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Evaluating Equity in Distribution Grid Access with California's Electric Vehicle Expansion

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Evaluating Equity in Distribution Grid Access with California's Electric Vehicle Expansion

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16. Abstract

The transition to a decarbonized energy system is creating significant changes in the electricity distribution grid, particularly with the rapid uptake of electric vehicles (EVs). This study explores the equity implications of these changes by analyzing needed distribution grid upgrades across various communities in California. Utilizing real-world distribution grid data and detailed simulations of light-duty, medium-duty, and heavy-duty EV charging behavior, we assess the spatial disparities in grid resource upgrade needs and utilization. Our findings show that by 2035, with the growth in EV charging demand, high-density residential areas are expected to have a higher fraction of feeders (neighborhood electric lines and transformers) that will need an upgrade. Additionally, communities with higher CalEnviroScreen scores (indicating greater pollution and socioeconomic burdens) generally exhibit lower EV adoption rates and are expected to have a higher share of feeders that will need to be upgraded, though with less extensive upgrades on average. Despite differences in capacity upgrade needs among different communities, the costs versus benefits from the upgraded distribution grid resources is expected to be quite proportional among different communities. While the top 20% disadvantaged communities utilize grid resources less than other communities due to their lower charging demand, the infrastructure upgrade costs in these communities are also lower.

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Executive Summary

Executive Summary

The U.S. federal Justice40 initiative and California Senate Bill 535 establish policies to allocatee benefits from clean energy transitions to disadvantaged communities. However, few studies have explored electric grid resources for electric vehicle (EV) infrastructure, which is important for ensuring equal access to EVs and their environmental benefits. This research addresses this gap by combining EV adoption models with real charging data from over 5,000 California distribution feeders. A feeder is a power line or wire connecting substations to end-users.

This study examines the equity considerations associated with California's efforts to decarbonization, including increased adoption of EVs. Using real-world grid data and detailed simulations of light, medium, and heavy-duty EV charging behavior, the study evaluates spatial differences in the need for grid resource upgrades. We project that by 2035, high-density residential areas will require upgrades to a significantly greater proportion of feeders (neighborhood electric lines and transformers). Conversely, communities with elevated CalEnviroScreen scores, which reflect increased exposure to pollution and socioeconomic challenges, are expected to have lower EV adoption rates, but will nevertheless need a higher percentage of feeder upgrades, However, these upgrades are anticipated to be less extensive on a peer-feeder basis.

The study combines feeder-level grid data with projections for hourly EV charging demand and baseline load profiles. Data from the Integration Capacity Analysis (ICA) maps, provided by California's three major investor-owned utilities—including feeder patterns, load profiles, and load capacity thresholds—was merged with community demographic information to estimate grid use needed upgrades. Light-duty EV charging patterns were simulated using the California Statewide Travel Demand Model (CSTDM) and EV Toolbox, while medium and heavy-duty EV needs were modeled using the HEVI-LOAD tool. The spatial relationships between grid capacity and charging demand was mapped, and an equity analysis was performed using residential density and CalEnviroScreen scores.

Key Findings

1. *Distribution Grid Congestion in High-Density Areas*: High-density residential communities will face greater grid congestion and more upgrades as EV adoption increases. When there is limited home charging access, especially in multi-unit dwellings, this boosts demand for public and workplace chargers, leaving these feeders with less capacity headroom and a higher upgrade need than those in low-density zones.
2. *Disparities in Disadvantaged Communities*: Communities with high CalEnviroScreen scores generally experience lower rates of EV adoption and a greater proportion of feeders requiring upgrades. These areas also contain higher levels of industrial, commercial, and agricultural land uses, which contributes to increased demand for public, workplace, and depot charging. Although these communities have a

need for more feeder upgrades, the average upgrade required per feeder is smaller, corresponding to lower overall EV charging intensity.

3. *Proportional Costs and Benefits of Upgraded Infrastructure*: Although upgrade needs vary, the cost-benefit ratio of upgraded grid resources is expected to be similar across communities. Disadvantaged areas face lower upgrade costs due to less charging demand, while higher-income areas with greater electricity use subsidize upgrades elsewhere. California utilities' proposal to set electricity bills by income highlights equity concerns. This study recommends basing fixed rates on local grid usage instead of income alone for fairer cost distribution.

Policy Implications

Policymakers should address geographic and demographic disparities in EV infrastructure by targeting incentives for disadvantaged communities, coordinating charging stations with grid accessibility needs, and adjusting charging tariffs to balance loads. Utilities should also update grid planning to reflect realistic load growth and avoid underinvestment in underserved areas.

This study evaluates equity in California's distribution grid as EV adoption grows, pinpointing areas needing upgrades to their electricity infrastructure and examining their economic effects on various communities. It outlines strategies for a fair clean energy transition with balanced costs and benefits for all.

Contents

1 Introduction

The energy system is going through an unprecedented evolution towards decarbonization. However, the benefits of this transition may not be distributed equally, and the costs or burdens might be borne by communities who receive a disproportionately small amount of benefit. Governments have established policies to ensure an equitable transition. The federal Justice40 initiative [1] and California Senate Bill 535 [2] both addressed prioritizing the distribution of benefits from clean energy investments towards disadvantaged communities. A growing body of research has begun to address the topic of energy equity under various transitions in the power system, such as renewable energy generation and deployment and fossil fuel phase out, distributed energy resources, and transportation electrification.

On the bulk generation level of the electricity grid, increased renewable energy penetration generally comes with social equity improvement [3] through emission reductions and health benefits. But there are also negative externalities borne by communities located next to renewable power plants, such as noise from wind turbines [4]. The decentralization of power generation that accompanies renewables gives rise to various new challenges to the electric distribution grid, including potential inequalities on the end-use side of the power system [5]. Rooftop solar, as one of the major distributed energy resources, has raised concerns about cross-subsidization where the burden of fixed cost recovery is shifted from the utilities to the ratepayers without rooftop solar, since the solar adopters get to offset a part of their electricity bills with solar generation [6].The circuit capacity available for rooftop solar installation is also distributed inequitably, with disadvantaged communities having less access to grid resources [7]. Studies have discussed possible methodologies to deploy distributed energy resources to help those communities with energy insecurity [8], as well as different electricity tariff design to distribute cost recovery in a more equitable manner [9,10].

The rapid uptake of electric vehicles (EVs) raises similar equity concerns as rooftop solar such as upstream emissions, supply chain issues, and resource access. While replacing internal combustion vehicles with electric vehicles is expected to reduce tailpipe emissions and benefit public health, there are concerns about possible emission increases from electricity generation, if the grid is not “clean” enough, affecting the communities near the power plants [11]. EV battery manufacturing significantly increases the demand for lithium and cobalt, and these minerals are associated with severe injustices, including child labor [12] and health risks [13] to upstream communities at both extraction and waste disposal sites. Most equity discussions, however, are focused on technology access. Studies have shown disparities in EV adoption across different communities [14]. Participation in EV incentive programs leans toward higher-income households, which are not the communities that need this subsidization the most [15–17].

Many studies have examined the accessibility of existing EV charging infrastructure and evaluated the spatial disparities related to social-economic factors [18–20]. Others explore the equity in electrical grid resource availability for potential EV charger installation in the future, by evaluating access to electrical outlets near parking spaces [21], or circuit hosting capacity (the amount of electricity that local infrastructure can handle at the neighborhood level) [7]. Studies that combine grid resource availability and EV charging demand projection are lacking in the field of equity and environmental justice. Steinbach and Blaschke [22] estimate the grid reinforcement costs for EV owner groups with different income, using power flow simulation on hypothetical distribution grid feeder models. In this study, we use an EV adoption model together with real-world distribution grid network data and EV charging data, to estimate needed distribution grid upgrades in different California communities at the census tract level across the three major investor-owned utilities. This analysis covers over 5000 distribution feeders (local neighborhood level electricity infrastructure) all over California. Additionally, we use separate models to project light-duty passenger EV and medium- and heavy-duty EV charging demands, which has not been covered in previous studies. We explore not only the physical access to grid resources, but also the utilization of these resources, and discuss the differences across communities.

The remainder of this report is structured as follows: Section 2 describes the methodology and data sources used in this study. Section 3 describes the distribution circuit upgrades needed due to EV uptake across different communities. And in Section 4, we conclude with a discussion of the major implications of our work and outlook for the future.

2 Methods and Data

The general framework of this study can be seen in **Figure 1**. We utilized spatial and temporal data at the feeder level from both the grid and the EV side to project the hourly EV charging load and baseload profile by feeder in the future. We then compared these results with the feeder capacities to determine the upgrades needed for each feeder resulting from EV uptake. Lastly, we categorized the type of community that each feeder is located in and analyzed the equity of grid resource access in different communities.

In Section 2.1, we describe the distribution grid data that we used. In section 2.2, we explain how we simulated light-duty EV travel and charging behavior. And in Section 2.3, we describe our method for simulating medium- and heavy-duty EV travel demand and charging profiles. Finally in Section 2.4, we describe the datasets used to categorize different types of communities.

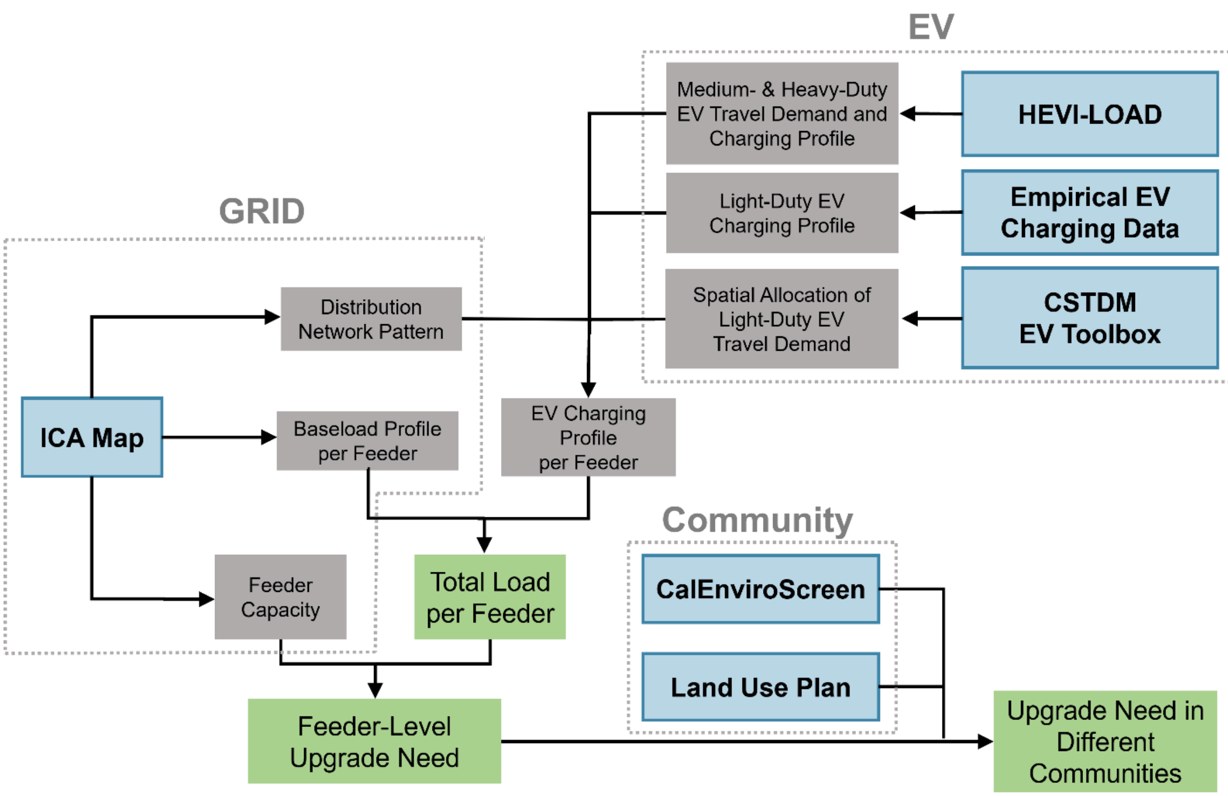

Figure 1. General research framework.
Note: Data sources (blue), intermediate data (gray), and outputs (green).

2.1 Distribution Grid Data

We obtained the baseload and capacity of each circuit in the distribution system from the Integration Capacity Analysis (ICA) maps of the three major Investor Owned Utilities (IOUs) in California: Pacific Gas and Electric (PG&E) [23], Southern California Edison (SCE) [24], and San Diego Gas and Electric (SDG&E) [25]. The dataset contains information on distribution network patterns, hourly load profiles per feeder, as well as both thermal and voltage load thresholds for each feeder on an hourly basis.

We derived the cost of upgrading the electrical distribution grid infrastructure from PG&E's Distribution Investment Deferral Framework map. The distribution grid upgrade projects were grouped into different sizes to address the economies of scale of grid upgrade cost. Then we calculated the per-kW investment of each project. In each scale group, we used the 25th, 50th, and 75th percentiles of the per-kW costs to calculate future upgrade costs in the same scale range.

2.2 Light Duty EV Charging Load Simulation

We used the California Statewide Travel Demand Model (CSTDM) [26] to simulate the number of light duty vehicle trips traveled to each Traffic Analysis Zone studied, as well as the purpose of each trip, which can be categorized into three major types: "home," "workplace," and "public." We used the EV Toolbox [27,28] to project future light-duty EV adoption in each area to determine which of these trips would be made by EVs. The EV Toolbox is based on a regression and diffusion of innovations model, and we calibrated it to make sure that the growth in EV sales meets the Advanced Clean Cars II regulations in California [29], which requires all new light-duty vehicles sold in 2035 to be EVs.

To determine the charging loads from the simulated EV trips, we first determined where the EVs would need to be charged during the trips. Short distance and long-distance trips were treated separately. For short distance trips, the CSTDM indicates which trips belong to the same tour, and we assume that EV owners charge after certain trips in each tour. The major types of charging locations (home, workplace, and public charging) correspond to the trip purposes, and we perform a statistical bootstrap on the owner's choice of charging locations in each tour from a survey dataset of electric vehicle miles travelled [30]. For long distance trips, we assumed that public charging would take place in the middle of the trip, and each EV would charge at the destination as well. The demand of each charging event is proportional to the split of travel distance within the corresponding tour or trip.

Finally, we simulated the charging profiles by bootstrapping from empirical charging session records. For each charging event, we sampled charging session data from the pool of records weighted based on same charging location (home, workplace, or public) and on similar amounts of charging energy demand. The data for each charging session includes charging start and end times, as well as charger power. By adding up the total charging power for each hour on each feeder, we derived the light-duty EV charging profile by feeder. The spatial distribution of light-duty EV charging energy on an average day in 2035 is depicted in **Figure 2a** by feeder. Feeders in areas with higher population density are more likely to have higher charging energy. More details about light-duty EV charging load simulation process and data can be found in Li and Jenn [31].

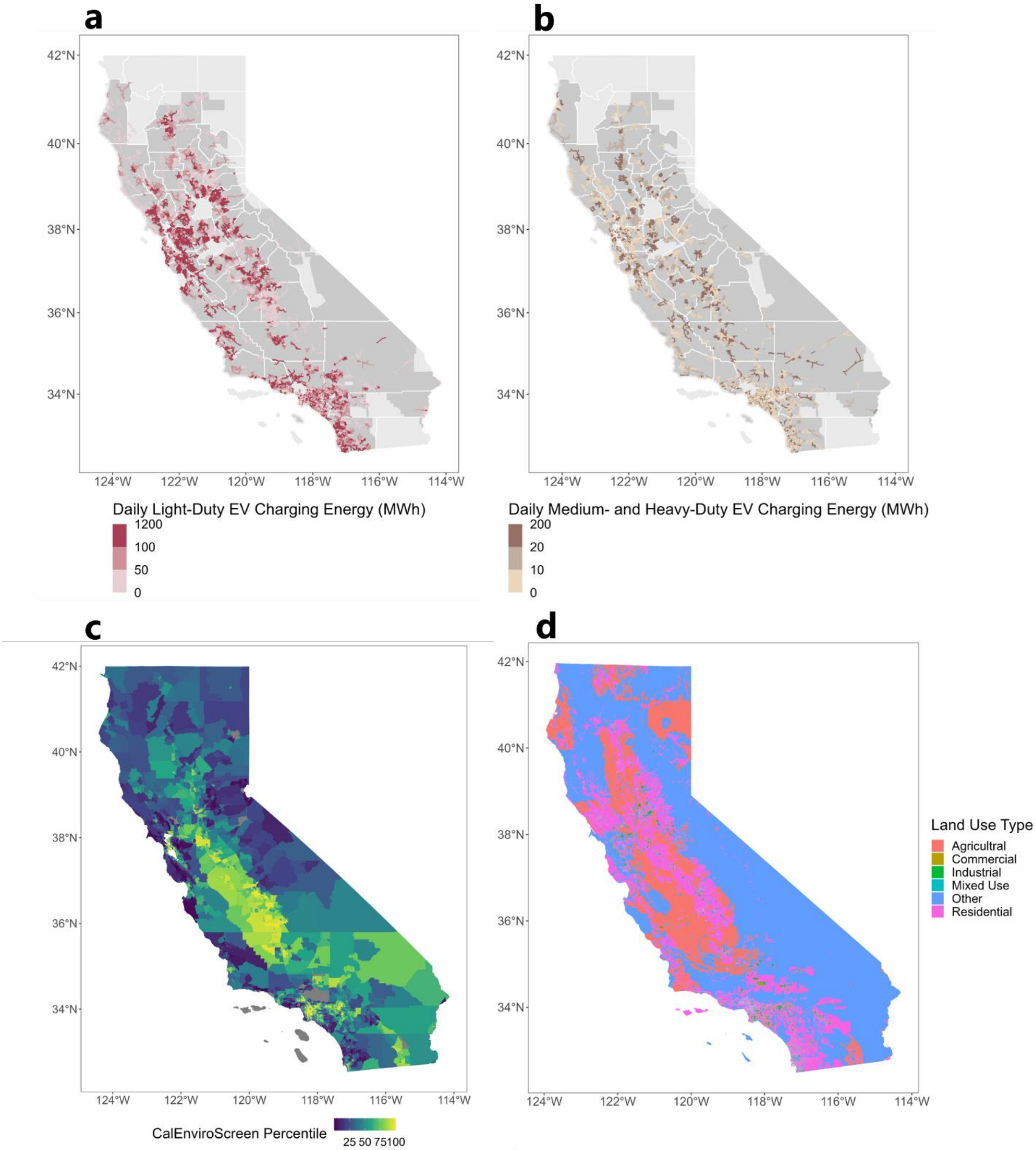

Figure 2. Spatial distributions of: a) Light duty EV daily charging energy by feeder in 2035; b) Medium- and heavy-duty EV daily charging energy by feeder in 2035; c) CalEnviroScreen percentile by census tract; d) Parcel-level land use pattern.

Note: Areas in darker gray are the territories of the three major IOUs in California.

2.3 Medium- and Heavy- Duty EV Load Simulation

We used the Medium and Heavy-Duty Electric Vehicle Infrastructure – Load Operations and Deployment (HEVI-LOAD) modeling tool [32,33] to simulate future medium- and heavy-duty EV charging loads. This model performs agent-based simulations of the travel and charging behavior of each individual medium- and heavy-duty EV along the road network in California, at 10-minute intervals. The assumptions about the pace of fleet electrification for different classes of vehicles used by HEVI-LOAD are based on the Advanced Clean Trucks (ACT) [34] and Advanced Clean Fleets (ACF) [35] regulations in California, which are shown in **Figure 3**.

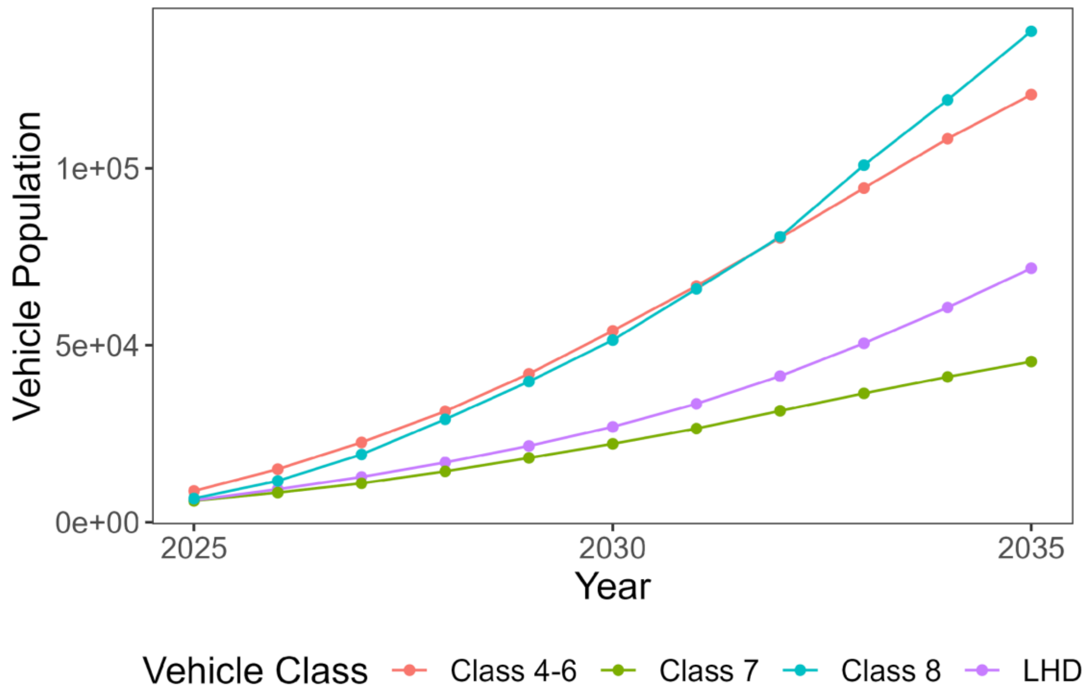

Figure 3. The growth of medium- and heavy-duty EV adoption by vehicle classes in HEVI-LOAD model (2025-2035)

Medium- and heavy-duty EV charging is expected to be much faster than for light-duty EVs. **Table 1** shows HEVI-LOAD's assumptions for the charger power level for different vehicle classes. In our light-duty EV load simulation (Section 2.2), the maximum charging power was 100 kW for public DC fast charging. But in the HEVI-LOAD model, depot charging can be as high as 150 kW. The model assumes that public charging for medium- and heavy-duty EVs should be faster than depot charging, with a charging power of at least 350 kW, to save the en-route charging time for commercial fleets. Class 7 and 8 EVs have lower energy efficiency and would need even higher charger power, up to 1.5 MWs. We mapped each charging event to the nearest distribution feeder, and aggregated the hourly charging power on each feeder to obtain the medium- and heavy-duty EV charging profiles. The spatial distribution of medium- and heavy-duty EV charging energy on an average day in 2035 is depicted in **Figure 2b** by feeder. Compared to **Figure 2a**, the distribution pattern of higher charging energy areas is quite different from that of the light-duty EVs as they are noticeably smaller in magnitude.

Table 1. Charger power range of different medium- and heavy-duty EV classes in HEVI-LOAD model.

	Public Charging	Depot Charging
Light-Heavy-Duty (LHD) Trucks	350 kW	20 kW – 150 kW
Class 4-6	350 kW	20 kW – 150 kW
Class 7	350 kW – 1 MW	20 kW – 150 kW
Class 8	350 kW – 1.5 MW	20 kW – 150 kW

2.4 Community Categorization

We categorize the communities in California in two different ways. The first is by land use [36]. This parcel-level statewide Geographic Information System dataset integrates all county and some city general plans in California, combining the individual zoning designations into six broad land use classifications, including Agricultural, Commercial, Industrial, Mixed Use, Other and Residential. The spatial distribution of six combined land use categories are depicted in **Figure 2d**. The ”Other” category covers lands that are not developed, such as water and open space.

The other categorization method that we use is the CalEnviroScreen tool [37,38]. This tool generates census tract level scores that represent the relative statewide ranking of communities based on pollution exposure, environmental effects, sensitive populations, and socioeconomic factors for each census tract. The higher the score, the higher the pollution burdens and population sensitivity in the area. Under Senate Bill 535 the census tracts with the highest 25 percent of overall CalEnviroScreen scores are designated as disadvantaged communities by the California Environmental Protection Agency (CalEPA)[2]. The spatial distribution of each census tract’s percentile of CalEnviroScreen scores among all census tracts is shown in **Figure 2c**. **Table 2** shows ICA statistics, as described in Section 2.1, for different categories of communities based on their CalEnviroScreen scores.

Table 2. ICA statistics for communities by CalEnviroScreen percentiles

CalEnviroScreen Percentile Bin	Number of Feeders	Average Capacity per Feeder (MW)	Average Peak Baseload per Feeder (MW)
[0,10)	614	10.39	6.55
[10,20)	633	10.71	6.68
[20,30)	606	10.52	6.40
[30,40)	573	10.60	6.64
[40,50)	598	10.82	6.57
[50,60)	558	10.06	6.17
[60,70)	507	10.49	6.63
[70,80)	512	10.35	6.52
[80,90)	481	9.61	6.21
[90,100]	470	9.37	5.88

3 Results

We ran the models from 2022 to 2035 and determined the needed upgrades for each feeder based on the size of the maximum overload value in each year. Then we categorized each feeder based on the predominant type of area that it passes through, under the two different sets of area categorization described in Section 2.4. In this way, we were able to investigate the distribution grid access and upgrade need caused by EV adoption in different communities.

In Section 3.1, we analyze the distribution grid access and congestion conditions for different residential density areas. In Section 3.2, we discuss the impact of EV uptake in communities in different CalEnviroScreen percentiles, with special attention paid to disadvantaged communities.

3.1 Distribution Grid Congestion in Different Residential Density Areas

Community design and distribution grid planning can be significantly different in residential areas with different densities. Higher density residential areas have more dwellings per acre on average, and thus generally have more multi-unit dwellings. After categorizing each feeder by land use type, we calculated the population served by each feeder according to the census blocks nearest to this feeder, with population data from the American Community Survey [39]. As shown in the purple bars in **Figure 4** (left), the higher the residential density, the more population served per feeder on average. While more population does not necessarily translate into more electricity consumption, population density can still affect grid infrastructure access and availability in different communities. The orange bars, which depict the average charging energy per feeder among the communities, show a different trend. In high-density residential areas, while each feeder serves the most people compared to other residential areas, access to home charging can be limited in multi-unit dwellings, which leads to a lower charging demand on average.

We calculated the remaining capacity left in each feeder excluding the baseload in 2022 (the electricity load before further growth of the EV charging load), which is referred to as headroom. The average headroom per feeder in different residential density areas are depicted by the green bars in **Figure 4** (right), and it shows that generally, less headroom is left in the higher density residential areas. This contributes to the reverse trend in the red bars, which represent the fraction of overloaded feeders within all feeders in each residential density category, after adding the projected EV load in 2035 to the current feeder capacities. This implies that a higher percentage of feeders will need upgrade in higher density residential areas to accommodate future EV uptake.

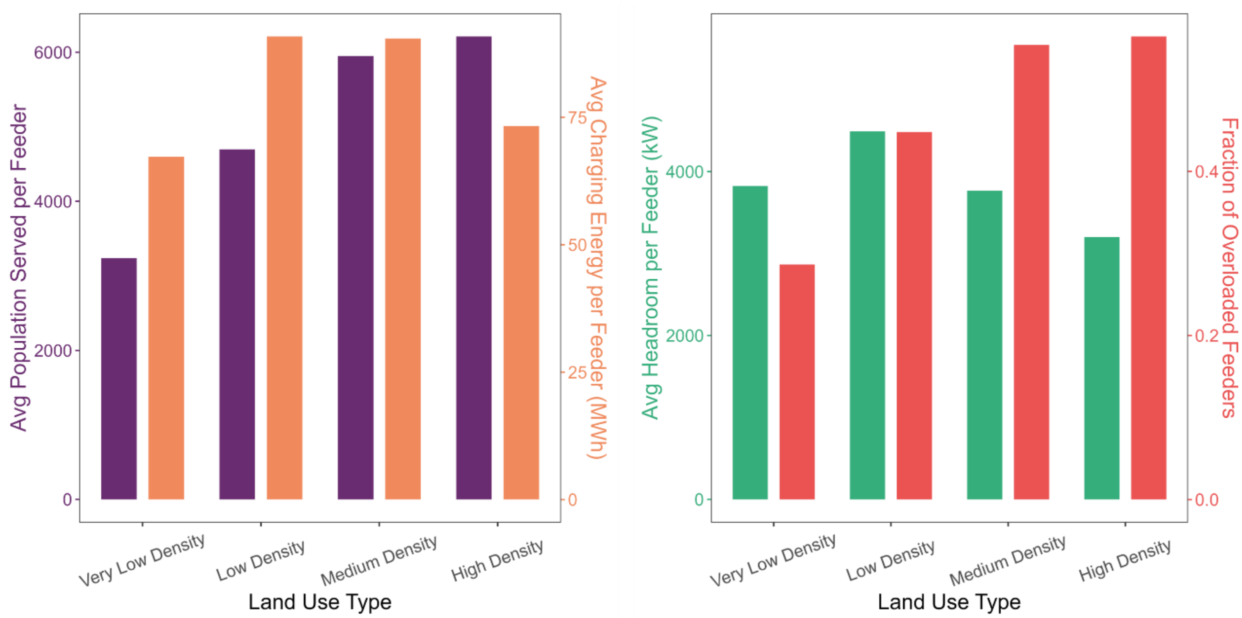

Figure 4. Average population served per feeder (left in purple), average charging energy per feeder (left in orange), average remaining capacity headroom (excluding baseload) per feeder in 2022 by residential densities (right in green), and fraction of overloaded feeders due to the growth of EV charging load in 2035 by residential density areas (right in red).

Note: High density residential areas are expected to have a higher fraction of feeders that will need an upgrade.

3.2 Distribution Grid Upgrade Need in Disadvantaged Communities

We examined EV adoption in census tracts with different CalEnviroScreen scores, results of which are shown in **Figure 5**. We obtained EV ownership rates per capita in 2022 from the EMission FACtor (EMFAC) Fleet Database [40], developed by the California Air Resources Board, based on vehicle registration data from the California Department of Motor Vehicles. We projected the percentage of EVs per capita in 2035 using the EV Toolbox, which was used in the light-duty EV charging load simulation in this study, as described in Section 2.2. For both current EV adoption and the future projection, the higher the CalEnviroScreen percentile of a community, the lower EV ownership in general. So disadvantaged communities have less EV adoption compared to other communities.

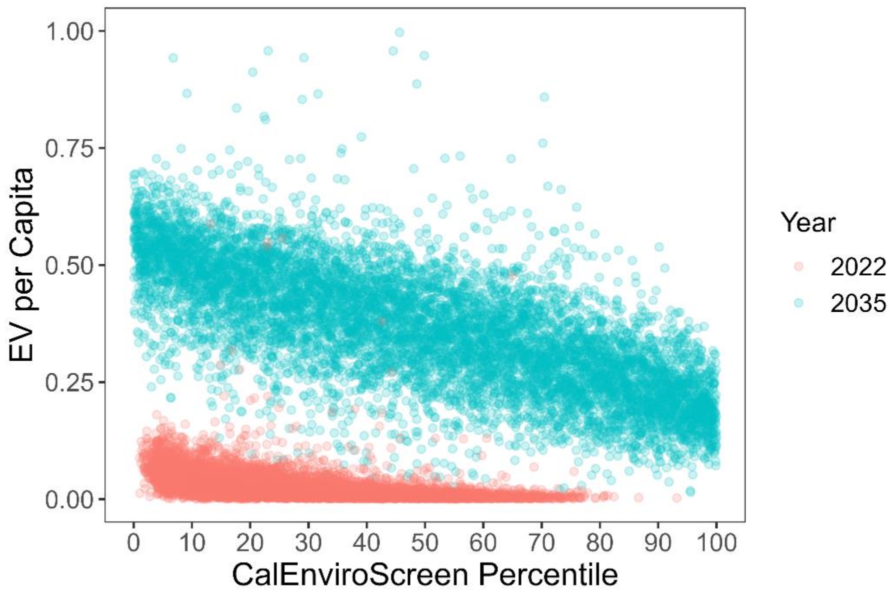

Figure 5. EV adoption per capita in 2022 and 2035 by CalEnviroScreen scores.

Note: The higher the CalEnviroScreen percentile of a community, the lower the EV ownership.

Then, how does travel and charging behavior differ in different communities? In the top graph of **Figure 6**, the percentage of various EV charging load types are shown in communities with different CalEnviroScreen scores. We examined the load contribution at peak load of each feeder, which is what determines the size of the capacity upgrade needed. Communities with a higher score tend to have more public and workplace charging from light-duty EVs, as well as slightly more depot charging from medium- and heavy-duty EVs. This is related to the land use characteristics of different communities. The bottom graph of **Figure 6** shows the share by area of different land use types in different communities. Communities below the 80th percentile (representing less impacted communities) have substantially more areas that are categorized as “Other,” which are the lands that are not developed, such as water and open space. The top 20 percent of communities (representing more disadvantaged communities), on the other hand, have a much higher utilization rate of their lands, with higher shares of agricultural, commercial, and industrial areas, which contribute to higher pollution exposure in these communities, as well as higher shares of public, workplace, and depot charging demand.

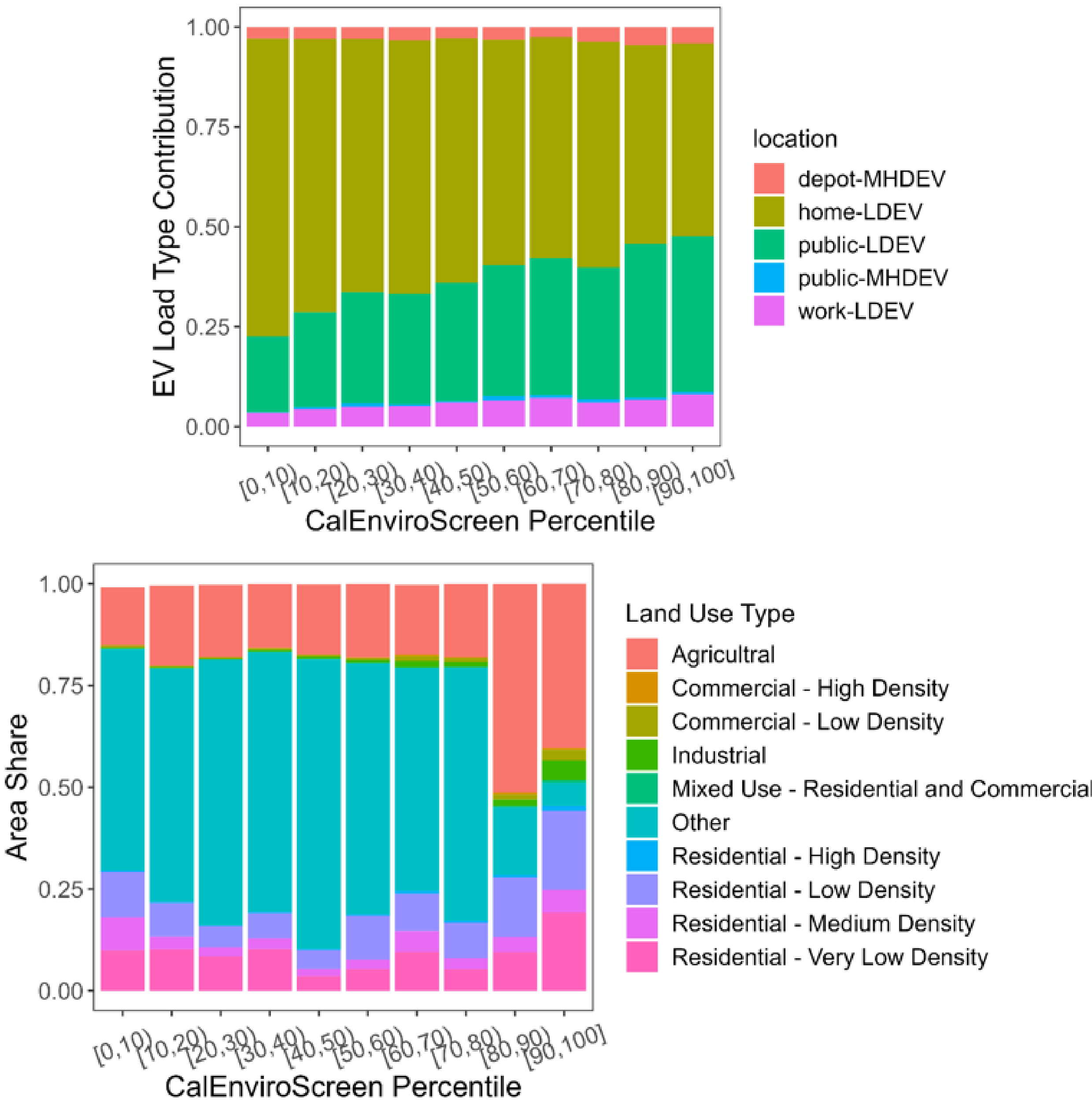

Figure 6. Contribution of different EV load types at peak load in 2035 (top), and share by area for different land use types (bottom) by CalEnviroScreen scores.

Note: Communities with a higher score tend to have a higher land utilization rate, as well as a higher share of public, workplace, and depot charging.

The needed distribution grid upgrades are a result of both existing infrastructure availability and the growing EV charging demand. The green bars in **Figure 7** shows that in communities with higher CalEnviroScreen scores, especially the top 20th percentile, less capacity headroom was left in the feeders in 2022. This could be due to a lower expected demand growth in these areas. However, the EV load growth can be higher than expected in these areas, which leads to a higher fraction of feeders that need upgrade, as is shown by the red bars of **Figure 7**. While the share of feeders that need upgrade are higher, the average size of upgrade needed per feeder tends to be lower in these communities, as shown by the blue bars in **Figure 8**. This is related to the lower EV adoption rate in the higher-score communities overall, which results in lower charging demand intensity on average in the disadvantaged communities, as shown by the yellow bars in **Figure 8**.

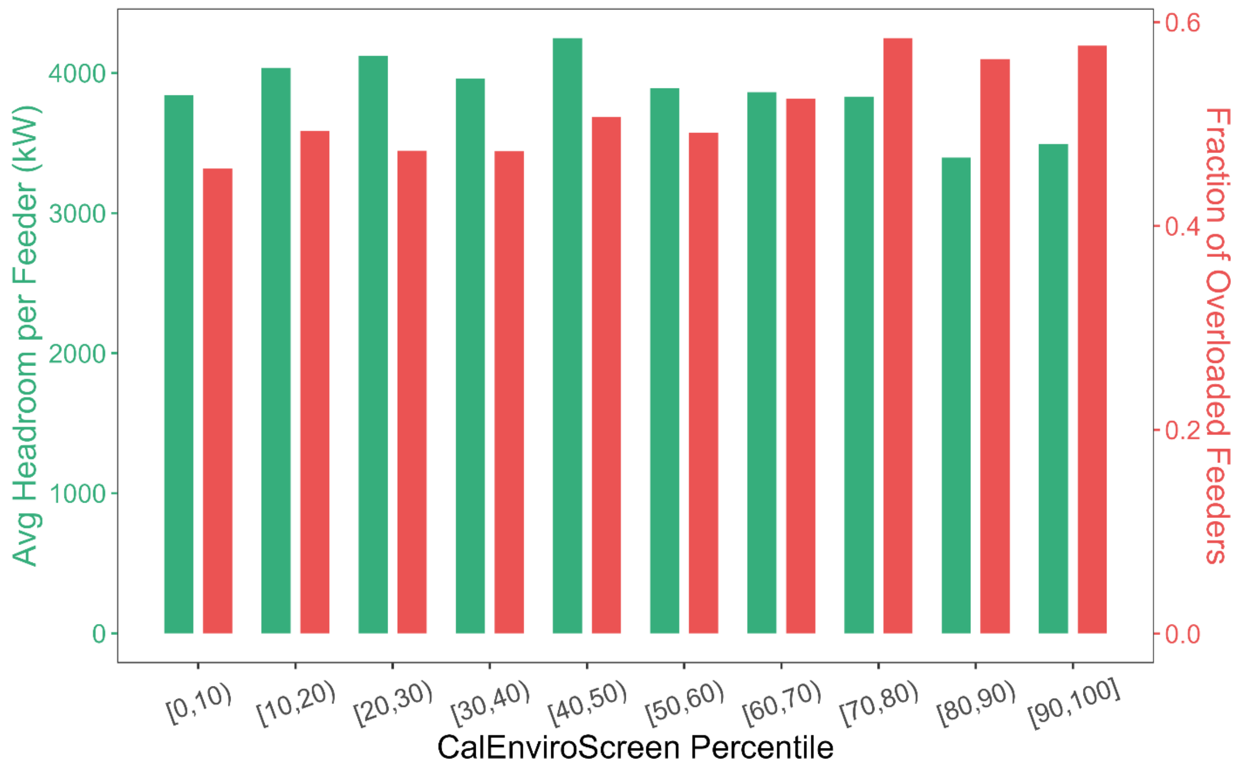

Figure 7. Average capacity headroom remaining (excluding baseload) per feeder in 2022 (green), and fraction of overloaded feeders due to the growth of EV charging load in 2035 (red) by CalEnviroScreen scores.

Note: In the top 20% disadvantaged communities, less capacity headroom is left when feeders are built, and a higher fraction of feeders will need to be upgraded by 2035.

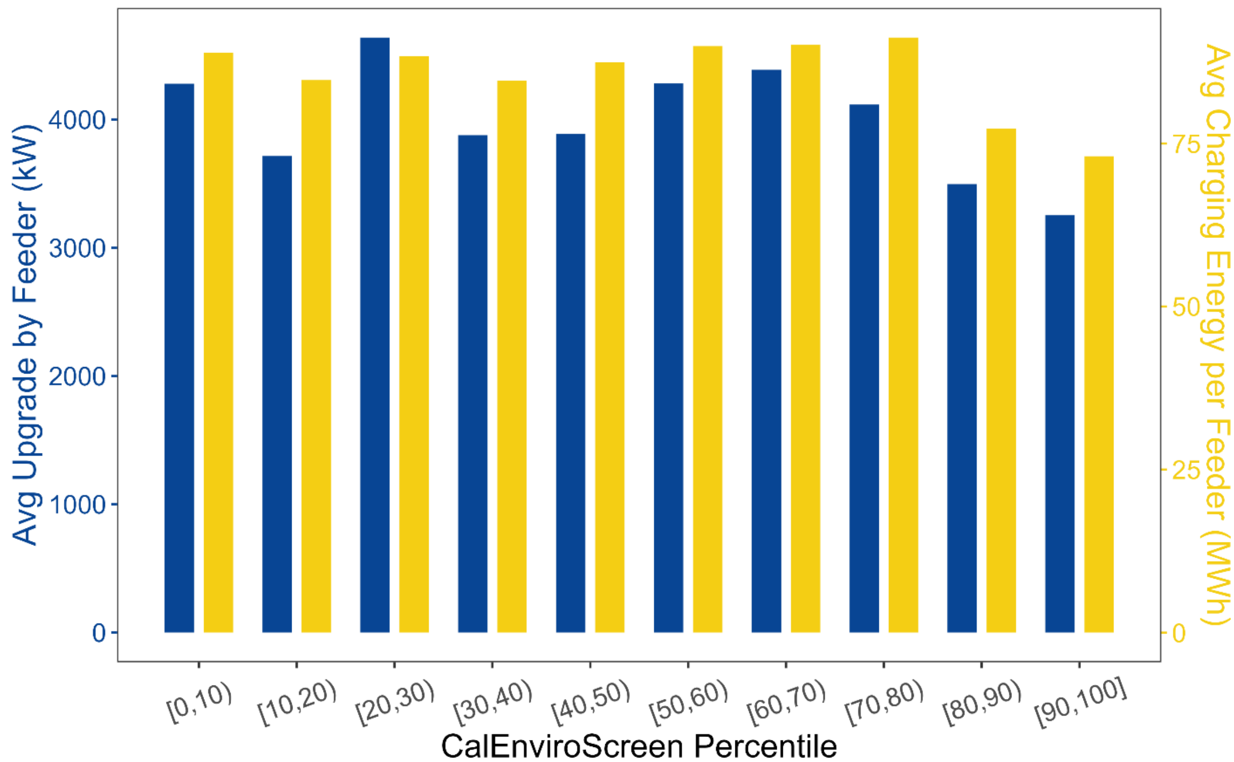

Figure 8. Average upgrade needed per feeder (blue) and average total charging energy per feeder (yellow) in 2035 by CalEnviroScreen scores.

Note: In disadvantaged communities, charging energy intensity is lower, and smaller feeder upgrades are needed on average.

Finally, to evaluate the grid access benefits versus costs for EV owners in different communities, we estimated the total rate base increment (i.e. feeder upgrade cost) and the rate base payment portion of electricity bills for each feeder. The range of the total upgrade cost by 2035 was calculated for each feeder as described in Section 2.2, which is expected to be added on to the current distribution grid rate base [41]. The rate base payment per kWh is calculated by assuming a 7.5 percent annual rate of return [41] dividing by the total load for the year. This price is calculated separately for each IOU territory, and for each feeder, the annual total rate base payment is the price times the annual total load on this feeder projected in 2035. The average cost and payment per feeder in each CalEnviroScreen decile is presented in **Figure 9**. The rate base increment covers the cost of grid access, while the rate base payment reflects consumers' benefit from using distribution grid resources.

Generally, the cost and utilization of upgraded grid resources are rather proportional. In **Figure 9**, communities which receive more future upgrades in the distribution grid also utilize it more in the meantime, due to the growth in total electricity consumption. Disadvantaged communities need fewer upgrades than other communities and utilize less electricity as well. There are some communities that have slightly higher utilization rates, such as those within 10-20th and 30-40th percentiles. The rate base payments in these communities, to some extent, subsidize the distribution grid upgrades in other communities.

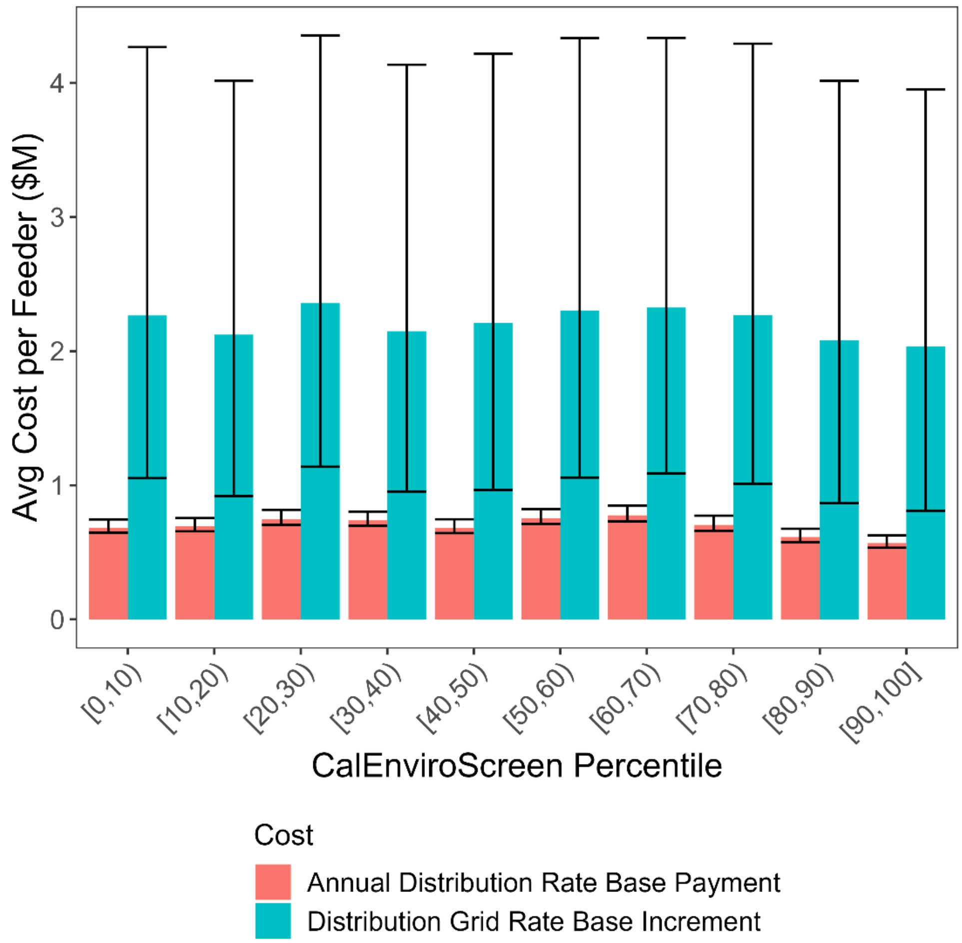

Figure 9. Average distribution grid rate base increment (upgrade cost) and annual rate base payment (through electricity bills) per feeder in 2035 by CalEnviroScreen scores.

Note: The bars are calculated using the median of reported costs, and the upper and lower edges of the whiskers are calculated with the 75th and 25th percentile of reported costs. The cost versus utilization of the upgraded distribution grid resources is quite proportional among different communities.

4 Conclusion and Discussion

This study highlights the critical intersection between energy equity and the evolving electricity distribution grid under the influence of rapidly accelerating EV uptake. By leveraging real-world distribution grid data and detailed simulations of light-duty, medium-duty, and heavy-duty EV charging behavior, we have provided a comprehensive analysis of the distribution grid infrastructure upgrade needs and equity implications across different communities in California.

Our results show spatial disparities in distribution grid resource need and utilization across different communities. Different density residential areas are expected to have significantly different levels of congestion. The distribution feeders in the higher-density residential areas are currently left with less capacity headroom, leading to a higher percentage of feeders requiring upgrades to support future EV uptake.

Communities with higher CalEnviroScreen scores, indicating higher pollution and socioeconomic burdens, often have higher electric utilization rates, especially those with more agricultural, industrial, and commercial land uses, contributing to increased public, workplace, and depot charging demands. Higher-score communities exhibit lower EV adoption rates both currently and in future projections. Distribution feeders in the higher-score communities are generally left with less present capacity headroom, due to lower expected electricity load growth when the grid infrastructure is built out. These spatial disparities in EV adoption and capacity access result in a higher share of feeders in disadvantaged communities needing future upgrades, though less extensive upgrades compared to other communities. This implies lower than expected electricity load growth in disadvantaged communities and indicates that utilities should re-evaluate future load growth with respect to EV uptake to ensure sufficient grid reinforcement, with potential prioritization of resource distribution in disadvantaged communities.

Despite the difference in capacity upgrade needs among different communities, the costs versus benefits from upgrading distribution grid resources is expected to be quite proportional among different communities. While disadvantaged communities utilize grid resources less than other communities, due to lower charging demand, the associated costs for infrastructure upgrades in these areas are also comparatively lower. Some less environmentally impacted communities have slightly higher electricity utilization rates, which indicates they may partly subsidize other communities' distribution needs. The three major IOUs in California recently proposed to convert part of consumers' electricity bills to a flat rate based on their income (42). According to our study, income-based electricity charges might not be equitable, since our results do not show higher-income households (which are more likely to be located in the less pollution burdened communities) paying disproportionally less in rate base recovery. Setting the flat rate in proportion to the fixed costs of the grid resources that the household have access to (such as the local distribution network) might be a more equitable approach.

This study evaluated the spatial disparities in distribution grid resource costs and benefits generated from future growth in EV charging demand. These inequities are expected to be potentially mitigated through incentives for EV adoption in disadvantaged communities, proper charging infrastructure allocation to ensure grid resource access, as well as EV charging tariff design to guide charging behavior and ease congestion in the distribution grid. These topics remain to be explored by future studies.

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