INFO 247 2021 Spring
Final Project Report

GEAR

# Gaps Explorer for Accessibility and Readiness of California Electric Vehicle Charging Infrastructure

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## 1. Project Goal

To fight against climate change and reduce air pollution, California must rapidly transition its vehicle fleets to zero-emission in the next decade. The latest California Air Resources Board (CARB) decarbonization scenario modeling suggested 100% of new cars sales in 2035 need to be Zero-Emission Vehicles (ZEVs). As a result of the new sales goal, it is then estimated that 8 million light-duty ZEVs will be on the road by 2030 (CARB, 2020) and 1.5 million public and shared private chargers are needed (CEC, 2021). The current gaps are prominent. California currently has about 73,000 public chargers available (CEC, 2021), less than 5% of what is needed by 2030. All of these require strong public support to accelerate deployment. These essential steps will help break the “chicken-and-egg” problem in the early days for would-be EV adopters who refrain from buying EVs due to a lack of public charging stations.

Our project is designed at this critical time to explore the gaps in scale and equity about access to charging infrastructure in order to monitor our readiness. The next steps for policy makers to think about are, first, how to provide the correct incentives and reduce the need for public investment to close the gaps in scale, and, second, how to make plans and allocate resources to ensure charger equity across different demographic groups and geographic regions. How we understand these gaps are fundamental to the success of electrifying California’s vehicle fleets.

## 2. Discussion of Related Work

1. <u>City charging infrastructure in SF _ 2020 ICCT</u>

This study generates applicable steps for cities to proactively plan infrastructure. First, it gathers data on EV adoption, baseline infrastructure deployment, and charging behaviors to analyze the charging infrastructure required to support the EV plan. CA plans to have 100% new vehicle sales by 2030.   Second, it identifies infrastructure gaps, develops policies to fill the gaps, reevaluates early deployment lessons, and continually examines updated data. So the study data and its visualization can be referred to as our project goal.

The result of the study shows that the supporting policies and public-private partnerships are important to achieve EV goals and charging infrastructure. And the cross-cutting city policies to reduce personal car use are important to reduce charging infrastructure needs.

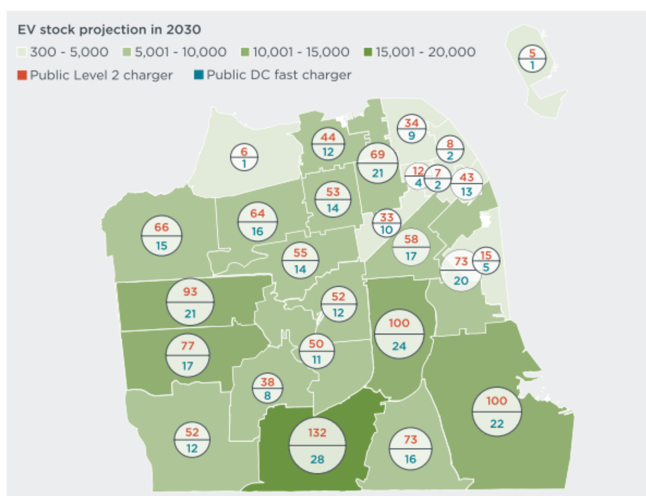



**Figure 2.** Public Level 2 (orange numbers) and DC fast (blue numbers) chargers needed in 2030.

Figure 1: Example 1 of information visualization in the study: quantify public level 2 and DC fast charger needs by zip codes, in 2030

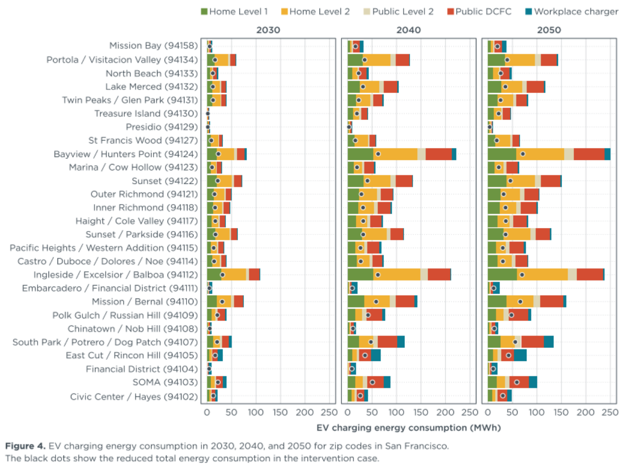



Figure 2: Example 2 of information visualization in the study: quantify charging energy demand

2. <u>Charging infrastructure in cities_ICCT (international council on clean transportation)</u>
This study explains the hardness to design public infrastructure. The differing percentages of households with overnight private charging, power grids that vary in their regulatory structures and electrical specifications, different driving patterns, and a diverse mix of battery electric vehicle (BEV) and plug-in hybrid electric vehicle (PHEV) models makes building charging infrastructure contains lots of metrics. It compares the charging infrastructure growth rates, ratios, and densities so the availability and coverage in metropolitan regions can be seen.

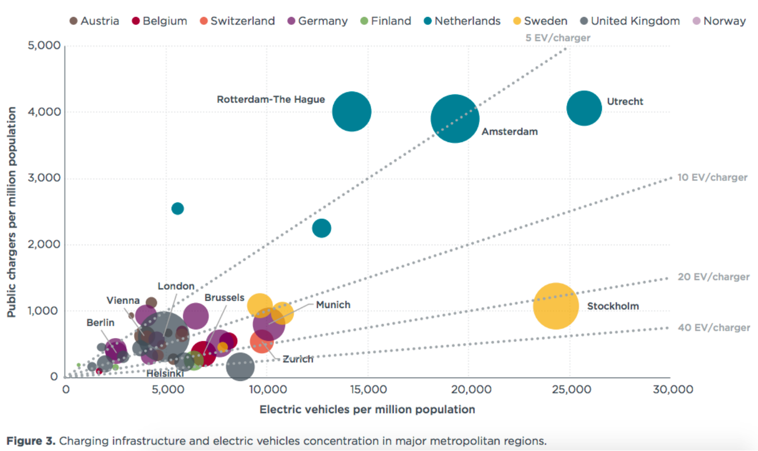



Figure 3 :Example 1 of information visualization in the study: (normalization) #of chargers by pop VS #of EV by pop EV/charger

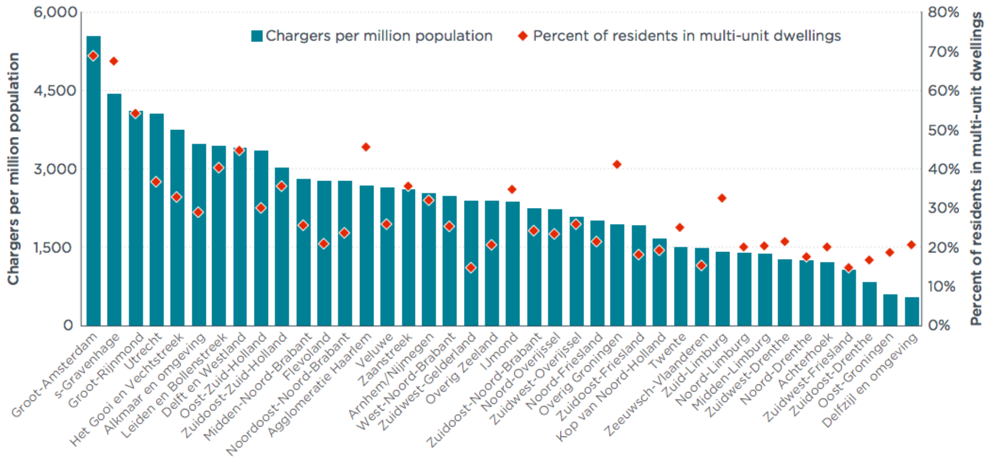



Figure 4 : Example 2 of information visualization in the study: charger per population VS %of resident in multi-unit dwellings

3. <u>Quantifying the electric vehicle charging infrastructure gap across U.S. markets_ICCT (international council on clean transportation</u>)
This study discusses the analytical methodology behind the charging gap analysis, including the analysis of each market's electric vehicle and charging infrastructure baseline in 2017, assessment of existing charging by metropolitan area, the evolution of vehicle to charging ratios, and the shift beyond early adopters. It also presents key findings of the work in terms of the charge points of different types needed by the metropolitan area and a relative progress report for 2017 charging versus 2020 and 2025 charging needs.

They count 36 typologies, based on four vehicle types (short- and long-range PHEVs and BEVs), three home-charging options (no home charging, Level 1, and Level 2), and three workplace categories (non-commuter, commuter with ability to charge near workplace, and commuter unable to charge while working.

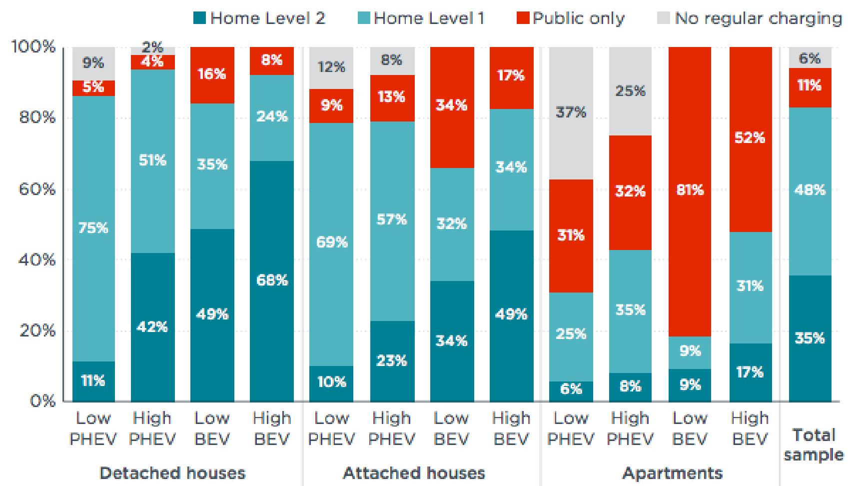



Figure 5: Example 1 of information visualization in the study: charging behavior by housing type

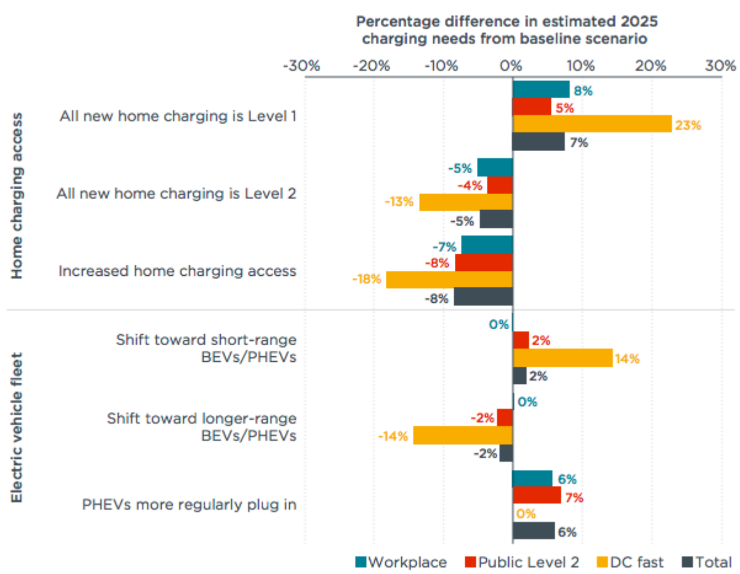



**Figure 13.** Sensitivity of 2025 charging needs to changes in home charging and fleet composition compared with baseline scenario

Figure 6: Example 2 of information visualization in the study: different percentage charging needs for 2025 ( estimated)

# 3. Description of The Visualization

## 3.1 Section 1:Charger Types and EV persona

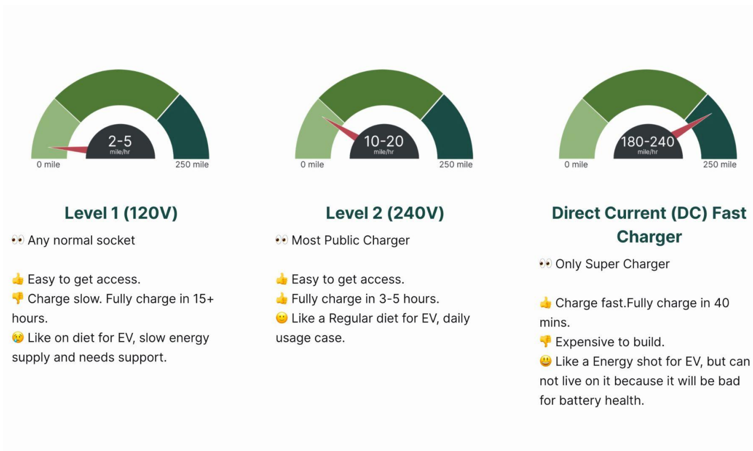



Figure 7: Frequency of Waiting for a Public Charger.

This contains both charts and icons in the prototype version, but when we realize that the rest sections will include some complicated charts, we decided that Persona will only be icons and numbers so it's easier to read and harmonious.

We use icons to show different EV charger types in the first place, but we came across the gauge broad in another article. It inspired us that the gauge fits our topic of vehicles and it's a creative way to show the charging rate in numbers. So we iterate the EV charger type to this idea. Another iteration is the text description for each charger type. In this first version, we did not list the features at the same level, for example, from pros to cons. Then we found a solution to list each feature not only in the same category, but we also add emoji in front of each bullet point so it's clear to see what it stands for.

## 3.2 Section 2: EV driver issue

### 1. Waiting Time for Public Charger

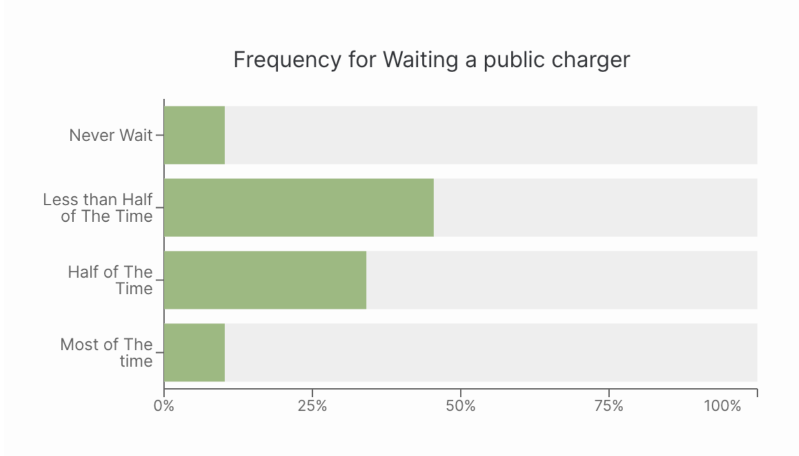



Figure 8: Frequency of Waiting for a Public Charger.

We wanted to understand whether EV drivers face a problem of always having to wait for public chargers. It's bothersome and might cause great inconvenience for people in a rush. We looked into the survey and visualized respondents' answers to the question "What's your frequency of experience waiting for a public charger in the past month." The bar chart above shows that only a few people reported to have never been in this situation. Over 50% of drivers have to wait for chargers; some even report that they have to wait most of the time.

After our hypothesis is confirmed, we try to add another variable to see if there's any relationship between the driving distance to the public charger and waiting time. However, we found out the survey used two metrics to measure driving distance, miles and minutes, and the trend was not very significant. Besides that, it's hard to visualize the result because most distance answers are 5,10,15. The numbers are selected, not random, so it's hard to plot. We tried the plot chart, but it did not work. So we decided to simply show the results of the bar chart and iterated our idea. The iteration is provided in Figure24 in Appendix.

**Number of observed nearby public charging stations by people of different income levels**

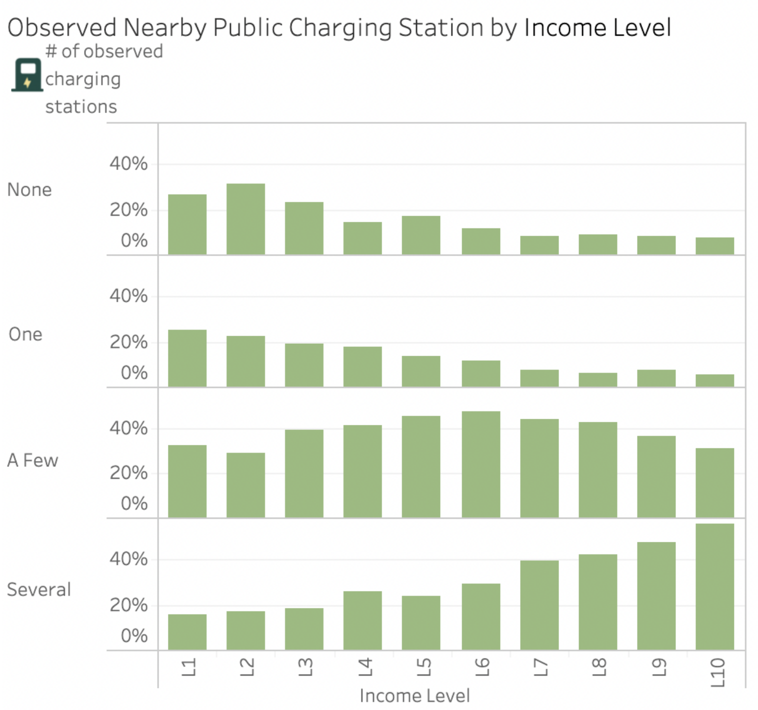



Figure 9 : Observed public charging stations by survey respondents' income level

We compared respondents' (regardless of EV ownership) reported number of EV charging spots in any of the parking facilities they frequent by their income level. Each bar is denoted by a percentage --- what is the percentage of people of X income level reported they observed Y charging stations. We put a specific income range for each income level, and a specific percentage indicated by each bar in the interactive tooltip for simplicity, considering the long legend and crowded texts made the graph look busy in previous iterations (see Figure20 and Figure21 in Appendix). Despite the different max/min percentage for each row, we consistently customize them to a range of 0%-60% for easier visual comparisons across panels.

The main goal of this chart is to show some clear trends: the higher the income level, the more charging stations people are likely to observe (in parking lots they frequent). Conversely, people who are lower in income are more likely to never observe charging stations in parking lots they frequent. This graph shows that economically disadvantaged communities may be again put into a more disadvantageous position in EV charging, who may face more inconvenience and barriers in EV adoption.

**Many EV drivers have hesitated using their EVs out of charger availability concerns**

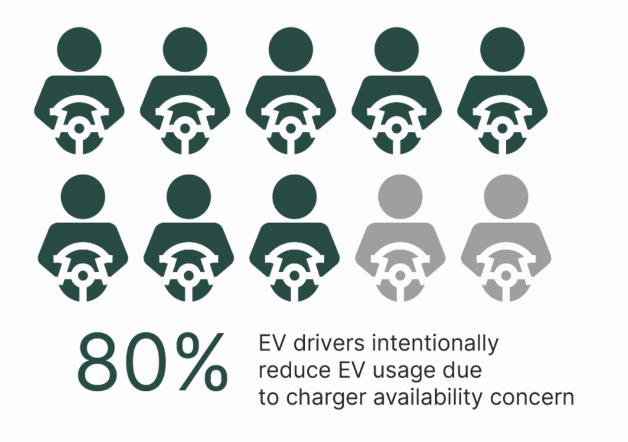



Figure 10: Charger availability concern and EV usage

About 80% EV driver respondents expressed that they have experiences of intentionally reducing EV usage due to concerns about charging station availability. We chose to use an isotype chart to represent such a percentage. We filled 8 out of 10 driver icons with green color to represent EV drivers who suffer from such charging availability concerns, in order to make such proportions look more intuitive to readers. We hope to use an icon chart to make the message that “most EV drivers have experienced some degree of range anxiety and hesitate using their EV” easier to read. Such concerns are not just concerns, but are real barriers in normal EV usage as well as future EV penetration.

## 3.3 Section 3: Gaps in Charger Equity

**Public charger accessibility across race**

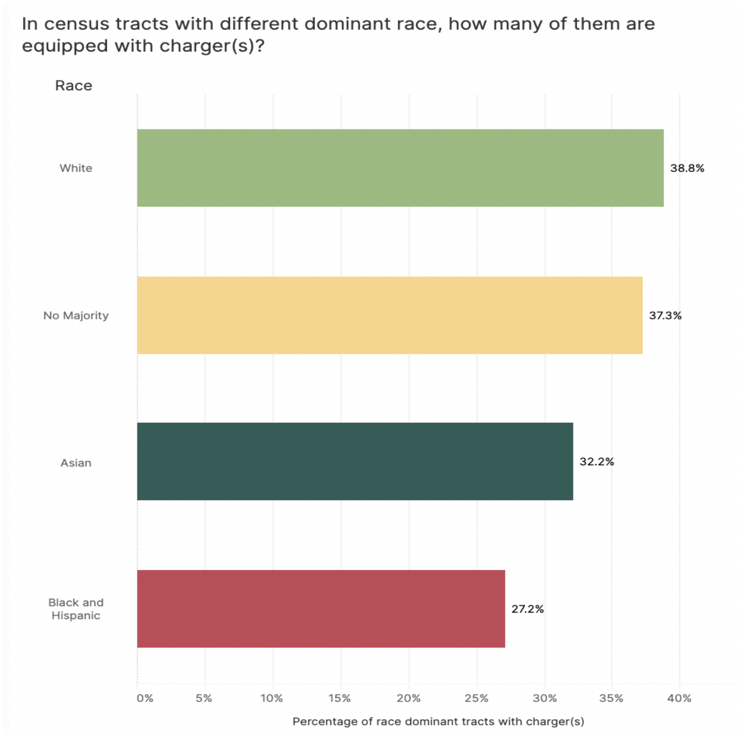



Figure 11: racial disparity in public charger access

In this graph, we used a bar chart to explore charger access disparities across races to test our hypothesis that racial minority groups have less access to public chargers than the white group. We used census tract data (smaller unit than zip code level) to have a more micro level understanding of the relationship between race & charger availability. Inspired by the work of Hsu and Fingerman (2020) who similarly used census block data in charger equity analysis, we first defined a majority race for each census tract as the race greater than 50% of the entire tract population, and assigned “no majority” to tracts without any dominant race. We combined Hispanic and Black as a new group, where hispanic population and black population altogether take more than 50% of the total population, thenwe calculate the percentage of each racial dominant tract that has charges.

**CalEnviroScreen Score & SB 535 Disadvantaged Communities**

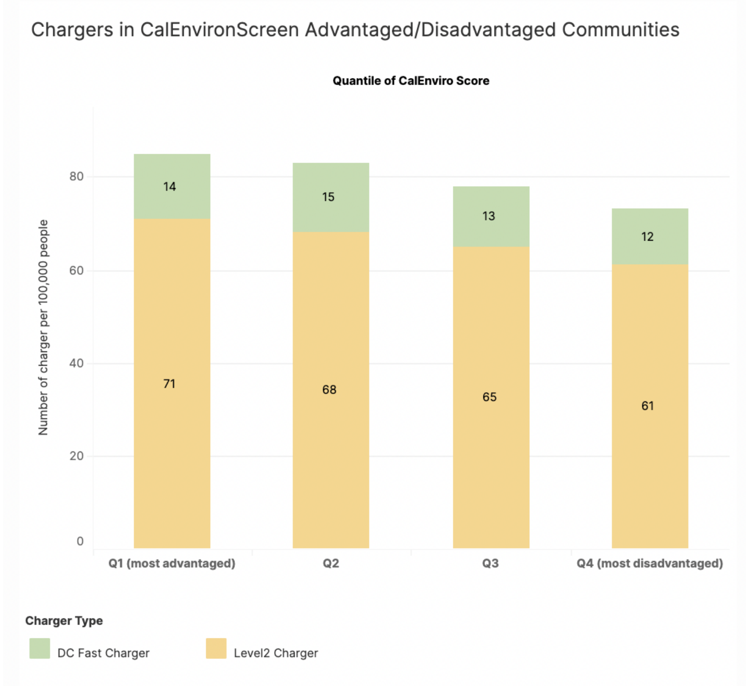



Figure 12: Charger distribution by census tract quartile of CalEnviroScreen Score

The California Office of Environmental Health Hazard Assessment used CalEnviroScreen Score to holistically measure communities' vulnerability to pollution effects, by taking into consideration environmental, health and socioeconomic factors such as poverty, employment and race. 2007 communities scoring top 25% from CalEnviroScreen Score were designated as SB 535 Disadvantaged communities (see Quartile 4 in the bar chart above). The CA Government is planning to specifically target those communities for investment to reduce pollution, while improving their health and economic outcomes (OEHHA, 2018). By grouping all communities by the quartile of CalEnviroScreen, the graph shows disadvantaged communities that are most likely to suffer from pollution, have the least amount of both Level 2 charger and DC fast charger per capita. More investments are indeed needed in building charging infrastructure for disadvantaged communities to advance an equitable as well as green transition to EV.

### Charger disparity across different housing types

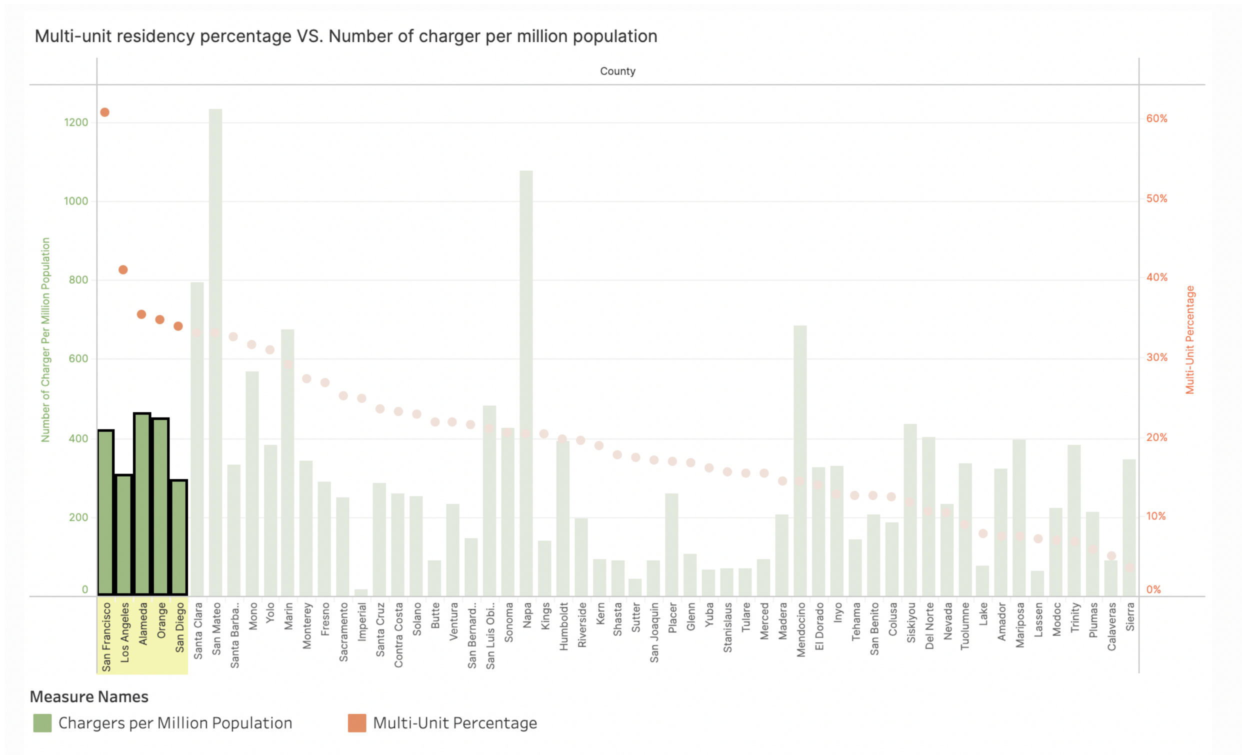



Figure 13: Multi-unit dwelling percentage VS number of charger per capita by county

EV drivers' need for public chargers can be heavily determined by their housing type. Multi-unit dwelling residents are less able to install home chargers and thus rely more on public chargers (UC Davis, 2018). Ideally, regions with more multi-unit dwelling should have greater public charging deployment; this trend is observed in some frontrunner countries of EV uptake such as the Netherlands (ICCT, 2020). To explore if such a trend also holds in California, we used a dual-axis chart to simultaneously plot the number of chargers per million population (green bars) and percentage of multi-unit residency (orange dots) at each county. Two axises are also colored in accordance with the measure's color to avoid confusion. The counties were ordered by multi-unit percentage from highest to lowest by default. Ideally, those counties on the very left with more than 30% residents living in multi-unit dwelling supposedly have most chargers per million population. However, they didn't show any advantage of charger access than other counties with a lower multi-unit percentage. We thus highlighted those counties by default to help readers quickly locate the most "problematic" regions. The old design can be found in Figure23 in Appendix, which violated some basic design principles (eg. mismatch of axis color and bars, counterintuitive measure for y axis) and was thus improved to the current version.

### Charger Utilization Rate

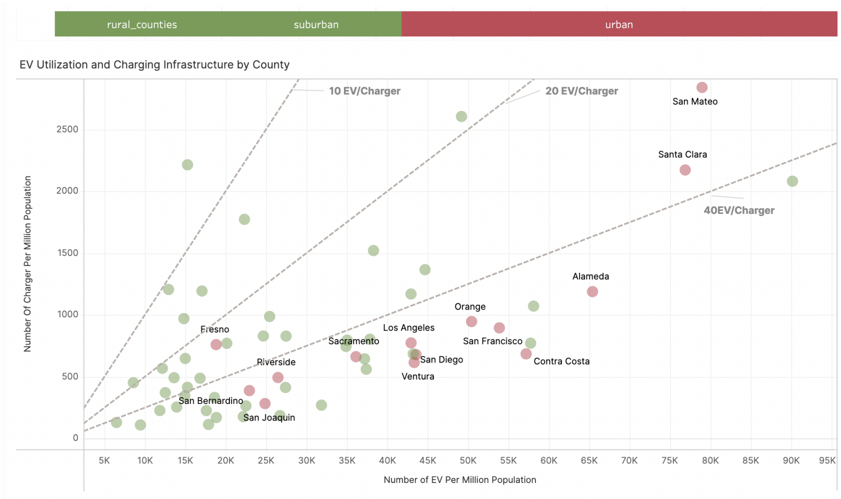



Figure 14: Default Layout

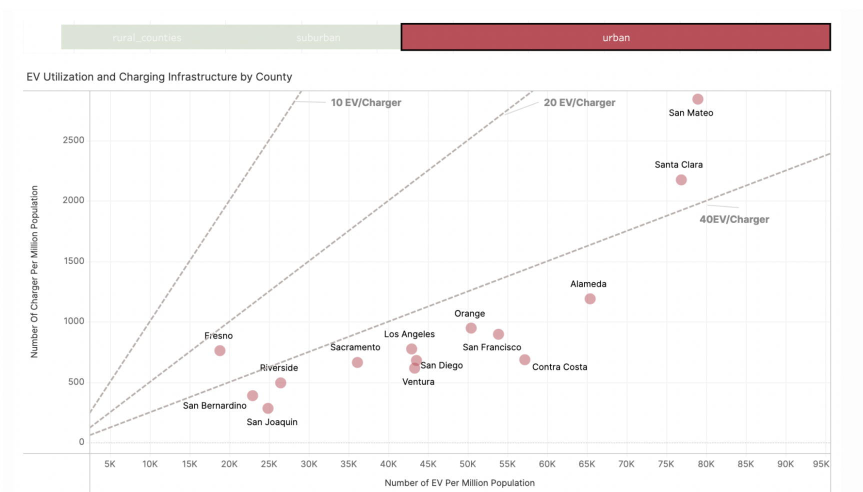



Figure 15: Use Interactive Filter Bar

In Figure14 and Figure15, we plotted each county's EV utilization rate against the number of public EV chargers per million population. Each county is represented by a dot and colored by whether it's an urban county (red) or not (green), defined by California State Association of Counties. We also drew three reference lines to suggest

EV/charger ratio so readers can more quickly get a sense of the charger accessibility level. We added an interactive filter bar on the top so users can click between urban/rural regions to better explore disparity in charger accessibility. The chart suggests that most urban cities have an EV/charger ratio over 40:1. Non-urban counties are in general low in EV adoption, indicated by the X axis. It's worth noting though that the majority of those highly adopting non-urban counties still have very limited EV charger access per vehicle. Results here implied a barrier in more widespread EV adoption. There are no commensurate public chargers even if ev uptake surges as hoped.

### 3.4 Section 4: Gaps in Chargers Scale

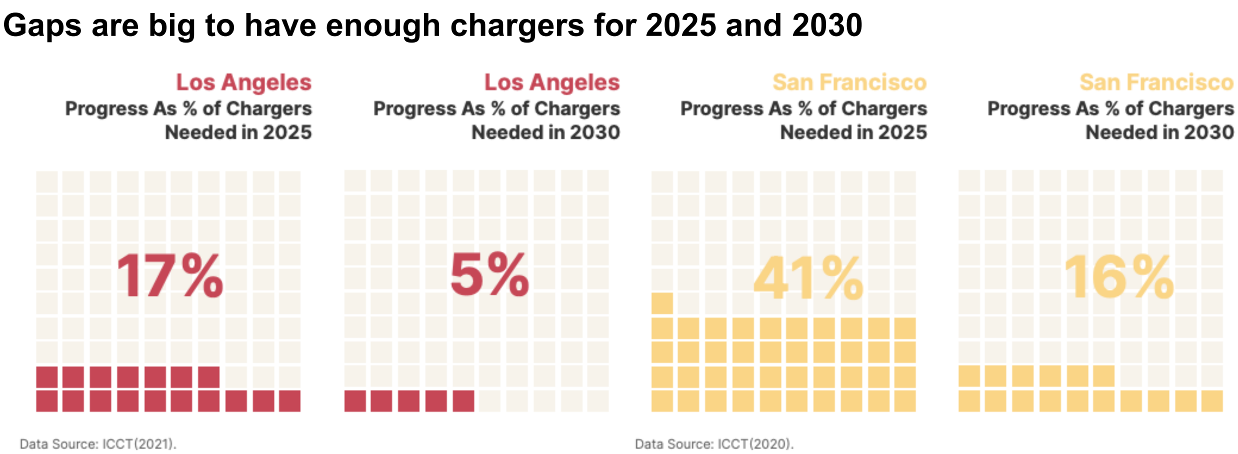



Figure 16: Progress as percentage of chargers needed in 2025 and 2030 for LA and SF.

From the two case study reports by ICCT (2020, 2021), we acquired the data of the numbers of chargers by 2019, and the forecasted needed chargers in the base case (without other policy interventions) in 2025 and 2030 for LA and SF. We found it can be useful to show the progress as a percentage of chargers needed in future years to highlight the gaps.

To show the percentages in an intuitive and straightforward way, we decided to use waffle charts in Figure9 below. The two charts on the left are compared to the demand in 2025 and 2030 for LA, and the two charts on the right are compared to the demand in 2025 and 2030 for SF. In early interactions, we used to have two charts on one row and have two rows for the four charts (see Figure25 in Appendix). However, we found it to be more organized to have LA on the left and SF on the right consistently. We also keep consistent color codings of red for LA and yellow for SF for the whole section. The percentage in the middle of each chart is bolded and color coded, corresponding to the information expressed in the waffle charts.

As we can see, both cities have very big gaps to reach the goals in the next 4 years and 9 years. Having LA and SF side by side, we can tell the gaps in LA are much larger than that in SF, which means LA has more pressure to grow faster in charger numbers to reach the goals.

**Transport policies making the charging infrastructure goals more attainable**

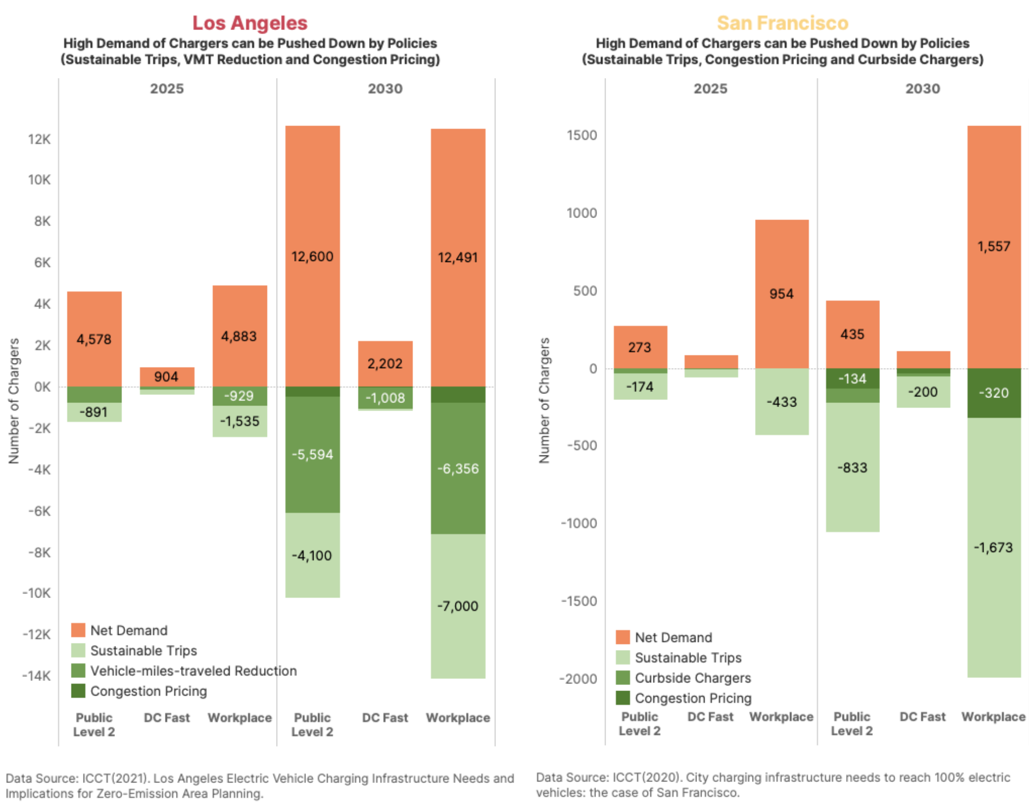



Figure 17: High demand for chargers can be pushed down by policies in both cities.

We adopted the modeled data of forecasted number of chargers under the base case and intervention case from the two ICCT case study reports (ICCT, 2020 and 2021), categorized by charger types demand in 2025 and 2030 for both cities. The key message we would like to convey is that the impacts of policies are incredibly great, not only because they can substantially reduce the number of chargers needed, but also because their benefits are getting larger over time.From a policy maker's standpoint, this is a really amazing future to look forward to.

We used stacked bar charts to visualize the demand of chargers in 2030 for LA on the left and SF on the right. In the early iteration, we used red and yellow for the net demand of LA and SF (see Figure26 and Figure27 in Appendix), but it confused users that these variables were different. The orange part encoded the Net Demand after enforcing all the three selected policies, and the green part encoded the amount of demand reduced by different policies. If we click any policy in the legend, we will be able to see the amount of demand reduced by that policy. Looking at each charger type, we can also have a sense of the estimated demand of chargers in the base case (the length of the whole bar), a large share of demand is pushed down by the policies (green part) and the remaining Net Demand (orange part) is more realistic to achieve given the resource constraints.The scale on the y-axis is different from each other, but the website user may have an intention to compare the demand of LA with SF since they are on the same row.

We also realized the problem in having the same scale for both y-axis: the bars for SF will become too tiny to view. There are also benefits in having the two cities side by side so that the flow of reading in this section can be more smooth. With these considerations, we could not come up with a perfect solution. Our current solution is to have more white space between the charts, so hopefully we can create some visual inconnection. The alternative solution can be having a line striking in between the two charts, or having a frame for each chart, so that visually they are more separate.

**Mapping the gaps in the base case and the policy intervention case**

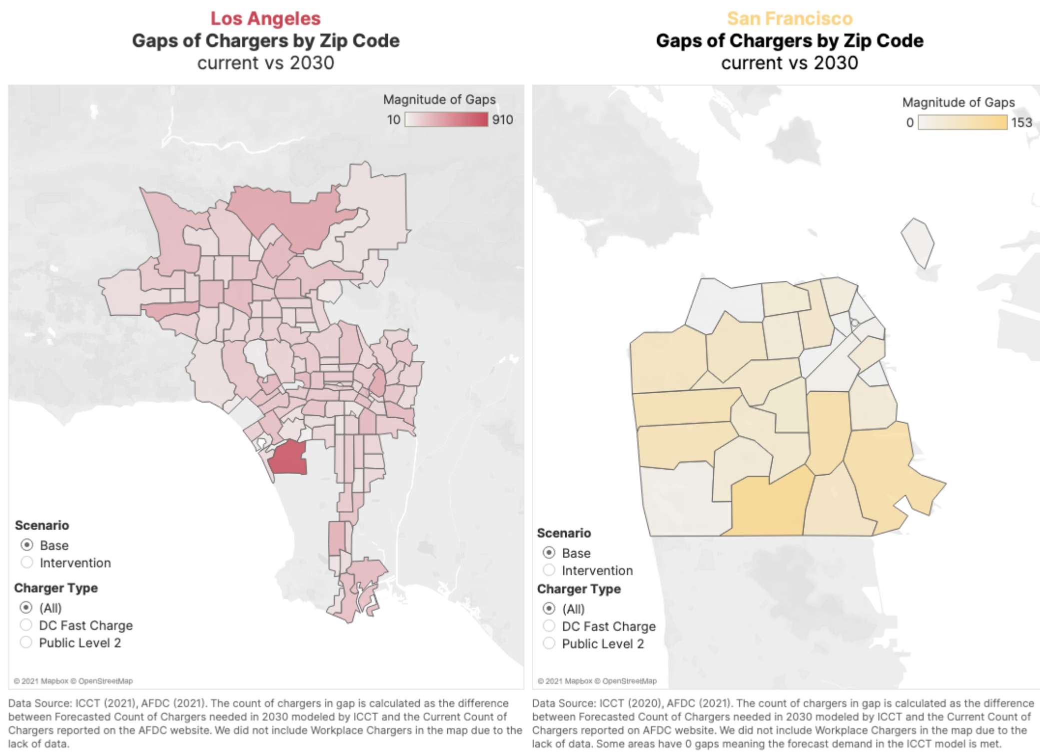



Figure 18: Gaps of Chargers by Zip Code, comparing current count and 2030 forecasted demand of chargers.

To visualize the locations and magnitude of charger gaps in the two cities, we used two choropleth maps. We used inputs of forecasted demand in 2030 from the same models as the previous two charts (ICCT, 2020 and 2021). We used the current number of chargers acquired from the alternative fuels stations database (NREL, 2021). The gaps were calculated as the difference between the forecasted count and the current count of specific types of chargers aggregated by zip code level. The filter of Base Scenario and Intervention Scenario can help users visualize the substantial impacts of implementing policy interventions. The filter of Charger Type can show the count of chargers in gaps in more details. Due to the lack of data of Workplace chargers in the NREL database, we didn’t include it in the Charger Type filter. It is also worth noting that the forecasting study for San Francisco was finalized in 2020. While the growth pace of new chargers is noticeably fast (by May 2021, the number of chargers almost doubled since we first requested data from NREL database in November 2020), a number of neighborhoods in

San Francisco have already reached or even surpassed the forecasted demand of chargers in 2030. In these neighborhoods, we marked the gaps as 0. Lastly, we also keep the color coding for Los Angeles and San Francisco consistent with the last two charts to improve the readability of the storyline in this section.

### 3.5 Information Visualization Heuristic Evaluation

We used the visualization heuristic guideline to improve our design.

- H1: Use correct & Meaningful visual encoding
  We chose our data type and made meaningful encoding. We are fine for H1.
- H2: Supports key visual insights
  Most of the charts support the hypothesis or insights. For example, the data value supports that higher income levels get more EV chargers. We also highlight key information, like the urban city in the capital city gap chart. But this helps us figure out some charts do not show trends as we expected, for example, the unemployed chart has too much noise.
- H3: Uses principles and Organization and Consistency
  We label out details using a tooltip or legend. This evaluation helps us realize our first color pattern is not consistent. Using all green color patterns makes the website harmonious, but in some charts, the level 2 charger is light green while another chart is red. We modify the color pattern: all “normal data” as light green, the "continual value" from light to dark green, "discontinuous category" as a different color (red, yellow, orange), and all "text title" as dark green.
- H4: Presents Information Honestly
  In some icon charts, we omit decimals to make it more user-friendly and accessible for icons, but the trend and value are presented honestly.
- H5: Successfully Communicates
  We use narrative and tell a story for the content. Viewers can follow our story to take a journey about it.

# 4. Data and Tools

## 4.1 Data

- 2019 California Vehicle Survey

Conducted by the California Energy Commission, the 2019 California Vehicle Survey collected 6,549 Californian light-duty fleet owners' vehicle preference and usage experience data. The dataset consists of 4,248 residential surveys and 2,301 commercial surveys. For the purpose of the current study, we only used residential survey data for analysis, which contains responses from 718 PEV (plug-in electric vehicles) owners on their economic and demographic characteristics, including income, race/ethnicity, and type of housing. Besides, it recorded different aspects of EV drivers' charging behaviors, and choice & preference of vehicle and charger type. We mainly used this dataset to build EV driver persona and understand their charging experiences including any pain points related to the availability of public charging infrastructure.

- Charger Data

The charger data was acquired by calling NREL (The National Renewable Energy Laboratory) Data API. The dataset contains the most up-to-date information on public chargers, including their geographic location, type, and quantity. We leveraged this dataset to analyze the status quo of public charging infrastructure at scale so as to further quantify the gap to reach the 2035 goal.

- 2017 Census Data (from American Community Survey)

Census Data were obtained through the Data API of the United States Census Bureau. We selected data on race/ethnicity, household median income, type of housing, and population density for 58 counties and 8057 census tract. We incorporated this dataset with charger data in order to (1) first map the current distribution of charger from a demographic perspective and (2) test if there is a charger access disparity among different socio-economic/demographic groups.

- Urban/Rural Code

We used urban/suburban/rural code organized by the California State Association of Counties that assigned each county in California an urbanization level.

- CalEnviroScreen 3.0 Score and SB 535 Disadvantaged Communities

Each census tract in California gets a score for its vulnerability to pollution effects by the California Office of Environmental Health Hazard Assessment. The metric takes into the “cumulative impacts” of various environmental, health and socioeconomic factors for different communities, and thus can be considered a more holistic measure than using poverty, income, or PM 2.5 alone. The dataset also provides classification labels of SB 535 Disadvantaged Community, defined as “top 25% scoring areas from CalEnviroScreen along with other areas with high amounts of pollution and low populations” (OEHHA, 2018). Disadvantaged communities are identified for better targeting funding to the most needed to reduce greenhouse emission and improve health & economic outcomes.

- Forecasted number of chargers in San Francisco and Los Angeles

We used the results of charging infrastructure needs in San Francisco and Los Angeles from the two case studies by the International Council on Clean Transportation (ICCT, 2020; ICCT, 2021). The granularity of the forecast data is at zip code level for charger types including public level 2 chargers, DC fast chargers and workplace chargers.

### 4.2 Tools

- Notion: For prototype, documentation
- Python (Pandas, GeoPandas, Numpy, Seaborn, Plotly, NLTK, PyTorch, Scikit-learn)： For data explore analysis and explore
- Tableau: For data explore analysis, information visualization charts
- React.js: Website language
- Create-react-app: Frontend build pipeline
- Rechart, Nivo: D3 chart libraries
- Adobe Illustrator: For UI design and icons

## 5. Results

Our visualization website can be found in this link:https://alison626k.github.io/MIMS21-GEAR/

## 5.1 Visualization Website Storyline

To help users understanding and get involved to our project content and takeaways, we draw a narrative storyline to for our visualization website:

- **Landing page**: What ZEV and chargers goals do we have in California? Why is it important to understand the gaps of EV charging infrastructure?
- **EV Charger Types**: What are the three EV charger types? What are their characteristics and use cases?
- **EV Users Persona**: What kind of people own an EV in California (income level, housing type, vehicle brand decision, and charger type decision)?
- **EV Charging Issues**: What are the three prominent issues faced by EV drivers in charging (wait time, access disparity by income, charging convenience)?
- **Gaps in Equity**: What are the gaps in equity using different angles (race, income, housing type, charger utilization rate, disadvantaged communities vs others)?
- **Gaps in Scale**: What are the gaps in scale for two example cities, Los Angeles and San Francisco? How can policies help close the gaps faster/easier?
- **A Future to Look Forward**

The first version of the storyline did not include EV charger types, but from the usability test, we found out some people would ask about the differences of charger types. Since potential EV drivers are also our target audience, we decided to add an overview of EV charger types at the beginning. Another adjustment was to bring the EV users persona forward in order to make the storyline flow more smoothly. The flow is as “Users, Problems, Gaps and Future”.

## 5.2 Usability Test

Our ideal target audiences of the website are those who can make policy decisions and recommendations in the e-mobility transition, or those driving the advocacy for clean air and sustainable transportation. We also appreciate the feedback from current and potential EV users in California. While their awareness and opinions about EVs and EV charging are critical in the scale-up of EV markets, our website is intended to reflect their issues at the micro-level and also the current gaps at the macro-level. It is beneficial to validate the main messages with EV users in our website iterations.

With these considerations, we invite the users from the following categories to participate in our usability test:

- Policy makers, policy advocates and researchers, who can influence decision making in clean transportation, climate change and clean energy
- Current EV owners in California, who are current users of EV charging infrastructure
- Potential EV buyers in California, including gasoline vehicle drivers who may switch to EV in the future

The usability test recruiting strategy is to start from the second and third category in the prototype phase and then invite target users from the policy maker category for their feedback when we have a more advanced version of the website. To implement this strategy, we sample from people we know that can meet the criteria but outside of MIMS to avoid convenience bias as much as we can. Therefore, we identified one EV owner and one gasoline vehicle driver who is interested in EV for our usability test.

We aimed to evaluate whether our visualization design is effective in conveying the messages in the sections of EV charging overview, charger gaps in equity and charger gaps in scale for the overall topic of infrastructure accessibility. Our test includes three specific tasks to test each section. The detailed questions and website prototype screenshots are provided in Appendix.

We planned to measure two key factors: 1) Where do users stop scrolling the webpage or spend extended time figuring out one visualization or narrative, and how much time do they spend in the confusing part. 2) What questions did they ask about our website or visualizations. The first measurement can help us mark the visualization or narrative that users get confused about, and the second measurement can help us identify what information is missing or not clear in our website.

**Task 1:** In the sections of EV Driver Persona and EV Driver Issue, what are the problems that EV drivers are currently facing?

> **Goal:** We are going to test if users can understand the first two sections, figuring out the EV driver issue.
>
> **Result:** The interviewees performed well for the EV Driver Persona part and did not get any confusion. However, both interviewees stopped at the EV issue section for the Waiting Time Chart, because they did not understand what the chart was talking about. They spent 1 minute on it until they figured it out through the text. They both got a little confused about the third chart of charging inconvenience and misunderstood the key message. They understood the narratives but could not relate to the chart. One of the interviewees asked about the direction of the causation in the charging inconvenience chart. He suspected it can be interpreted as the other way around: some groups prefer gasoline cars so they avoided using EVs.

**Task 2:** In the EV Charger Equity section, which gap do you have most impressions on? After reading this section, which housing type and income level has the highest and lowest numbers of chargers?

> **Goal:**We are going to test if users can recall the key messages of any specific charts, and if the chart and text can successfully show the EV charger gaps.
>
> **Result :** Interviewees spent more time reading the four charts. They stopped at every chart and were not sure about meaning. After reading it carefully, the county's chart is clear for them to understand that there is a gap. One interviewee made one error about how to read the unemployment chart. He cannot tell the trend of unemployment and charger numbers. One interviewee expressed that income level and unemployment seemed a little similar because they are all related to spending power.

**Task 3:** After reading the EV Charger Scale section, can you tell us about the impacts of implementing policy interventions on the two cities' charging demand?

**Goal:** We are going to test if users can understand the information of the two bar charts.

**Results:** One interviewee spent almost 10 minutes reading the bar chart. He did not understand what the minus number means and the relationship with the positive number. After explanation, he can get the idea. Both interviewees got at least one error where they did not get the negative section of the bar chart.

After the interview, we learned that communicating too many concepts in one chart will confuse users. Presenting over 3 variables in one chart makes it look fancy, but hard to understand the main insight. Users have to think through and spend time on it to figure out the content. So less is more. Clear but easy to understand is better than complicated. Besides that, the text will help a lot. Some of our charts lack text when we conduct the interview, and users have to spend more time on it. The precise content can help users to understand each main insight. Using all green color patterns makes the website harmonious, but users cannot tell the difference if dark and light green represent different categories or a different amount.

We summarized the following feedbacks to be included in our website:

- EV persona part is fine. Will change the charger type chart to the icon. Make the context more related to “Persona”.
- Change the charging convenience chart(chart 3). Users are unable to understand the relationship between having gasoline and avoiding EV usage, so we plan to remove the gasoline preference category, just focus on talking about why drivers avoid using EVs after they bought them.
- Change the waiting time chart. The plot is confusing and users do not understand it. We found out if we want to deliver the message about waiting for a charger, we just have to present the percentage or waiting time. Another variable is too noisy.

- The EV gap on different metrics works fine. The unemployment is not significant, so we will remove that part. We will add a reference line on the county chart and change the color, so it will be more user-friendly. The income level and race chart are too complicated, so we will reduce the variables and focus on the main insight.
- The policy city bar is okay. But it lacks some explanation to help users get into it more quickly, so we plan to add more precise deception on that text and labels.
- Change the color pattern. Make dark green and light green represent different amounts, and find a new color for different categories.

### 5.3 Website Development Process

We used React and created React Apps to build the website and host it on the Github page. Because our website only contains front-end sites, we chose React as a common front-end development framework. Our visualization contents are original, and the website is building on top of an open-source template. Our website has gone through three iterations, from wireframe, usability test to finalization.

Based on the storyline, we made the scratch for the website wireframe on paper (see Figure28). We want to avoid making the website a boring collection with charts, so we plan to tell the concept as a narrative story. This is the first version of the website. The second iteration is before usability testing. We make a draft with charts on Notion as a prototype, and take it to conduct usability testing. After the test, we finally go on developing the website.

| Before iteration | After iteration |
| --- | --- |

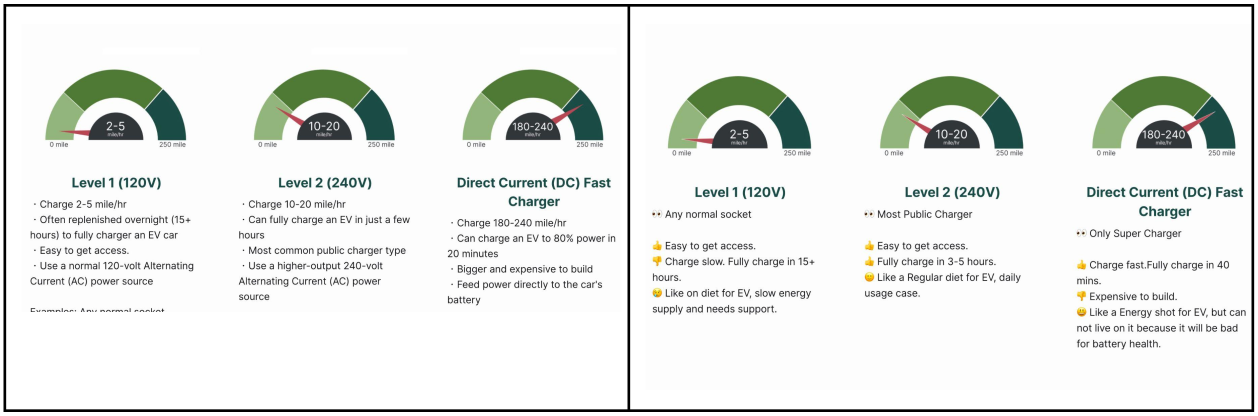



Figure 19: Example iteration for EV charter type sections: icon adding, recategorize description

Our website includes 5 main sections based on our storyline: 1) Background storytelling and animation. We try to use some animation and fade in sections to make it more accessible. 2) EV charger type, driver persona and issue. This section contains both charts and icons in the prototype version, but when we realize that the rest sections will include some complicated charts, we decided that Persona will only be icons and numbers so it's easier to read and harmonious. 3) EV charger equity gap. We plan to deliver 5 variables in the first place, but then some charts are deleted because it does not communicate any significant trends or differences. Some charts include too many axis contents, so we put it as the whole page so that users can read them. The rest of the sections, 4) City Compare and 5) NLP do not change a lot, so it speeds up our development.

When we embed the Tableau charts to the webpage, we struggle to get rid of the scrolling bars and the toolbar of Tableau. We found the solution to removing the scrolling bar by setting Tableau sheets to "entire view", but we failed to remove the toolbar defaulted by Tableau Public. Another problem that we tried to solve is that the D3 library chart we used should display animation when loading, but we failed to conduct the intersection observer. So we can only use fade in fade out as default. We make the website responsive, but some charts are unable to do so. These are some issues due to our technical limitation and would like to solve it afterward.

The last thing to iterate for the website is our color pattern. As mentioned in *3.5 Information Visualization Heuristic Evaluation*, the first idea of our color pattern is using all green so it stays harmonious, and only red and yellow for highlight. But then we realize we need more color to separate title, icons, data, and category. The modified version is: all “normal data” as light green, the "continual value" from light to dark green, "discontinuous category" as a different color (red, yellow, orange), and all "text title" as dark green. The color pattern from first to infinalization is attached in Figure29 in the Appendix.

## 6. Contribution

<table>
<tr><th>Team Member</th><th>Contributions</th></tr>
<tr><td>Alison Kuo</td><td><ul>
<li>Whole Website Development, including building design guidelines, color palette,prototyping and final implementation</li>
<li>UI Design, including drawing all icon and isotypes, website icon and logo</li>
<li>Data exploration and building visualizations on EV driver persona and EV charging issues</li>
<li>Add interaction bar to Visualization charts(see figure 15)</li>
<li>Responsible for Usability Testing, including guideline set up, conduct 1 interview and associate for the second</li>
<li>Project Management</li>
<li>Report Writing:
<ul>
<li>In the infovis final report, write for 2. Discussion of Related Work, fist 2 part and 3.5(Heuristic Evaluation) of 3 Description of Visualization, 4.Data and Tools, 5.Results, 6 Contribution and 7 Appendix.</li>
<li>1. Project Goal is contributed by other team</li>
</ul></li>
</ul></td></tr>
</table>

| | |
|---|---|
| | **members. Rest part of 3 *Descriptions of Visualization* are modified from other team member's versions.** |
| Wenqi Luo | Data collection, processing and exploration for EV driver behavior issues, EV market share & registration and equity analysis (30%)<br>Build visualizations to show on website and write section associated texts<br>Literature review<br>Natural language processing, mainly literature review, human annotations of review sentiment and result analysis<br>Report writing |
| Yin Qiu | Literature review and project scoping<br>Building visualizations and storyline, mainly on gaps analysis of EV charger scale and EV charger types<br>Data collection, processing and exploration<br>Report writing<br>Natural Language Processing, mainly on literature review and data annotation<br>Usability testing |
| Chuhan Wang | Natural Language Processing, mainly on literature review, data collection and preprocessing, model training and tuning, result evaluation and analysis<br>Literature review<br>Report writing |

# 7. Appendix

## 7.1 links

Website: https://alison626k.github.io/MIMS21-GEAR/

Github Repository :https://github.com/alison626k/MIMS21-GEAR.git

## 7.2 Usability Testing Guide

***Introduction***

We are trying to get feedback on our website for a Berkeley course assignment about information visualization. We're grateful that you can take the time to help us improve the user experience. Please think aloud and tell us your thoughts as you go through this usability test. Before we start,  we would kindly have your consent and signature on the informed consent form. All the information collected in this usability test interview will be used and kept only for the stated purpose. There are no right or wrong answers for the questions. Please use your best judgement to provide your answers and feel free to be as critical as you would like.
We're testing the website, NOT you, so anytime you feel something odd about it - feel free to share, be as critical as you like.
Do you have any questions before we begin?
Let's begin with some background questions.

***Test: Background Questions***

We asked the selected participants a set of pre-test questions which provided us further understanding of their relation to EV :

1. Do you own an electric vehicle?
    1. If so, how often do you drive it?
    2. If not, are you planning to get one or do you feel interested in getting access to it? Have you driven an electric vehicle before?
2. What is the most common transport mode you use?

***Moderator Script***

We are now going to see the website wireframe. It's just a draft and sketch, so please ignore the layout. Again, feel free to point out anything you feel odd about as you're going through it.

***Questions***

**Task 1**: Looking at the EV driver persona and EV driver issue, what are the problems of EV drivers currently facing?

- What do you first see in the Persona section?
- What do you first see in the EV driver issue section?

- What information do you get from the last “charger convenience “chart?
- After reading these two sections, can you tell us what problems EV drivers are currently facing?

  *Note for the interviewer: We’re looking for if users can understand the first two sections, figuring out the EV driver issue. They should answer: 1) Ev drivers often wait in line for a public charger, 2) higher income level groups get more public chargers in surroundings, and 3)Charging is not convenient enough so some EV drivers regard buying EVs and still prefer gasoline vehicles.*

**Task 2**: Now let's scroll to the next section. In the EV Charger Gap section, which gap do you have most impressions on?

- What do you first see in the EV Charger Gap section?
- Can you tell us what you learn from this section?
- After reading this section, which capital, housing type and income level has the highest and lowest numbers of chargers?

  *Note for the interviewer: We’re looking for if users can memorize any specific charts, and also if the chart and text can successfully show up the EV charger gaps.*

**Task 3**:After reading the last section, can you tell us about the impacts of implementing policy interventions on the two cities' charging demand?

- Do you find out anything different or in common about the charger situations in LA and SF?
- What are your main takeaways about the last section?

  *Note for the interviewer: We’re looking for if users can understand the information of the two bar charts. They should be able to answer the implementation of the policy and reduce the demand and gaps of public chargers.*

Thanks so much, with that we’ve concluded our testing process!
Do you have any last comments/closing feedback on this website? Anything is helpful!
Thank you so much for helping us to investigate the usage of the project. We really appreciate all your time and input!

## 7.3 Early Iterations of Visualizations

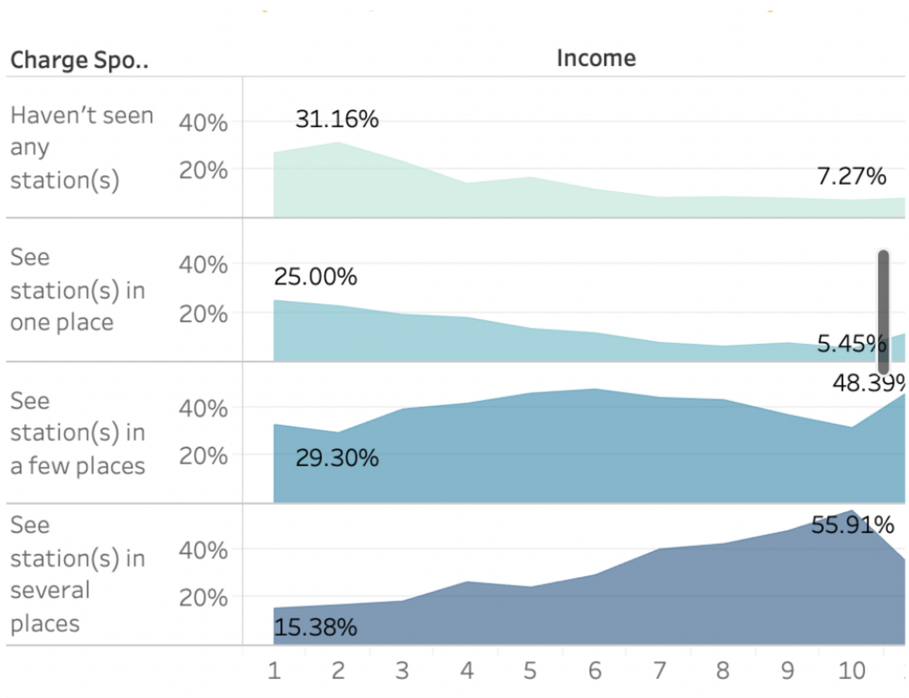



Figure 20: Early iteration 1 of income chart.

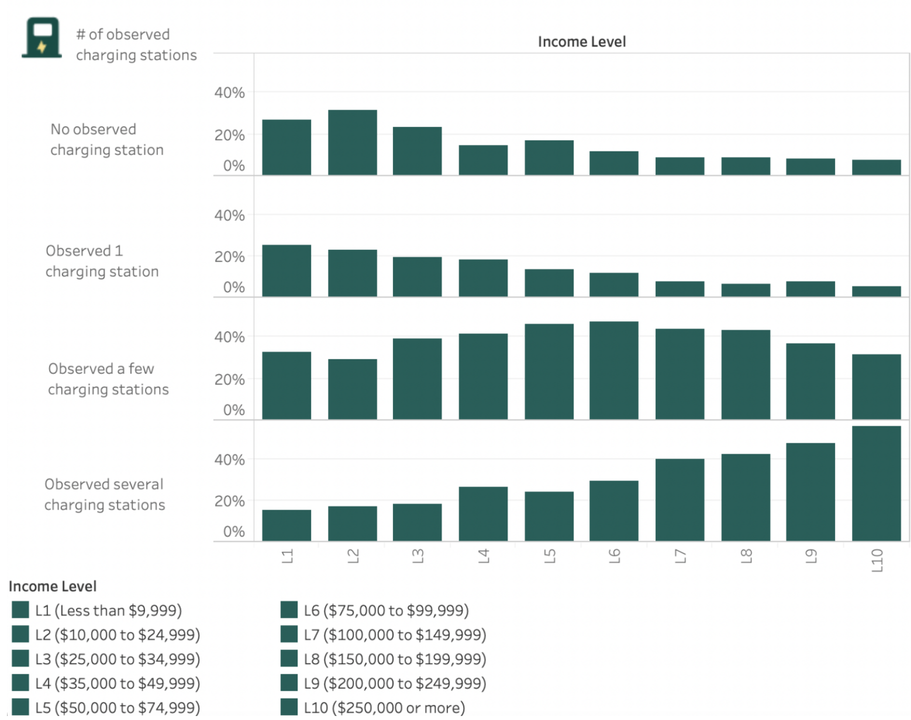



Figure21 : Early iteration 2 of income chart.

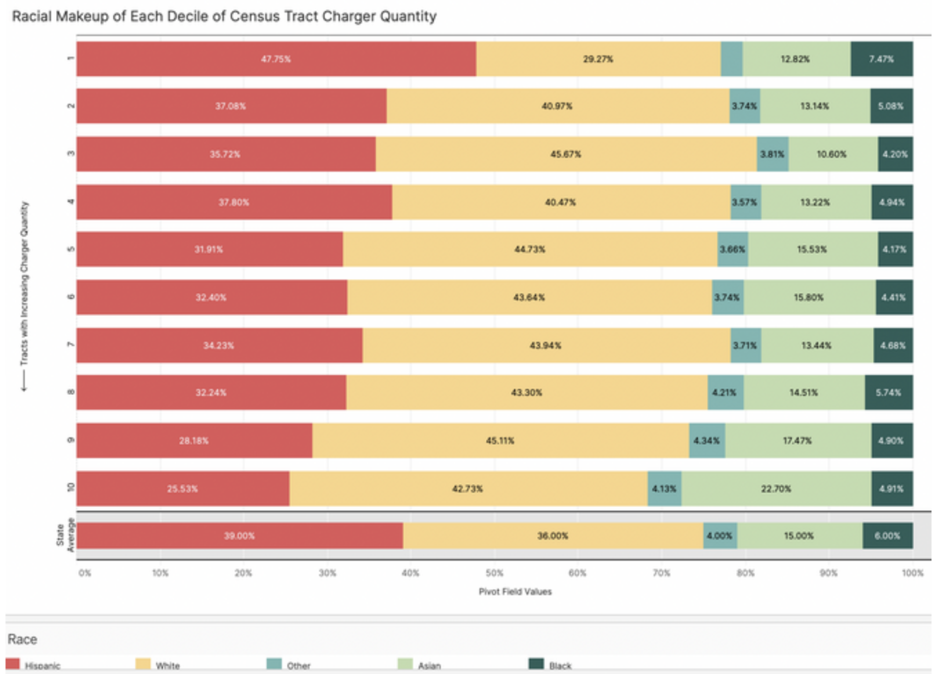



Figure 22: Early iteration of race chart.

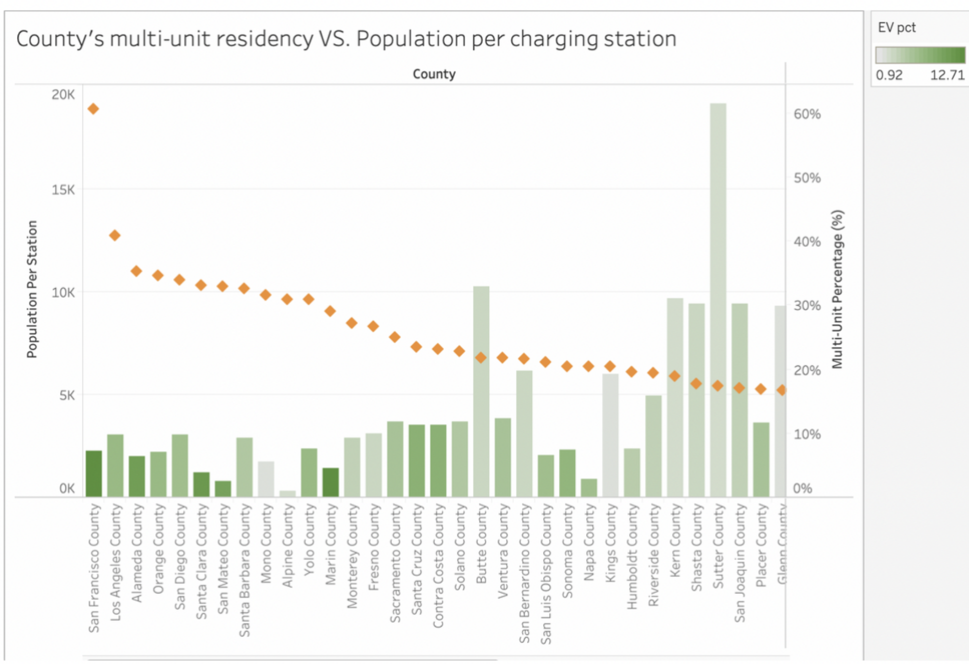



Figure 23: Early iteration of multi-unit housing chart.

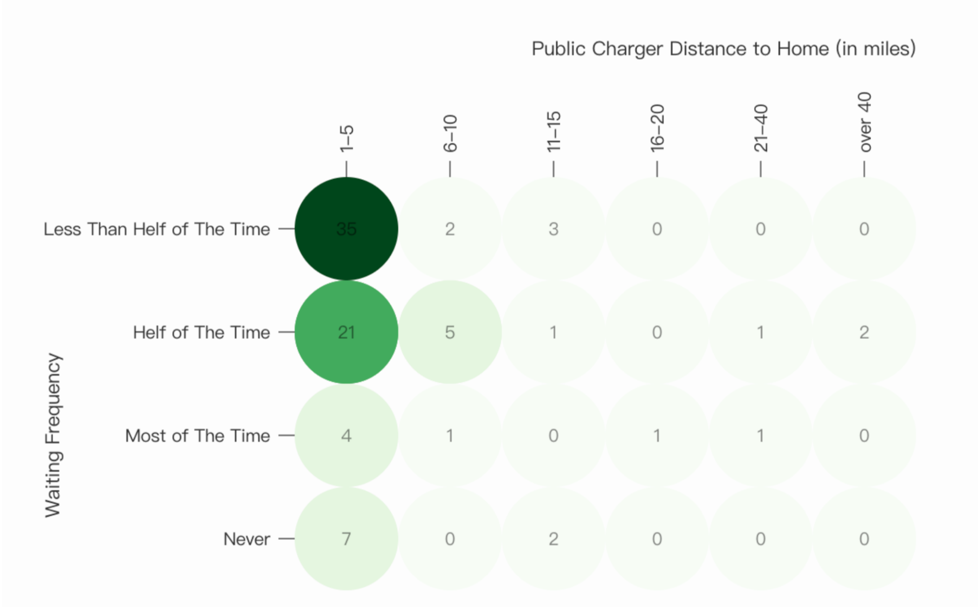



Figure 24:: Early iteration of wait time chart.


Figure 25: Early iteration of progress % waffle charts.

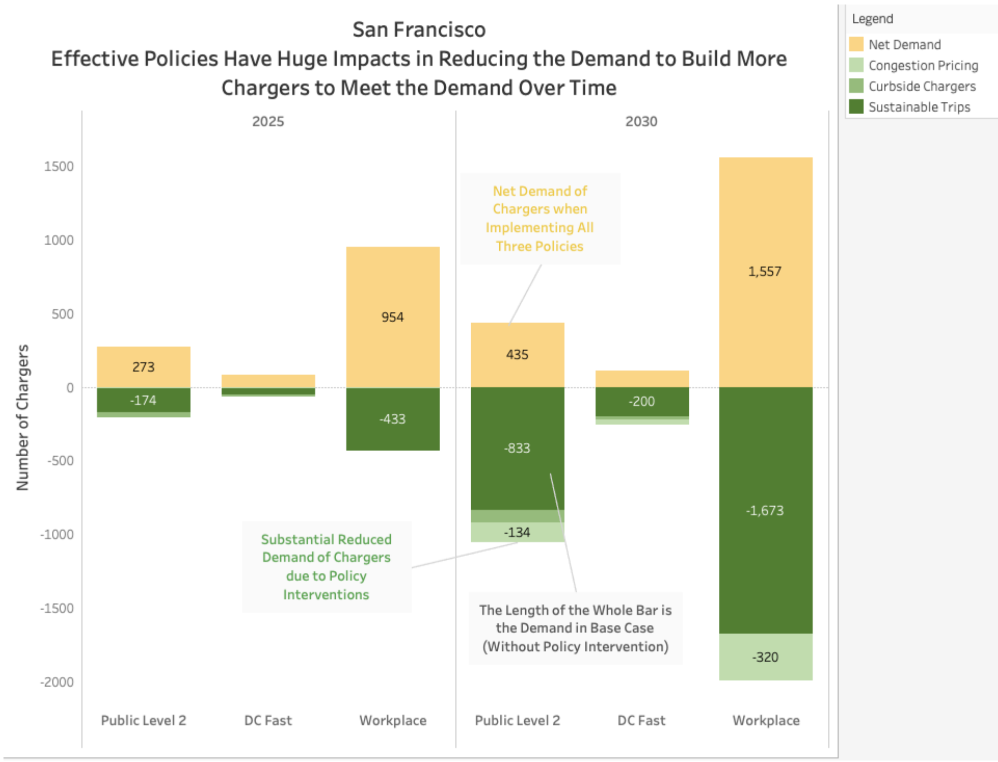



Figure 26: Early iteration of SF forecast demand chart.

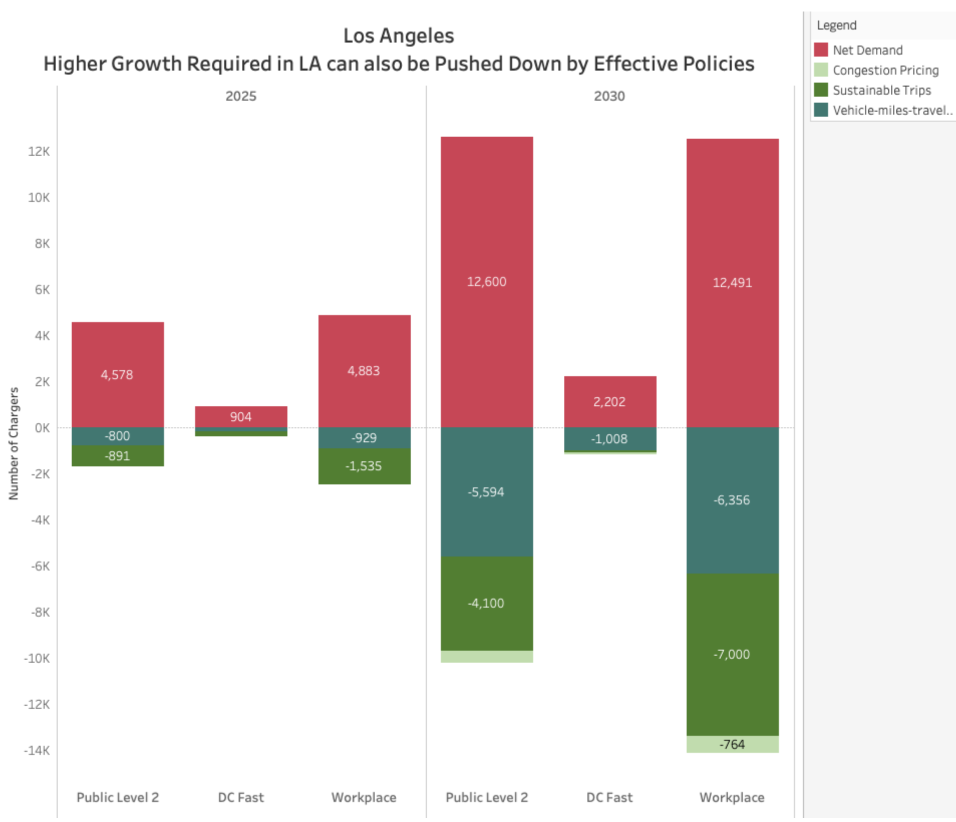


Figure 27: Early iteration of LA forecast demand chart.

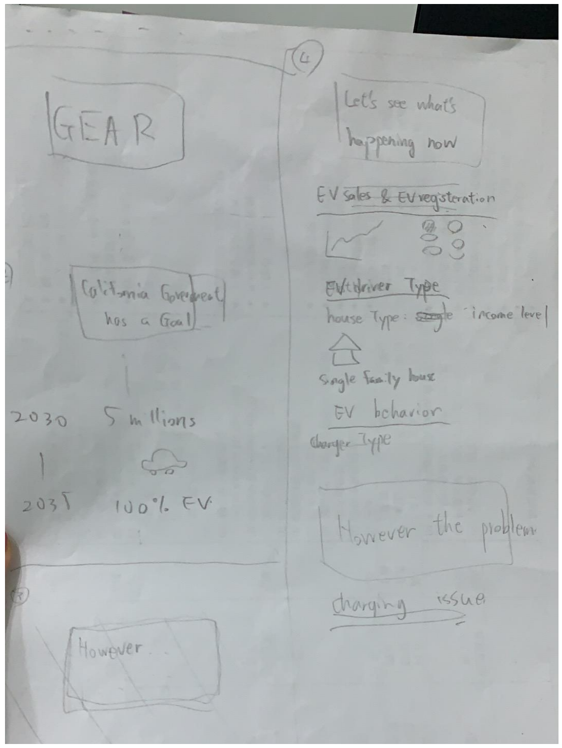
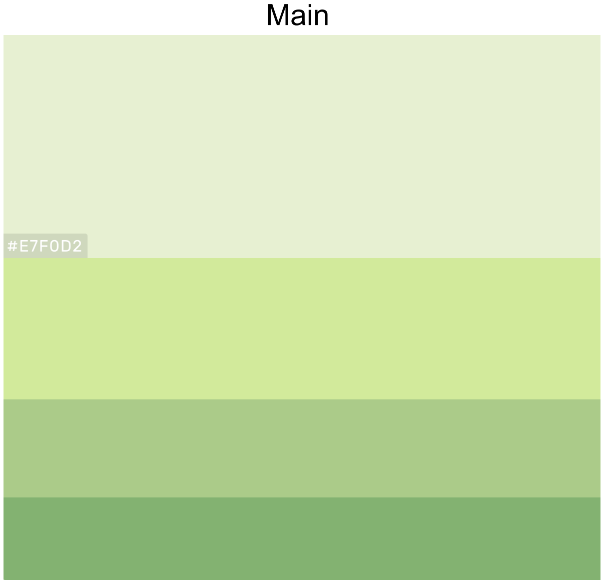



Figure 28: Early iteration of website wireframe.

| Before | After |
| --- | --- |
| Main   | |

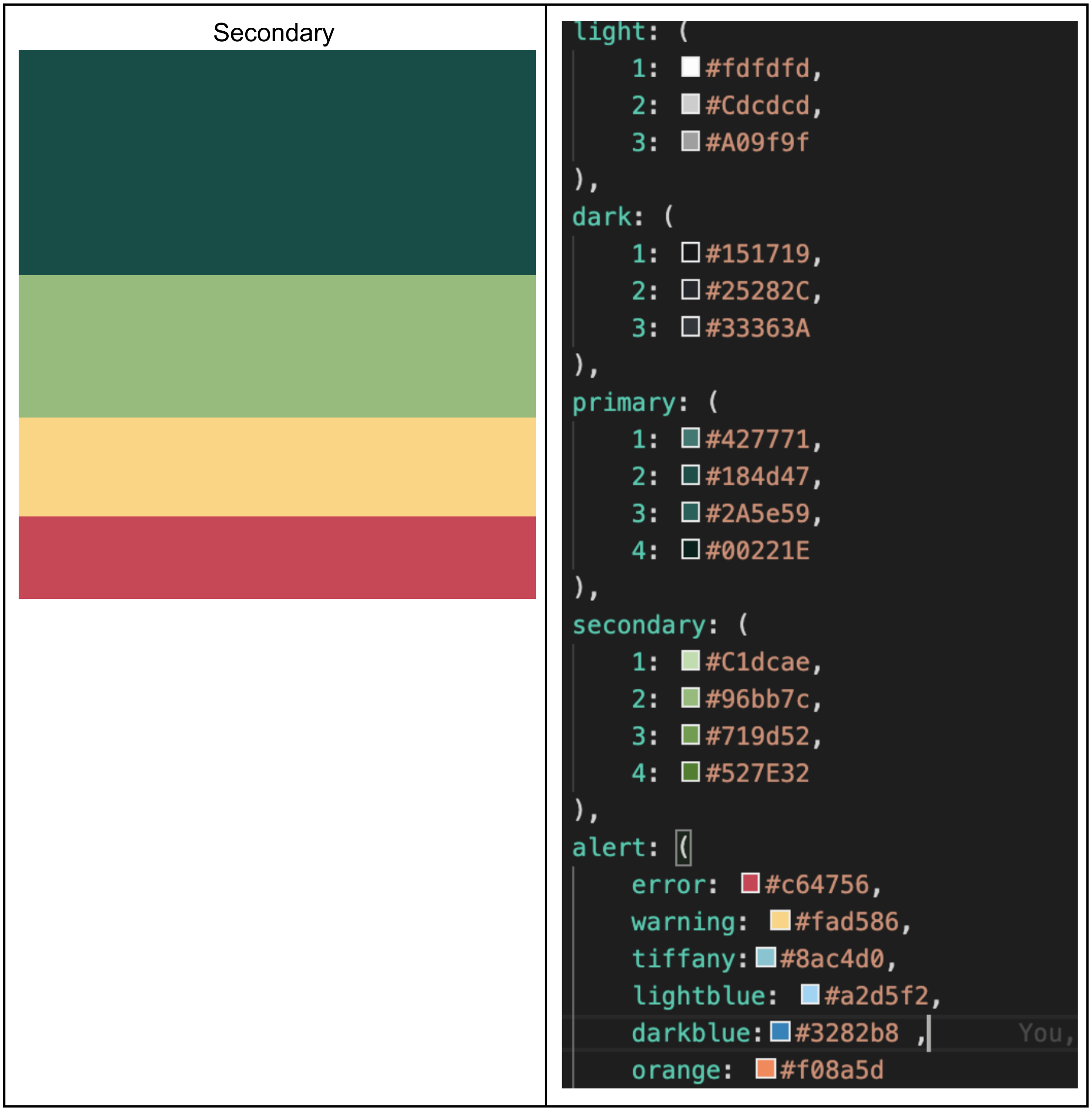



Figure 29: Color palette for website.

## 7.4 Reference

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