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STAFF REPORT

Home Charging Access in California

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ABSTRACT

The convenience, reliability, low cost, and often low-grid impact of charging plug-in electric vehicles (PEVs) at home are among the primary benefits of owning a PEV. Access to these benefits can be a key enabler for the increasing rate of PEV adoption in California. However, home charging access is not ubiquitously available, posing challenges to achieving the level of PEV adoption needed to meet the state's transportation electrification goals and to attain equitable access to charging. To better understand home charging access in California, California Energy Commission (CEC) staff and the National Renewable Energy Laboratory (NREL) conducted the "Residential Parking Facility Survey Among California Residents" in July 2020, collecting nearly 1,300 responses.

The survey results show that residents of single-family homes have greater access to home charging than residents of multifamily homes. Higher-income respondents reported greater access, and additional disparities were observed among race and ethnicity groupings, with those who identified as White having the greatest access. Access is limited in all scenarios, and if infrastructure and parking conditions remain business as usual, access does not surpass 33 percent. Even the most optimistic scenario (combining parking behavior changes and new electrical installations) results in 66 percent access for all survey respondents.

Building upon the survey results, a "PEV likely adopter" model was developed to estimate access in the future as the PEV fleet share increases. For the most optimistic access scenario, a fully PEV fleet results in about 70 percent of vehicles with home charging. This finding highlights a potential upper bound of home charging availability and emphasizes the importance of public charging infrastructure. Three key gaps that impact PEV adoption and home charging access as PEV uptake transitions from the early adopter phase and toward widely available mainstream consumers are 1) education about PEVs and charging, 2) installing electricity in homes, and 3) shifting parking behavior.

Keywords: Charging, infrastructure, transportation electrification, electric vehicle, home charging, access

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EXECUTIVE SUMMARY

The transportation sector in California is responsible for more than 50 percent of the state's greenhouse gas (GHG) emissions and is part of the category of sources responsible for more than 80 percent of smog-forming nitrogen oxide pollution and 95 percent of toxic diesel particulate matter. The associated impacts of these emissions are detrimental to the climate and harmful for the health of California's residents. The electrification of California's transportation system is urgently needed, and the state has continued to pave the way for transportation electrification. Executive Order (EO) B-48-18 established a goal of 250,000 electric vehicle (EV) chargers by 2025 and 5 million zero-emission vehicles (ZEVs) on the road in 2030. Assembly Bill (AB) 2127 (Ting, Chapter 365, Statutes of 2018) tasked the California Energy Commission (CEC) with preparing a statewide assessment of the charging infrastructure needed to achieve these goals and reduce GHG emissions to 40 percent below 1990 levels by 2030. More recently, Governor Gavin Newsom set a goal in EO N-79-20 that 100 percent of in-state sales for new passenger vehicles will be ZEVs by 2035 and expanded the AB 2127 assessment to examine infrastructure requirements to support increased EV adoption.

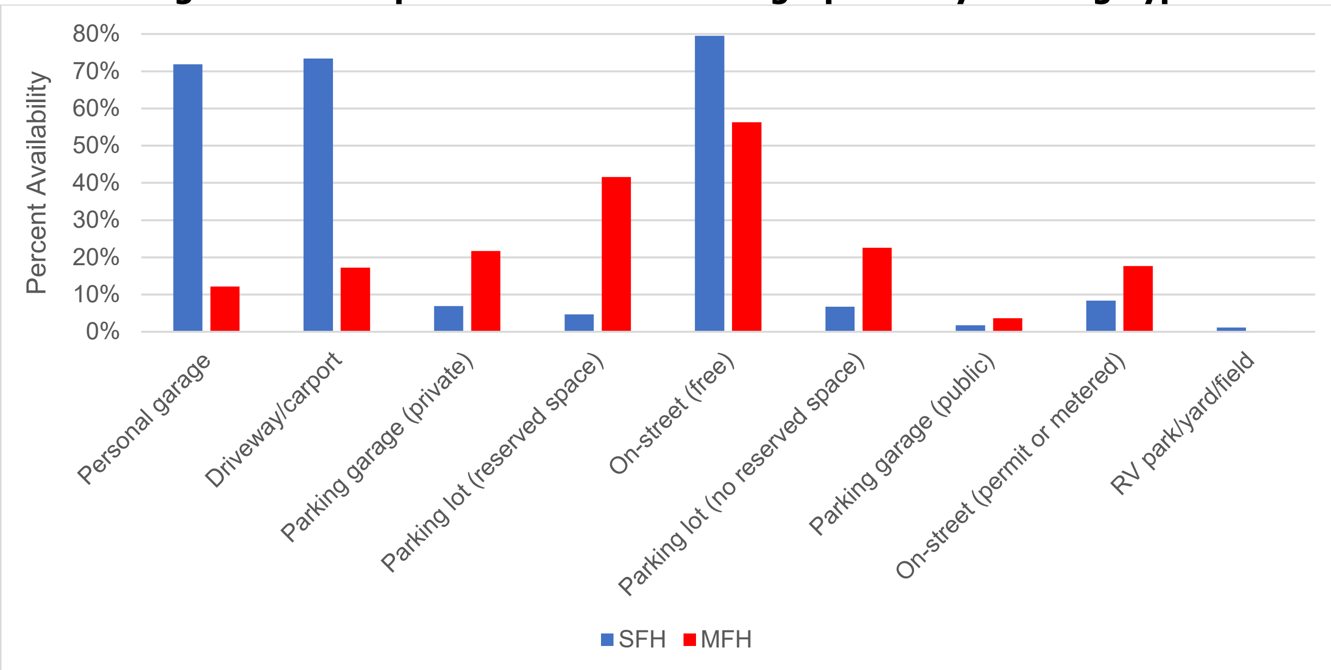
Home charging provides a convenient, reliable, low-cost, and often low-grid-impact method of charging a vehicle. The ability to charge at home is a key benefit and potential enabler of plug-in electric vehicle (PEV) adoption. However, access to home charging is not ubiquitous, especially as EV uptake moves out of the early-adopter phase and into the mainstream market. The inability to charge at home may discourage PEV adoption and slow California's ability to meet the state's aggressive ZEV goals. Importantly, inequities are created when some drivers are able to charge at home while others are not. Understanding home charging access in California is needed to maximize home charging availability and design a public and workplace charging network that is comparable to home charging in terms of affordability and convenience. Building such a network will remove barriers and enable EV adoption for those without the ability to charge at home.

The CEC collaborated with the National Renewable Energy Laboratory to conduct a survey and gather information on parking options, parking behavior, access to electricity, and more for home charging. The survey was executed in July 2020 and received nearly 1,300 responses.

Available Parking Options

The survey results provide a breakdown of respondents' available parking options. The researchers grouped respondents by housing type, with single-family homes composed of detached and attached (for example, townhouse) homeowners and renters, and multifamily homes composed of low-rise (2–4 units), mid-rise (5–19 units), and high-rise (20+ units) apartments. As Figure ES-1 illustrates, single-family homes have much greater access to preferred parking options like driveways and personal garages. In contrast, multifamily homes have less access to preferred options and more commonly have access to options such as on-street parking, shared parking garages, and parking lots. These results reveal a fundamental difference in parking options available by housing type. The survey also investigated parking option availability based on income. In general, households with higher incomes have greater access to preferred parking options.

Figure ES-1: Reported Available Parking Options by Housing Type



Single-family homes have greater access to driveways, personal garages, and free on-street parking compared to multifamily homes. Multifamily homes are limited primarily to parking garages, parking lots, and on-street parking.

Source: CEC and NREL

Home Charging Access

Building upon the available parking options results, the researchers calculated home charging access from the survey responses. Five access scenarios were investigated, defined in Table ES-1.

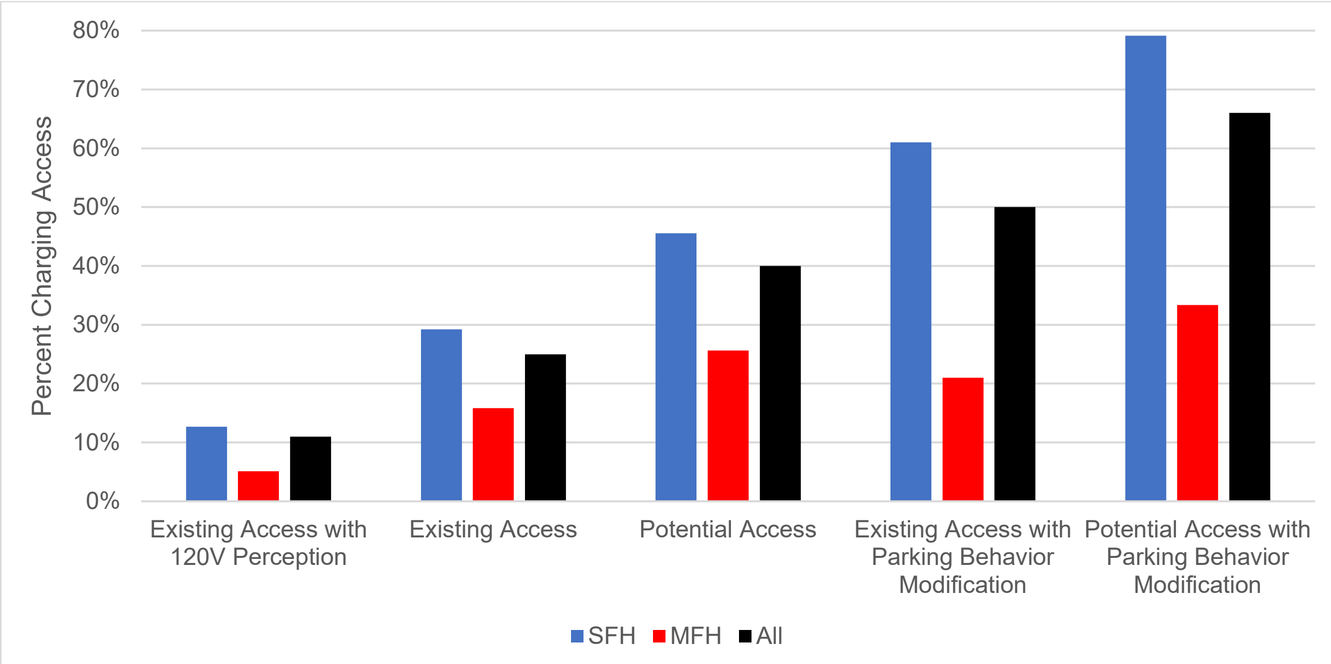
Table ES-1: Home Charging Access Scenario Definitions

Scenario	Definition
Existing Access with 120 volt (V) Perception	Share of vehicles that currently park near 120V electricity and where respondent believes a standard 120V outlet can be used to charge an EV.
Existing Access	Share of vehicles that currently park near 120V electricity.
Potential Access	Share of vehicles that currently park near 120V electricity or park in a location where respondents think new 120V electrical installation could occur.
Existing Access with Parking Behavior Modification	Share of vehicles that currently park near 120V electricity or could park near 120V electricity if they changed their parking behavior.
Potential Access with Parking Behavior Modification	Share of vehicles that currently park near 120V electricity or could park in locations where respondents think new electrical installation could occur.

Source: CEC and NREL

The results in Figure ES-2 show that single-family homes have greater access to home charging than multifamily homes in all scenarios. Critically, the Existing Access scenario results, which assume business-as-usual electrical infrastructure and parking conditions, show that no dwelling type surpasses 30 percent home charging access.

Figure ES-2: Calculated Home Charging Access by Housing Type for Each Access Scenario



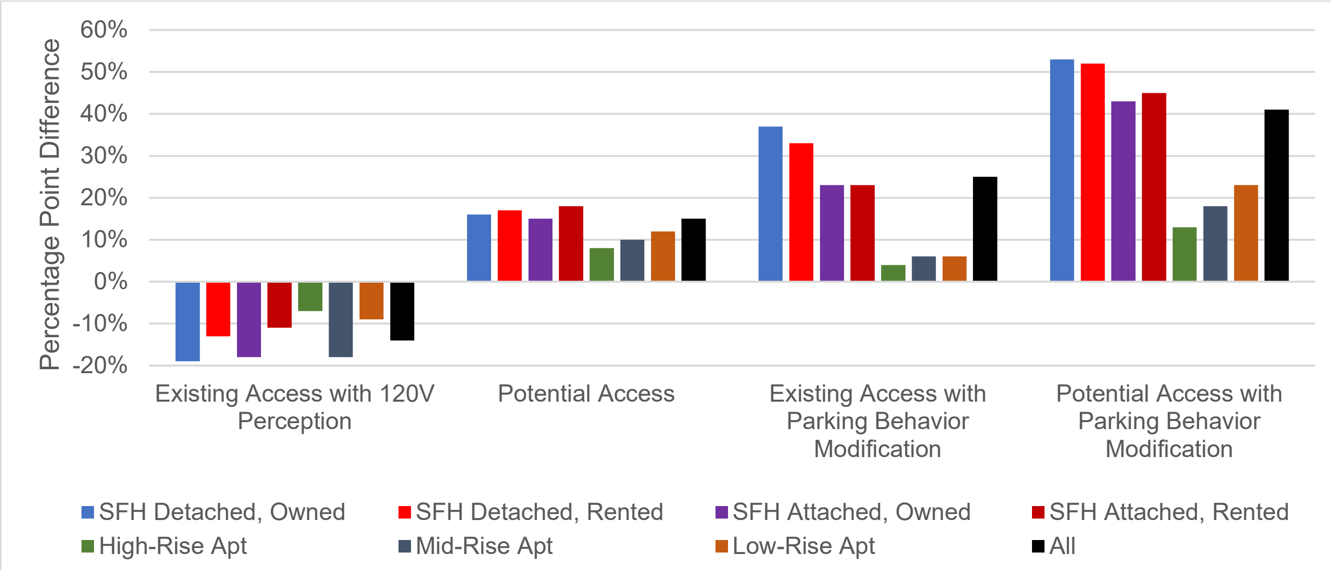
Single-family homes have greater home charging access than multifamily homes across all scenarios. Even in the most optimistic scenario, home charging access does not surpass 66 percent overall (gray bars), and multifamily homes do not surpass 33 percent.

Source: CEC and NREL

The difference in home charging access among scenarios (Figure ES-3) reveals several key takeaways:

1) Respondents are unaware of existing home charging opportunities.
2) Maintaining business-as-usual electrical infrastructure and parking conditions will limit access to home charging for the mainstream market.
3) New electrical installations have limited potential to increase home charging availability.
4) Shifts in parking behavior can significantly increase home charging access, but primarily in single-family homes, not multifamily homes.
5) Even with the combination of new electrical installations and shifts in parking behavior, access to home charging in multifamily homes does not exceed 40 percent.

Figure ES-3: Difference in Home Charging Access Compared to the Existing Access Scenario



These difference plots show the change in home charging access for each housing type compared to the corresponding Existing Access scenario condition.

Source: CEC and NREL

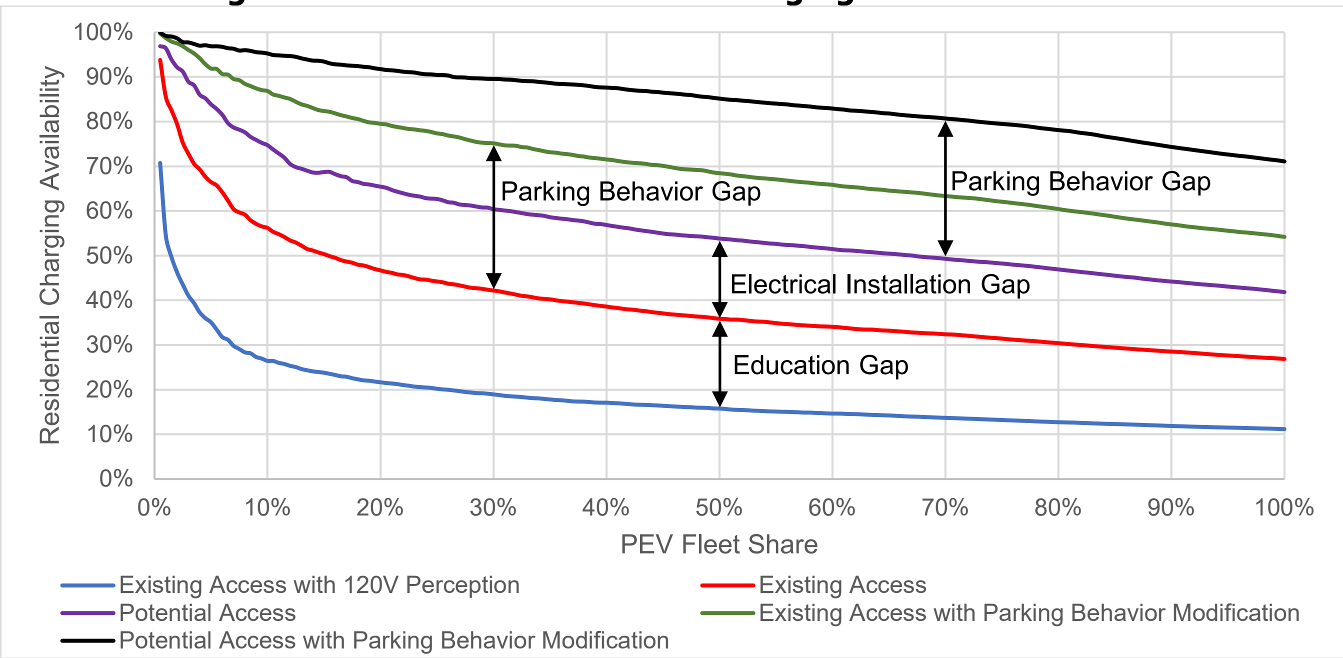
The researchers investigated variability among income and race groups. In general, higher-income households have greater access to home charging, particularly for multifamily housing residents who saw access more than double compared to the lowest income group in three scenarios, with the other two scenarios resulting in more modest increases. Respondents were grouped into three race/ethnicity categories to maintain reasonable sample sizes: Group 1) White; Group 2) Asian, Native Hawaiian, Other Pacific Islander, American Indian, or Alaska Native; and Group 3) Black, African American, Hispanic, or Latino. Respondents who identified as Group 1 had the highest access to home charging for all scenarios except one in multifamily households, where Group 2 reported higher access. Besides that instance, respondents in Group 2 reported 0–9 percentage points less access than Group 1 respondents, while respondents in Group 3 reported 2–13 percentage points less access than Group 1 respondents.

Evolution of Home Charging Access

The researchers used the survey results to create a PEV adoption model and estimate future home charging access as the PEV fleet share increases. The PEV adoption model quantifies the influence of several variables on households' PEV adoption decision, including income housing characteristics (building type and tenure) and population density class (for example, suburban, rural). Figure ES-4 shows the relationship between the PEV fleet share and the home charging access ratio. In all scenarios, access decreases as the PEV fleet share increases, which is a result of the PEV likely adopter model design that assumes households with higher PEV adoption probabilities are likely to become PEV owners earlier. If the state's light-duty fleet were entirely composed of PEVs, business-as-usual conditions (Existing Access scenario) would result in fewer than 30 percent of vehicles having access to home charging. The most optimistic scenario (Potential Access with Parking Behavior Modification) reveals an upper bound of about 70 percent of PEVs that would have home charging access. However, it is important to note that fuel cell electric vehicles will also play a role in the state's transition to clean transportation, so a 100 percent PEV future is unlikely.

These results highlight three key gaps that could facilitate PEV adoption and home charging: 1) education, 2) electrical installation and 3) parking behavior.

Figure ES-4: Evolution of Home Charging Access Over Time



In all scenarios, home charging access decreases as the PEV fleet share increases. The Existing Access with 120V Perception scenario results in the lowest home charging access with only 11 percent of PEVs having access to home charging at 100 percent PEV fleet share. The most optimistic scenario, the Potential Access with Parking Behavior Modification scenario, results in 71 percent of PEVs with home charging access, emphasizing the upper bound on home charging access.

Source: CEC and NREL

Conclusions

This analysis represents a significant step forward in the understanding of home charging access and suggests critical disparities that could hinder EV adoption. Home charging access is observed to be lower for multifamily residents, single-family renters, low-income residents, and residents of color. While it will be critical to prioritize access to home charging, it is also clear that building a network of reliable, convenient, and cost-effective public charging options is vital for those that cannot charge at home to ensure all Californians can join the transition to ZEVs.

The results of this survey and analysis provided updated modeling input in the CEC's inaugural AB 2127 assessment to assess and project California's charging infrastructure needs. However, this report shows that numerous barriers will require the efforts of a diverse grouping of stakeholders to overcome.

CHAPTER 1: Introduction

Mobile sources including cars, trucks, tractors, and a myriad of other on-road vehicles and off-road equipment contribute the majority of smog-forming oxides of nitrogen, the largest portion of greenhouse gas (GHG) emissions. Furthermore, these sources contribute significantly to toxic air contaminants.[1] The associated impacts of these emissions are detrimental to the climate and harmful for the health of Californians. State policies such as Senate Bill (SB) 32[2] address these negative outcomes by requiring statewide greenhouse gas emissions to be reduced to 40 percent below the 1990 level by 2030.

To achieve these goals, it is critical that California's vehicle fleet convert to zero-emission vehicles (ZEVs). The State of California has continued to pave the way for ZEVs. Assembly Bill (AB) 118[3] established the Clean Transportation Program. AB 118 directed the California Energy Commission (CEC) to accelerate the development and deployment of innovative technologies that would transform California's fuel and vehicle types and attain the state's climate change policies. The Clean Transportation Program funding is up to $100 million per year. AB 8[4] extended the Clean Transportation Program through January 1, 2024.

Executive Order (EO) B-16-2012[5] set the initial benchmark for ZEV adoption in California at 1.5 million ZEVs by 2025. EO B-48-2018[6] established additional targets for 5 million ZEVs by 2030 and 250,000 electric vehicle (EV) chargers in California, including 10,000 direct current fast chargers (DCFC), by 2025. EO B-48-2018 also set a goal of 200 hydrogen refueling stations by 2025. These policies have been instrumental in promoting ZEV adoption and deploying needed charging infrastructure, with nearly 636,000 ZEVs registered by the end of 2020 and more than 76,000 public and shared private chargers in the state as of October 2021.[7] Of these chargers, nearly 6,800 are DCFCs.[8] Most recently, Governor Gavin Newsom issued EO N-79-

1 California Air Resources Board staff. 2021. *Revised Draft 2020 Mobile Source Strategy*. California Air Resources Board.

2 Senate Bill 32 (Pavley, Chapter 249, Statutes of 2006). https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201520160SB32.

3 Assembly Bill 118 (Núñez, Chapter 750, Statutes of 2007). https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=200720080AB118.

4 Assembly Bill 8 (Perea, Chapter 401, Statutes of 2013). https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201320140AB8.

5 Governor Edmund G. Brown, Jr. Executive Order B-16-2012. Issued March 23, 2012. https://www.ca.gov/archive/gov39/2012/03/23/news17472/index.html

6 Governor Edmund G. Brown, Jr. Executive Order B-48-18. Issued January 26, 2018. https://www.ca.gov/archive/gov39/2018/01/26/governor-brown-takes-action-to-increase-zero-emission-vehicles-fund-new-climate-investments/index.html.

7 CEC. 2021. "California Energy Commission Zero Emission Vehicle and Infrastructure Statistics." Data last updated April 30, 2021. Retrieved May 26, 2021, from https://www.energy.ca.gov/zevstats.

8 Ibid.

20,[9] which calls for all in-state sales of new passenger cars and trucks to be zero-emission by 2035, along with other goals for medium-, heavy-, and off-road vehicles.

PEVs have been the most popular type of ZEV adopted by consumers. With the increasing adoption of PEVs, a widespread and diverse network of public chargers is critical to maximizing the fraction of vehicle miles traveled on electricity, alleviating range anxiety, and facilitating the further adoption of PEVs. Assembly Bill 2127[10] requires the CEC to prepare and biennially update a statewide PEV charging infrastructure assessment. The CEC must assess levels of PEV adoption, and required charging infrastructure support, to meet 2030 ZEV and GHG emission reduction goals. EO N-79-20 expanded this analysis to consider the infrastructure required to support the 2035 sales targets.

The inaugural AB 2127 assessment[11] leveraged the latest Electric Vehicle Infrastructure Projection tool (EVI-Pro 2) to evaluate the number, locations, and types of chargers required to meet the needs of light-duty PEV drivers. EVI-Pro, the predecessor to EVI-Pro 2, was developed with the National Renewable Energy Laboratory (NREL), and the analysis[12] informed the EO B-48-18 target of 250,000 EV chargers by 2025. EVI-Pro 2 made numerous improvements upon the previous version. Using EVI-Pro 2, the CEC projected that nearly 1.2 million chargers would be needed to support 8 million ZEVs by 2030.

A key determinant of the need for public and shared private charging infrastructure is access to home charging (the ability to charge a vehicle at home). AB 2127 Alternative Future results indicated public and workplace infrastructure networks decreased by about 50 percent when the home charging access for 8 million ZEVs was increased from 67 percent to 95 percent.[13]

Recent research has uncovered significant disparities in access to public charging based on racial and ethnic majority, median household income, and housing type in California.[14] The

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9 Governor Gavin Newsom. Executive Order N-79-20. Issued September 23, 2020. https://www.gov.ca.gov/wp-content/uploads/2020/09/9.23.20-EO-N-79-20-text.pdf.

10 Assembly Bill 2127 (Ting, Chapter 365, Statutes of 2018). https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180AB2127.

11 Alexander, Matt, Noel Crisostomo, Wendell Krell, Jeffrey Lu, and Raja Ramesh. July 2021. *Assembly Bill 2127 Electric Vehicle Charging Infrastructure Assessment: Analyzing Charging Needs to Support Zero-Emission Vehicles in 2030 – Commission Report*. California Energy Commission. Publication Number: CEC-600-2021-001-CMR, https://www.energy.ca.gov/programs-and-topics/programs/electric-vehicle-charging-infrastructure-assessment-ab-2127.

12 Bedir, Abdulkadir, Noel Crisostomo, Jennifer Allen, Eric Wood, and Clément Rames. 2018. *California Plug-In Electric Vehicle Infrastructure Projections: 2017-2025.* California Energy Commission. Publication Number: CEC-600-2018-001, https://www.energy.ca.gov/publications/2018/california-plug-electric-vehicle-infrastructure-projections-2017-2025-future.

13 Alexander, Matt, Noel Crisostomo, Wendell Krell, Jeffrey Lu, and Raja Ramesh. July 2021. *Assembly Bill 2127 Electric Vehicle Charging Infrastructure Assessment: Analyzing Charging Needs to Support Zero-Emission Vehicles in 2030 – Commission Report.* California Energy Commission. Publication Number: CEC-600-2021-001-CMR, https://www.energy.ca.gov/programs-and-topics/programs/electric-vehicle-charging-infrastructure-assessment-ab-2127.

14 Hsu, Chih-Wei, Kevin Fingerman. January 2021. "Public Electric Vehicle Charger Access Disparities Across Race and Income in California." *Transport Policy,* Vol. 100, pp. 59–67, https://www.sciencedirect.com/science/article/pii/S0967070X20309021.

CEC's SB 1000[15] analysis has further investigated whether charging infrastructure has been disproportionately deployed in the state. The analysis has found that public chargers are unevenly distributed geographically, with fewer chargers deployed in high-population-density areas and fewer chargers per capita in low-income communities.[16]

However, PEV charging today predominantly occurs at home.[17] It is also is one of the key benefits of owning a PEV, providing a convenient, reliable, and often cheaper option than public charging or refueling a conventional internal combustion engine vehicle (ICEV).[18] It is critical to improve decisionmakers' understanding of home charging access for all Californians, including for renters, multifamily housing residents, low-income residents, and people of color. These groups may not have the same home charging options as early EV adopters. Any barriers to EV adoption could limit health and air-quality benefits to those disproportionately burdened.

The most recent data source on home charging access before this report was from the Residential Energy Consumption Survey (RECS).[19] This nationwide survey is conducted by the U.S. Energy Information Administration. To evaluate home charging access, the 2015 survey included a question on whether there was an electrical outlet within 20 feet of the respondent's vehicle parking location. However, the RECS survey has many limitations. In addition to being more than five years old, the survey lacked state-specific results, excluded apartment buildings with five or more units and excluded other possible parking options besides garages. While the RECS included results broken down by household income, it did not include results for different races and ethnicities.

To address this gap in the RECS data, in July 2020, CEC staff collaborated with NREL to execute a California-specific survey to investigate home charging access. The results of this survey provided a more robust foundation for assumptions of home charging access for the most recent EVI-Pro 2 analysis. This survey provided a key update to the RECS data and a better assessment of public and workplace charging needs in the state. The goal of this report is to detail the survey methods, publish the results, and discuss the implications of these findings.

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15 Senate Bill 1000 (Lara, Chapter 368, Statutes of 2018). https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180SB1000.

16 Hoang, Tiffany. 2020. *California Electric Vehicle Infrastructure Deployment Assessment: Senate Bill 1000 Report*. California Energy Commission. Publication Number: CEC-600-2020-009, https://ww2.energy.ca.gov/transportation/new_reports_cms.html.

17 Lee, Jae Hyun, Debapriya Chakraborty, Scott J. Hardman, Gil Tal. 2020. "Exploring Electric Vehicle Charging Patterns: Mixed Usage of Charging Infrastructure." *Transportation Research Part D: Transport and Environment,* Vol. 79, p. 102249, https://www.sciencedirect.com/science/article/abs/pii/S136192091831099X.

18 Gee, Quentin, Stephanie Bailey, Jane Berner, Michael Comiter, Jim McKinney, and Tim Olson. 2021. *Final 2020 Integrated Energy Policy Report Update*. California Energy Commission. Publication Number: CEC-100-2020-001-V1-CMF.

19 U.S. Energy Innovation Administration. Residential Energy Consumption Survey. https://www.eia.gov/consumption/residential/.

CHAPTER 2: Survey Description and Method

Survey Sample

In March 2020, NREL conducted a survey investigating home charging access at the national scale, recruiting more than 5,000 respondents from a panel maintained by Prolific.[20] To gain a deeper understanding of access in California, the CEC and NREL executed the "Residential Parking Facility Survey Among California Residents" ("California's Home Parking Survey") in July 2020. This survey asked the same questions of 1,436 California respondents as NREL's national survey.[21] Of this total, surveyors removed 150 responses because of quality issues.[22]

Respondents were concentrated primarily in the metropolitan regions of the San Francisco Bay Area, Los Angeles, San Diego, and Sacramento Valley, though responses were collected from nearly every county in California. Figure 1 shows the geographic distribution of the home zip codes for the remaining 1,286 respondents. Figures 2 and 3 compare the demographics of the survey respondents with housing[23] and income data,[24] respectively, from the 2019 American Community Survey (ACS)[25]. Figure 2 shows the California respondents' housing types were closely comparable to those with the ACS data. The major differences between the two surveys were an underrepresentation of single-family detached homes and an overrepresentation of single-family attached homes in California's Home Parking Survey compared to the ACS data. There were larger differences in the income distribution, with California's Home Parking Survey overrepresenting households below $100,000 in annual income and underrepresenting households above $100,000 in annual income compared to the ACS data.

These distributions suggest that the survey sample is fairly representative of California's population. The sample differs from the average characteristics of early EV adopters, as it includes lower incomes and more attached homes and apartments.

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20 Ge, Yanbo, Christina Simeone, Andrew Duvall, and Eric Wood. 2021. *There's No Place Like Home: Residential Parking, Electrical Access, and Implications for the Future of Electric Vehicle Charging Infrastructure*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5400-81065. https://www.nrel.gov/docs/fy22osti/81065.pdf.

21 Refer to Appendix A for the full survey instrument used in this analysis.

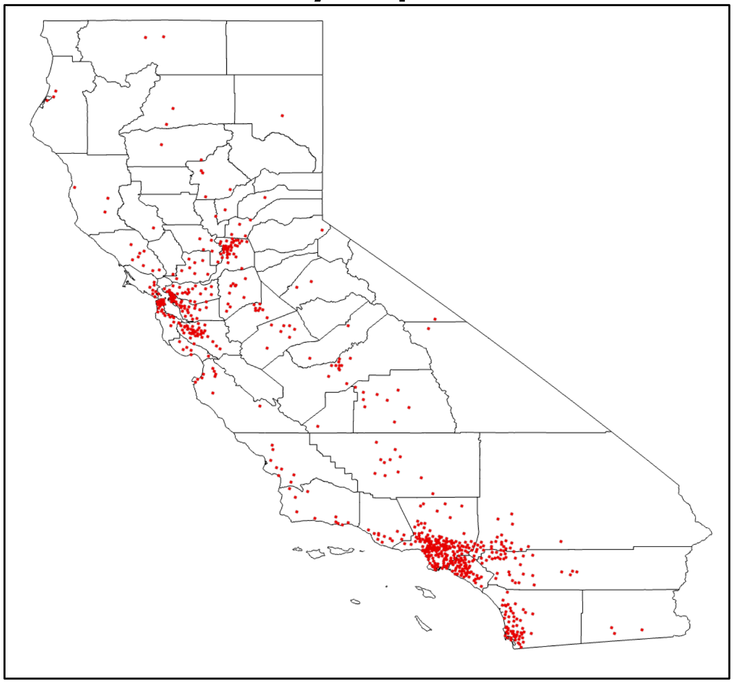
22 For details on quality control, please refer to NREL's report cited above.

23 U.S. Census Bureau. American Community Survey. 2019 American Community Survey 1-Year Estimates, Table B25032.
https://data.census.gov/cedsci/table?t=Units%20and%20Stories%20in%20Structure&g=0400000US06&tid=ACSDT1Y2019.B25032.

24 U.S. Census Bureau. American Community Survey. 2019 American Community Survey 1-Year Estimates, Table S1901.
https://data.census.gov/cedsci/table?t=Income%20and%20Poverty&g=0400000US06&tid=ACSST1Y2019.S1901.

25 U.S. Census Bureau. American Community Survey. https://www.census.gov/programs-surveys/acs.

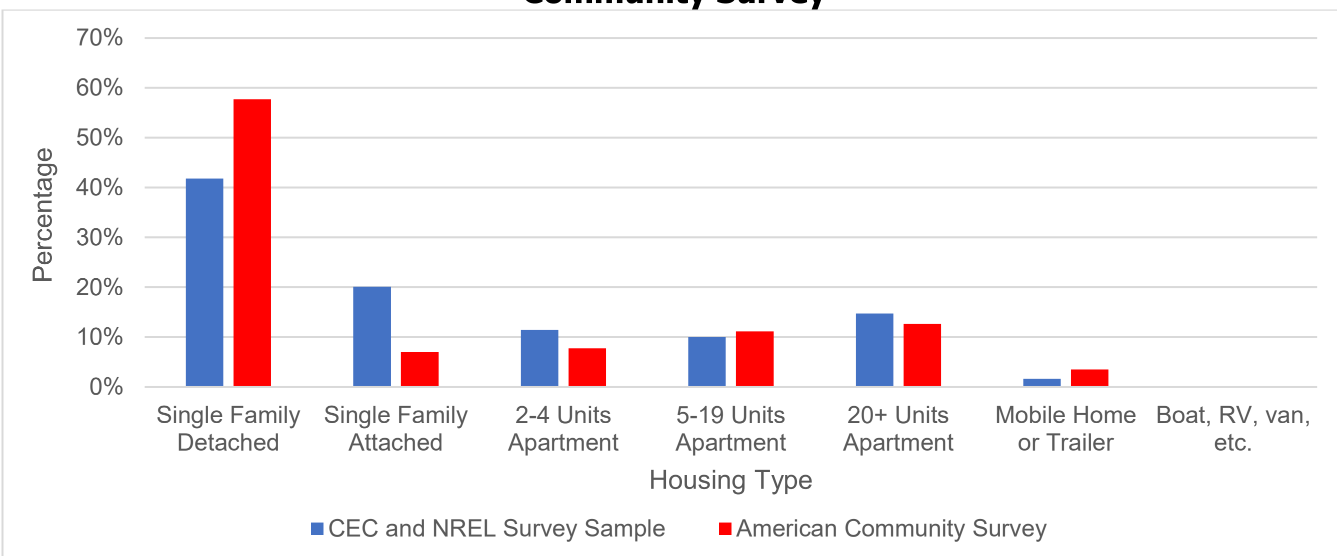
Figure 1: Distribution of Survey Responses in California by Zip Code



Survey responses were primarily concentrated in the four major metropolitan areas of California (Bay Area, Los Angeles, San Diego, and Sacramento).

Source: CEC and NREL

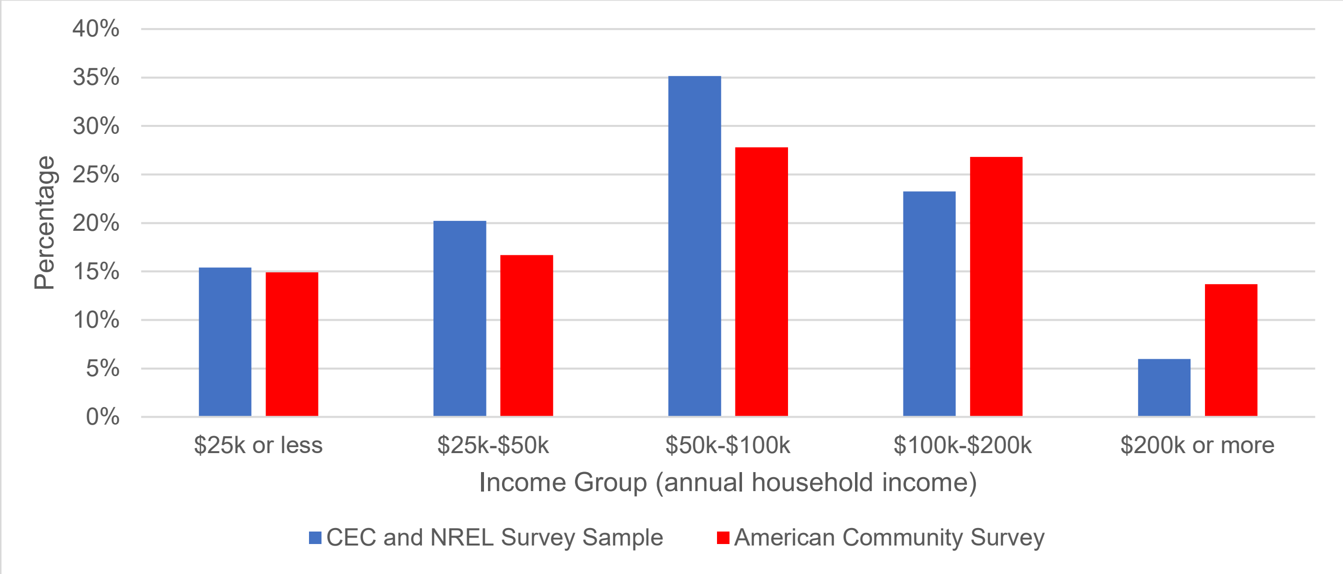
Figure 2: Comparison of Survey Housing Type Distribution With American Community Survey



The housing type distribution from the survey is mostly in line with the American Community Survey distribution. The most significant difference is an undersampling of single-family detached homes and an oversampling of single-family attached homes in the CEC and NREL Survey Sample when compared to the American Community Survey.

Source: CEC and NREL

Figure 3: Comparison of Survey Income Distribution With American Community Survey



The CEC and NREL survey slightly oversampled income groups below $100,000.

Source: CEC and NREL

Survey Description

The survey first asked several sociodemographic and housing data questions, including home zip code, age, annual household income, education level, gender, race/ethnicity, number of adults and children in household, possession of a driver's license, and housing type and tenure. The survey collected information on available home parking options, existing 120 volt (V) electricity and ability to install 120V electricity for the applicable parking options, knowledge of EV charging, Wi-Fi and cellular availability, number of vehicles in the household, and details of each vehicle in the household (including make, model, year, powertrain, and typical parking location). The full survey instrument can be found in Appendix A.

Respondents were able to select all available parking options from the following list:

- On-street (permit or metered)
- On-street (free)
- Driveway/carport
- Personal garage
- Parking garage (public)
- Parking garage (private)
- Parking lot (reserved space)
- Parking lot (no reserved space)
- RV park/yard/field
- None

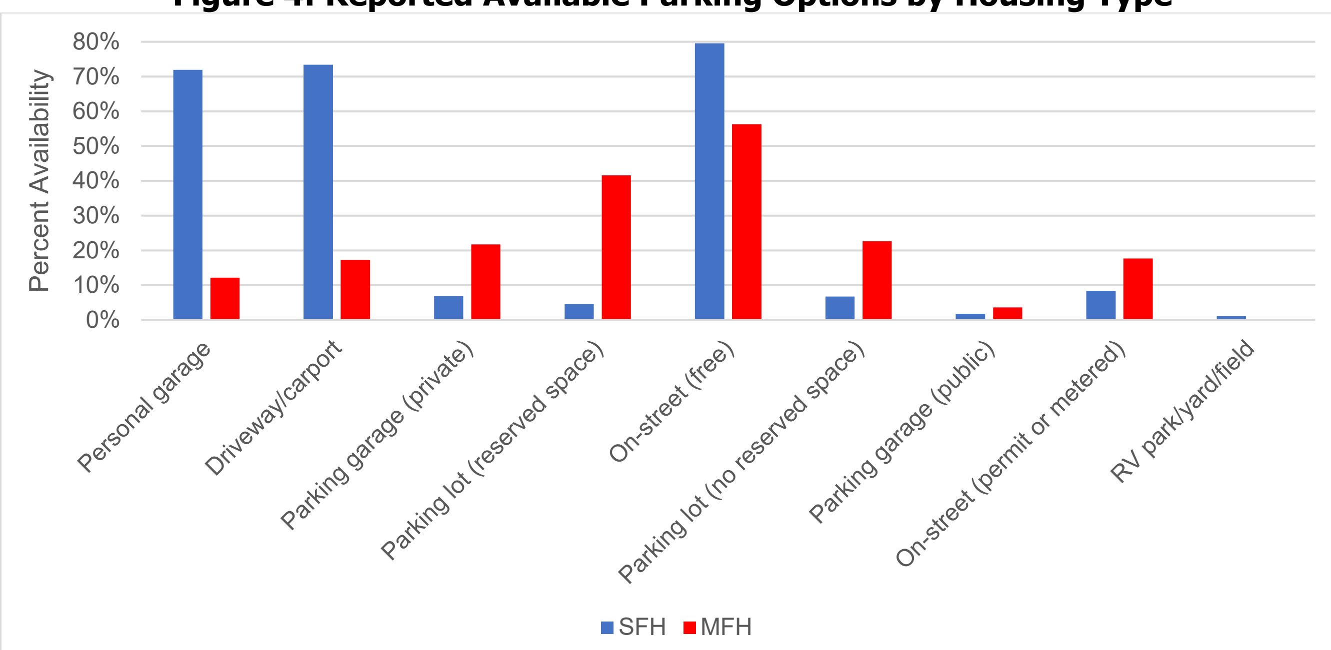
For the reported available parking options, respondents were asked to designate which have an existing 120V electrical outlet available or could have one installed if necessary. These answers formed the basis for calculating home charging access. Making the distinction of 120V electricity in the survey means the results and analysis are based on access to Level 1 charging (which uses 120V electricity) for home charging and do not allow any conclusions about access to Level 2 charging (which uses 240V electricity).

CHAPTER 3: Survey Results

Available Parking Options

Figure 4 shows the available parking options broken down by housing type. In these results, all single-family homes (SFHs) (detached and attached owners and renters) are aggregated, and all multifamily homes (MFHs) (low-, mid- and high-rise apartments) are aggregated. The parking options on the x-axis are ordered according to the author's perspective of most to least preferred for PEV charging. The results show that SFHs have greater access to preferred parking locations such as driveways and personal garages. SFHs also have greater access to on-street free parking, though this is also the highest reported parking option for all MFHs. Parking options such as paid or permitted on-street parking, parking garages, and parking lots are more frequently available to MFHs than SFHs. In addition, the three highest-reported parking options for SFHs (driveways, personal garages, free on-street) were available to more than 70 percent of SFH respondents, indicating that SFH residents typically have access to several high-quality parking options from which to choose. In contrast, with the exception of free on-street parking, no parking option received more than 50 percent of responses from MFHs, suggesting MFH residents may have limited parking options available. These results indicate a fundamental difference in the parking options available to different residents, posing challenges for home charging that will be discussed below.

Figure 4: Reported Available Parking Options by Housing Type

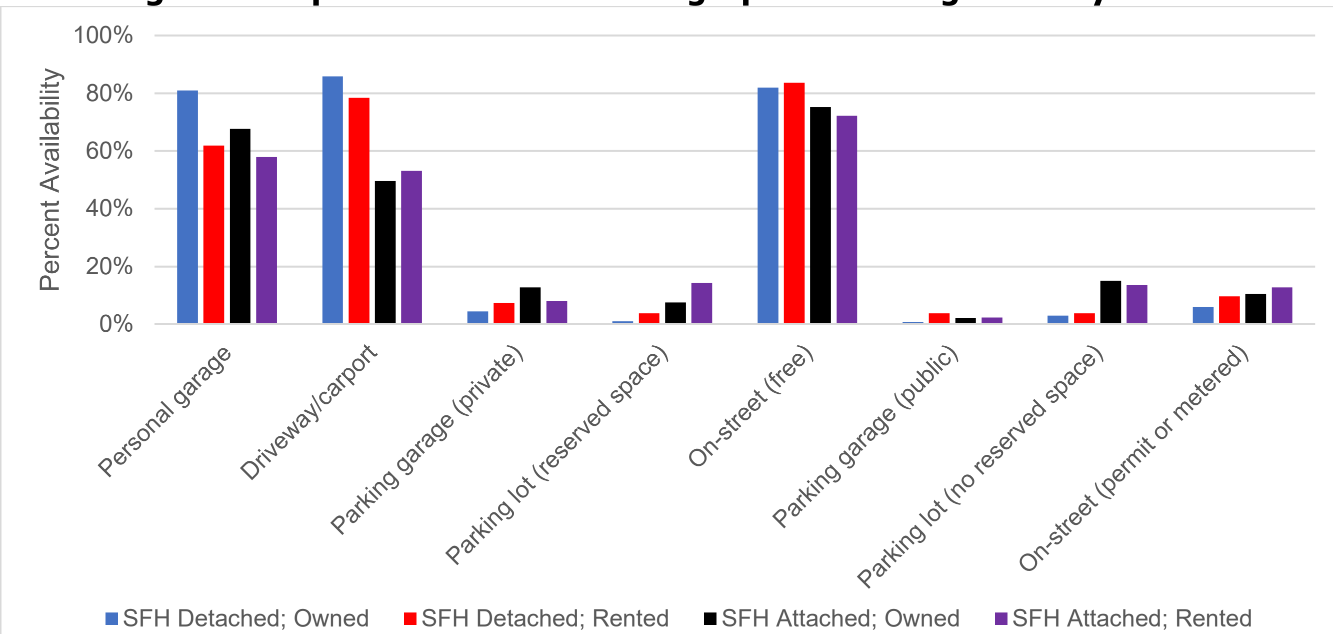


SFHs have greater access to driveways, personal garages, and free on-street parking than MFHs. MFHs are limited primarily to parking garages, parking lots, and on-street parking.

Source: CEC and NREL

Figures 5 and 6 illustrate the variability in available parking options for different types of SFHs and MFHs, respectively. The results show that SFH attached homes tend to have lower access to preferred parking options than detached homes. Renting in detached homes leads to lower access to the most preferred parking options, but this trend is not as apparent for attached homes. For MFHs, high-rise apartments have greater access to parking garages and lots, while low- and mid-rise apartments have greater access to personal garages and driveways.

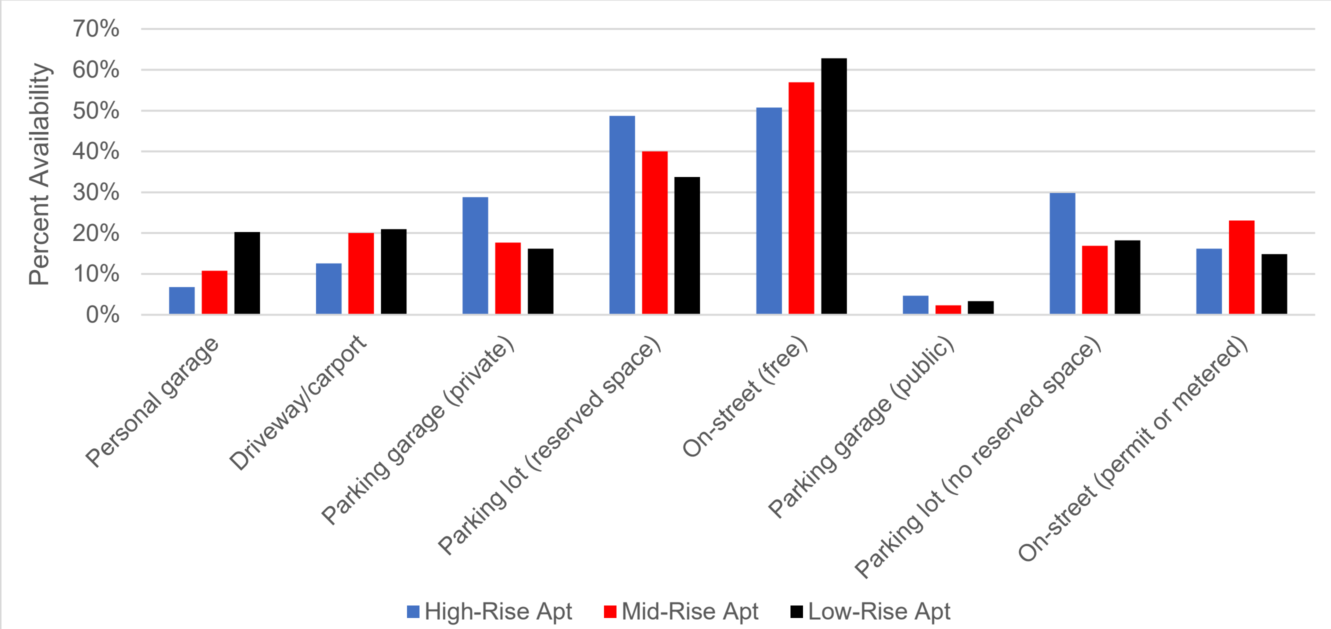
Figure 5: Reported Available Parking Options in Single-Family Homes



Detached SFHs tend to have greater access to preferred parking options like personal garages and driveways compared to attached SFHs.

Source: CEC and NREL

Figure 6: Reported Available Parking Options in Multifamily Homes



High-rise apartments have greater access to parking garages and lots, while low- and mid-rise apartments have greater access to personal garages and driveways.

Source: CEC and NREL

Home Charging Access

Home charging access was calculated under five scenarios as defined in Table 1. For the first scenario, awareness of the ability to use 120V electricity for home EV charging (henceforth referred to as "120V electricity perception") was evaluated through a question that showed respondents a picture of a standard home 120V, three-wire self-grounding wall outlet and asked whether they thought it could be used to charge an EV. The second scenario, "Existing Access," looked at the share of vehicles that currently park in a location where 120V electricity is available, whether or not the respondent thought that 120V electricity could be used to charge a PEV. The third scenario, "Potential Access," considered the possibility of installing 120V electricity in locations where vehicles are currently parked. Potential Access is based on a resident's perspective/experience and does not represent a certified electrician's assessment. The fourth scenario, "Existing Access with Parking Behavior Modification," expanded the definition of home charging access to include vehicles that could move to a different parking location where 120V electricity is currently available. The fifth scenario, "Potential Access With Parking Behavior Modification," took the most optimistic approach and factored in vehicles that could move to a different parking location where residents believe electrical installations *could* occur.

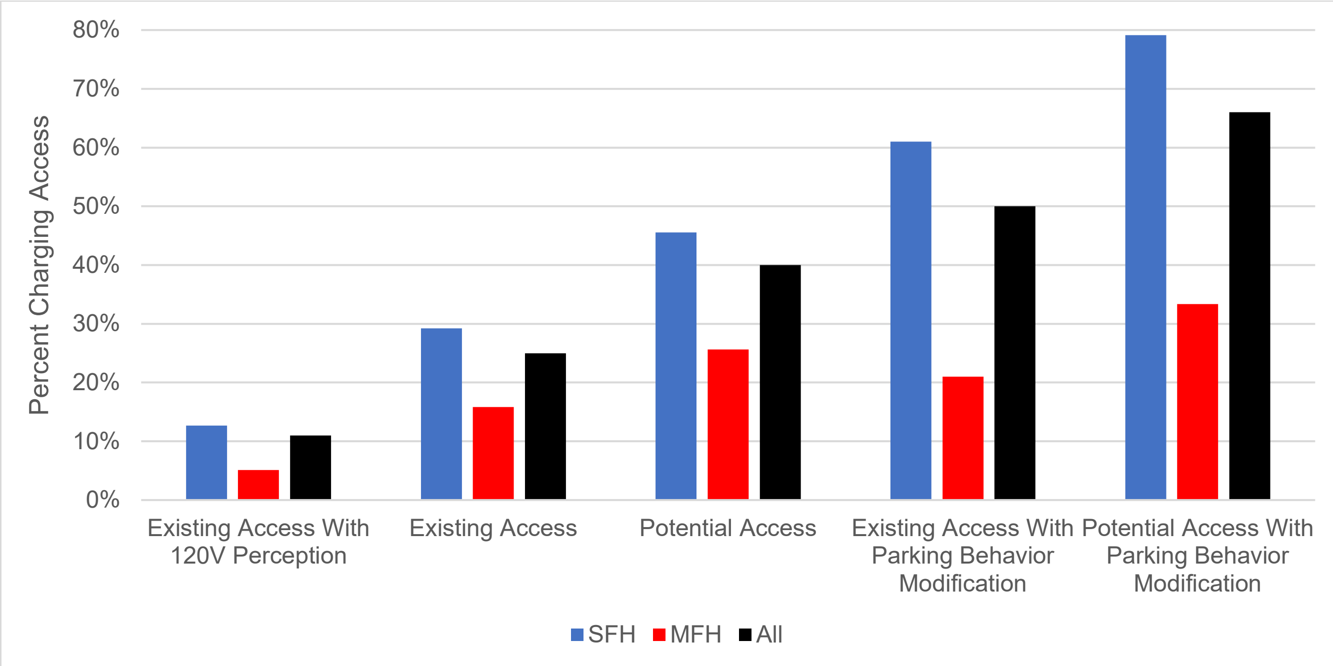
Table 1: Home Charging Access Scenario Definitions

Scenario Name	Definition
Existing Access With 120V Perception	Share of vehicles that currently park in a location where 120V electricity is available and where the respondent believes a standard 120V outlet can be used to charge an EV.
Existing Access	Share of vehicles that currently park in a location where 120V electricity is available.
Potential Access	Share of vehicles that currently park in a location where 120V electricity is available or park in a location where owners think new 120V electrical installation could occur.
Existing Access With Parking Behavior Modification	Share of vehicles that currently park in a location where 120V electricity is available or could park in such a location if the drivers changed their parking behavior.
Potential Access With Parking Behavior Modification	Share of vehicles that currently park in a location where 120V electricity is available or could park in locations where owners think new electrical installation could occur.

Source: CEC and NREL

Figure 7 shows the home charging access results for each scenario broken down by housing type. In all scenarios, SFHs have greater access than MFHs. This follows the available parking options results, as SFH homes have greater access to driveways and personal garages than MFHs. Interestingly, while home charging access for SFHs continues to incrementally increase across the five access scenarios, the same is not true for MFHs. Home charging access in the Existing Access with Parking Behavior Modification scenario is lower for MFHs than in the Potential Access scenario. This finding could suggest that MFH residents have limited parking alternatives to increase home charging access and instead would benefit more from electrical installations.

Figure 7: Calculated Home Charging Access by Housing Type for Each Access Scenario

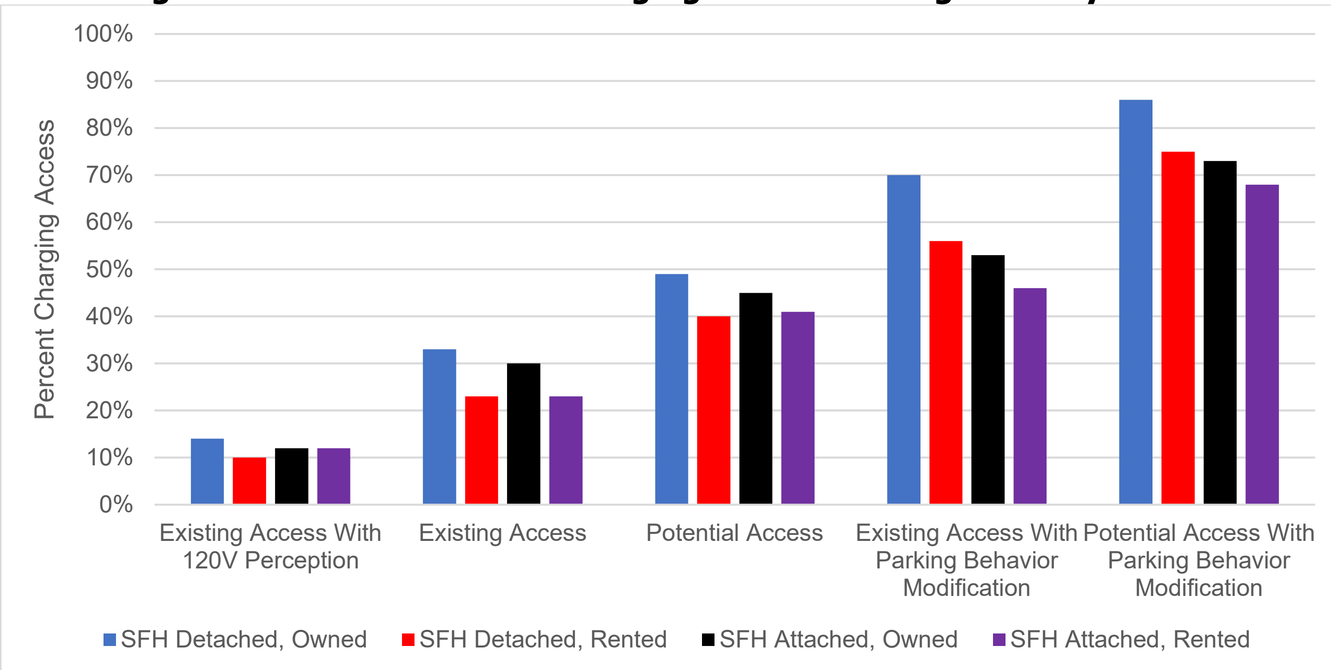


SFHs have greater home charging access than MFHs across all scenarios. Even in the most optimistic scenario, home charging access does not surpass 66 percent overall, and MFHs do not surpass 33 percent.

Source: CEC and NREL

Figure 8 breaks down the SFH results for four housing type categories. SFH detached homes that are owner-occupied have the highest access to home charging out of the four SFH categories. Trends vary for the other SFH types based on the access scenario. For Existing Access and Potential Access, ownership of the home leads to higher access compared to renting, regardless of whether the home is detached or attached. This finding is potentially because renters do not have as much ability to control electrical access and installations in their existing parking locations. In contrast, both parking behavior modification scenarios result in greater access for detached homes than attached homes, regardless of whether the homes are rented or owned. This finding suggests that residents living in attached homes may have more limited parking options than detached homes.

Figure 8: Calculated Home Charging Access for Single-Family Homes

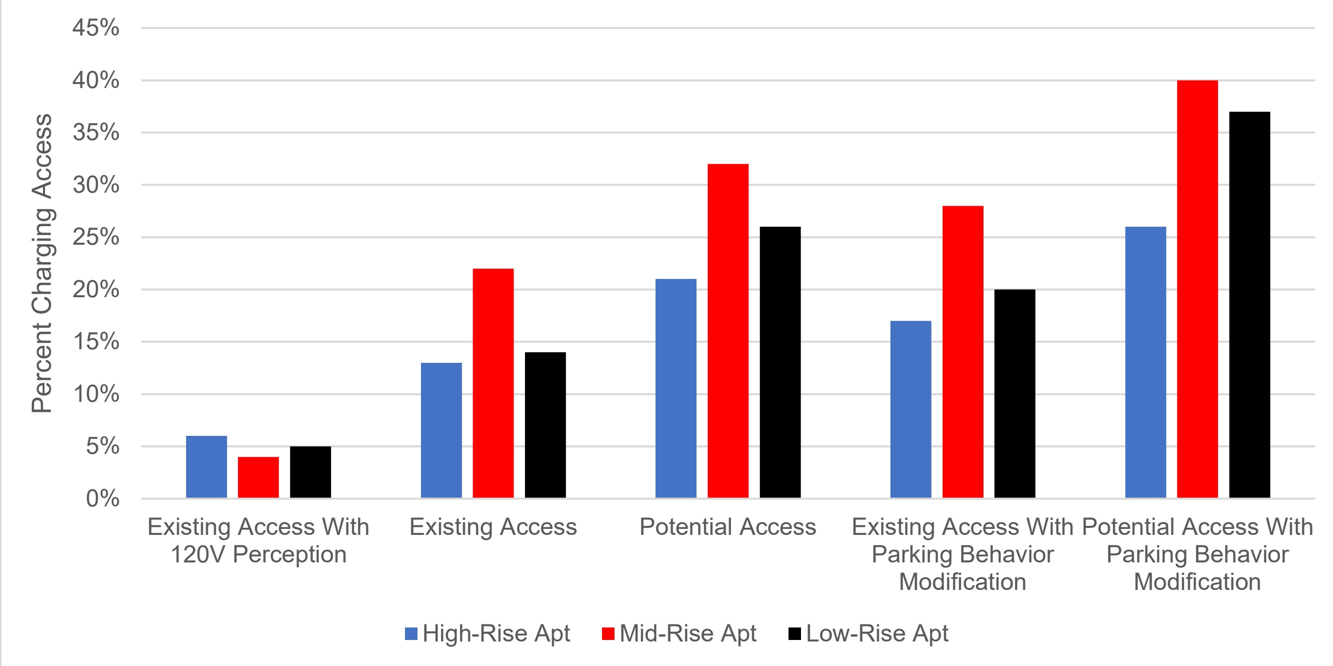


Single-family detached homes have the greatest home charging access in all scenarios. Ownership of homes leads to greater home charging access in the Existing Access and Potential Access scenarios. Living in detached homes, regardless of whether owned or rented, leads to greater home charging access in the parking behavior modification scenarios.

Source: CEC and NREL

Figure 9 breaks down the MFH results for three housing type categories. Midrise apartments have the greatest access in almost all scenarios, followed by low-rise apartments and then high-rise apartments with the lowest access. The lone exception is the Existing Access with 120V Perception scenario, where this trend is reversed, though the variability is minor. These trends generally follow the parking option availability results, as mid- and low-rise apartments have greater access to the preferred parking options of personal garages and driveways than high-rise apartments.

Figure 9: Calculated Home Charging Access for Multifamily Homes



Home charging access is highest for midrise apartments, followed by low-rise and then high-rise apartments in all scenarios except Existing Access with 120V Perception.

Source: CEC and NREL

Using the Existing Access scenario as a baseline case, Figure 10 shows the absolute change in home charging access for the other access scenarios for each housing type. There are several key takeaways:

1) **Respondents are unaware of existing home charging opportunities.**

   The Existing Access with 120V Perception scenario results in a significant decrease in home charging access from the Existing Access scenario across all housing types. This difference ranges from 7 to nearly 20 percentage points. On a relative basis, home charging access at almost all housing types decreased by more than 50 percent, indicating that awareness of EV charging, or lack thereof, is relatively consistent regardless of housing type. Overall, 14 percent of survey respondents currently park near 120V electricity but do not know that this can be used to charge an EV.

2) **Maintaining business-as-usual electrical infrastructure and parking conditions will limit access to home charging for the mainstream market.**

   The Existing Access scenario results shown in Figures 10 and 11 show that home charging access does not surpass 33 percent for any housing type, with MFHs much lower than that. This finding suggests that if infrastructure and parking conditions were to remain business as usual, many drivers would not be able to charge at home.

3) **New electrical installations have limited potential to increase home charging availability.**

   The Potential Access scenario results indicate that there is the potential to improve home charging access by installing 120V electricity where drivers currently park.

However, this increase was relatively modest and comparable across all housing types, ranging from an 8 to 18 percentage point increase. It is important to reiterate that the potential for new installation was based on the perspective of the survey respondent, not a certified electrician’s assessment, so these results could be an under- or overestimate.

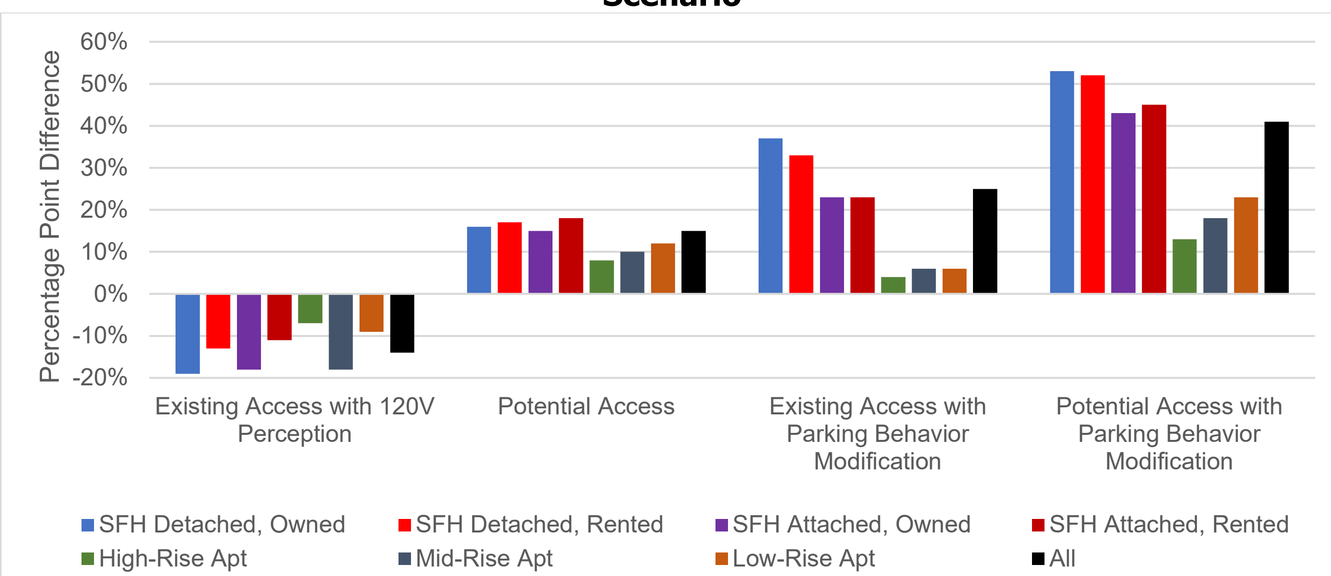
4) **Shifts in parking behavior can significantly increase home charging access but primarily in SFHs, not MFHs.**

   The two scenarios that incorporate parking behavior modifications result in the largest increases in home charging access, highlighting the importance of driver behavior. However, the improvement in access is primarily seen in SFHs, with detached homes increasing by 37 percentage points and attached homes increasing by 23 percentage points in the Existing Access with Parking Behavior Modification scenario. In contrast, MFH access increases by only 4 to 6 percentage points, demonstrating the limited parking options and room for behavior modification to improve access at MFHs.

5) **Even with the combination of new electrical installations and shifts in parking behavior, access to home charging in MFHs does not exceed 40 percent.**

   The most optimistic scenario, Potential Access with Parking Behavior Modification, results in the highest overall charging access at 66 percent. Once again though, these conditions benefit primarily SFHs, which achieve 73 and 86 percent access for attached and detached homes, respectively. SFHs have about double the access in this scenario compared to MFHs, which never surpass 40 percent access as shown in Figure 9.

Figure 10: Difference in Home Charging Access Compared to the Existing Access Scenario



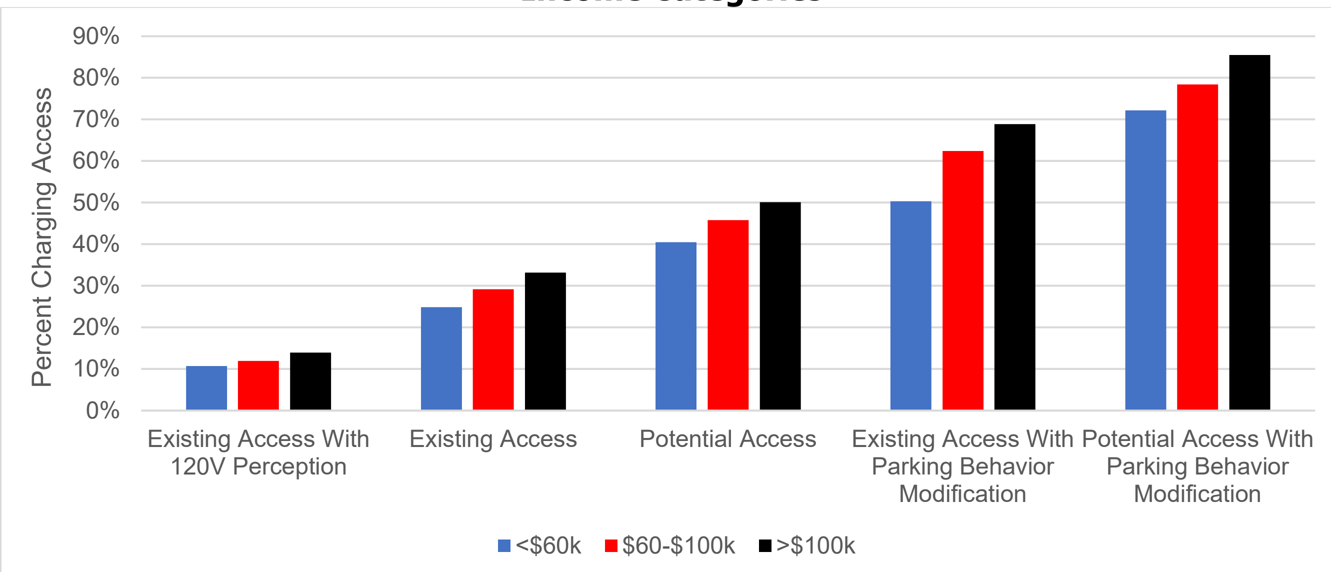
These difference plots show the change in home charging access for each housing type compared to the corresponding Existing Access scenario condition.

Source: CEC and NREL

The research team also investigated home charging access for three income levels. Although 18 income brackets were available as survey responses, the CEC and NREL grouped survey respondents into three categories based on annual household income: 1) $60,000 or less; 2) $60,000 to $100,000; and 3) $100,000 or more. These income groupings maintain reasonable sample sizes[26] while aligning closely with the low, middle, and high-income definitions that are used in the CEC's SB 1000 analysis.[27]

Figure 11 shows the variability in home charging access for SFH survey respondents. In all scenarios, home charging access increases with increasing income. The access scenarios that include shifts in parking behavior result in the largest increases, while the three income groups are all within 10 percentage points of each other for the other three access scenarios.

Figure 11: Home Charging Access for Single-Family Home Respondents in Three Income Categories



In all cases, home charging access for SFH respondents increases with increasing income.

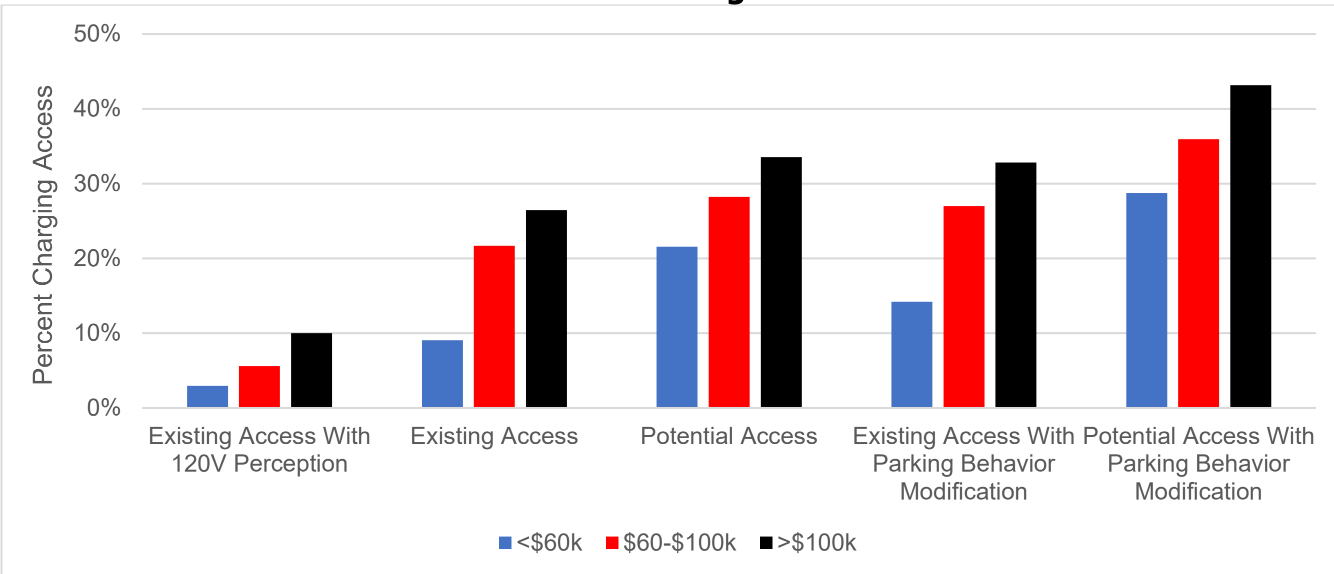
Source: CEC and NREL

Figure 12 shows the variability in home charging access for MFH survey respondents. Once again, in all cases home charging access increases with income. However, the changes in home charging access are more significant for MFHs than SFHs. There are several instances of a higher-income group reporting more than double the home charging access compared to the lowest income group. Nevertheless, as described earlier, home charging access remains low for all MFH respondents, never surpassing 45 percent for any income group or access scenario.

26 See Appendix C for details on survey sample sizes.

27 Hoang, Tiffany. 2020. *California Electric Vehicle Infrastructure Deployment Assessment: Senate Bill 1000 Report*. California Energy Commission. Publication Number: CEC-600-2020-009, https://www.energy.ca.gov/programs-and-topics/programs/electric-vehicle-charging-infrastructure-assessment-ab-2127.

Figure 12: Home Charging Access for Multifamily Home Respondents in Three Income Categories



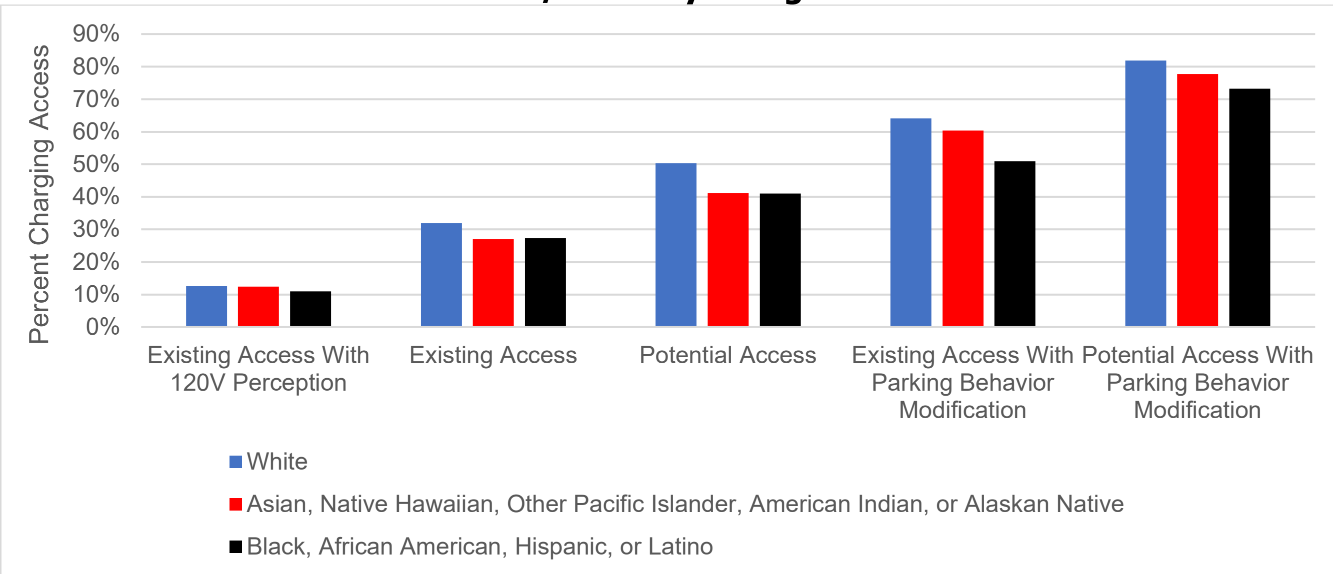
In all cases, home charging access for MFH respondents increases with increasing income. These increases are more dramatic than for SFH respondents, and there are several instances of home charging access more than doubling compared to the lowest income group.

Source: CEC and NREL

Home charging access was also investigated for different races/ethnicities. To conduct this analysis, respondents were grouped into three broad classifications to maintain reasonable sample sizes: Group 1) White (585 responses); Group 2) Asian, Native Hawaiian, Other Pacific Islander, American Indian, or Alaskan Native (373 responses); and Group 3) Black, African American, Hispanic, or Latino (229 responses). Respondents who identified as two or more races (88 responses) or chose not to respond (12 responses) were not included for these comparisons because the sample sizes were too small to perform analysis.

Figure 13 shows the variability in home charging access for SFH survey respondents. In all cases, Group 1 respondents had the greatest home charging access. Respondents in Group 2 had the same or greater home charging access than respondents in Group 3 in all access scenarios.

Figure 13: Home Charging Access for Single-Family Home Respondents in Three Race/Ethnicity Categories

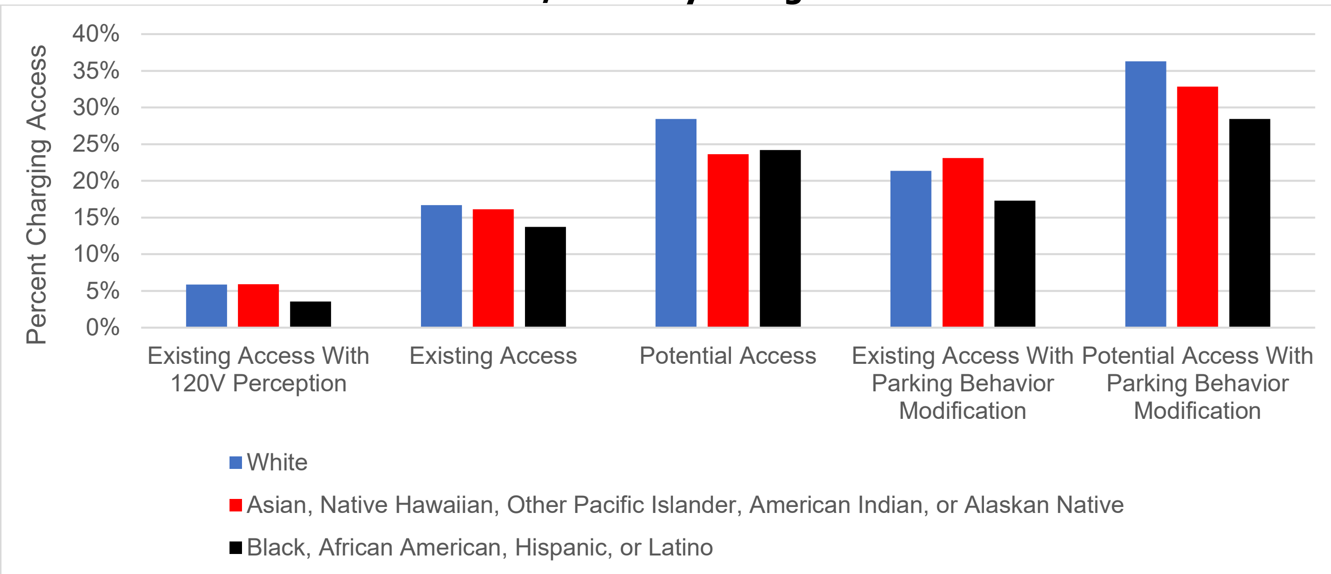


Group 1 respondents have greater home charging access than Group 2 and 3 respondents in all scenarios. Group 2 respondents have home charging access equivalent to or greater than Group 3 respondents in all scenarios.

Source: CEC and NREL

Figure 14 shows the variability in home charging access for MFH survey respondents. Similar trends are seen here, with Group 1 respondents almost always having greater home charging access than the other races/ethnicities. The lone exception is in the Existing Access with Parking Behavior Modification scenario, where respondents in Group 2 have slightly greater home charging access than respondents in Group 1.

Figure 14: Home Charging Access for Multifamily Home Respondents in Three Race/Ethnicity Categories



Group 1 respondents have greater home charging access than Group 2 and 3 respondents in all cases except Existing Access With Parking Modification. Group 2 respondents have home charging access equivalent to or greater than Group 3 respondents.

Source: CEC and NREL

These results show that people who identify as White generally have the greatest access to home charging, while those who identify as Black, African, Hispanic, or Latino have lower access. This finding emphasizes the significance of racial/ethnic diversity in the transportation electrification transition. It is critical to reemphasize that the grouping of races and ethnicities in this analysis was done to preserve survey sample sizes. Evaluating outside these groups could show more significant disparities.

While variations in home charging access are clearly present for different income levels and races/ethnicities, dwelling type remains the most significant determinant of home charging access. For example, the lowest income category in SFHs still has equivalent or greater home charging access to the highest income category in MFHs for all access scenarios. This trend is even more apparent for races/ethnicities, as SFH respondents in Group 3 have much greater home charging access than MFH respondents in Group 1 for all access scenarios.

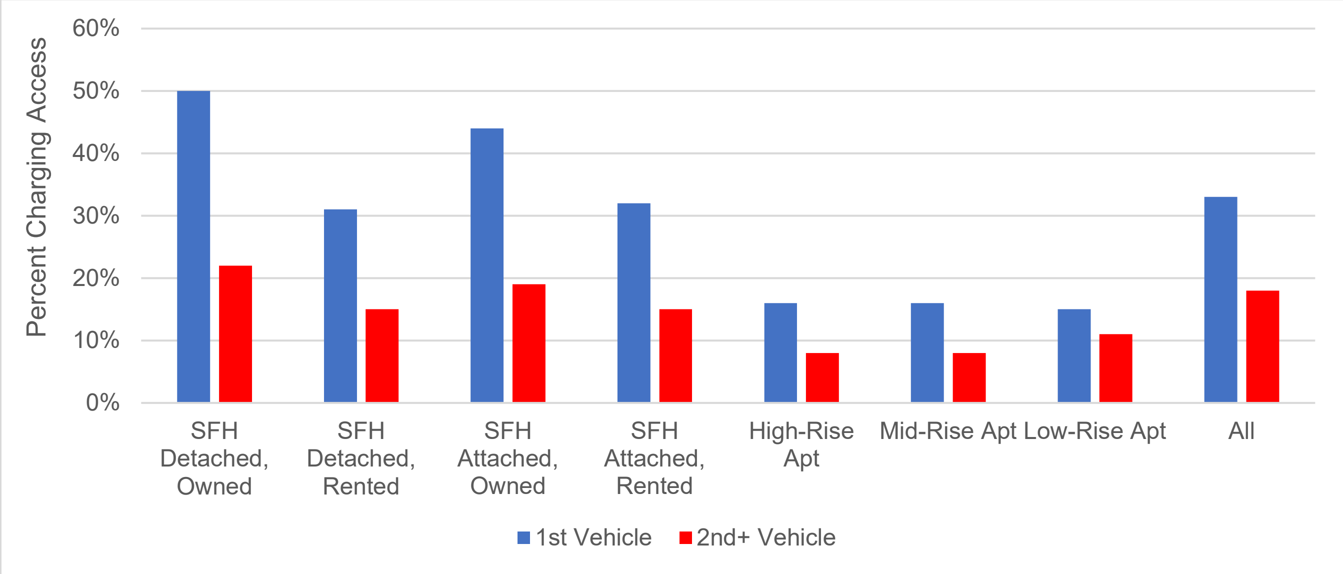
The results presented thus far have aggregated the home charging access for all vehicles in the respondents' households. However, if the respondent owned multiple vehicles, the survey also allowed respondents to designate which was the "first" vehicle in the household, which was the "second," and so on. (Refer to Appendix A for details on the survey instrument.) This characterization allowed comparisons to be made between the home charging access for different vehicles in the household. This is relevant as the electrification of multivehicle households will be critical to achieving the state's ZEV goals. The analysis shown below looks at the first vehicle in households with two or more vehicles compared to what is referred to as the "second plus" vehicle. This analysis allows consideration of home charging access for all additional vehicles in the household, not just the vehicle designated as "second" from the survey.

Figure 15 shows the difference in home charging access between the first and second plus vehicle under the Existing Access scenario. It is clear that the second plus vehicles have lower access to charging. Every housing type has a decrease of 50 percent or more except for low-rise apartments. Similar decreases in home charging access are seen in the Existing Access with 120V Perception and Potential Access scenarios, which can be found in Table C-7 in Appendix C.

In contrast, Figure 16, which illustrates the change in home charging access for the Potential Access With Parking Behavior Modification scenario, shows a different result. In this case, no change in home charging access is observed between the first and second plus vehicles. The same result is seen in the Existing Access With Parking Behavior Modification scenario. Since these two scenarios incorporate parking behavior modifications to change home charging access, it would be expected that survey respondents would report the same ability to shift the parking location of the first vehicle, second vehicle, and so on to achieve equal access to home charging.

Multi-PEV households will be necessary to reach the state's goals and decarbonize the transportation sector. While these results are significant and could reflect a barrier to multi-PEV adoption, this is primarily in the context of 120V, Level 1, charging. As PEVs with larger batteries and longer ranges enter the market, most drivers likely will not need to charge at home every single day, particularly when using faster Level 2 charging. This will allow households to share a single charger in most cases and have reliable charging for multiple vehicles. That said, there could be instances where charging multiple vehicles at home is still a barrier, and this should be considered as the number of multi-PEV households grows.

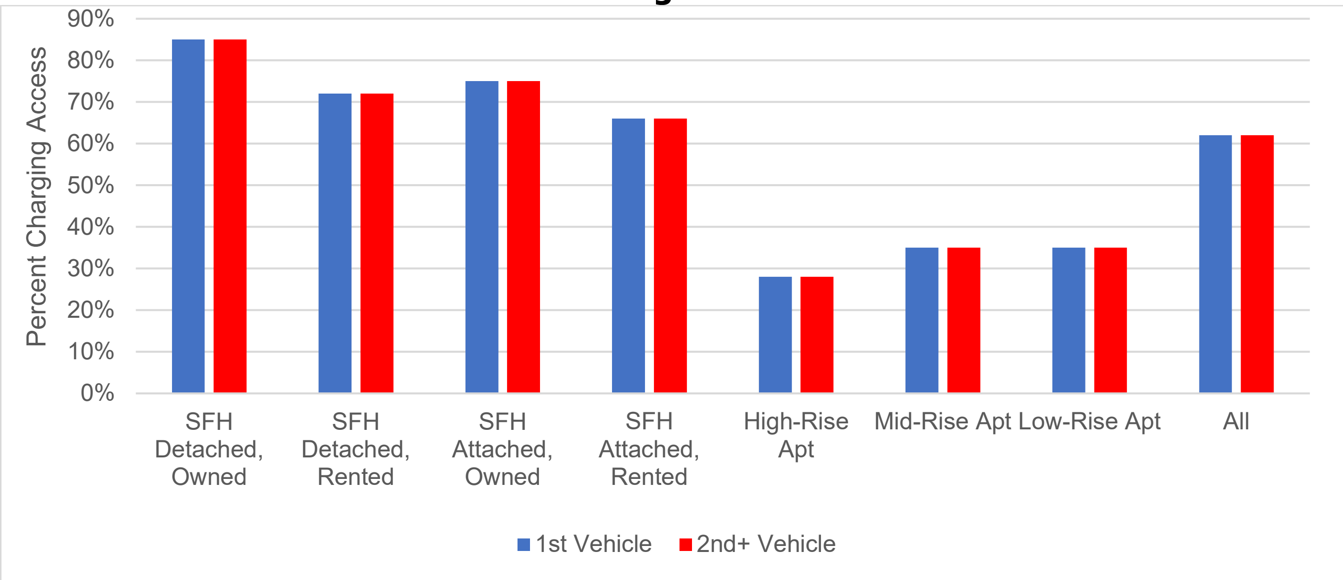
Figure 15: Home Charging Access for First and Second Plus Vehicles in a Household – Existing Access Scenario



Second vehicles in the household have lower home charging access than the first vehicle. All housing types see a relative decrease in home charging access of 50 percent or more on a relative basis except for low-rise apartments.

Source: CEC and NREL

Figure 16: Home Charging Access for First and Second Plus Vehicles in a Household – Potential Access With Parking Behavior Modification Scenario



This scenario results in no change in home charging access for second plus vehicles. Since this incorporates parking behavior modifications, it would be expected that any vehicle in a household would have the same ability to change parking locations and have equal access to home charging.

Source: CEC and NREL

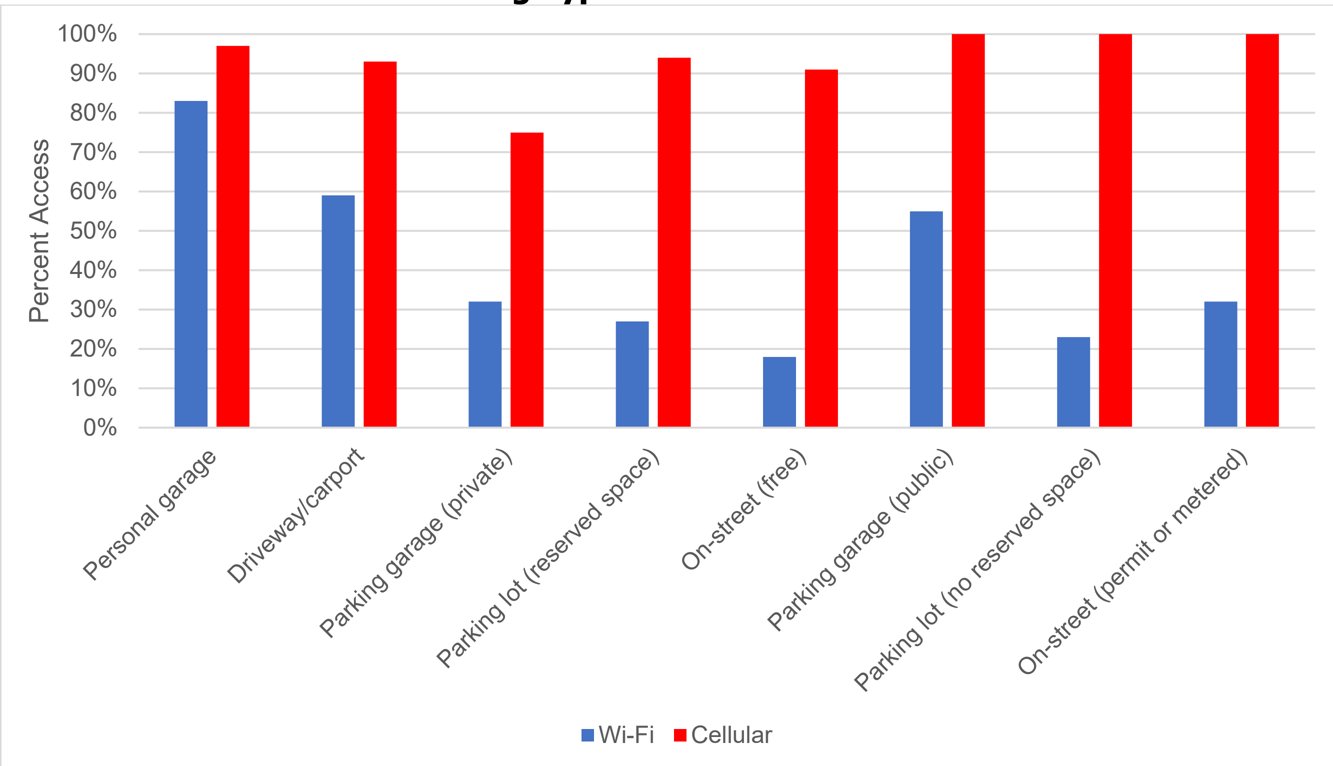
Wi-Fi and Cellular Access

The survey results also provided insights into Wi-Fi and cellular access. Respondents were asked whether they had reliable Wi-Fi/cellular reception at the parking locations available to them. While not directly related to home charging access, these characteristics could have implications for access to home networked charging. Networked chargers use Wi-Fi or cellular connections to manage and monitor charging, which can be particularly beneficial for MFHs where several residents may rely on the same charger. Networked charging also enables participation in smart charging. "Smart charging" is a basic form of vehicle-grid integration that can reduce the power or shift the timing of charging based on electricity pricing, carbon intensity, demand response, or other grid signals, while ensuring that a driver's range and departure time requests are met.[28] Smart charging can yield significant cost savings for drivers in an automated and consistent manner.

While cellular and Wi-Fi connections can enable smart charging, they come with differing benefits and hurdles. As Figure 17 shows, cellular reception is generally high, with greater than 90 percent availability at all parking options except private parking garages. However, adding cellular connectivity to EV chargers often carries an additional cost that can be a burden to site hosts and drivers. On the other hand, if Wi-Fi reception is present, connecting a charger to that network typically comes at no added cost. However, Figure 19 shows that Wi-Fi access is variable, ranging from a low of 18 percent for on-street free parking to a high of 83 percent in personal garages. Notably, the two parking options with the highest Wi-Fi access, personal garages and driveways, are overwhelmingly associated with SFHs, as shown in Figure 4. These results are not surprising but highlight the challenges, and possible inequities, that could arise with home smart charging if MFH residents are predominantly limited to parking options that may require additional costs associated with cellular connectivity. These residents could be restricted from opportunities for cost savings and more convenient charging that would also limit benefits to the overall grid and EV charging ecosystem.

28 Alexander, Matt, Noel Crisostomo, Wendell Krell, Jeffrey Lu, and Raja Ramesh. July 2021. *Assembly Bill 2127 Electric Vehicle Charging Infrastructure Assessment: Analyzing Charging Needs to Support Zero-Emission Vehicles in 2030 – Commission Report*. California Energy Commission. Publication Number: CEC-600-2021-001-CMR.

Figure 17: Wi-Fi and Cellular Reception at Available Parking Locations for All Housing Types and Income Levels



Cellular access is high across all parking options, but Wi-Fi access is much more variable, ranging from a low of 18 percent for on-street free parking to a high of 83 percent in personal garages. The two parking options with the highest Wi-Fi access, personal garages and driveways, are overwhelmingly associated with SFHs.

Source: CEC and NREL

CHAPTER 4: Evolution of Home Charging Access

To estimate the change in home charging access over time as the PEV fleet share increases, NREL created a PEV adoption model that leverages the survey results presented above. Details on the design of this PEV adoption model can be found in NREL's technical report discussing its national survey results.[29]

The PEV adoption model is used to enhance the 2017 five-year Public Use Microdata Sample (PUMS)[30] data by calculating PEV adoption probabilities to the vehicles in the dataset. The original PUMS dataset includes more than 7.5 million household survey records with many variables such as household and vehicle ownership traits, building type, and household income, which happen to be the input variables of the PEV adoption model. This dataset is then scaled for the Californian population and for each household the probability of PEV adoption is calculated based on the PEV adoption model. The records are then rank-ordered so that households with a higher PEV adoption probability are assumed to become PEV owners earlier. For a given PEV fleet size, these rankings are used to estimate the distributions of characteristics such as home charging access.

Figure 18 shows the results of this process aggregated for all housing types, income levels, and races, for each scenario described in Chapter 3. On the x-axis is PEV fleet share, where 100 percent fleet share means that 100 percent of the light-duty vehicles in California are PEVs. On the y-axis is home charging availability, which represents the percentage of PEVs in the fleet that have access to home charging. The evolution of home charging access across the five scenarios follows the same pattern seen in the survey results. Existing Access With 120V Perception yields the lowest access, and Potential Access With Parking Behavior Modification results in the highest access. In all scenarios, access decreases as the PEV fleet share increases. This decrease in access is a result of the PEV likely adopter model, which assumes that households with a higher PEV adoption probability are more likely to become PEV owners sooner.

California is far to the left side of this curve. As of the end of 2020, there were 628,473 PEVs registered in California out of more than 28.5 million light-duty vehicles, giving a PEV fleet share of about 2.2 percent.[31] In the most optimistic scenario, this share translates to about 98 percent of PEVs with home charging access, while the Potential Access scenario (assuming drivers will install home charging, if possible) results in about 92 percent of PEVs with access.

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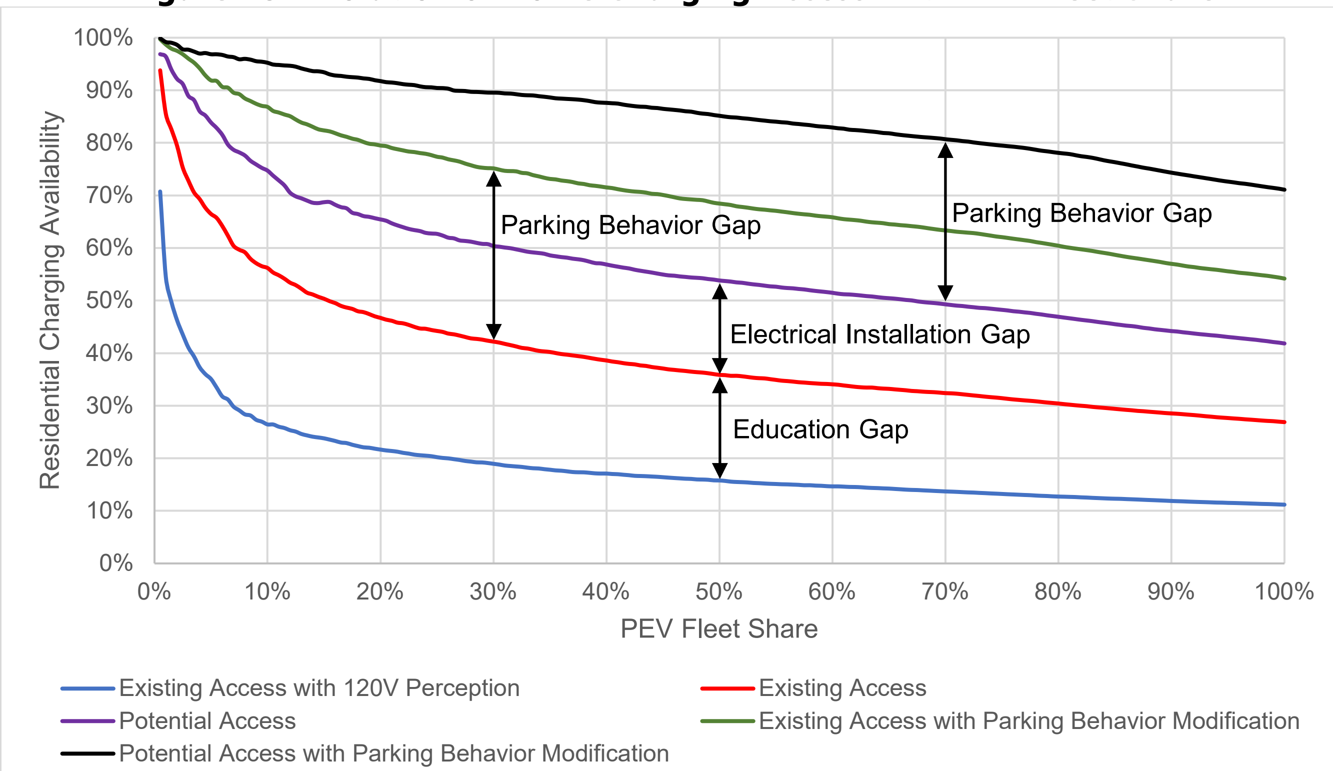
29 Ge, Yanbo, Christina Simeone, Andrew Duvall, and Eric Wood. 2021. *There's No Place Like Home: Residential Parking, Electrical Access, and Implications for the Future of Electric Vehicle Charging Infrastructure*. Golden, Colorado: National Renewable Energy Laboratory. NREL/TP-5400-81065. https://www.nrel.gov/docs/fy22osti/81065.pdf.

30 U.S. Census Bureau. Public Use Microdata Sample. https://www.census.gov/programs-surveys/acs/microdata.html.

31 CEC. 2021. *California Energy Commission Zero-Emission Vehicle and Infrastructure Statistics*. Data last updated April 30, 2021. Retrieved May 26, 2021, from https://www.energy.ca.gov/zevstats.

The expansion of PEV adoption into the mainstream market to meet the 100 percent ZEV in-state sales goal is likely to lead to a decrease in home charging access. For example, if the total light-duty fleet size remains the same, state goals of 1.5 million ZEVs by 2025, 5 million ZEVs by 2030, and 8 million ZEVs by 2030 would lead to access rates in the Potential Access scenario of 85, 72, and 67 percent, respectively.

Figure 18: Evolution of Home Charging Access With PEV Fleet Share



In all scenarios, home charging access decreases as the PEV fleet share increases. The Existing Access With 120V Perception scenario results in the lowest home charging access with only 11 percent of PEVs having access to home charging at 100 percent PEV fleet share. In the most optimistic case, the Potential Access With Parking Behavior Modification scenario results in 71 percent of PEVs with home charging access, revealing an upper bound on charging access.

Source: CEC and NREL

These five evolution curves show that there are three key gaps that could hinder PEV adoption and home charging:

1) **Education**

   The results suggest that with 100 percent PEV fleet share, only 11 percent of the vehicles would have access to home charging as perceived by the driver in the most conservative case. Simply raising awareness and educating consumers about PEVs and charging could boost access anywhere from 16 to 33 percentage points, depending on the PEV fleet share.

2) **Electrical Installation**

   While it is likely that prospective PEV owners living in SFHs would plan to install home charging to capitalize on this key benefit of PEV ownership, this may not always be the case depending on the specific circumstances and costs, which could hinder access. Electrical installations at MFHs are a tougher challenge given building and parking constraints and, frequently, split incentives for landlords and tenants. In these cases, public and private funding to support charging infrastructure installations at MFHs or in public locations that could be used overnight by MFH residents (for example, curbside chargers) could increase access for residents of these dwelling types.

3) **Parking Behavior**

   Achieving the highest levels of access will require significant behavioral modifications among drivers to change where they typically park. While these modifications present the largest gains in access, they could also be the most challenging to accomplish since they would require a widespread change in individuals' parking patterns. Furthermore, as Figure 12 showed, shifting parking behavior primarily improves access for SFH residents, not MFH residents.

In a hypothetical 100 percent PEV future, these results indicate that there is an upper bound on home charging access, with the most optimistic case resulting in only about 70 percent access. At the other extreme, only 11 percent of the PEV fleet is projected to have access to home charging when factoring in awareness of home charging opportunities. This scenario highlights the importance and need for continued infrastructure investment and deployment in public infrastructure, as many drivers will not have home charging and will depend on other reliable, convenient, and cost-effective options for charging. Fuel cell electric vehicles will play a role in the state's clean transportation transition, and a 100 percent plug-in EV future is unlikely. This dynamic will reduce the need for public charging infrastructure but replace it with hydrogen refueling infrastructure demand.

As in Figure 20, the evolution of home charging access was also examined for different housing types, income levels, and races. Detailed results are presented in Appendix B. An important caveat is that these finer breakdowns, particularly for income levels and races, result in smaller sample sizes. As such, these results are meant to observe potential trends rather than offer conclusive takeaways.

SFHs continue to have greater access than MFHs over time. This disparity becomes especially apparent for the scenarios that include parking behavior modifications, emphasizing the point made previously that MFHs are limited in parking option flexibility. Within MFHs, low- and mid-rise apartments are generally similar to each other, while high-rise apartments have the lowest charging access. At 100 percent PEV fleet share in the most optimistic scenario, SFHs have greater than 70 percent access, while MFHs have less than 40 percent access.

Differentiation in home charging access over time between income levels is not as extreme as housing types. However, in all scenarios, home charging access increases with rising income. In particular, the disparity between income groups is most pronounced in the scenarios that include shifts in parking behavior, highlighting the more diverse selection of high-quality parking options and increased ability for those with higher incomes increase their access to home charging. In the most optimistic scenario at 100 percent fleet share, the lowest income group reaches only 60 percent access to home charging, while the highest income group surpasses 80 percent.

Comparisons of home charging access over time among race groupings do not reveal differences as large as those for housing types, with no gap larger than 17 percentage points. Nevertheless, consistent trends indicate disparities. In all scenarios, respondents who identified as White have the highest home charging access, while respondents who identified as Black or African American and Hispanic or Latino have the lowest access. The group that identified as Asian, Native Hawaiian, Other Pacific Islander, American Indian, or Alaska Native fell in between the two. In the most optimistic scenario at 100 percent PEV fleet share, home charging access ranged from 60 to 77 percent for the three race/ethnicity groups.

CHAPTER 5: Conclusions and Policy Implications

This survey and analysis of the results represent a step forward in the understanding of home charging access in California. While the ability to charge at home is one of the key benefits of owning a PEV, the survey results presented in this report demonstrate a potential upper bound on home charging availability. Disparities are observed based on housing type, income level, and race/ethnicity. The results show that MFHs have less access to high-quality parking options and home charging than SFHs. The results also suggest that lower-income residents have less access to these as well. Finally, the analysis revealed disparities among different races/ethnicities — as respondents who identified as Black, African American, Hispanic, or Latino — generally have lower access to charging than other races/ethnicities.

Looking at the evolution of home charging access into the future reveals that access could fall rapidly as PEV adoption moves out of the early-adopter phase and into the mainstream market. In a fleet composed entirely of PEVs, even in the most optimistic scenario, which requires parking behavior changes and new electrical installations, about 30 percent of those vehicles are without access to home charging. Those drivers would have to rely on more of a gas station model or other public and workplace charging options.

To ensure all Californians benefit from transportation electrification and can participate in this transition, these gaps should be addressed. Home charging is often more reliable, convenient, and cheaper than public charging. For drivers who are unable to charge at home, public charging alternatives should be more comparable to home charging in terms of reliability, convenience, and cost.

These results have already played an important role in the state's plans. The inaugural AB 2127 assessment model results leveraged assumptions about home charging access based on this analysis.[32] For a fleet of 8 million ZEVs by 2030, identified in CARB's *Revised Draft 2020 Mobile Source Strategy*[33] as the trajectory needed to meet the goals of EO N-79-20, about 67 percent of vehicles were assumed to have access to home charging. This assumption was directly informed by the evolution curves presented in Chapter 4 and used the Potential Access scenario, assuming that homeowners would install electricity, if possible, to charge their vehicles. In addition, these results could inform the CEC's SB 1000 analysis, which investigates whether charging infrastructure is disproportionately deployed and whether access to charging stations is disproportionately available.

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32 Alexander, Matt, Noel Crisostomo, Wendell Krell, Jeffrey Lu, and Raja Ramesh. July 2021. *Assembly Bill 2127 Electric Vehicle Charging Infrastructure Assessment: Analyzing Charging Needs to Support Zero-Emission Vehicles in 2030 – Commission Report*. California Energy Commission. Publication Number: CEC-600-2021-001-CMR, https://www.energy.ca.gov/programs-and-topics/programs/electric-vehicle-charging-infrastructure-assessment-ab-2127.

33 California Air Resources Board staff. 2021. *Revised Draft 2020 Mobile Source Strategy*. California Air Resources Board.

A key question moving forward will be how to address home charging access. Strategies can increase access to home charging or provide alternatives for those without access. Chapter 4 identified three fundamental gaps hindering access: education, electrical installation, and parking behavior. Addressing these areas will require the efforts of individuals and many stakeholders, such as local governments, property owners, community-based organizations, nonprofits, automakers, and others. All have a critical role in educating the public about PEV charging and boosting consumer confidence and awareness. State agencies, utilities, community choice aggregators, and building developers are just a few of the entities that could address electrical installation. For example, the CEC released a solicitation in November 2021 targeting projects that serve residents of MFHs.[34] Recently funded innovative charging solutions such as curbside charging,[35] shared home chargers,[36] and power management technologies[37] could offer other options and alternatives for home charging. In addition, the California Building Standards Commission has been reviewing options in CALGreen[38] codes to require PEV capable parking spaces in new buildings, including homes. The most challenging gap to fill could be parking behavior. While it is certainly possible that drivers will naturally change their parking behavior once they purchase an EV to charge at home, this may not always be the case. Furthermore, the survey results showed that improvements in charging access from shifts in parking behavior were realized mainly in SFHs, not MFHs, emphasizing the limited options and flexibility for MFH residents.

Home charging access for multi-PEV households will be a challenge. As the results showed, the second vehicle in a household is expected to have drastically lower access to home charging than the first vehicle. The University of California Institute of Transportation Studies' recent carbon neutrality transportation study projects that after 2030, new ZEV sales will be roughly evenly split between households that are electrifying their first vehicle and households that are electrifying additional vehicles.[39] The lack of home charging, or other convenient, reliable, and cost-effective charging options away from home, may hinder the adoption of second PEVs.

There is still room for improvement in further understanding of home charging access. Most notably, the questions in this survey were based on access to basic 120V electricity for Level 1 charging. However, access to Level 2 charging at home may become increasingly important, especially as the battery sizes and ranges of PEVs continue to increase. In fact, a recent study found that having access to Level 2 charging at home compared to Level 1 correlated with about 50 percent lower odds of EV owners reverting back to an ICEV. The presence of Level 1

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34 CEC. "GFO-21-603 — Reliable, Equitable, and Accessible Charging for multi-family Housing (REACH)." https://www.energy.ca.gov/solicitations/2021-11/gfo-21-603-reliable-equitable-and-accessible-charging-multi-family-housing.

35 California Energy Commission Agreement ARV-21-004 with FLO Services USA, Inc., for $750,000.

36 California Energy Commission Agreement ARV-21-002 with EVmatch, Inc., for $728,250.

37 California Energy Commission Agreement ARV-21-009 with PowerFlex Systems, Inc., for $699,736.

38 California Building Standards Commission. CALGreen. https://www.dgs.ca.gov/BSC/CALGreen.

39 Brown, A. L, D. Sperling, B. Austin, JR DeShazo, L. Fulton, T. Lipman, et al. 2021. *Driving California's Transportation Emissions to Zero.* UC Office of the President: University of California Institute of Transportation Studies*.* http://dx.doi.org/10.7922/G2MC8X9X Retrieved from https://escholarship.org/uc/item/3np3p2t0.

charging compared to no charging at home did not have a significant effect on EV discontinuance.[40] It is likely that access to Level 2 charging will be even more restricted due to the potential need for electrical upgrades and more infrequent availability of 240V electricity near parking locations. This need should be more explicitly investigated in the future. As NREL noted in its technical report, a larger sample would allow a more robust and refined analysis. Furthermore, further research focused specifically on frontline equity communities using survey instruments that are context and community sensitive could help inform models and investment policies that engage all California consumers.

GLOSSARY

ASSEMBLY BILL (AB) — A proposed law, introduced during a session for consideration by the Legislature, and identified numerically in order of presentation; also, a reference that may include joint, concurrent resolutions, and constitutional amendments, by Assembly, the house of the California Legislature consisting of 80 members, elected from districts determined on the basis of population. Two Assembly districts are situated within each Senate district.

CALIFORNIA AIR RESOURCES BOARD (CARB) — The state's lead air quality agency consisting of an 11-member board appointed by the Governor and more than 1,000 employees. CARB is responsible for attainment and maintenance of the state and federal air quality standards, California climate change programs, and motor vehicle pollution control. It oversees county and regional air pollution management programs.

CALIFORNIA ENERGY COMMISSION (CEC) — The state agency established by the Warren-Alquist State Energy Resources Conservation and Development Act in 1974 (Public Resources Code, Sections 25000 et seq.) responsible for energy policy. The CEC's five major areas of responsibilities are forecasting future statewide energy needs; licensing power plants sufficient to meet those needs; promoting energy conservation and efficiency measures; developing renewable and alternative energy resources, including providing assistance to develop clean transportation fuels and zero-emission vehicle infrastructure; and planning for and directing state response to energy emergencies. Funding for the Commission's activities come from the Energy Resources Program Account, Federal Petroleum Violation Escrow Account, and other sources.

COMMUNITY CHOICE AGGREGATOR — A local entity that represents a group of individual customers within a prescribed geographic region to pool purchasing power and secure alternative energy supply contracts.

DIRECT CURRENT FAST CHARGER (DCFC) — Electric vehicle charging anywhere from 200 to 1,000 volts using direct current.

40 Hardman, S., and G. Tal. 2021. *Discontinuance Among California's Electric Vehicle Buyers: Why Are Some Consumers Abandoning Their Electric Vehicles?* UC Davis: National Center for Sustainable Transportation. http://dx.doi.org/10.7922/G26971W0 Retrieved from https://escholarship.org/uc/item/11n6f4hs.

ELECTRIC VEHICLE (EV) — A broad category that includes all vehicles that can be fully powered by electricity or an electric motor.

ELECTRIC VEHICLE CHARGING STATION — An electric vehicle charging station, also called EV charging station, electric recharging point, charging point, charge point, electronic charging station (ECS), and electric vehicle supply equipment (EVSE), is an element in an infrastructure that supplies electric energy for the recharging of plug-in electric vehicles — including electric cars, neighborhood electric vehicles, and plug-in hybrids.

ELECTRIC VEHICLE INFRASTRUCTURE PROJECTIONS (EVI-Pro) — A modeling tool developed by the California Energy Commission and National Renewable Energy Laboratory to project electric vehicle charging infrastructure needs and associated load impacts in California.

ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE) — Equipment designed to supply power to EVs. Most EVSEs can charge BEVs and PHEVs.

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

GREENHOUSE GAS (GHG) — Any gas that absorbs infrared radiation in the atmosphere. Greenhouse gases include water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (NO_x), halogenated fluorocarbons (HCFCs), ozone (O_3), perfluorinated carbons (PFCs), and hydrofluorocarbons (HFCs).

LEVEL 1 (L1) CHARGING — Electric vehicle charging at 120 volts using alternating current.

LEVEL 2 (L2) CHARGING — Electric vehicle charging at 240 volts using alternating current.

MULTIFAMILY HOME (MFHs) — (also known as multidwelling unit or MDU) is a classification of housing where separate housing units for residential inhabitants are contained within one building or several buildings within one complex. Units can be next to each other (side-by-side units) or stacked on top of each other (top and bottom units). A common form is an apartment building. Many intentional communities incorporate multifamily residences, such as in cohousing projects.

NATIONAL RENEWABLE ENERGY LABORATORY (NREL) — The United States' primary laboratory for renewable energy and energy efficiency research and development. NREL is the only federal laboratory dedicated to the research, development, commercialization, and deployment of renewable energy and energy efficiency technologies. Located in Golden, Colorado.

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

PLUG-IN HYBRID ELECTRIC VEHICLE (PHEV) — PHEVs are powered by an internal combustion engine and an electric motor that uses energy stored in a battery. The vehicle can be plugged into an electric power source to charge the battery. Some can travel nearly 100 miles on electricity alone, and all can operate solely on gasoline (like a conventional hybrid).

VEHICLE-GRID INTEGRATION (VGI) — Methods to align electric vehicle charging with the needs of the electric grid. To do this, electric vehicles must have capabilities to manage charging or support two-way communication between vehicles and the grid.

ZERO-EMISSION VEHICLE (ZEV) — Vehicles that produce no emissions from the onboard source of power (for example, hydrogen fuel cell vehicles and electric vehicles).

APPENDIX A:
Survey Instrument

Residential Parking Facility Survey Among CA Residents

Consent Form

Eric Wood, National Renewable Energy Laboratory, Eric.Wood@nrel.gov
Yanbo Ge, National Renewable Energy Laboratory, Yanbo.Ge@nrel.gov

Purpose of the Study
This study is intended to investigate the availability of residential parking facilities for California residents and how residential parking options are associated with housing type and potential for electric vehicle charging.

The estimated time of completion of this survey is 7-10 minutes.

Research Statement
The purpose of this consent form is to give you the information you will need to help you decide whether to participate in this study. Please read the form carefully. This process is called "informed consent." You should keep a copy of this form for your records. You should only complete this form if you understand it in full. If you have any questions about this form, please contact the researchers listed above.

Study Procedures
If you volunteer to participate in this study, we would ask you to do the following things: Provide your background information (gender, age, education level, etc.). Answer questions related to your vehicle ownership, residential parking options, how many vehicles you own, where each vehicle is parked, and whether there is an electrical outlet available at each residential parking location.

Cessation of Participation
Your participation in this study is voluntary and you can stop participating at any time if you do not wish to answer a question or for any other reason.

Benefits of the Study
This survey will provide insights into the availability of residential parking facilities and advance the knowledge on future electric vehicle charging infrastructure planning.

Confidentiality of Research Information
Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. No system for protecting confidentiality is completely secure and the information about you could be inadvertently accessed or seen by someone outside the research team.

Government or university staff sometimes review studies such as this one to make sure they are being done safely and legally. If a review of this study takes place, your records may be examined. The reviewers will protect your privacy. The study records will not be used to put you at legal risk of harm.

Subject's Statement
I volunteer to take part in this research. If I have questions later about the research, or if I have been harmed by participating in this study, I can contact one of the researchers listed on this consent form.

ELECTRONIC CONSENT: Please select your choice below.

Clicking on the "Next" button below indicates that:

- You understand the information above.
- You voluntarily agree to participate, and have not been pressured to do so.
- You are at least 18 years of age.

1. What is the Zip Code of your home location?

2. What is your age?
    a. 18-24
    b. 25-34
    c. 35-44
    d. 45-54
    e. 55-64
    f. >=65
    g. Prefer not to answer

3. What is your annual household income?
    a. $9,999 or less
    b. $10,000 to $14,999
    c. $15,000 to $19,999
    d. $20,000 to $24,999
    e. $25,000 to $29,999
    f. $30,000 to $34,999
    g. $35,000 to $39,999
    h. $40,000 to $44,999
    i. $45,000 to $49,999
    j. $50,000 to $59,999
    k. $60,000 to $74,999
    l. $75,000 to $99,999
    m. $100,000 to $124,999
    n. $125,000 to $149,999
    o. $150,000 to $199,999

    p. $200,000 to $249,999
    q. $250,000 or more
    r. Prefer not to answer

4. What is your highest level of education?
    a. Less than high school
    b. High school graduate
    c. 2-year college/Associate degree
    d. Bachelor's degree
    e. Master's degree
    f. Doctoral and professional degree
    g. Prefer not to answer

5. What is your gender?
    a. Male
    b. Female
    c. Other
    d. Prefer not to answer

6. Which of the following can best describe your race/ethnicity?
    a. Hispanic or Latino or Spanish Origin of any race
    b. American Indian or Alaskan Native
    c. Asian
    d. Native Hawaiian or Other Pacific Islander
    e. Black or African American
    f. White
    g. Two or more races
    h. Prefer not to answer

7. How many adults (including yourself) are there in your household? (Adults: at least 16 years old)
    a. 1
    b. 2
    c. 3
    d. 4
    e. 5
    f. 6
    g. 7
    h. 8+

8. How many children are there in your household? (Children: younger than 16 years old)
    a. 0
    b. 1
    c. 2
    d. 3
    e. 4
    f. 5

g. 6
h. 7
i. 8+

9. How many people in your household own a driver's license?
   a. 0
   b. 1
   c. 2
   d. 3
   e. 4
   f. 5
   g. 6
   h. 7
   i. 8+

10. In which type of housing do you currently live?
    a. Mobile home or trailer
    b. Single family home (attached; e.g. rowhome, townhome, condo, etc.)
    c. Single family home (detached; e.g. ranch, split-level, two-story, etc.)
    d. 2 units apartment
    e. 3-4 units apartment
    f. 5-9 units apartment
    g. 10-19 units apartment
    h. 20-49 units apartment
    i. 50 or more units apartment
    j. Boat, RV, van, etc.
    k. Other

11. Do you rent or own the place where you live?
    a. Own
    b. Rent
    c. Neither (Please specify)

12. How long have you been living at your current housing location?
    a. Less than 1 year
    b. 1-3 years
    c. More than 3 years

13. At home, which of the following parking options are currently available to you (Please check all that apply)?
    a. On-street (permitted or metered)
    b. On-street (free)
    c. Driveway/carport
    d. Personal garage
    e. Parking garage (public)
    f. Parking garage (private)
    g. Parking lot (reserved space)

h. Parking lot (no reserved space)
i. RV park/yard/field
j. None

14. At home, which of the following parking options of yours have an electrical outlet available (Please check all that apply)?
    a. On-street (permitted or metered)
    b. On-street (free)
    c. Driveway/carport
    d. Personal garage
    e. Parking garage (public)
    f. Parking garage (private)
    g. Parking lot (reserved space)
    h. Parking lot (no reserved space)
    i. RV park/yard/field
    j. None

15. At home, which of the following parking options of yours either have electrical outlets available "OR" possible to have one installed if necessary (please check all that apply)?
    a. On-street (permitted or metered)
    b. On-street (free)
    c. Driveway/carport
    d. Personal garage
    e. Parking garage (public)
    f. Parking garage (private)
    g. Parking lot (reserved space)
    h. Parking lot (no reserved space)
    i. RV park/yard/field

16. Could you please provide some details about your parking options at home? (Please skip those that do not apply to you.)

	Number of stalls/parking lots (even if they are used for purposes other than parking currently)	Is there reliable Wi-Fi at this parking option?	Is there reliable cellular service at this parking option?
On-street (permitted or metered)	a. 0 b. 1 c. 2 d. 3 e. 4+	a. Yes b. No c. Don't Know	a. Yes b. No c. Don't Know
On-street (free)			
Driveway/carport			

Personal garage			
Parking garage (public)			
Parking garage (private)			
Parking lot (reserved space)			
Parking lot (no reserved space)			
RV park/yard/field			

17. How many vehicles are there in your household? (Please count street-legal motor vehicles, such as cars, SUVs, and pickup trucks)
    a. 0
    b. 1
    c. 2
    d. 3
    e. 4
    f. 5
    g. 6
    h. 7
    i. 8+

18. In your opinion, is it possible to charge an electric vehicle from the type of electrical outlet shown below?

    a. No
    b. Probably Not
    c. Possibly Yet
    d. Probably Yes

e. Yes

19. In your opinion, is it possible to charge an electric vehicle from the type of electrical outlet shown below?

a. No
b. Probably Not
c. Possibly Yet
d. Probably Yes
e. Yes

20. If you have a personal garage, do you have an operational electric clothes dryer in (or adjacent to) your garage?
a. Yes
b. No
c. I don't have a garage

21. On what device are you doing this survey?
a. Desktop
b. Laptop
c. Tablet
d. Smartphone
e. Other (Please specify)

22. Are you currently working as a driver for a ride-hailing service (e.g. Uber, Lyft)?
a. Yes
b. No

23. Have you seen any electric vehicle charging stations at public locations?
a. Yes, frequently
b. Yes, a few times
c. Yes, once or twice
d. Never seen one
e. Don't know what an EV charger looks like

Please provide the following info of your vehicle #1 [#2, #3, #4, #5, #6, #7, #8+]

24. What is the make of this vehicle?

25. What is the model of this vehicle?

26. What is the model year of this vehicle?

27. Is this vehicle ____?
    a. Plug-in hybrid electric vehicle
    b. Battery electric vehicle
    c. Neither

28. When at home, where is this vehicle typically parked?
    a. On-street (permitted or metered)
    b. On-street (free)
    c. Driveway/carport
    d. Personal garage
    e. Parking garage (public)
    f. Parking garage (private)
    g. Parking lot (reserved space)
    h. Parking lot (no reserved space)
    i. RV park/yard/field
    j. Other (please specify)

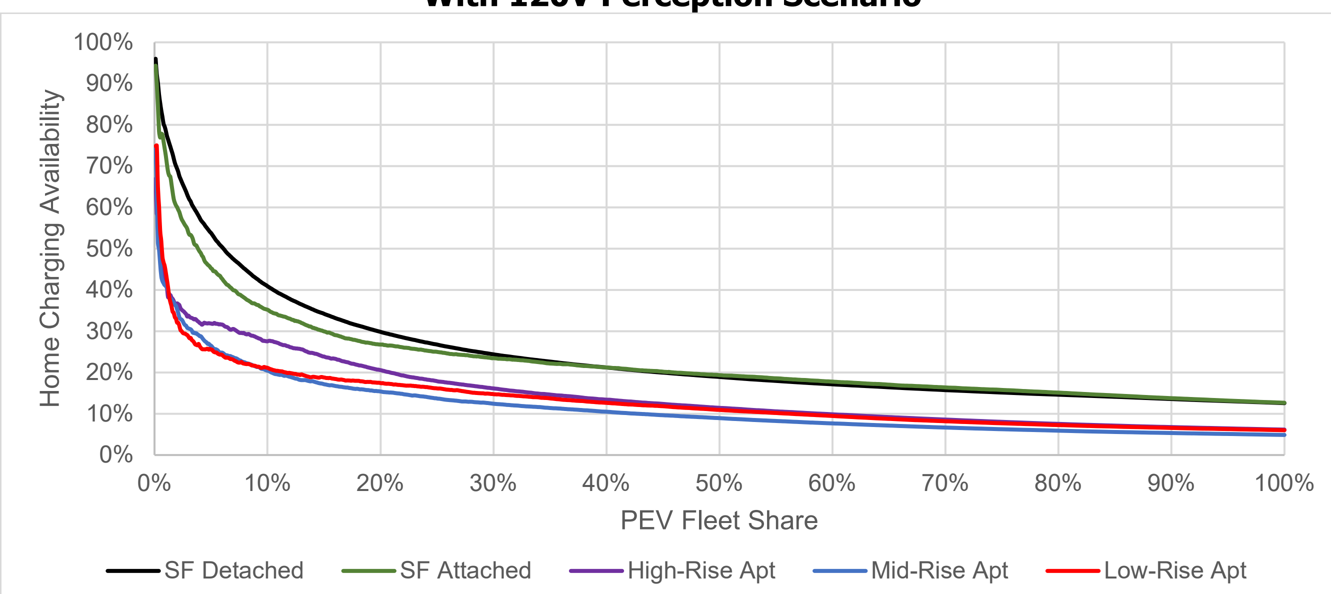
APPENDIX B: Evolution of Home Charging Access With Growing PEV Fleet Share

This appendix includes results for the evolution of home charging availability for all access scenarios and demographic breakdowns investigated, including housing type, income level, and race. The x-axis in these figures represents the PEV fleet share, where 100 percent means that 100 percent of the light-duty vehicles in California are PEVs. On the y-axis is home charging availability, which represents the percentage of PEVs in the fleet that have access to home charging.

Evolution of Home Charging Access by Housing Type

The figures below illustrate the evolution of home charging access broken down by housing type. The Existing Access With 120V Perception scenario always results in the lowest home charging access for each housing type, while the Potential Access With Parking Behavior Modification scenario results in the highest access. As discussed previously, SFHs have higher home charging access than MFHs in all scenarios, and the disparity becomes more apparent with scenarios that include parking behavior modifications. Within MFHs, low- and midrise apartments are generally similar to each other, with high-rise apartments having lower home charging access.

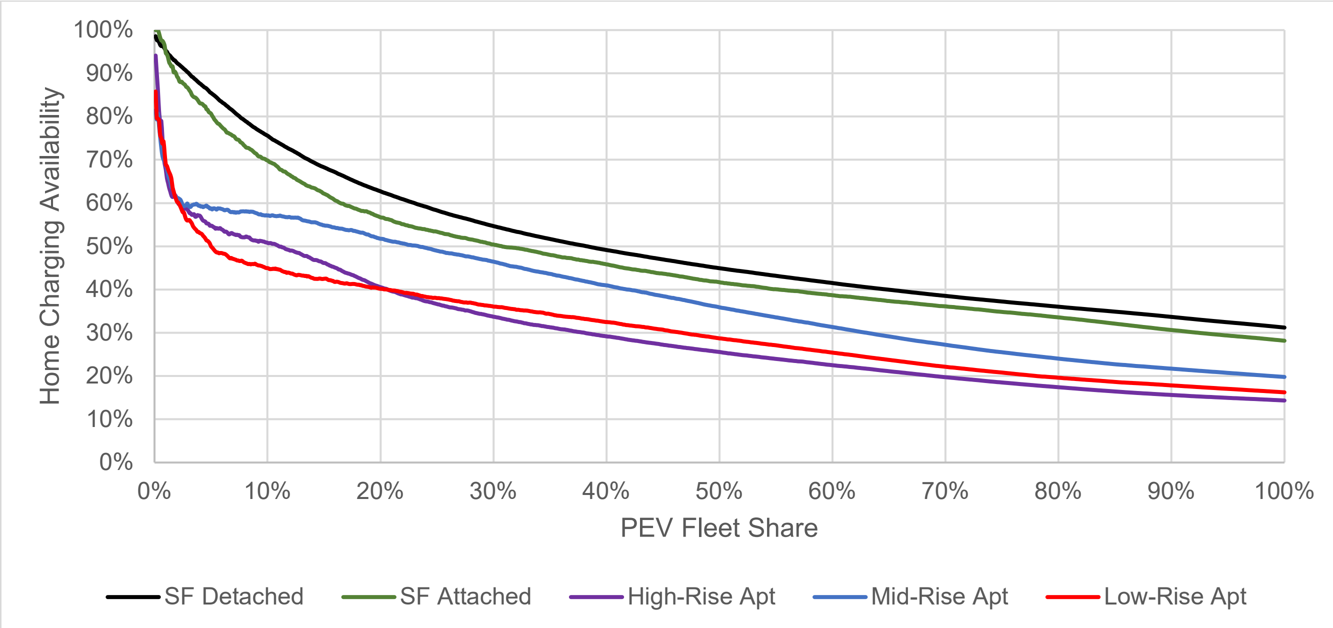
Figure B-1: Evolution of Home Charging Access by Housing Type – Existing Access With 120V Perception Scenario



Education could be a critical barrier to home charging access, as this scenario results in a home charging access below 15 percent for all housing types at a 100 percent PEV fleet share.

Source: CEC and NREL

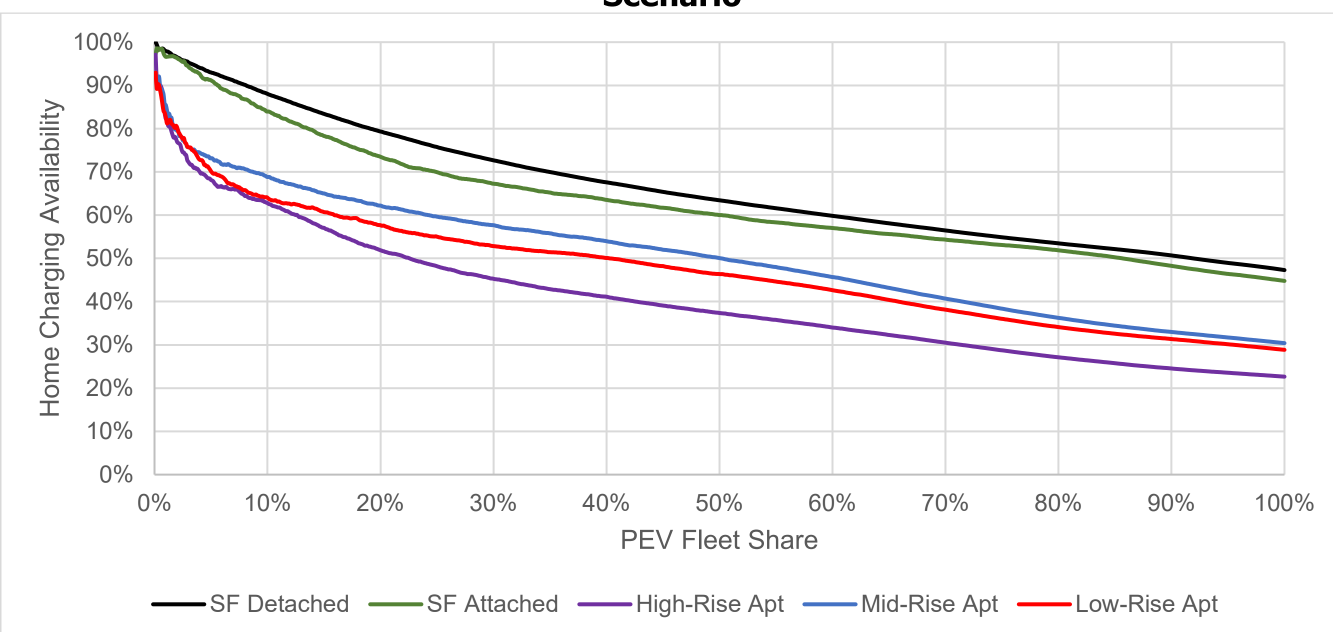
Figure B-2: Evolution of Home Charging Access by Housing Type – Existing Access Scenario



Following a business-as-usual case with existing access results in no more than a third of vehicles with access to home charging at a 100 percent PEV fleet share, regardless of housing type.

Source: CEC and NREL

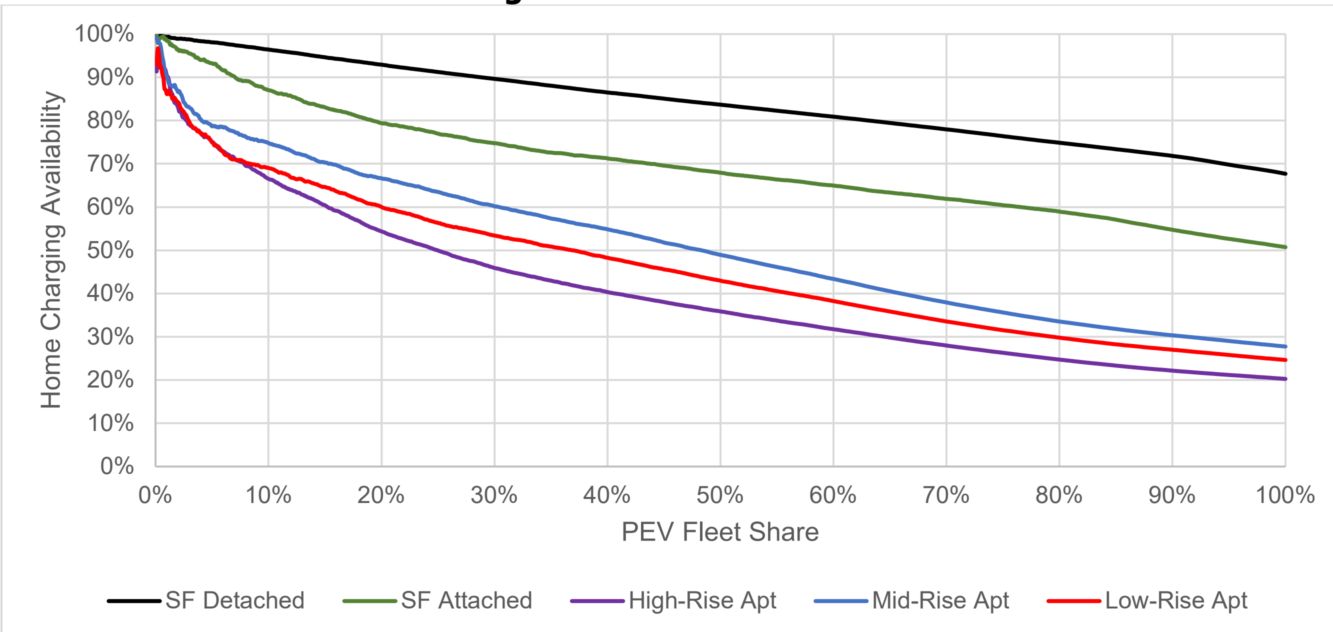
Figure B-3: Evolution of Home Charging Access by Housing Type – Potential Access Scenario



Installing 120V electricity can modestly boost home charging access in all housing types, though it is important to note that these results are not based on a professional electrician's assessment.

Source: CEC and NREL

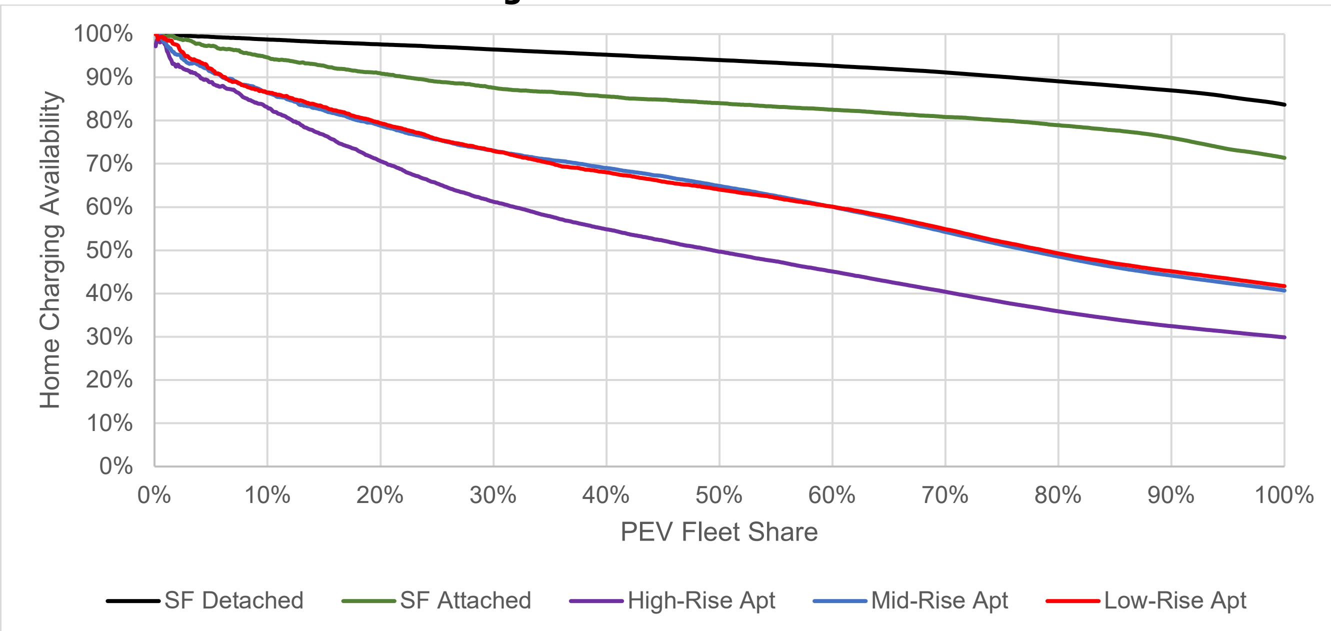
Figure B-4: Evolution of Home Charging Access by Housing Type – Existing Access With Parking Behavior Modification Scenario



Shifts in parking behavior create the starkest differentiation in home charging access between housing types. SFHs see a much larger increase in access compared to MFHs, emphasizing the limited high-quality parking options available to MFH residents.

Source: CEC and NREL

Figure B-5: Evolution of Home Charging Access by Housing Type – Potential Access With Parking Behavior Modification Scenario



The combination of shifting parking behavior and installing 120V electricity results in the highest home charging access for all housing types. At 100 percent PEV fleet share, more than 70 percent of the vehicles in SFHs are expected to have access to home charging. However, MFHs still experience low access, with only about 40 percent of vehicles or fewer having access to home charging.

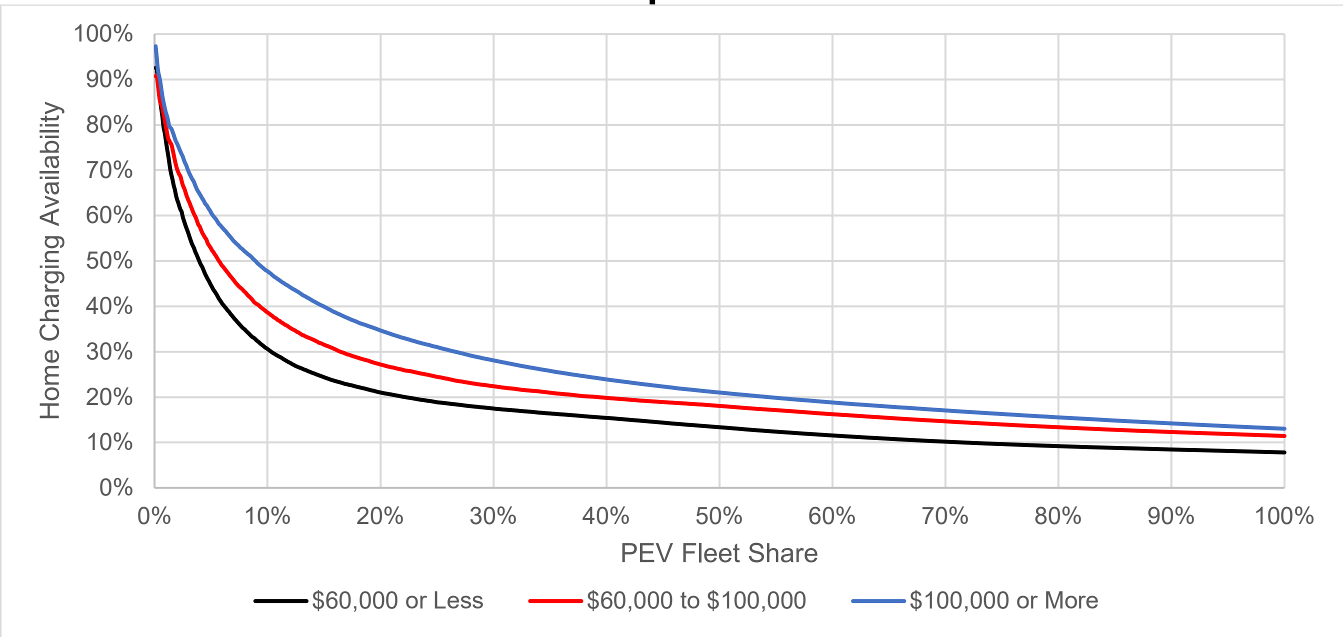
Source: CEC and NREL

Evolution of Home Charging Access by Income

The figures below illustrate the evolution of home charging access broken down by income level. As described previously, income was based on the total household income and respondents were broken down into three categories to keep sample sizes reasonable: 1) $60,000 or less; 2) $60,000 to $100,000; and 3) $100,000 or more.

In all cases, home charging access increases with increasing income as the PEV fleet share grows. However, differences in income do not make as big of an impact on home charging access as housing type. In the Existing Access With 120V Perception scenario, the three income groups are separated by only 5 percent when the PEV fleet share is 100 percent, suggesting that education about EV charging may not be significantly tied to income level. The differences in access are more pronounce in other scenarios, particularly those that incorporate shifts in parking behavior. This finding aligns with previous results showing that those with higher incomes have more flexibility to shift parking to more ideal locations and access charging.

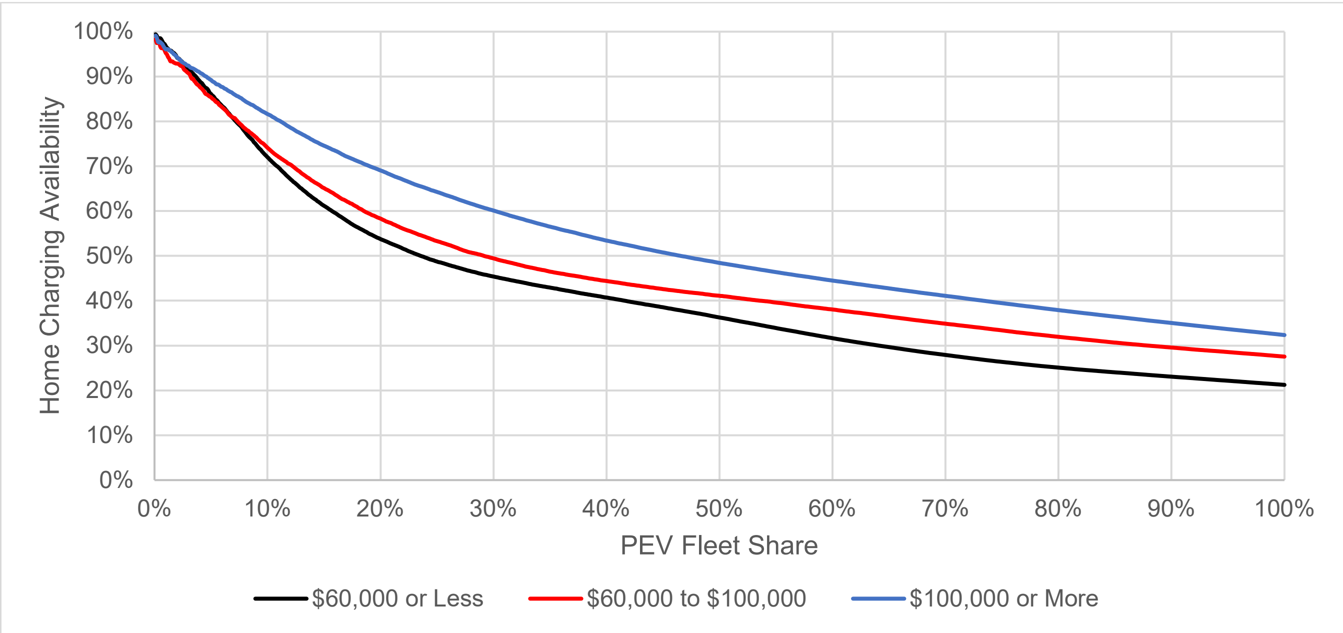
Figure B-6: Evolution of Home Charging Access by Income – Existing Access With 120V Perception Scenario



Awareness about 120V EV charging is consistently low across all income groups, ranging from 8 to 13 percent when the PEV fleet share is 100 percent.

Source: CEC and NREL

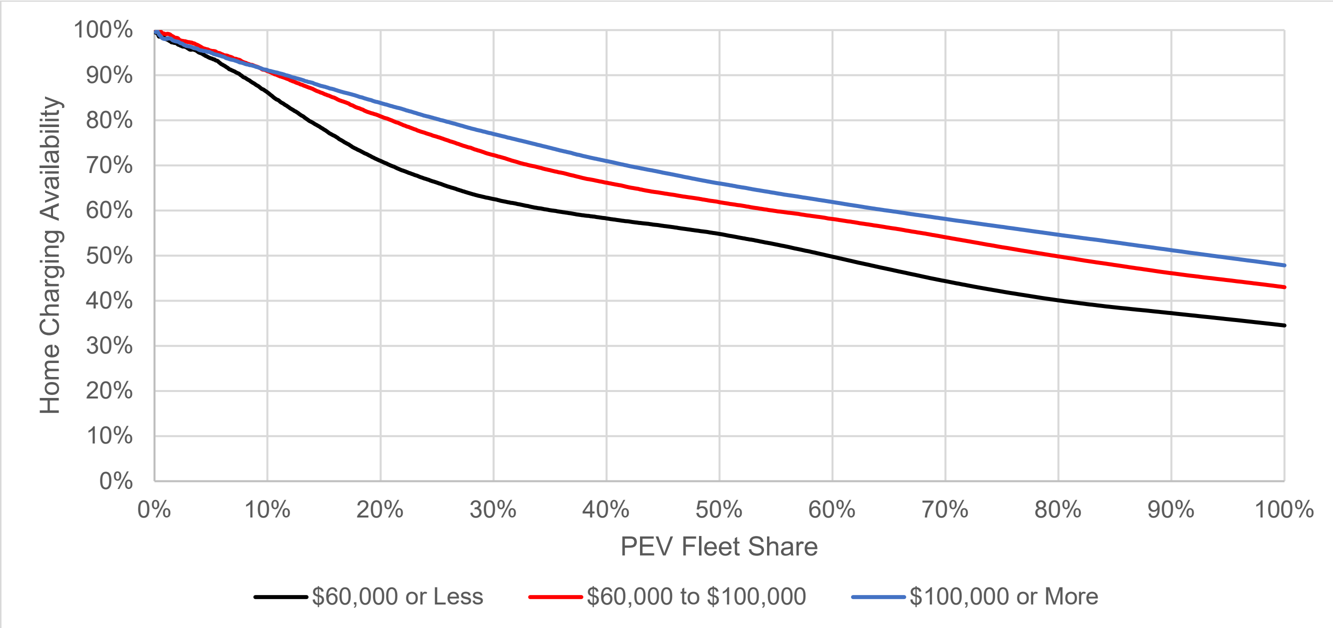
Figure B-7: Evolution of Home Charging Access by Income – Existing Access Scenario



Existing access to home charging does not surpass 33 percent even for the highest income group and drops to 21 percent for the lowest income group.

Source: CEC and NREL

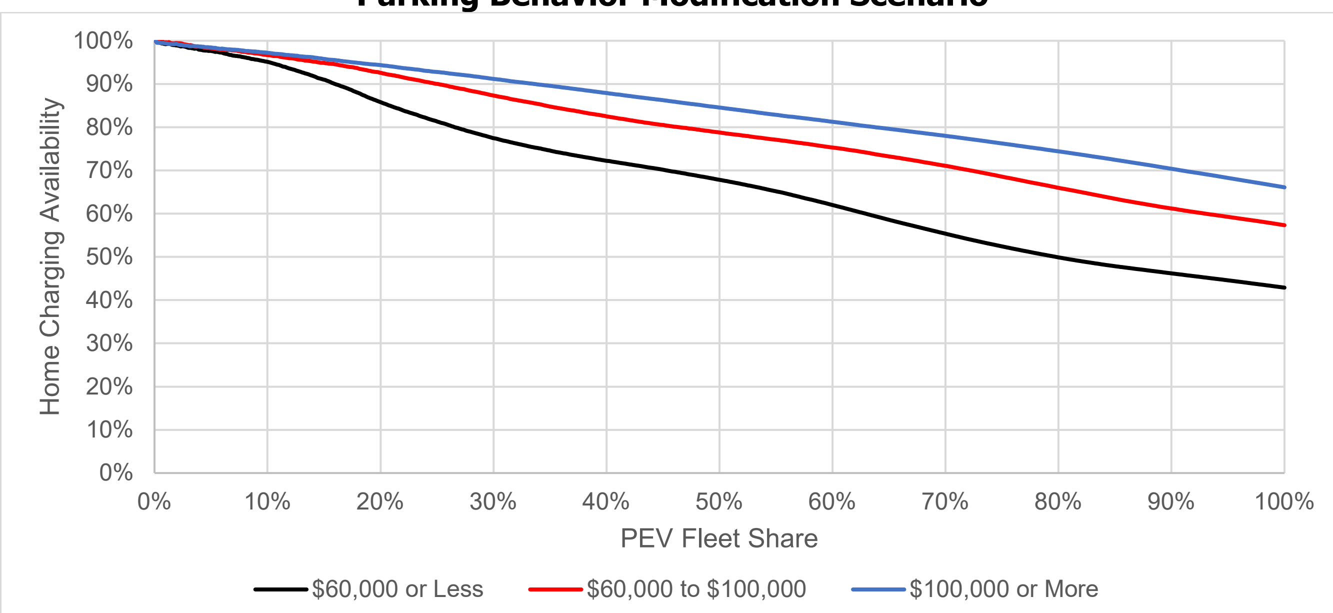
Figure B-8: Evolution of Home Charging Access by Income – Potential Access Scenario



Installing electricity provides increased charging access by 15 percent across all income groups.

Source: CEC and NREL

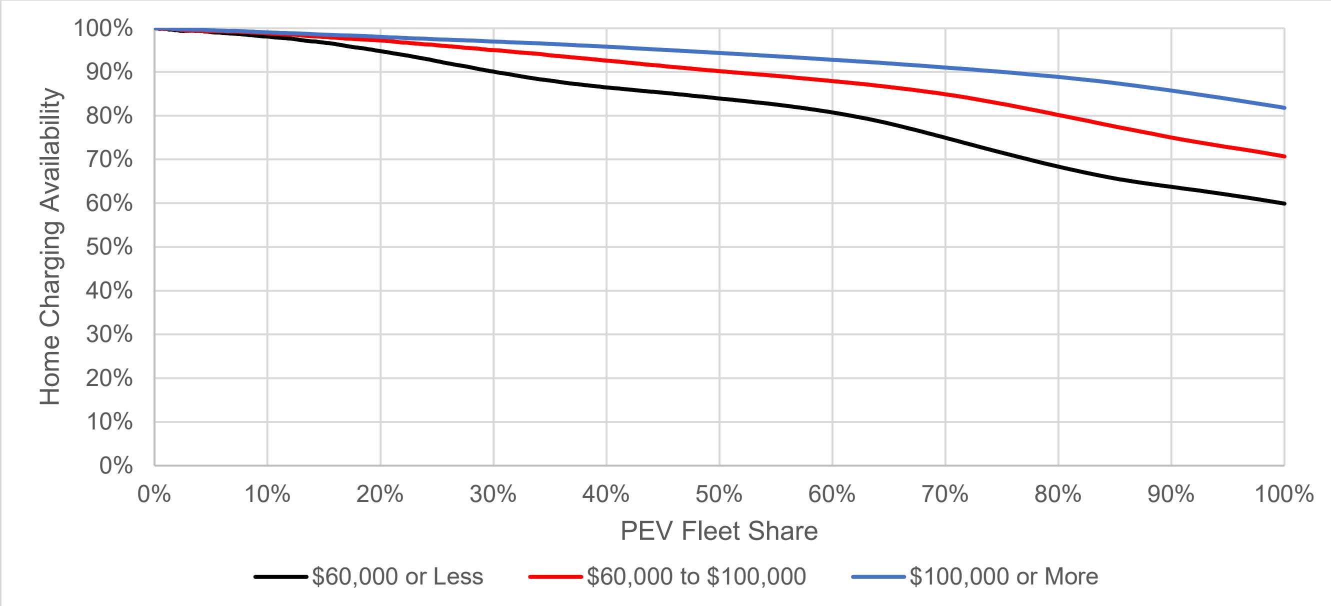
Figure B-9: Evolution of Home Charging Access by Income – Existing Access With Parking Behavior Modification Scenario



Shifts in parking behavior create a larger separation in home charging access among the three income groups, emphasizing the greater ability for those with higher income to move to more ideal parking locations and gain access to home charging.

Source: CEC and NREL

Figure B-10: Evolution of Home Charging Access by Income – Potential Access With Parking Behavior Modification Scenario



The $60,000 or less income group reaches 60 percent home charging access, while the $100,000 or more income group surpasses 80 percent.

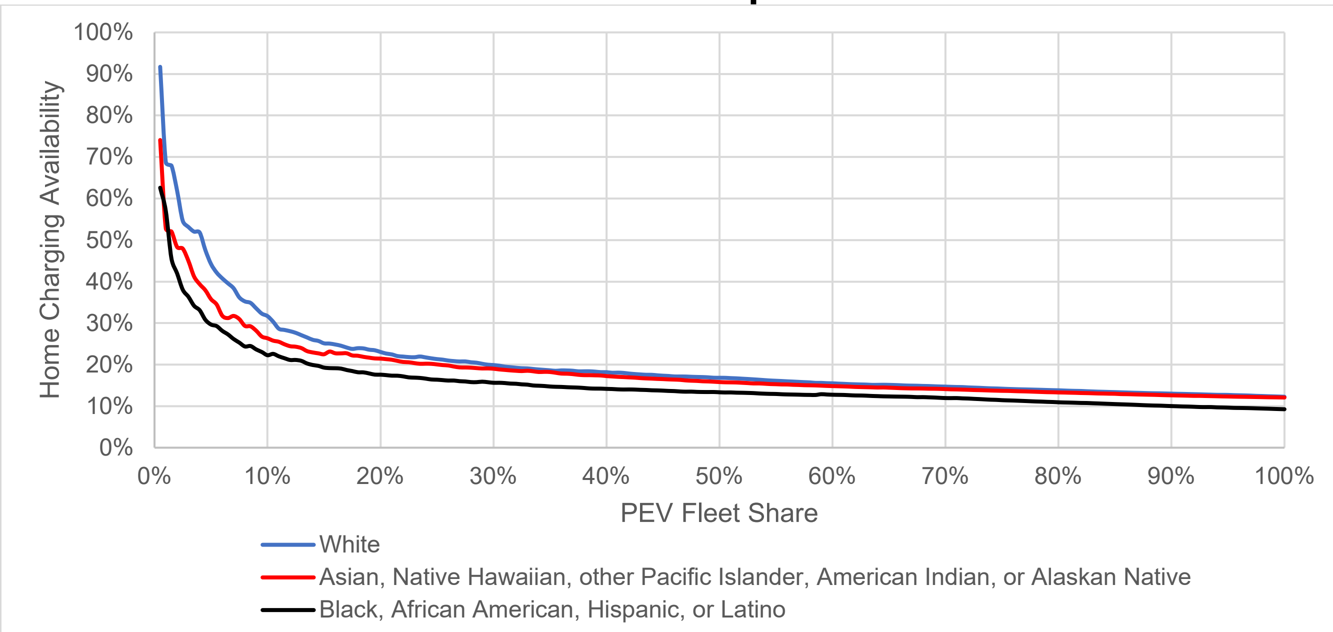
Source: CEC and NREL

Evolution of Home Charging Access by Race/Ethnicity

The figures below illustrate the evolution of home charging access by race/ethnicity. As described previously, respondents were assigned into three categories to keep sample sizes reasonable: 1) White; 2) Asian, Native Hawaiian, other Pacific Islander, American Indian, or Alaskan Native; and 3) Black, African American, Hispanic, or Latino.

Differences in home charging access by race/ethnicity are smaller than those by housing type. The largest gap in access was 17 percent between respondents who identified as White and respondents who identified as Black, African American, Hispanic, or Latino in the Potential Access With Parking Behavior Modification scenario. Nevertheless, disparities are observed, as all scenarios result in White respondents with the highest home charging access and Black, African American, Hispanic, or Latino respondents with the lowest access. Results for the group of respondents that identified as Asian, Native Hawaiian, Other Pacific Islander, American Indian, or Alaska Native always fell in between but sometimes leaned closer to one group than the other depending on the scenario. Interestingly, the Existing Access With 120V Perception scenario did not see significant variation by race/ethnicity, indicating that education about charging, or lack thereof, is a consistent issue.

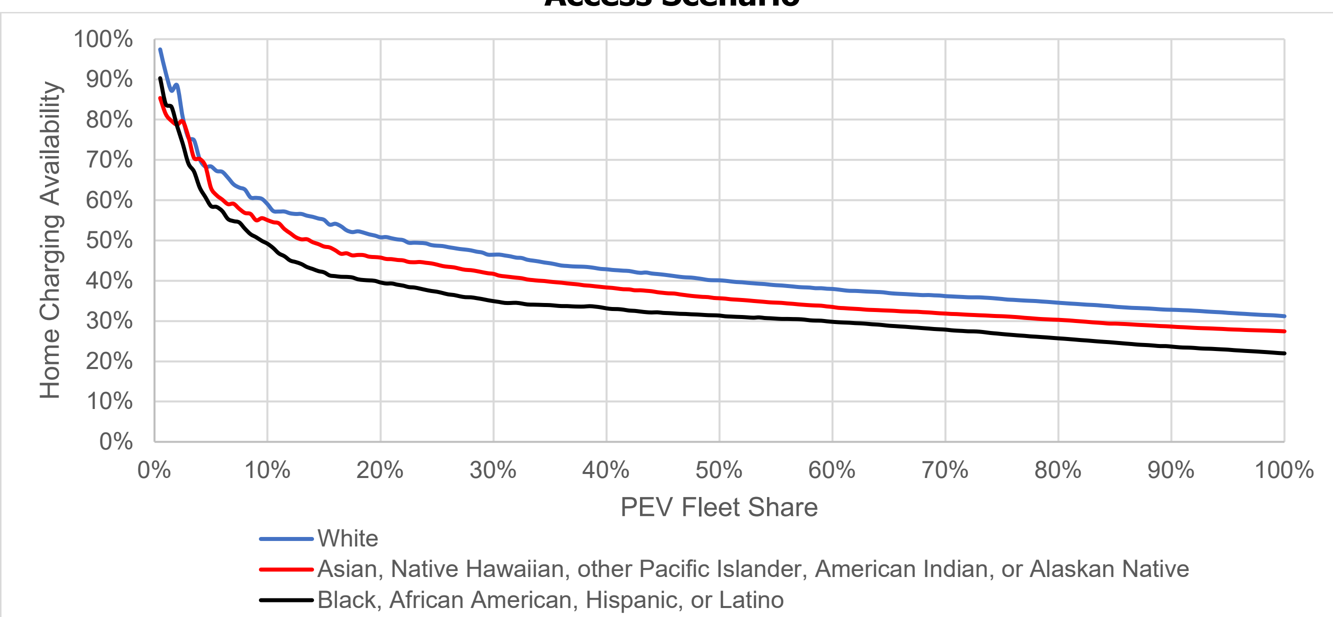
Figure B-11: Evolution of Home Charging Access by Race/Ethnicity — Existing Access With 120V Perception Scenario



Awareness about charging with 120V electricity is a common issue across all demographics.

Source: CEC and NREL

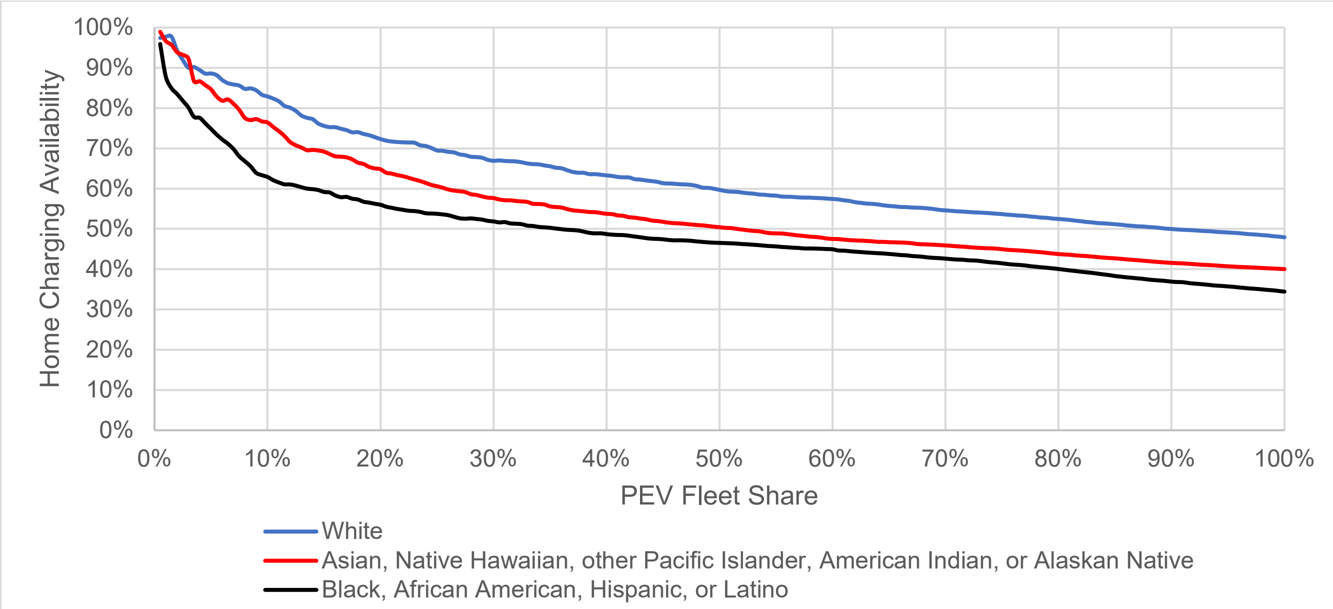
Figure B-12: Evolution of Home Charging Access by Race/Ethnicity — Existing Access Scenario



Similar levels of existing access are seen regardless of race/ethnicity, though respondents who identified as White had the highest home charging access, and those who identified as Black, African American, Hispanic, or Latino had the lowest access.

Source: CEC and NREL

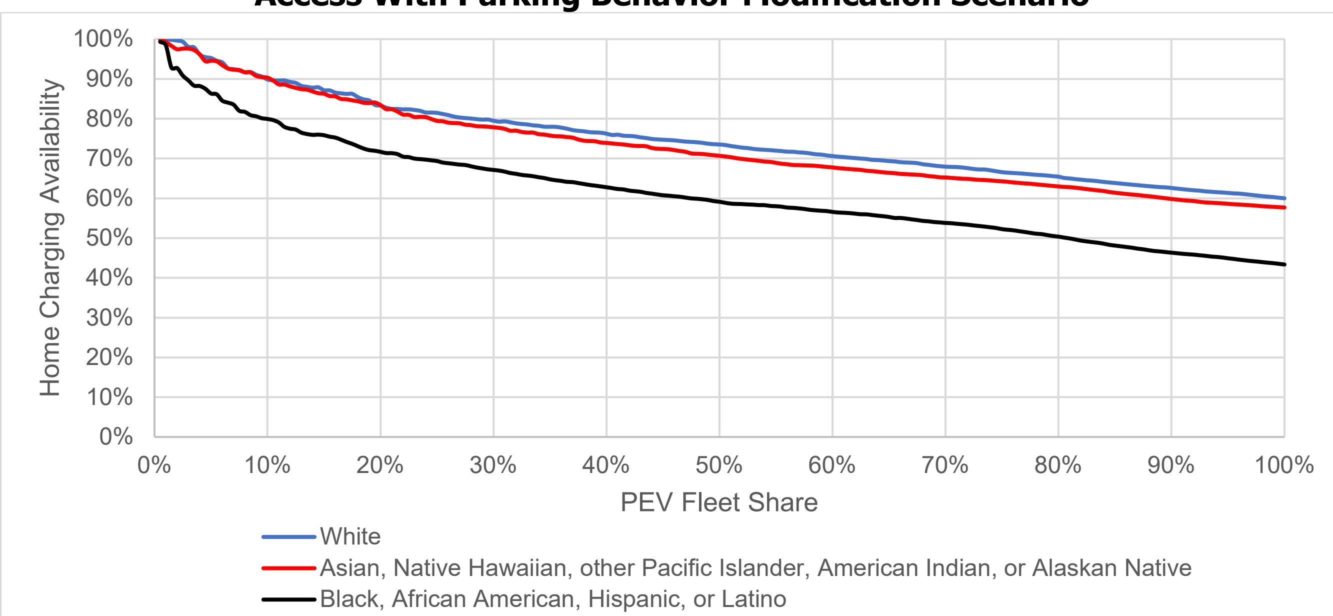
Figure B-13: Evolution of Home Charging Access by Race/Ethnicity — Potential Access Scenario



Respondents who identified as White have slightly greater ability to increase home charging access through the installation of 120V electricity.

Source: CEC and NREL

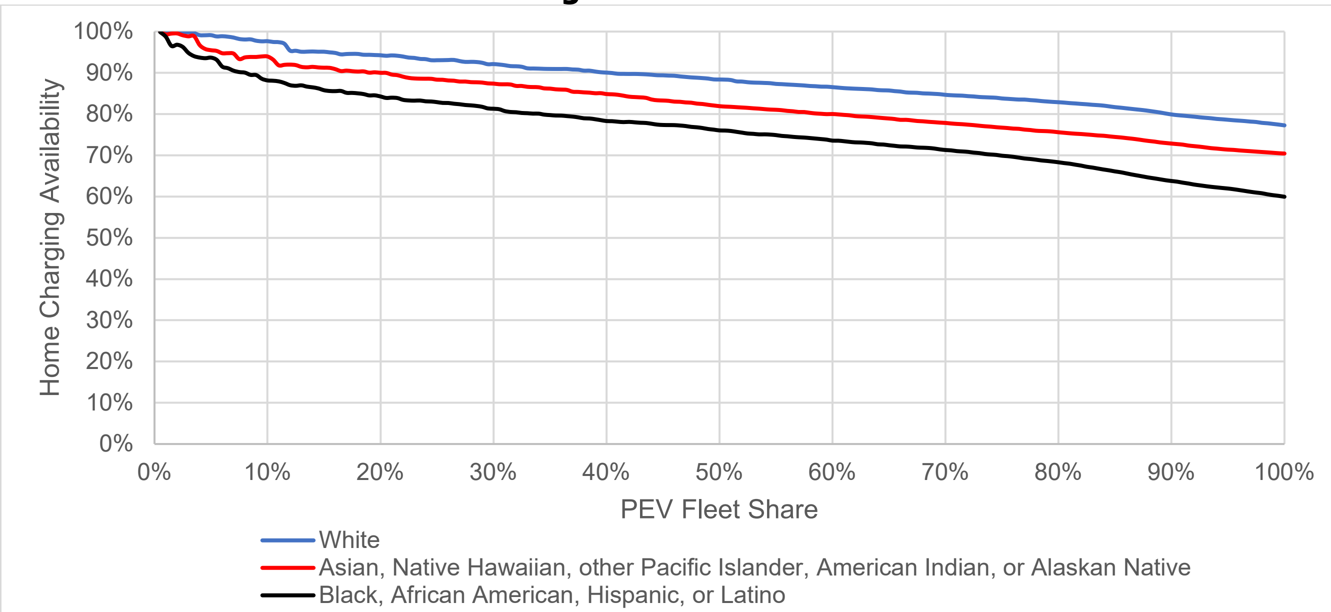
Figure B-14: Evolution of Home Charging Access by Race/Ethnicity — Existing Access With Parking Behavior Modification Scenario



Respondents who identified as White, Asian, Native Hawaiian, other Pacific Islander, American Indian, or Alaskan Native have greater ability to shift parking locations to gain access to home charging than those who identified as Black, African American, Hispanic, or Latino.

Source: CEC and NREL

Figure B-15: Evolution of Home Charging Access by Race/Ethnicity — Potential Access With Parking Behavior Modification Scenario



In the most optimistic scenario, home charging access reaches at least 60 percent for all race/ethnicity categories.

Source: CEC and NREL

APPENDIX C:
Raw Survey Data and Results

This appendix provides details on the raw survey data (including sample sizes) and results for the figures presented in this report.

Table C-1: Survey Respondent Breakdown by Income Group, Housing Type, and Housing Tenure

Income Group (Annual Household Income)	Housing Type	Tenure	Number of Respondents
$60,000 or less	High-Rise Apartment	Rent	110
$60,000 or less	Mid-Rise Apartment	Own	4
$60,000 or less	Mid-Rise Apartment	Rent	63
$60,000 or less	Low-Rise Apartment	Own	5
$60,000 or less	Low-Rise Apartment	Rent	90
$60,000 or less	Mobile Home	Own	8
$60,000 or less	Mobile Home	Rent	6
$60,000 or less	Single Family Home, Attached	Own	50
$60,000 or less	Single Family Home, Attached	Rent	69
$60,000 or less	Single Family Home, Detached	Own	89
$60,000 or less	Single Family Home, Detached	Rent	71
$60,000 or less	**Total**	**All**	**565**
$60,000 to $100,000	High-Rise Apartment	Own	1
$60,000 to $100,000	High-Rise Apartment	Rent	42
$60,000 to $100,000	Mid-Rise Apartment	Own	1
$60,000 to $100,000	Mid-Rise Apartment	Rent	39
$60,000 to $100,000	Low-Rise Apartment	Own	5
$60,000 to $100,000	Low-Rise Apartment	Rent	26
$60,000 to $100,000	Mobile Home	Own	2
$60,000 to $100,000	Mobile Home	Rent	5
$60,000 to $100,000	Single Family Home, Attached	Own	40
$60,000 to $100,000	Single Family Home, Attached	Rent	32

Income Group (Annual Household Income)	Housing Type	Tenure	Number of Respondents
$60,000 to $100,000	Single Family Home, Detached	Own	118
$60,000 to $100,000	Single Family Home, Detached	Rent	34
$60,000 to $100,000	**Total**	**All**	**345**
$100,000 or more	High-Rise Apartment	Own	5
$100,000 or more	High-Rise Apartment	Rent	32
$100,000 or more	Mid-Rise Apartment	Own	3
$100,000 or more	Mid-Rise Apartment	Rent	19
$100,000 or more	Low-Rise Apartment	Rent	22
$100,000 or more	Mobile Home	Own	1
$100,000 or more	Single Family Home, Attached	Own	43
$100,000 or more	Single Family Home, Attached	Rent	25
$100,000 or more	Single Family Home, Detached	Own	197
$100,000 or more	Single Family Home, Detached	Rent	29
$100,000 or more	**Total**	**All**	**376**
All	**All**	**All**	**1,286**

Source: CEC and NREL

Table C-2: Survey Respondent Breakdown by Race, Housing Type, and Housing Tenure

Race	Housing Type	Tenure	Number of Respondents
American Indian or Alaskan Native	Low-Rise Apartment	Rent	1
American Indian or Alaskan Native	Single Family Home, Attached	Own	2
American Indian or Alaskan Native	Single Family Home, Detached	Own	1
American Indian or Alaskan Native	**All**	**All**	**4**
Asian	High-Rise Apartment	Own	3
Asian	High-Rise Apartment	Rent	51
Asian	Mid-Rise Apartment	Own	2
Asian	Mid-Rise Apartment	Rent	26
Asian	Low-Rise Apartment	Own	1

Race	Housing Type	Tenure	Number of Respondents
Asian	Low-Rise Apartment	Rent	37
Asian	Mobile Home	Own	3
Asian	Mobile Home	Rent	1
Asian	Single Family Home, Attached	Own	44
Asian	Single Family Home, Attached	Rent	35
Asian	Single Family Home, Detached	Own	133
Asian	Single Family Home, Detached	Rent	24
Asian	**All**	**All**	**360**
Black or African American	High-Rise Apartment	Rent	13
Black or African American	Mid-Rise Apartment	Rent	5
Black or African American	Low-Rise Apartment	Rent	7
Black or African American	Single Family Home, Attached	Own	2
Black or African American	Single Family Home, Attached	Rent	8
Black or African American	Single Family Home, Detached	Own	5
Black or African American	Single Family Home, Detached	Rent	3
Black or African American	**All**	**All**	**43**
Hispanic, Latino, or Spanish Origin of any Race	High-Rise Apartment	Rent	21
Hispanic, Latino, or Spanish Origin of any Race	Mid-Rise Apartment	Own	4
Hispanic, Latino, or Spanish Origin of any Race	Mid-Rise Apartment	Rent	14
Hispanic, Latino, or Spanish Origin of any Race	Low-Rise Apartment	Own	1
Hispanic, Latino, or Spanish Origin of any Race	Low-Rise Apartment	Rent	31
Hispanic, Latino, or Spanish Origin of any Race	Mobile Home	Rent	3
Hispanic, Latino, or Spanish Origin of any Race	Single Family Home, Attached	Own	28
Hispanic, Latino, or Spanish Origin of any Race	Single Family Home, Attached	Rent	22

Race	Housing Type	Tenure	Number of Respondents
Hispanic, Latino, or Spanish Origin of any Race	Single Family Home, Detached	Own	39
Hispanic, Latino, or Spanish Origin of any Race	Single Family Home, Detached	Rent	24
Hispanic, Latino, or Spanish Origin of any Race	**All**	**All**	**187**
Native Hawaiian or Other Pacific Islander	Mid-Rise Apartment	Rent	1
Native Hawaiian or Other Pacific Islander	Single Family Home, Attached	Rent	1
Native Hawaiian or Other Pacific Islander	Single Family Home, Detached	Own	3
Native Hawaiian or Other Pacific Islander	**All**	**All**	**5**
Prefer Not to Answer	High-Rise Apartment	Rent	2
Prefer Not to Answer	Low-Rise Apartment	Rent	2
Prefer Not to Answer	Single Family Home, Attached	Own	1
Prefer Not to Answer	Single Family Home, Attached	Rent	2
Prefer Not to Answer	Single Family Home, Detached	Own	4
Prefer Not to Answer	Single Family Home, Detached	Rent	1
Prefer Not to Answer	**All**	**All**	**12**
Two or More Races	High-Rise Apartment	Rent	17
Two or More Races	Mid-Rise Apartment	Own	1
Two or More Races	Mid-Rise Apartment	Rent	9
Two or More Races	Low-Rise Apartment	Rent	5
Two or More Races	Mobile Home	Rent	2
Two or More Races	Single Family Home, Attached	Own	6
Two or More Races	Single Family Home, Attached	Rent	9
Two or More Races	Single Family Home, Detached	Own	30
Two or More Races	Single Family Home, Detached	Rent	9
Two or More Races	**All**	**All**	**88**

Race	Housing Type	Tenure	Number of Respondents
White	High-Rise Apartment	Own	3
White	High-Rise Apartment	Rent	80
White	Mid-Rise Apartment	Own	1
White	Mid-Rise Apartment	Rent	66
White	Low-Rise Apartment	Own	8
White	Low-Rise Apartment	Rent	55
White	Mobile Home	Own	8
White	Mobile Home	Rent	5
White	Single Family Home, Attached	Own	50
White	Single Family Home, Attached	Rent	49
White	Single Family Home, Detached	Own	189
White	Single Family Home, Detached	Rent	73
White	**All**	**All**	**587**
All	**All**	**All**	**1,286**

Source: CEC and NREL

Table C-3: Reported Parking Option Availability*

Parking Option	SFH Detached; Owned	SFH Detached; Rented	SFH Attached; Owned	SFH Attached; Rented	High-Rise Apartment	Mid-Rise Apartment	Low-Rise Apartment
On-street (permit or metered)	24	13	14	16	31	30	22
On-street (free)	331	112	100	91	97	74	93
Driveway/carport	347	105	66	67	24	26	31
Personal garage	327	83	90	73	13	14	30
Parking garage (public)	3	5	3	3	9	3	5
Parking garage (private)	18	10	17	10	55	23	24
Parking lot (reserved space)	4	5	10	18	93	52	50
Parking lot (no reserved space)	12	5	20	17	57	22	27
RV park/yard/field	9	0	0	0	0	0	1
Total Survey Responses	**404**	**134**	**133**	**126**	**190**	**129**	**148**

* Table excludes 22 responses from those who live in mobile homes.

Source: CEC and NREL

Table C-4: Calculated Home Charging Access by Housing Type for Each Access Scenario

Housing Type	Existing Access With 120V Perception	Existing Access	Potential Access	Existing Access With Parking Behavior Modification	Potential Access With Parking Behavior Modification
SFH Detached, Owned	14%	33%	49%	70%	86%
SFH Detached, Rented	10%	23%	40%	56%	75%
SFH Attached, Owned	12%	30%	45%	53%	73%
SFH Attached, Rented	12%	23%	41%	46%	68%
SFH Combined	**13%**	**29%**	**46%**	**61%**	**79%**
High-Rise Apartment; Rented	6%	13%	21%	17%	26%
Mid-Rise Apartment; Rented	4%	22%	32%	28%	40%
Low-Rise Apartment; Rented	5%	14%	26%	20%	37%
MFH Combined	**5%**	**16%**	**26%**	**21%**	**33%**
All	**11%**	**25%**	**40%**	**50%**	**66%**

Source: CEC and NREL

Table C-5: Calculated Home Charging Access by Income and Housing Category for Each Access Scenario

Income	Housing Type	Existing Access With 120V Perception	Existing Access	Potential Access	Existing Access With Parking Behavior Modification	Potential Access With Parking Behavior Modification

$60,000 or Less	All SFH	11%	25%	40%	50%	72%
$60,000 or Less	All MFH	3%	9%	22%	14%	29%
$60,000 to $100,000	All SFH	12%	29%	46%	62%	78%
$60,000 to $100,000	All MFH	6%	22%	28%	27%	36%
$100,000 or More	All SFH	14%	33%	50%	69%	85%
$100,000 or More	All MFH	10%	26%	34%	33%	43%

Source: CEC and NREL

Table C-6: Calculated Home Charging Access by Race/Ethnicity and Housing Category for Each Access Scenario

Race/ Ethnicity*	Housing Type	Existing Access With 120V Perception	Existing Access	Potential Access	Existing Access With Parking Behavior Modification	Potential Access With Parking Behavior Modification
Group 1	All SFH	13%	32%	50%	64%	82%
Group 1	All MFH	6%	17%	28%	21%	36%
Group 2	All SFH	12%	27%	41%	60%	78%
Group 2	All MFH	6%	16%	24%	23%	33%
Group 3	All SFH	11%	27%	41%	51%	73%
Group 3	All MFH	4%	14%	24%	17%	28%

* Group 1 – White; Group 2 – Asian, Native Hawaiian, Other Pacific Islander, American Indian, or Alaskan Native; Group 3 – Black, African American, Hispanic, or Latino

Source: CEC and NREL

Table C-7: Calculated Home Charging Access for First and Second Plus Vehicles in a Household

Housing Type	Vehicle Order	Existing Access With 120V Perception	Existing Access	Potential Access	Existing Access With Parking Behavior Modification	Potential Access With Parking Behavior Modification

SFH Detached; Owned	1st Vehicle	21%	50%	68%	70%	85%
SFH Detached; Owned	2nd+ Vehicle	10%	22%	37%	70%	85%
SFH Detached; Rented	1st Vehicle	12%	31%	50%	55%	72%
SFH Detached; Rented	2nd+ Vehicle	9%	15%	31%	55%	72%
SFH Attached; Owned	1st Vehicle	17%	44%	63%	55%	75%
SFH Attached; Owned	2nd+ Vehicle	7%	19%	32%	55%	75%
SFH Attached; Rented	1st Vehicle	15%	32%	53%	46%	66%
SFH Attached; Rented	2nd+ Vehicle	10%	15%	28%	46%	66%
High-Rise Apartment; Rented	1st Vehicle	7%	16%	25%	20%	28%
High-Rise Apartment; Rented	2nd+ Vehicle	3%	8%	14%	20%	28%
Mid-Rise Apartment; Rented	1st Vehicle	5%	16%	30%	19%	35%
Mid-Rise Apartment; Rented	2nd+ Vehicle	4%	8%	8%	19%	35%
Low-Rise Apartment; Rented	1st Vehicle	6%	15%	29%	19%	35%

Low-Rise Apartment; Rented	2nd+ Vehicle	5%	11%	21%	19%	35%
All	1st Vehicle	14%	33%	50%	47%	62%
All	2nd+ Vehicle	8%	18%	31%	47%	62%

Source: CEC and NREL

Table C-8: Reported Wi-Fi and Cellular Reception at Available Parking Locations

Parking Option	Wi-Fi Reception	Cellular Reception
Personal Garage	83%	97%
Driveway/Carport	59%	93%
Parking Garage (private)	32%	75%
Parking Lot (reserved space)	27%	94%
On-street (free)	18%	91%
Parking Garage (public)	55%	100%
Parking Lot (no reserved space)	23%	100%
On-street (permit or metered)	32%	100%

Source: CEC and NREL