locations of highest unmet need. This section describes the approach taken to identify potential chargers sites. The resulting sites are listed in a publically available excel file¹¹, on PG&E's website.

To bound this site analysis and retain the criteria used to identify each of the 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.

3.4.1 Site Selection Methodology

The project team considered three factors when identifying potential sites within each bubble:

1. Business type
2. Existing 480V, three-phase transformers with DCFC hosting capacity
3. Existing charger sites

A third-party database of places was used for this analysis. To follow the best practices identified the team kept site types that (a) most aligned with the DCFC use case (i.e. were favorable as a place to park while charging for 15-30 minutes rather than for long dwell times), and (b) that were most likely to include factors attractive to drivers. Finally, the team added existing Level 2 charger and DCFC sites from PlugShare's database that did not appear in the third-party database of business listings, because (a) existing hosts may be amenable to hosting additional chargers, and (b) providing multiple DCFCs at one site creates reliability benefits to drivers by providing redundancy, and can help reduce congestion.

¹¹ The file is on PGE.com called: "DC Fast Charger Micro-Siting Tool.xlsm".

Each of the resulting sites was then analyzed for co-location with existing 480V, three-phase transformers with available capacity, and tagged with the number of new DCFCs that could be supported by the transformer (see column X of the Tool tab). 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 transformer, total available capacity was divided by 65 kW (based on the CHAdeMO power rating of 62.5kW¹²). The existing transformer information was obtained from PG&E databases. Installing a new 480V, three-phase transformer is a significant cost driver for DCFC installation, and leveraging existing transformers is therefore extremely valuable. Due to the constantly changing nature of the grid, a site was deemed co-located with an existing transformer only if a minimum of 2 DCFCs were supportable with the existing capacity.

Further, 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 (see Tool tab columns T through W). This data were deemed useful as an 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.

Resulting Sites

This process resulted in 14,471 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 sites¹³ was 13,249.

Though 14,471 is a large total number of potential sites, the number of sites per bubble varies widely. Thirty-nine 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 64 out of 300 bubbles (21%) have ten sites or fewer.

4 Conclusions

The literature review, expert interviews and siting analysis performed for this project led to a number of conclusions:

1. Given a choice, EV drivers strongly prefer DC fast charging over Level 2.
2. Broadly, most EV charging stakeholders aim to install chargers that maximize EV adoption, minimize installation cost, and benefit stakeholders.
3. To get DCFC projects off the ground and maximize driver willingness to use the charging network, it is important to consider the perspectives of drivers, charger hosts, and network developers. It is important to site DCFCs in areas of high unmet charger need (macro-siting), and also to choose individual sites that will be agreeable to all three of these groups (micro-siting).
 - Drivers seek safety, comfort, reliability, and convenience.
 - Hosts must be willing to dedicate time to negotiations and contracting, and to advocate for site permitting. Finding hosts that are willing to do so can be tough, since there is not yet a clear business case 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 must try to fit varied hosts into standardized contracts and leases to avoid prolonged negotiations.

¹² 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/>

¹³ A unique site is defined as a unique combination of name, address, longitude and latitude

4. There are a number of cost drivers for DCFC installations. The most significant of these is the cost of any needed electrical transformer upgrades. Trenching and boring distance and hard surface materials can also increase costs significantly, and can vary considerably by site.
5. Disadvantaged communities are best served by siting DCFCs according to 3 criteria:
 - Placement of chargers within disadvantaged communities,
 - Proximity to multiple-unit dwellings, and
 - Proximity to minority-owned businesses.
6. Macro-siting with UC Davis' GIS EV Planning Toolbox for MPOs, augmented to include PlugShare data on the existing charging network and Ricardo's EV adoption estimates, resulted in the 300 locations of highest predicted unmet charging need in 2025 in PG&E's service territory.
7. An analysis of one-mile radius bubbles around these locations, filtering for on-site 480V, three-phase transformer capacity where this wasn't too restrictive, resulted in 14,471 businesses, parking lots, and other locations that match the DCFC use case.
8. Additional data is required to prioritize these sites. The *DC Fast Charger Micro-Siting Tool* (available on PGE.com) provides pre-filled data on transformer capacity, disadvantaged community status, and existing charging infrastructure at each site, and also presents a framework for collecting the on-the-ground data needed to prioritize potential sites. This Tool, along with the best practices detailed in this report, should guide network developers as they seek to install fast charging in PG&E's territory and beyond.

Acknowledgments

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