Visualizing EV Charging Stations:

Usage, Placement & Effects

Group Members 1, 2, 3, 4 & Chris Reynolds Info 246: Information Visualization

Dr. Michelle Chen

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Introduction

We would like to find out what makes a good location for an electric vehicle (EV) charging station. By understanding the current locations of EV charging hotspots, we plan to uncover what makes these locations appealing to users. By tying data to geographic locations in the form of time & financial incentives, we hope to build an understanding of the drivers using EV charging stations in Palo Alto, California. Our hope is to understand what is driving usage in different locations around the city. In turn this information can be presented to the city in order to find new locations, or to other cities that are planning on adding EV charging stations.

According to the City of Palo Alto's website, one in five households in Palo Alto drive an electric vehicle (EV) - "the highest adoption rate in the country". The city has also invested in a carbon neutral electricity supply and low electric retail rates. The City of Palo Alto stated:

> Since 2013, Palo Alto has provided 100% carbon neutral electricity and, as of July 1, 2017, we also provide 100% carbon neutral natural gas. For electricity, carbon neutral means that we match electricity demand with carbon free supply on an annual basis. For natural gas, carbon neutral means that we buy carbon offsets to balance emissions from natural gas use in Palo Alto.

Dataset Description

Data that will be useful in this study includes number and types of stations (Level2, DC fast, and or free), current locations, charge times, and user preferences. Three main datasets were used; EV charging usage data from Palo Alto, EV charging station data from across the US, and the California zip codes. Two of these were found on Kaggle but are originally posted from other sources. During our investigation, we found it essential to add to these datasets in order to fill in gaps we were interested in. Extra geographic and financial data was researched and incorporated into our data sets.

Design Process

In considering our data, we looked at the initial Palo Alto EV Charging dataset to consider not only why this dataset was created, but for whom it might benefit. This meant looking at the dataset to determine what other information we might need in order to answer questions about the importance and relevance of the data. Upon close inspection of the initial dataset, we determined that complementary datasets were necessary for a thorough investigation of our project’s scope.

To address our inquiries, we looked into the core aspects of our data. This meant considering the individual measurable points and to which larger group they belong. We came up with the following categorical lines of investigation: location, time, money & users (aka, Geographic, Time Based, Financial, and User Profiles). By creating these larger categories, we were able to each take a unique subset of data to individually analyze and visualize. This process helped to form our core questions within each category.

Geographic:

- What services are around hotspot locations?
- Are there underlying patterns regarding common services?

Time based:

- Which charging stations are most popular based on frequency of charging events?
- At which charging stations do customers spend the most time charging?
- At what hours of the day do most charging events occur?
- What is the most popular level of charging used?

Financial:

- What is the distribution of free EV charging stations? Where can more public stations be placed?
- On average, how much are customers saving compared to gas prices?

User profiles:

- Who are the customers using charging stations in Palo Alto?
- How far are they driving between their home and charging station?
- Which stations are the most popular? Which stations are visited by the most distinct customers?
- Which charging level is most popular?

After splitting the data, we would work separately to understand our sections, then come together once a week to compare findings, talk through issues, and learn from each other, especially regarding how to use our software of choice, Tableau.

With the use of Tableau, it was convenient to select different graphs that could be used to visualize the data when multiple variables were selected to be analyzed. This helped in the exploration of the data in an iterative fashion, trying different combinations of fields, filters, and graphs. Ultimately this led to the creation of visualizations that would help best answer our research questions and provide a deeper understanding of characteristics within the data set.

To gain a better understanding of where Palo Alto may consider installing new EV charging stations, we created visualizations based on datasets that included Palo Alto specific data and nationwide data to help identify patterns and gather insights. Tableau allowed for linking of different datasets to create visualizations. When creating these links, it was important for our team to understand mapping from one data set to another to ensure the data would communicate with each other correctly. By understanding how to link datasets together, we were able to import different Excel datasets created by a group member to connect geographical and business data to answer some of our research questions.

A visualization type we generated frequently are bar graphs. When using bar graphs, we opted for horizontal bars instead of vertical because “horizontal bars work especially well when…the text labels associated with the bars are long [and] there are many bars” (Few, 2025). We also used dual axis to compare multiple measures. To eliminate distortion and ensure integrity between the two measures, the axis for each graph was set to the same scale. This was made simple on Tableau by clicking “Synchronize Axis”. We also ensured that all quantitative scales start with zero “because the lengths of the bars encode their values but won’t do so accurately if those values don’t begin at zero” (Few, 2005). Bar graphs are also an optimal choice for sequencing data in ranking order. By reordering the data, it “not only reveals their sequence, but makes it much easier to compare values by placing those that are most similar near one another” (Few, 2005).

Other visualizations created to help with our exploration include area graphs, and geographical maps. These types of visualizations help the viewer to fully comprehend the spatial relationships that are being explored. The inclusion, particularly of maps, can help us understand the relative location of our dataset values and the patterns they create across the city of Palo Alto. In essence this data is showing the literal patterns these EV users traverse through the city.

Preprocessing

For the Palo Alto data set, we wanted to understand if there was a correlation between the types of business around a location and how much time was spent at each location. In order to do this, we needed to first gather the information about which businesses were around each station. By collecting the names of the businesses within 1-2 blocks of each location and reviewing either the data from Google maps or on their website, we were able to create groups of similar businesses and create excel sheets to house that information in a way Tableau would understand.

Similarly, when working with the larger USA datasets there were too many location types that could be combined into a larger group. An example of this was creating the Government type which included the predefined groups of Fire Station, Municipal Government, State Government, & Federal Government.

When looking at financial relationships, we separated out the EV charging stations and Palo Alto, we used the EV Charging Stations from February 2024 in Palo Alto. For this specific data set, we wanted to highlight the ten documented zip codes: 94020, 94022, 94024, 94028, 94301, 94302, 94303, 94304, and 94306. We crossmatched the addresses within the dataset and the information from *PlugShare* to see which charging stations were free.

Other pre-processing activities included cleaning the initial sheets we retrieved from Kaggle. Some of the locations were spelled differently or had inconsistent names that created more groups in Tableau then there actually were within the data. An example of this was addresses being listed as “Bryant St” and “445 Bryant St” even though the Latitude & Longitude fields matched.

Data Analysis

Geographic

Variables: Station Address, Business Types near Locations, Business Types Associated with Location, & Total Duration of Charging

USA Number of Stations per State (See Appendix A: p. 2)

The dimension “Total EV Stations 2024” was aggregated by their accompanying “State” field within a map formation. California was filtered out as an outlier to provide the other states a more distinct and accurate delineation.

Business Density of Selected Stations (See Appendix A: p. 12)

The dimension “Business Types” for each station from the Palo Alto dataset were counted to create individual treemaps. While a bar graph or dot plot might be easier to understand this data, the comparison between locations would have been overwhelming. “When examining data, we must sometimes compromise our ability to do something in order to increase our ability to do something else that’s more critical for that task at hand.” (Few, 2021)

Map of Selected Stations (See Appendix A: p. 12)

The fields “Address 1,” “State/Province,” “City,” and “Postal Code” were combined to create a complete location for the stations. This was uploaded to Google My Maps to create a map of the station's locations.

Percentage of Business Types (See Appendix A: p. 13)

The dimension “Business Types” for each station from the Palo Alto dataset were counted & aggregated across all address locations. A percentage of total calculation was applied for colors gradient & size of the bubble chart.

Total Hours Spent Charging by Business Type (See Appendix A: p. 13)

Working across data sets, the fields “Business Types” & calculated “Continuous Count of Total Hours of Duration” (from “Total Duration”) were compared to create a heat map list.

Geographic (Nationwide)

Variables: Facility Type, EV DC Fast Count, EV Level2 Num, EV Level1 Num, Access Code

EV Station Locations around the USA 2023 (See Appendix A: p. 3)

EV Station Locations around the USA 2024 (See Appendix A: p. 3)

The dimension “Facility Type” is compared to the total of “EV DC Fast Count”, total of “EV Level2 Num” and total of “EV Level1 Num” to create two horizontal bar graphs—one for 2023 and the other for 2024.

Time-based

Variables: Transaction Date, Station Address, Port Type, EV Usage Count, and Total Duration of Charging.

Total Station Use Count by Year (See Appendix A: p. 14)

The dimension “Transaction Date” (Year and Month) and the measure value “EV Charging Station Usage” were compared via an area chart.

Total Station Use Count by Weekday (See Appendix A: p. 14)

The dimension “Transaction Date” (Discrete Weekday) was compared with the measure value “EV Charging Station Usage” using a bar chart and filtered by text for “EV Charging Station Usage”

Total Charging Hours by Station and Port Type (See Appendix A: p. 15)

The dimension “Total Duration” was converted into a measure of “Distinct Count of Total Hours of Duration”, filtered by color for port type, by text for the “Distinct Count of Total Hours of Duration”, and visualized in a bar chart.

Total Charging Hours by Transaction Hour (See Appendix A: p. 15)

The dimension “Start Date” was converted to a “Discrete Hour of Start Date” measure value and compared to the “EV Charging Station Usage” measure and visualized in an area chart.

Financial

Variables: Station Name, Street Address, ZIP, City, State, Access Code

Map of Palo Alto Charging Stations (See Appendix A: p. 6)

Palo Alto based stations were filtered from the larger EV Charging Stations dataset. The fields “Street Address,” “City,” “State,” and “ZIP” were combined to create a complete location for the stations. This was uploaded to Google My Maps to create a map of the station's locations.

Free Charging Stations Heat Map (See Appendix A: p. 7)

Palo Alto free charging stations from the February 2024 EV Charging Stations dataset. PlugShare was used to filter which addresses for each charging station in the dataset are free. A new column was created to accommodate the charging stations that are free. The data was filtered to include “ZIP” and “Free Charging Stations.”

Financial (Nationwide)

Variables: Facility Type, EV DC Fast Count, EV Level2 Num, EV Level1 Num, Access Code

Distribution of Public vs. Private Access (See Appendix A: p. 3)

The dimension ‘Facility Type” is compared to the total number of “EV DC Fast Count”, total number of “EV Level2 Num” and total number of “EV Level1 Num” by year. The data is then filtered by “Access Code” to only display facilities with “Public” or “Private” access to generate bar graphs.

User profiles

Variables: User ID, Station Name, Driver Postal Code, Address, Total Duration, Port Type, End Date

Data Use: We used the cleaned data set and an additional data set with California zip codes.

Number of Stations by Zip Code (See Appendix A: p. 9)

The dimensions Postal Code and Station Name were used to create a map of the distribution of charging stations in each of the three zip codes of Palo Alto. Station names were filtered into a distinct count and labeled in the corresponding zip code area of the map.

Highest Charging Time and Distinct Customers (See Appendix A: p. 11)

The dimensions - Station Names, Address, Total Duration, and User ID - were used to create two side-by-side bar charts. The left bar chart was used to measure the total duration of usage by all customers at each station. The right bar chart shows the distinct number of unique customers at each station. The Total Duration of hours at each station was compared to Station Name and Address to create a bar graph. The dimension, User ID, was filtered by a distinct count to represent the number of unique customers at each Station Name and Address.

Total Customers per Year (See Appendix A: p. 10)

The dimension User ID was filtered by Distinct Count, and the dimension of End Date was filtered by Year. These dimensions were combined to make a line graph of unique customers per year.

Popular Port Type by Station (See Appendix A: p. 10)

The dimensions Port Type were compared to User ID, Station Name, and Addresses using two side-by-side bar graph.

Customer Zip Codes and Station Zip Codes (See Appendix A: p. 9)

The dimension, Driver Postal Code, was filtered by count and connected to the extra data set of California zip codes. The dimension, Post Office, matches up with zip codes and reveals which city each driver is from.

Results/Findings

Geographic

In the nationwide datasets, we examined the locations of physical EV station locations based on their charge type. Hotels were the top locations to include Level 2 charging stations in 2023 and 2024. Retail spaces and gas stations both included the most DC Fast stations in these years. In 2024, the number of DC Fast stations in retail spaces increased about 32% from the previous year. Similarly, Level 2 and DC Fast charge stations also increased significantly in parking lots in 2024. Government locations, gas stations, office buildings and car dealers are other popular locations for charging stations.

The local dataset found that charging stations tended to be placed near restaurants, financial institutions, & service providers in the beauty area. In terms of percentage this comes out to roughly 43% of the businesses around the Palo Alto charging stations belonging to one of these 3 categories. While the bottom 8 categories only make up 7% of the businesses. If this data is properly interpreted in conjunction with the time data sets, user preferences and needs may be discovered.

Time-based

Overall station usage by use count and total hours of charging was influenced by station creation date and, most notably, the COVID-19 pandemic. 2016 was the year with the highest use count, but the most active years in EV charging were 2016-2020 before the pandemic lockdown. Wednesday, Thursday, and Friday were the most popular charging days, and Sunday was the least popular day to charge in examining overall usage data. In terms of time of day use, 78% of total charging events occurred between the hours of 8am through 7pm. Level 2 charging was preferred in 97% of charging events.

Financial

Across the United States, EV stations are primarily public access, with a majority being Level2 charging. From 2023 to 2024, there was significant growth in the number of EV stations built, with an increase of about 52% of public and private access DC Fast charge stations. The distribution of Level2 public access stations are most commonly located at hotels, parking areas, and schools. Most public access DC Fast Charging stations are located in retail areas, gas stations, and grocery stores.

From the Palo Alto data within the US dataset, we found that in the 94022 area code, there are 0 free charging stations, 4 free charging stations in 94301, 8 free charging stations in 94303, 27 free charging stations in 94304, and 10 free charging stations in 94306. Of these 49 free charging stations, 47 are available to the public.

User profiles

The number of unique drivers peaked in 2019, before declining sharply in 2020. This was likely influenced by the 2020 shelter-in-place policies and global pandemic.

The zip code 94306 has the most charging stations, followed by 94301 then 94303. However, the zip code 94301 has the highest number of unique customers, even though it has the middle value of charging stations.

We filtered the drivers' postal code to figure out which cities most drivers came from. To no surprise, most of the people that use charging stations in Palo Alto are people who live in Palo Alto. San Jose residents were the second most popular customers, except for stations in zip code 94303, who had more customers from Mountain View.

Stations with the most unique customers also had the most hours spent charging. Level 2 charging stations have the most distinct customers. This makes sense because level 2 chargers are faster than level 1. More customers can use level 2 charging stations because they finish charging faster.

Insights

Based on the evaluation of our data, we can make the following recommendations to the city of Palo Alto, or to other similar cities. By and large, level 2 chargers were preferred by customers, and since the release of this data, it is likely that DC Fast charging use is also on the rise. We noticed popularity in charging stations that were surrounded by certain businesses. Food/Drink, beauty, and financial services surrounded heavily frequented charging stations.

For user profiles, we analyzed Venkatasai Rao Dheekonda's Palo Alto dataset because it had collected information on the customers who used charging stations in Palo Alto. We found the charging stations that were visited by the most unique customers and for the longest amount of time, so we can make recommendations to add more charging stations in those areas to accommodate for the higher volume of usage. We discovered that the largest number of customers live in the 94301 zip code, which is the northwestern side of Palo Alto; however, there are only 15 charging stations there (compared to 9 in zip code 94303 and 22 in zip code 94306). We recommend the City of Palo Alto build more charging stations in zip code 94301. We also had more data for customers who used charging level 2 stations, but those stations were lacking data for charging level 1. The City of Palo Alto may need to perform maintenance checks on the stations that were missing data.

Our findings revealed that most stations available are public access and primarily offer Level 2 charging followed by DC Fast charging. The most common areas where these stations are located are hotels, retail spaces, and parking areas. Finding new areas for stations to be built may be complex and funding them may be costly, especially for fast-charging services. However, new builds may be good investments for cities and property management. When viewed through the lens of investment, building EV stations may be a good opportunity for property management companies looking for new strategies and tactics to attract potential tenants, and companies looking to move their organization to a sustainable facility and environment. EV stations are also an opportunity for cities looking to stimulate business and increase economic growth. By strategically placing stations in areas such as retail spaces, grocery stores, or parking areas that surround popular businesses such as food/drink, beauty, or financial services, cities like Palo Alto can increase local spending and drive economic growth. Other locations that may be considered are schools, museums and libraries. By placing stations in these areas, cities have the opportunity to build and strengthen their community and cultural development. Offering free charging services for a limited time may be another incentive to attract users to these specific areas.

Taking into consideration the financial insights, we think it’s important to further analyze these specific areas of Palo Alto, beyond the types of stores or offices near these locations, and how Palo Alto is managing the demand for charging stations. Palo Alto is considered an expensive area to live in California. As of 2021, the median household income in Palo Alto was $194,782 and the median property value was set at $2 million (Palo Alto, ca | Data USA, n.d.). Looking closely at the five zip codes that contain charging stations, these are considered expensive areas to live in. As of 2023, the median price of a home in 94022 was $3.98 million, $3.5 million in 94301, $1.93 million in 94303, and $2.7 million in 94306 (Combos, 2023). The median price of a home in 94304 during 2022 was almost $4 million (94304 Real Estate Market Trends, 94304 Average Home Prices, 2024).

After analyzing the area of Palo Alto and the amount of people who own an electric car, we can assume that many turn to these types of cars over gas-powered cars to reduce costs and/or turn to these cars due to how accessible it is to own one where they live. The City of Palo Alto states the US Department of Energy “estimates that driving an EV costs about half as much as driving a gas vehicle” (EV FAQs, 2024). The city estimates that if someone were to make a 30-mile round trip commute, it would cost about $2.40/day to charge their car or $6.66/day for their gas-fueled car. To keep up with the demands of EV charging stations, Palo Alto has now allowed and encouraged homeowners to install their electric charging stations (Weston, 2024). Palo Alto has pledged to give out incentives to homeowners who install charging stations, with both single-family and multi-family homes receiving different amounts (EV FAQs, 2024). The city is actively trying to encourage people to purchase their charging stations, but there is a lack of push for more free and accessible charging stations in more areas.

Discussion

This project was a significant undertaking for our team. In addition to learning the fundamentals of what makes good visualizations, we took on learning a new software package from scratch, aggregating multiple data sets, and dissecting data sets to discover insights into our chosen topic. While these tasks were not easy, it was more manageable through collaboration. Working as a team was helpful in allowing us to share different perspectives and approaches to data analysis and visualization. It also allowed us to share tips and tricks picked up along the way when learning to use Tableau. Teamwork also afforded us the opportunity to share our frustrations and tackle them collectively.

Although collaboration aided in learning new skills and gathering information, it posed an unexpected challenge when it came time to piece together all our findings into one collective report and demo. Since each section was worked on individually, creating a cohesive and seamless report and demo was difficult as it required some time to understand how each section worked together. We also encountered redundancy and inconsistency when transitioning from individual work to piecing together the final project. In all, we've gained new technical skills in utilizing new software, a foundation for creating effective and aesthetic visualizations, and some new knowledge on EV charging stations.

These datasets and our comprehensive collection of visualizations have implications for not only Palo Alto, but for the rest of the United States as well. The adoption of renewable energy systems, products, and infrastructure is key to reducing our impact on the planet, and datasets such as the ones we studied are key to creating well-informed decisions, plans, and strategies on both the micro and macro levels.

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Additional Gathered Data Excel Links:

Palo Alto Charging Stations – Nearby Businesses:

https://docs.google.com/spreadsheets/d/1A36R_6fbJY6wib6KIwMu3YQvKBrhcPT3/edit?usp=sharing&ouid=112713062535825491589&rtpof=true&sd=true

Edited Palo Alto EV Data – Free Charging:

https://drive.google.com/file/d/1ikyjtYwM4LE9uCLJyGQx4Zg47XUmSOJn/view?usp=sharing

Visualizing EV CHARGING STATIONS

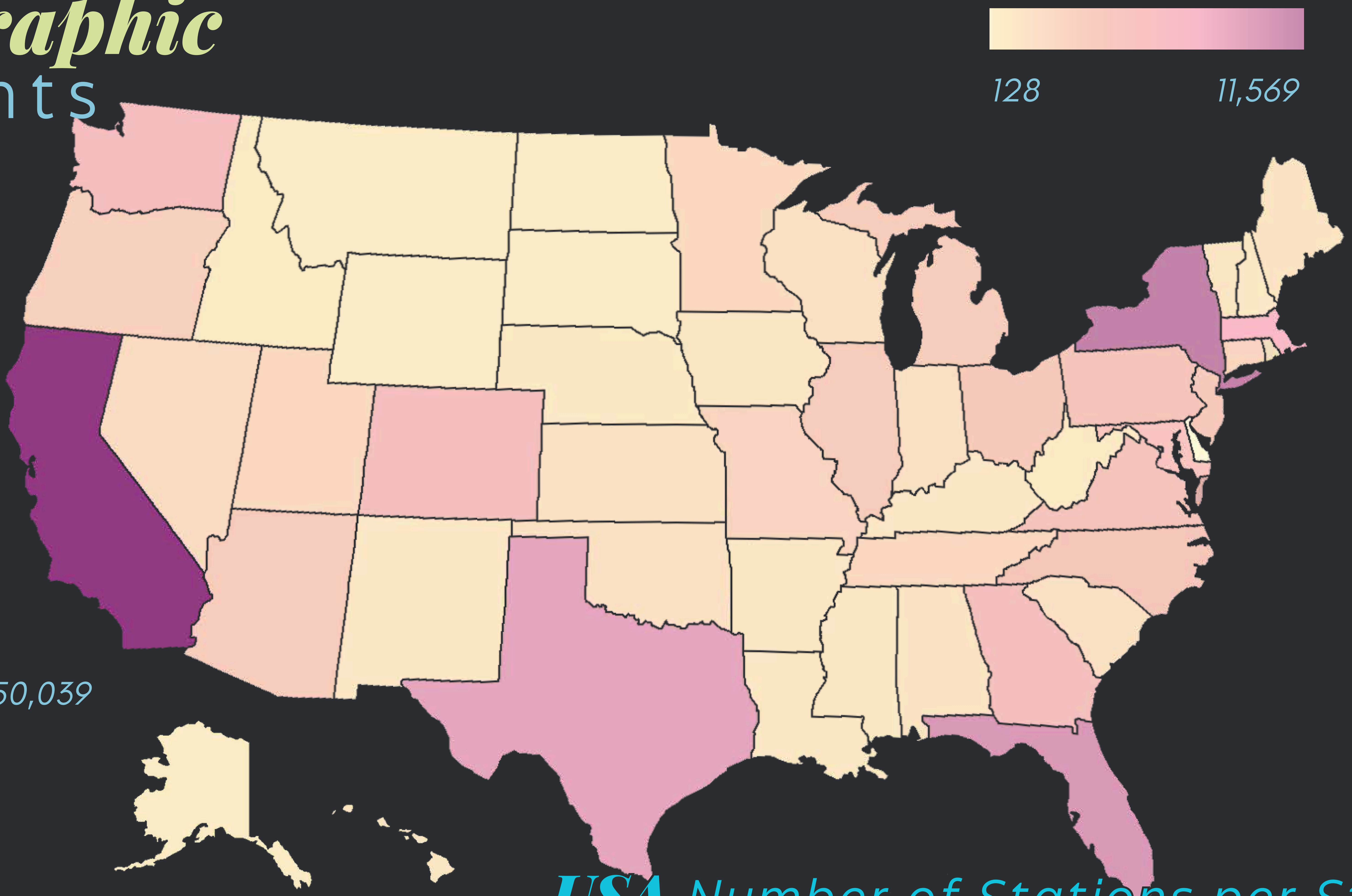
usage, placement & effects

Jennie Yates, Rebecca Fong, Alexis Evans,
Angeline Ma, & Chris Reynolds

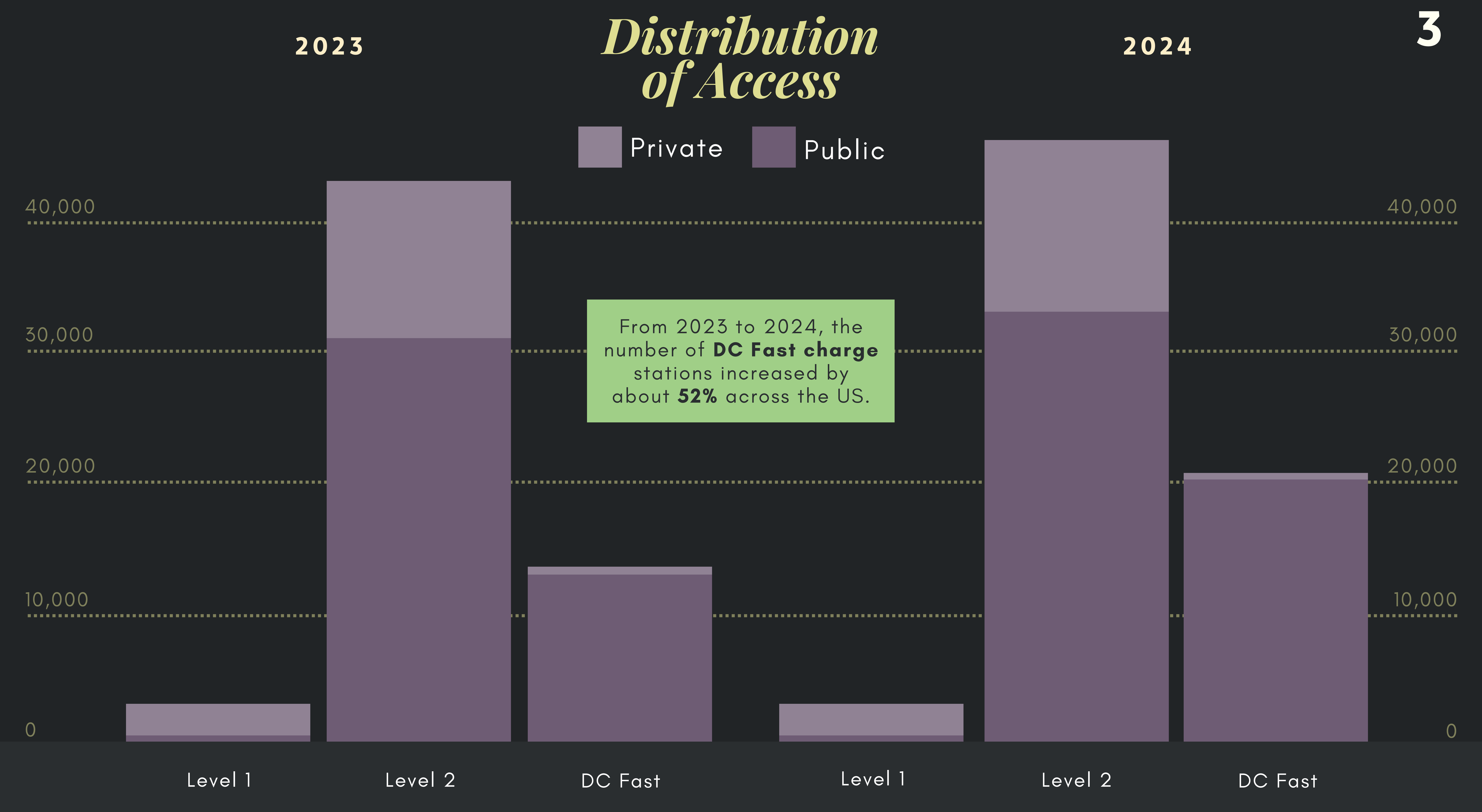
Spring 2024

Storytelling through Visualization

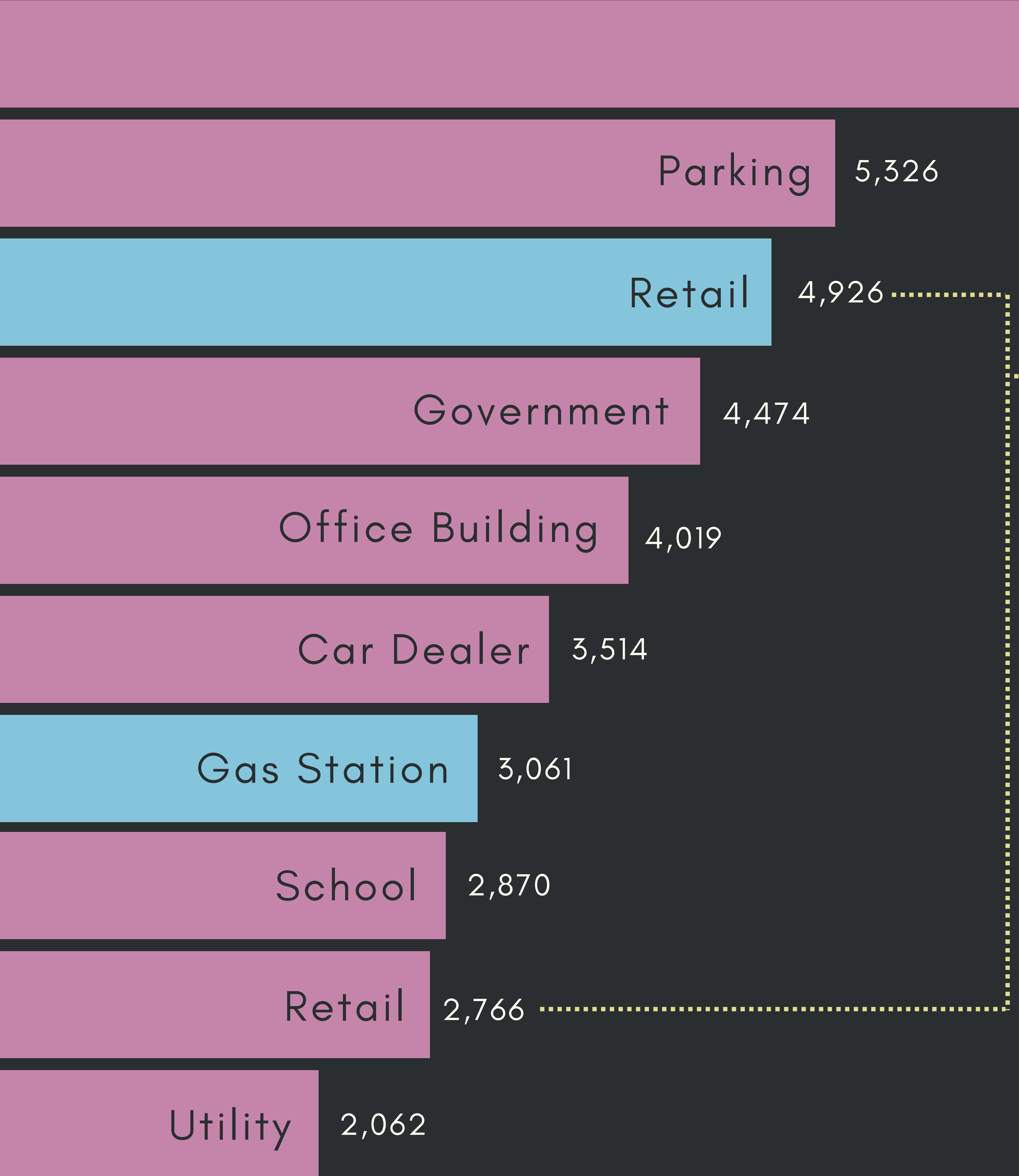
Geographic insights



USA Number of Stations per State



Distribution of Access
2023
2024
Private
Public
40,000
30,000
20,000
10,000
0
From 2023 to 2024, the number of **DC Fast charge** stations increased by about **52%** across the US.
Level 1
Level 2
DC Fast
Level 1
Level 2
DC Fast



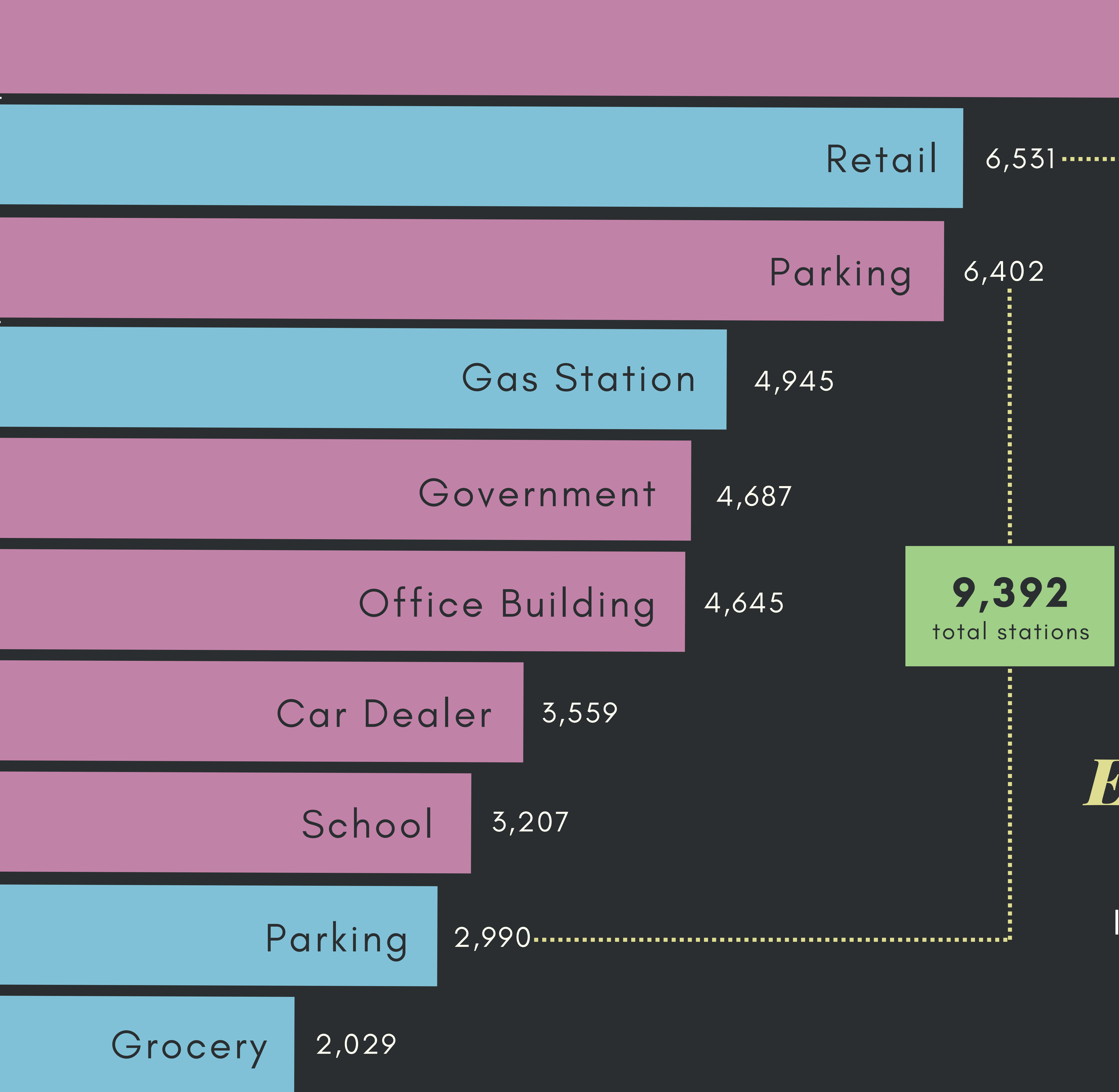
Retail locations have a combined total of **7,692** EV charging stations.

Level 2 **DC Fast**

EV Station Location Types

around the USA in 2023

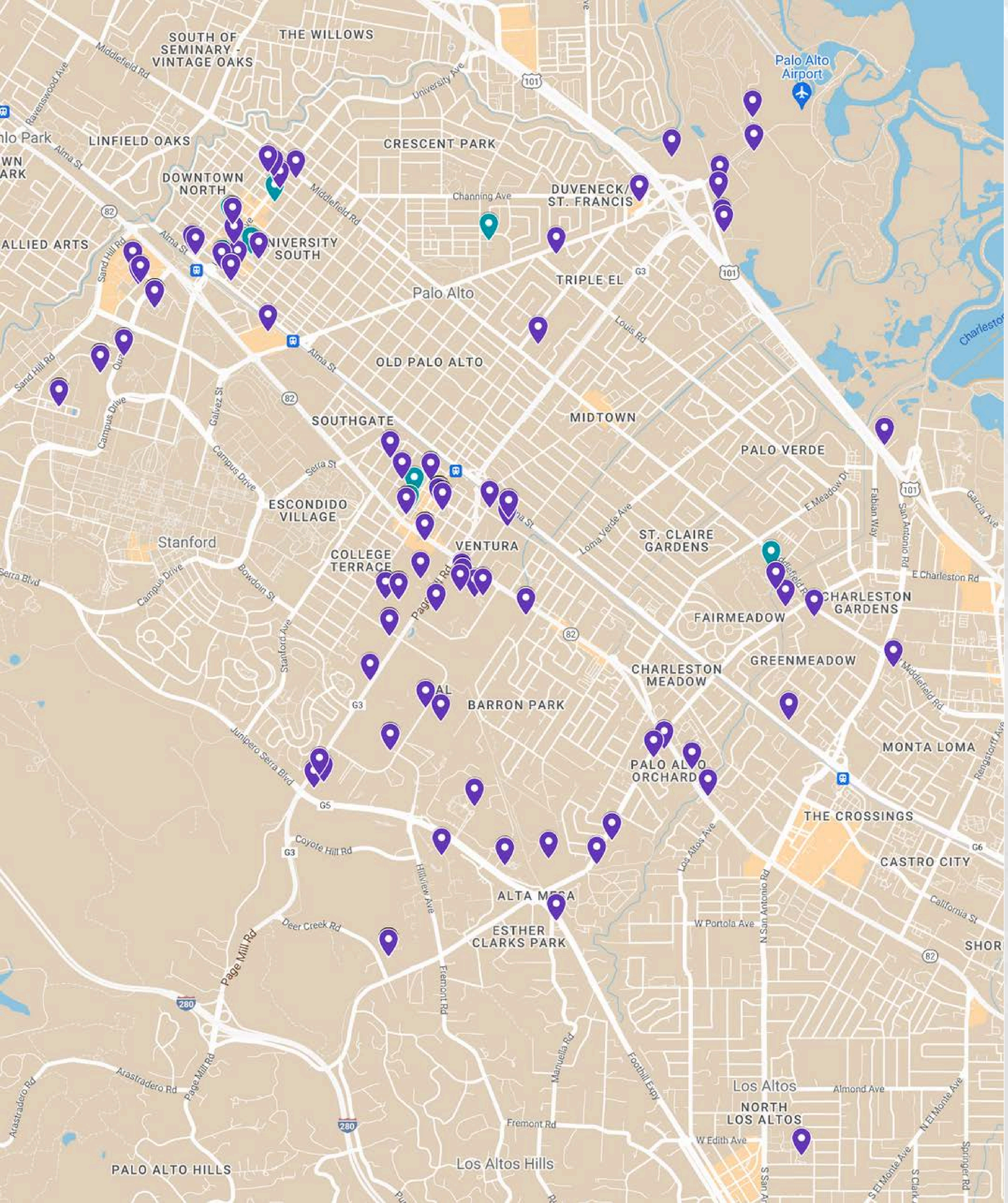
The top locations in 2023 to have EV stations only included Level 2 and DC Fast Charging.

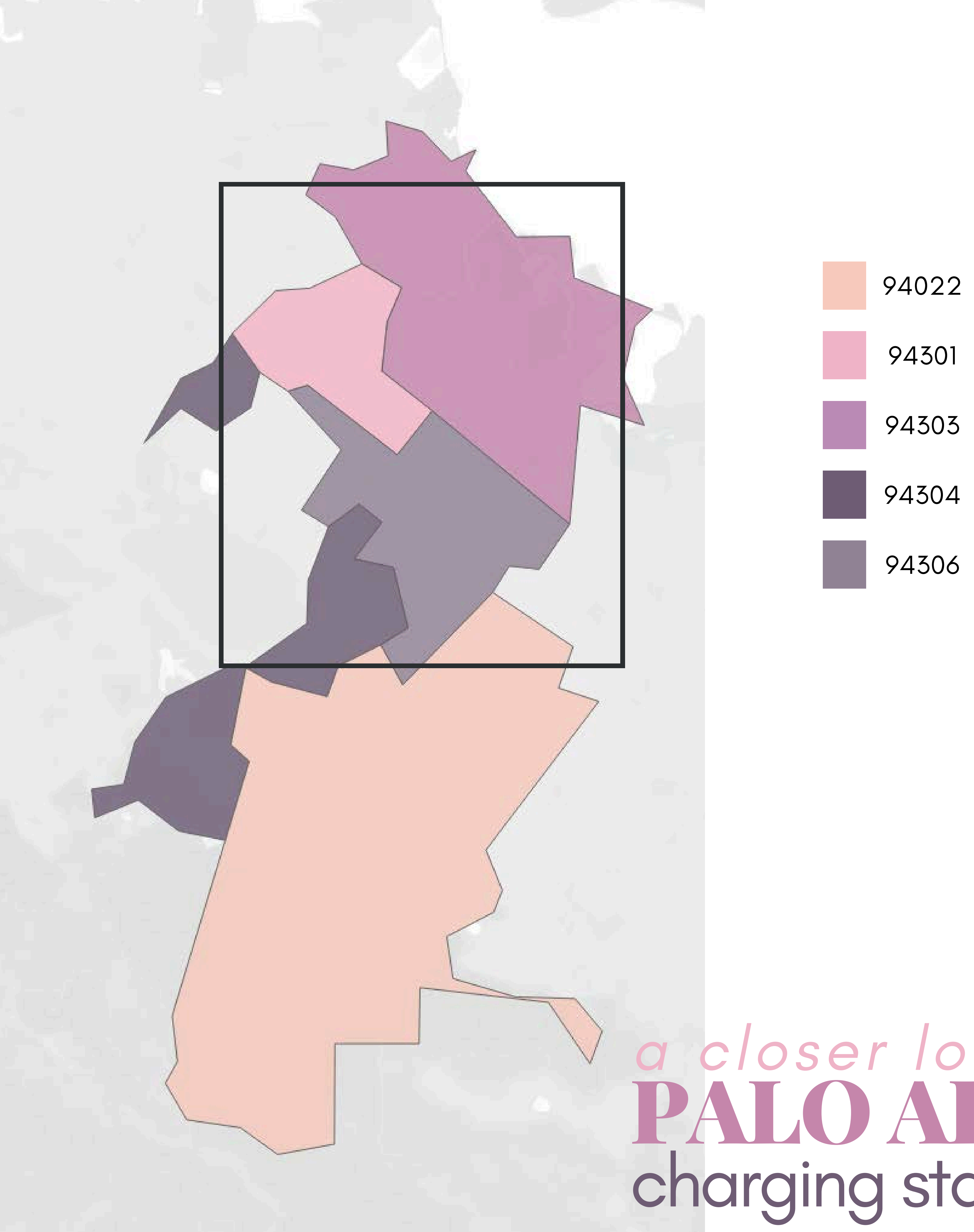


EV Station Location Types

around the USA in 2024

In 2024, more DC Fast Charging was made available in retail spaces, gas stations, parking areas, and grocery stores.





a closer look at

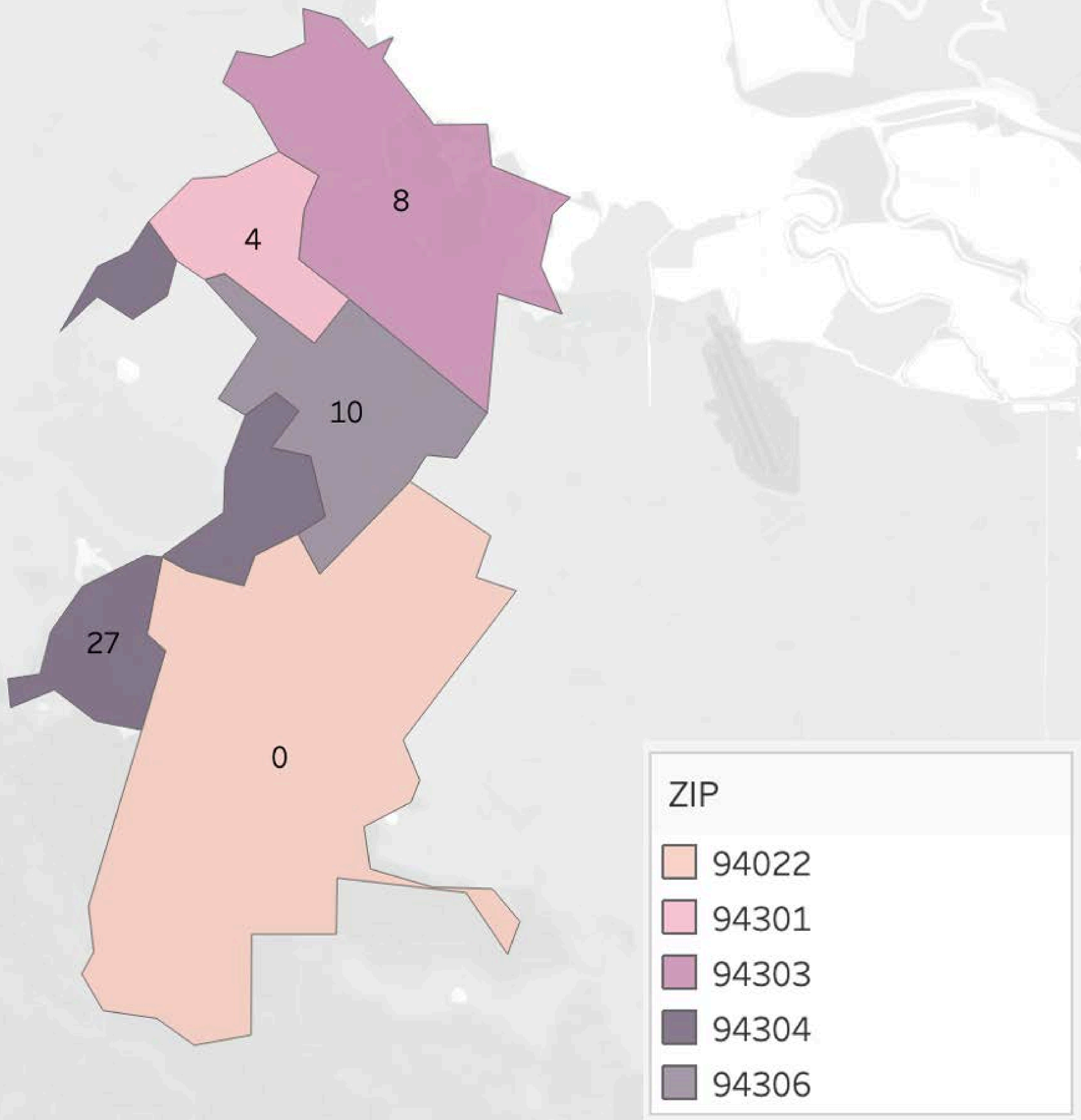
PALO ALTO

charging stations

Financial

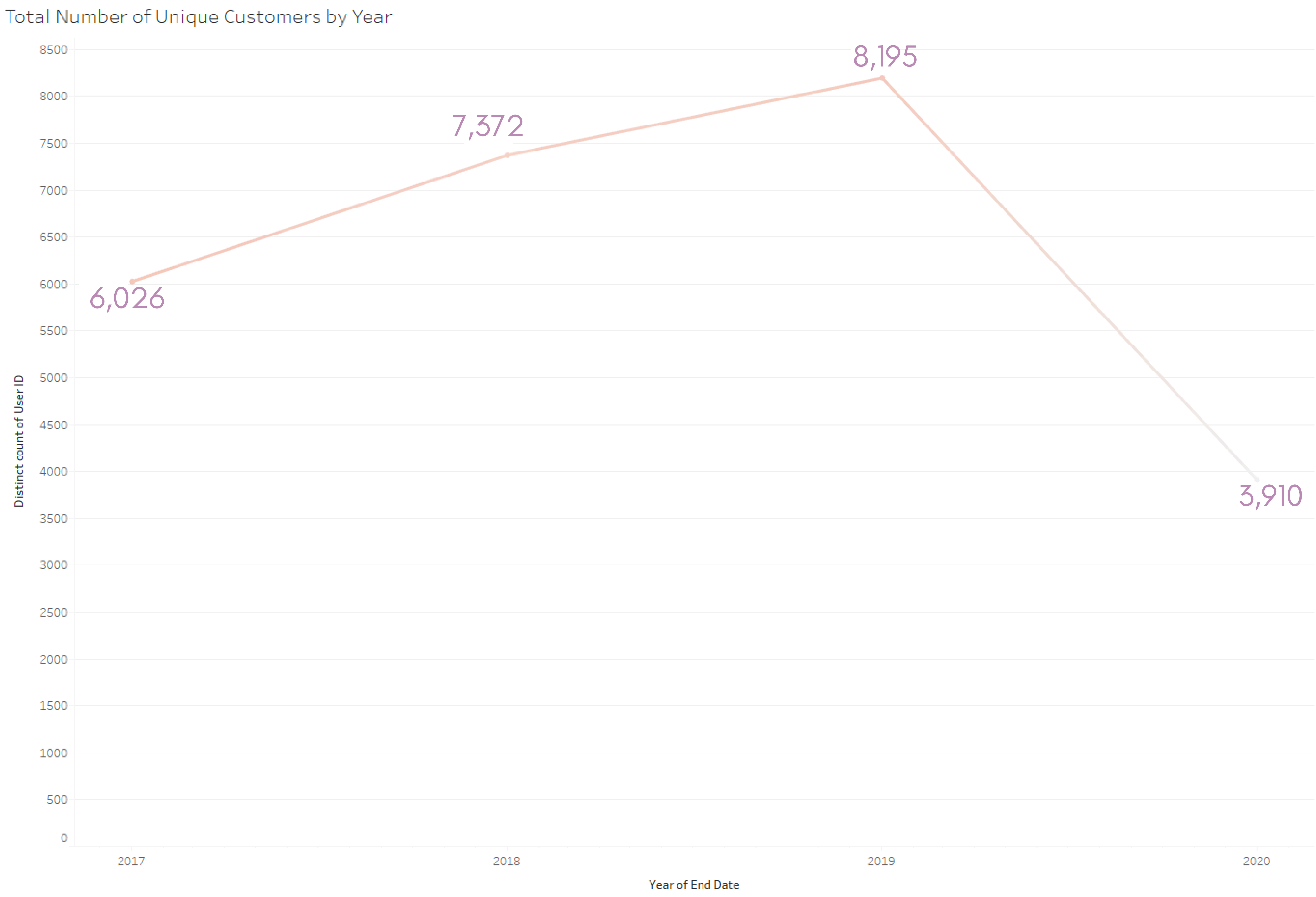
94304 contains the most free charging stations whereas 94022 contains 0.

Free Charging Stations in Palo Alto

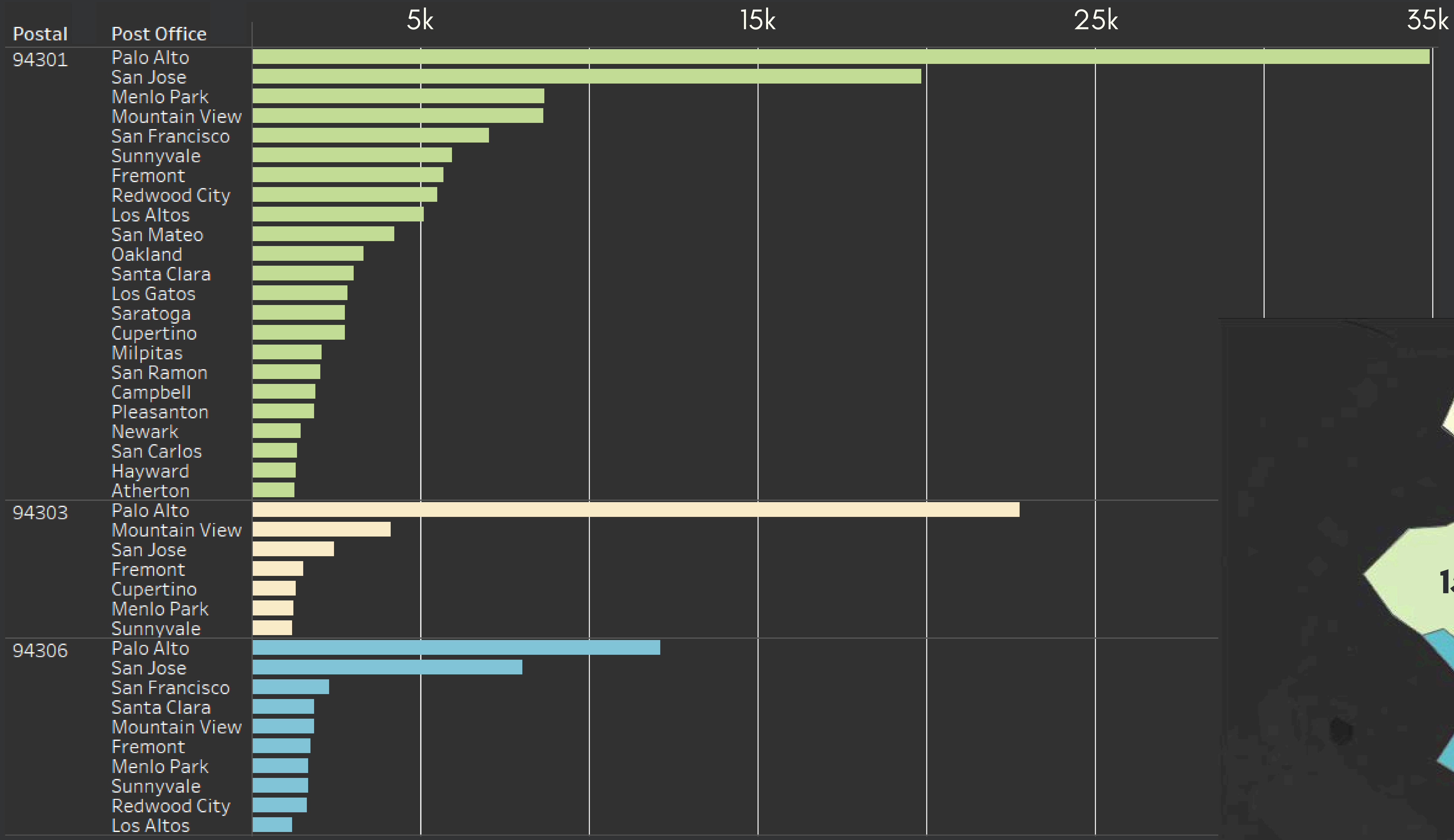


User Profiles

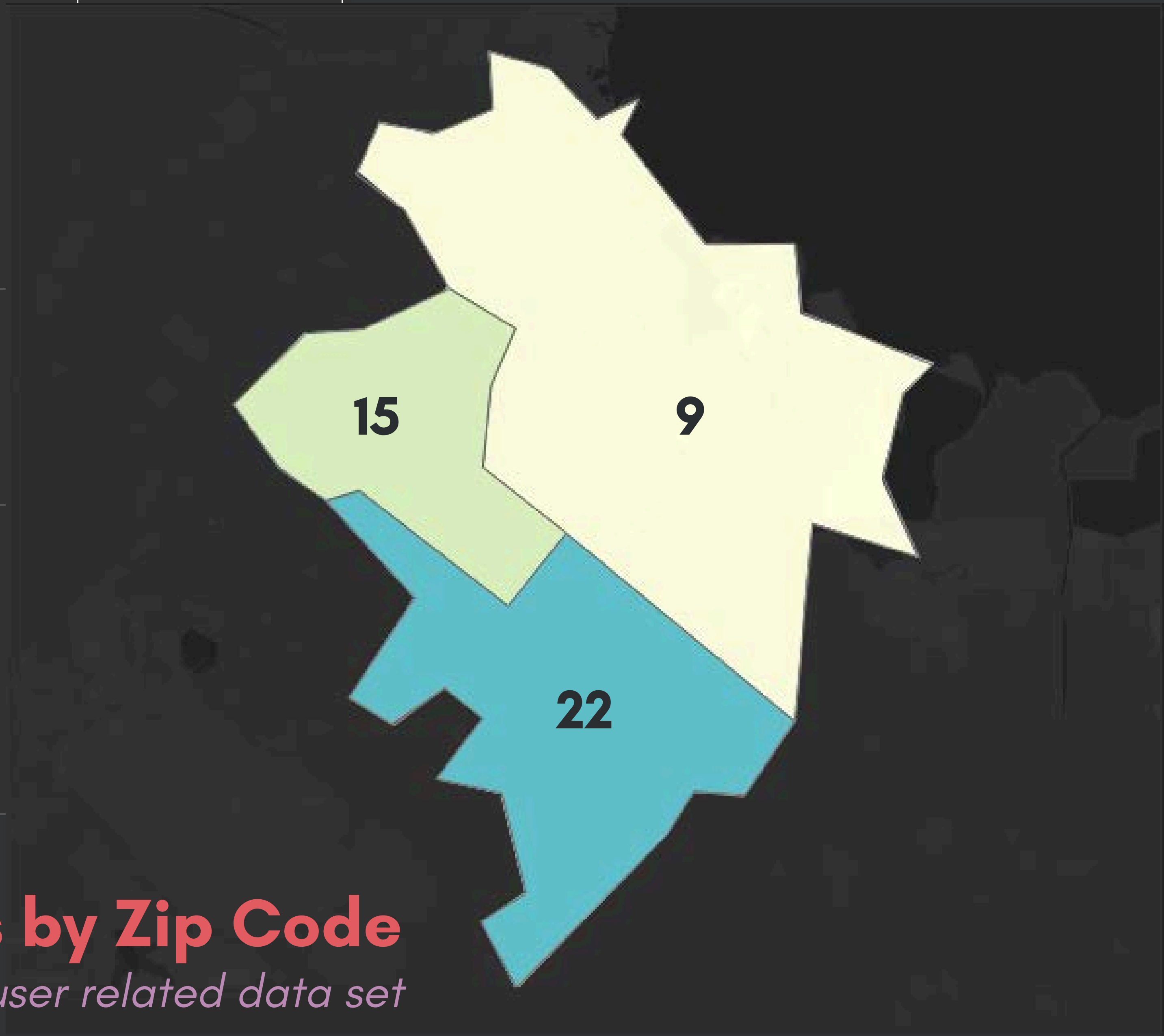
The number of unique drivers peaked in 2019, before **declining sharply in 2020**. This was likely influenced by the 2020 shelter-in-place policies and global pandemic.



Customer Zip Codes & Charging Station Usage



Palo Alto residence use the stations most often, followed by **San Jose residents & Mountain View residents.**



94301 has the **most unique customers**, but the **middle value of charging stations**.

Number of Stations by Zip Code

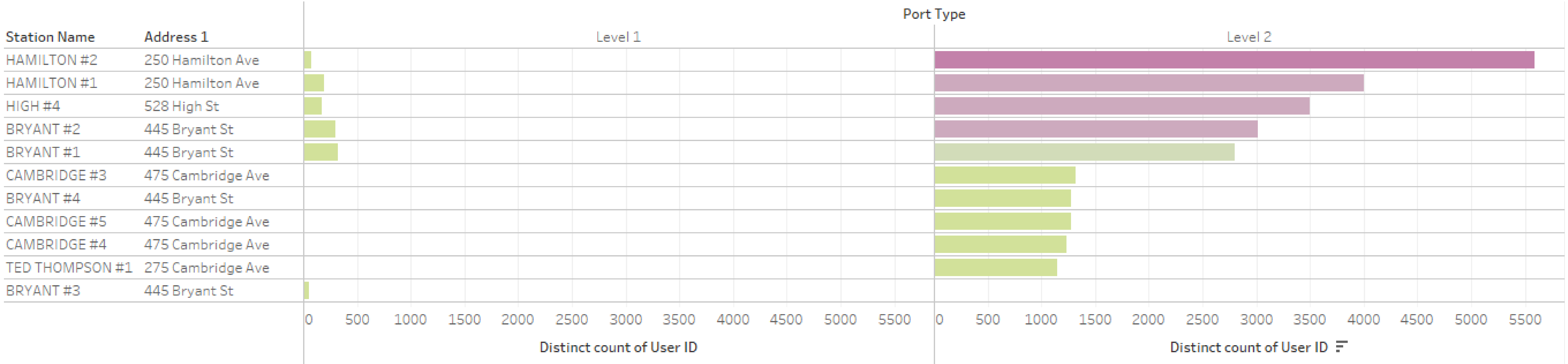
from the user related data set

User Profiles

Level 2 charging stations have the most distinct customers. This makes sense because level 2 chargers are faster than level 1.

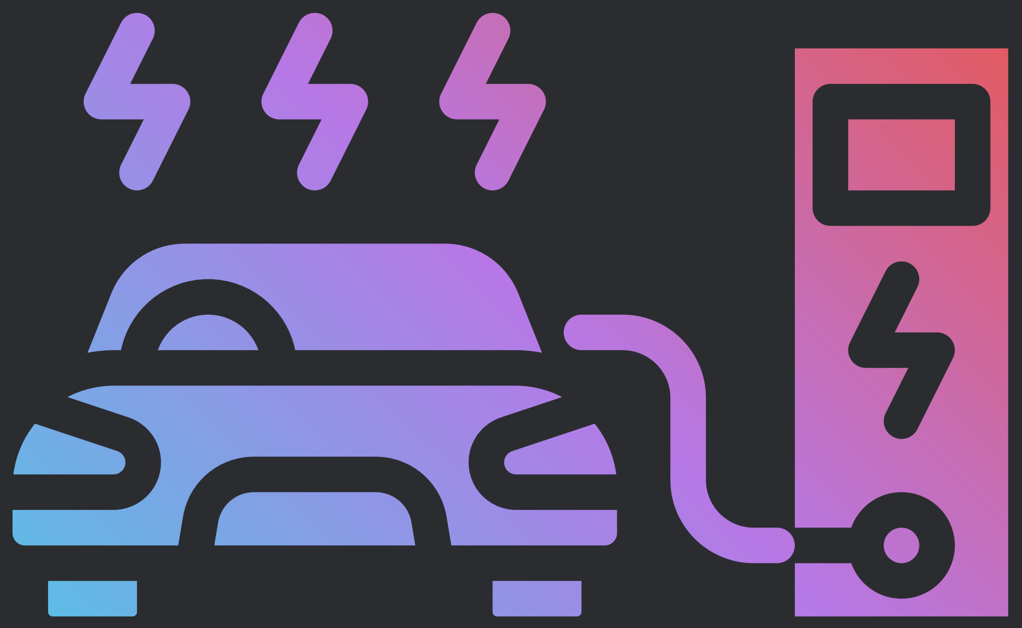
More customers can use level 2 charging stations because they finish charging faster.

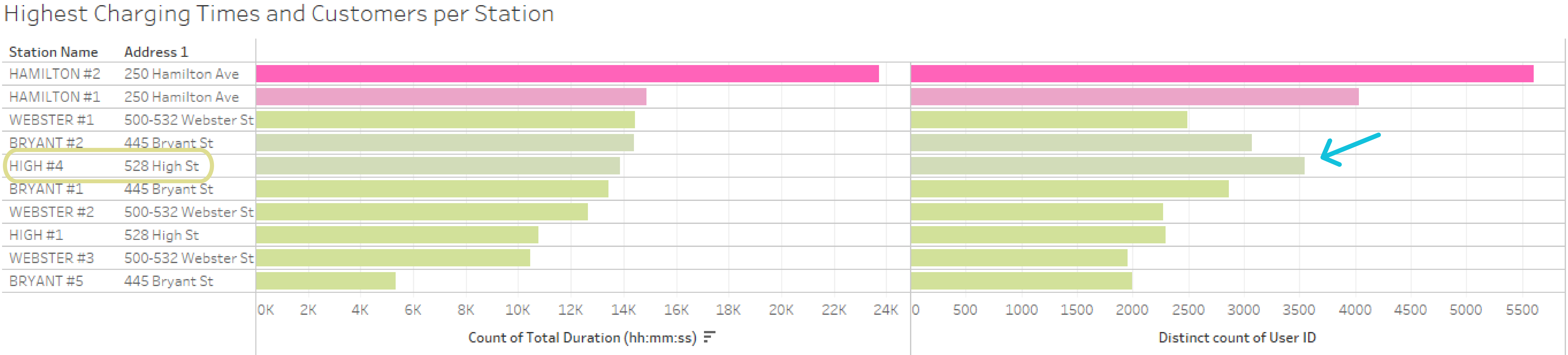
Port Type Usage by Station



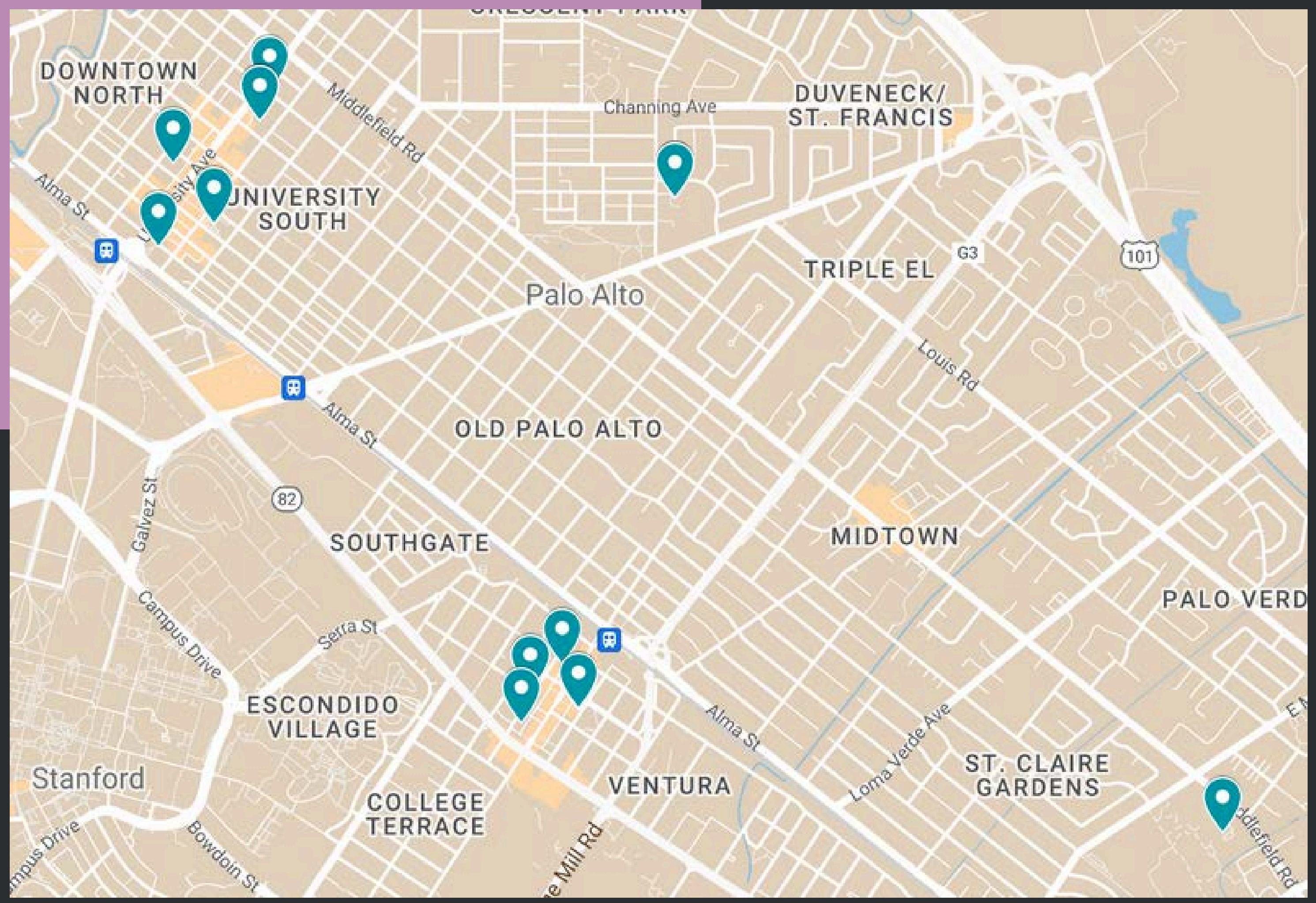
User Profiles

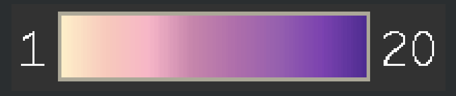
Stations with the most unique customers also had the most hours spent charging.

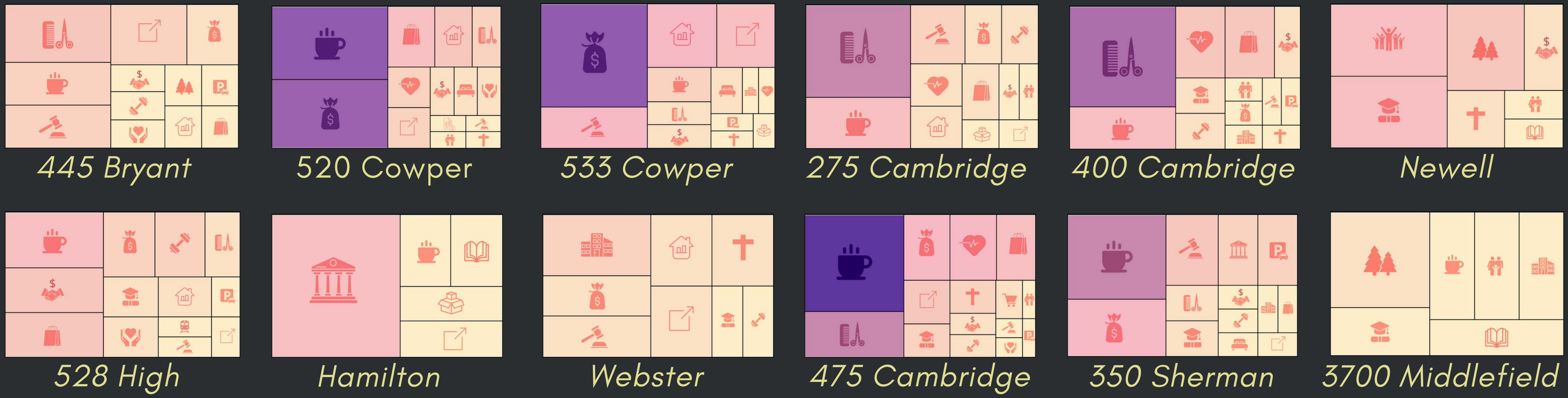




BUSINESS DENSITY
of selected stations





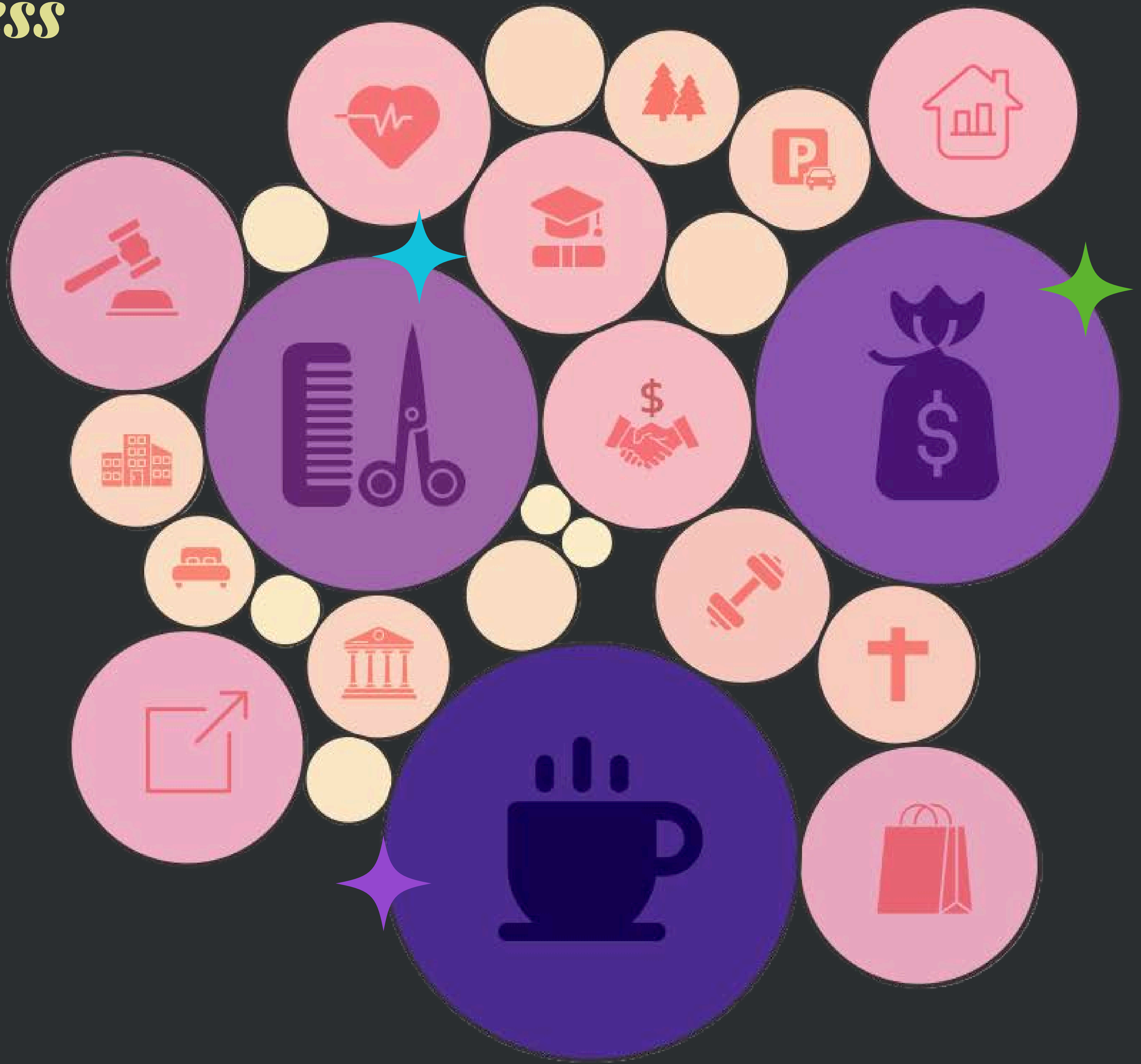


Top 3 Business Types (count)

Food & Drink

Financial

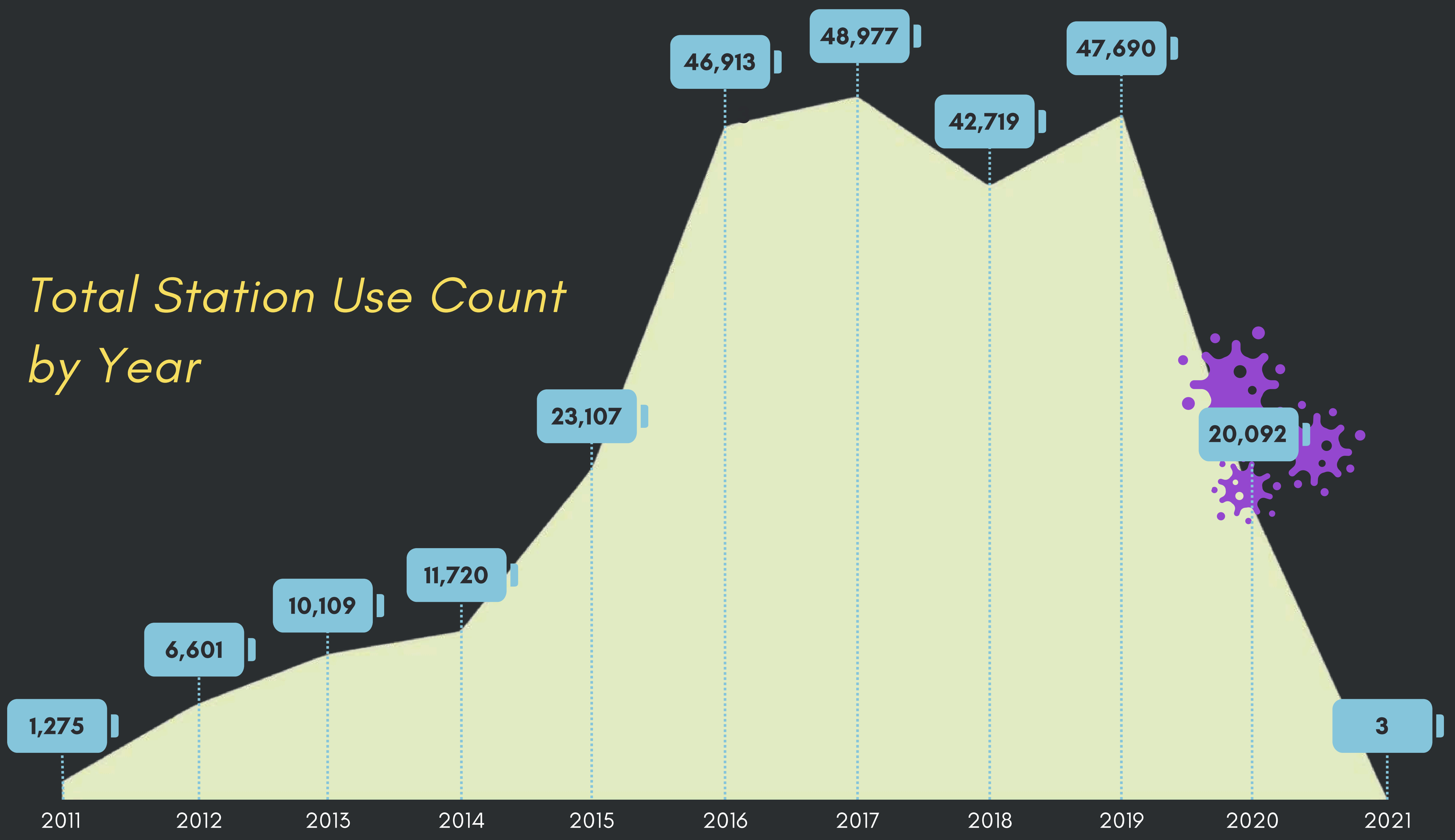
Beauty

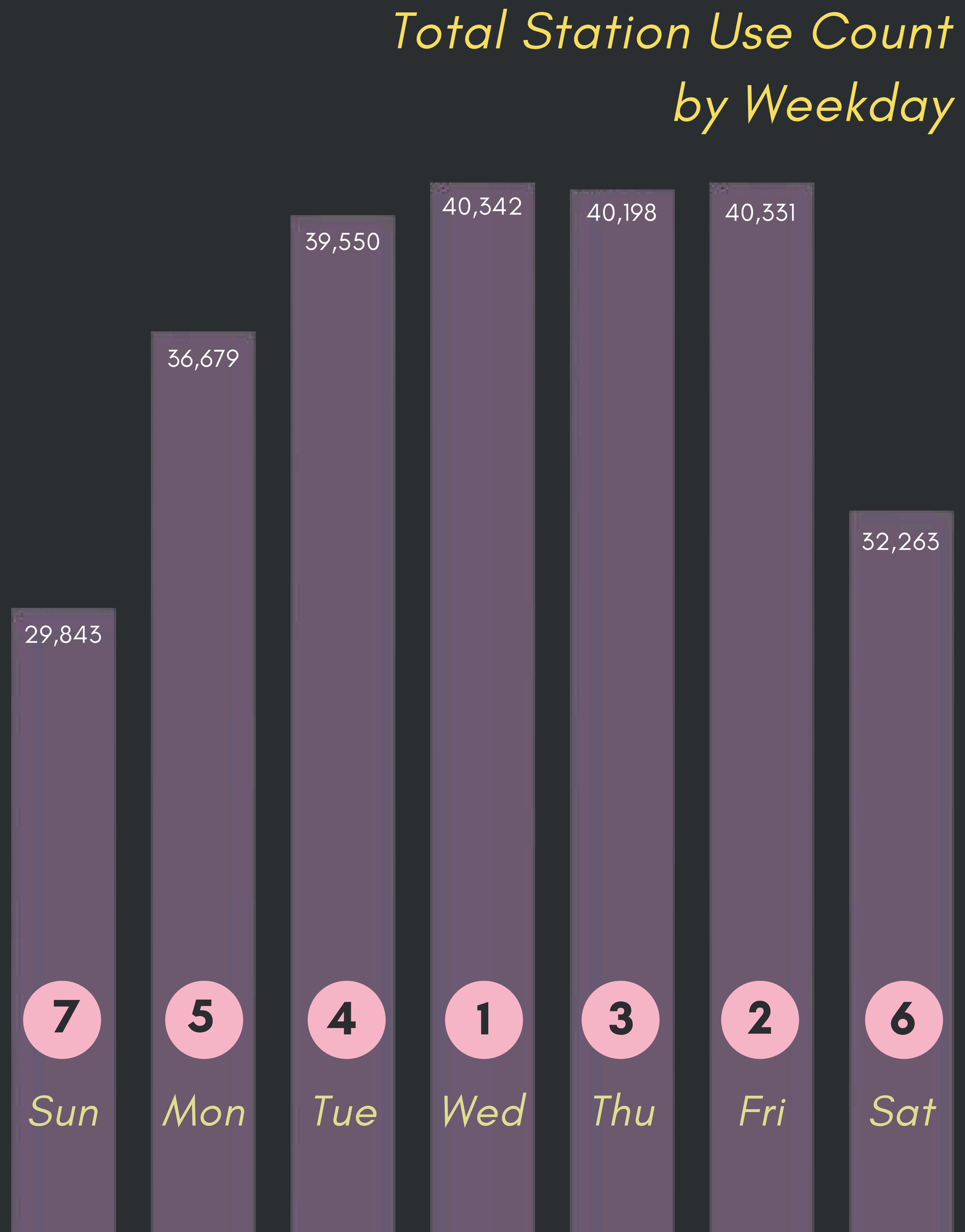


Percentage of Businesses Types

Total hours spent by Business Type (hrs)

Food & Drink	28,049
Software	27,425
Education	26,494
Law Office	26,194
Finances	26,194
Fitness	26,192
Real Estate	24,938
Beauty	23,879
Clothing	23,877
Park	23,232
Family Services	23,067
Parking	22,918
Residencial	22,727
Library	22,666
Non profit	21,977
Religious	21,972
Architect	21,138
Shipping	18,942
Business	18,393
Home Improvement	18,218
Medical	17,902
Apartments	16,682
Government	16,512
Telecom	16,169
Home Goods Store	16,163
Electronics Store	16,163
Caltrain Station (Acr..	16,163
Massage	15,144
Media	14,990
Flower Shop	11,139
Sign Shop	11,133
Groceries	11,133
Game Store	10,862
Engineering	10,862
Community	8,961
Hotel	64
Cars	19





Time-based insights

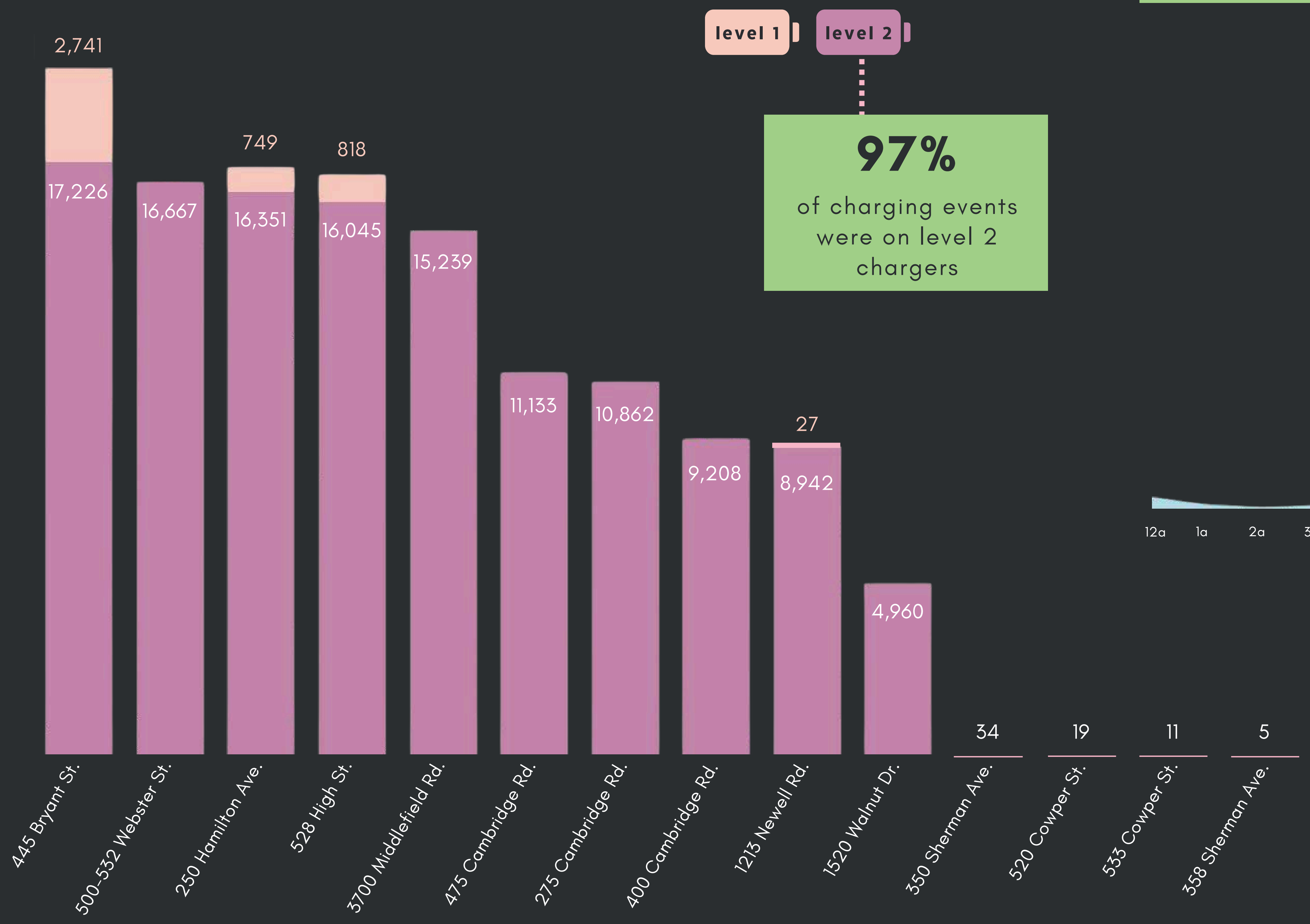
Which charging stations are most popular based on the total number of charging events?

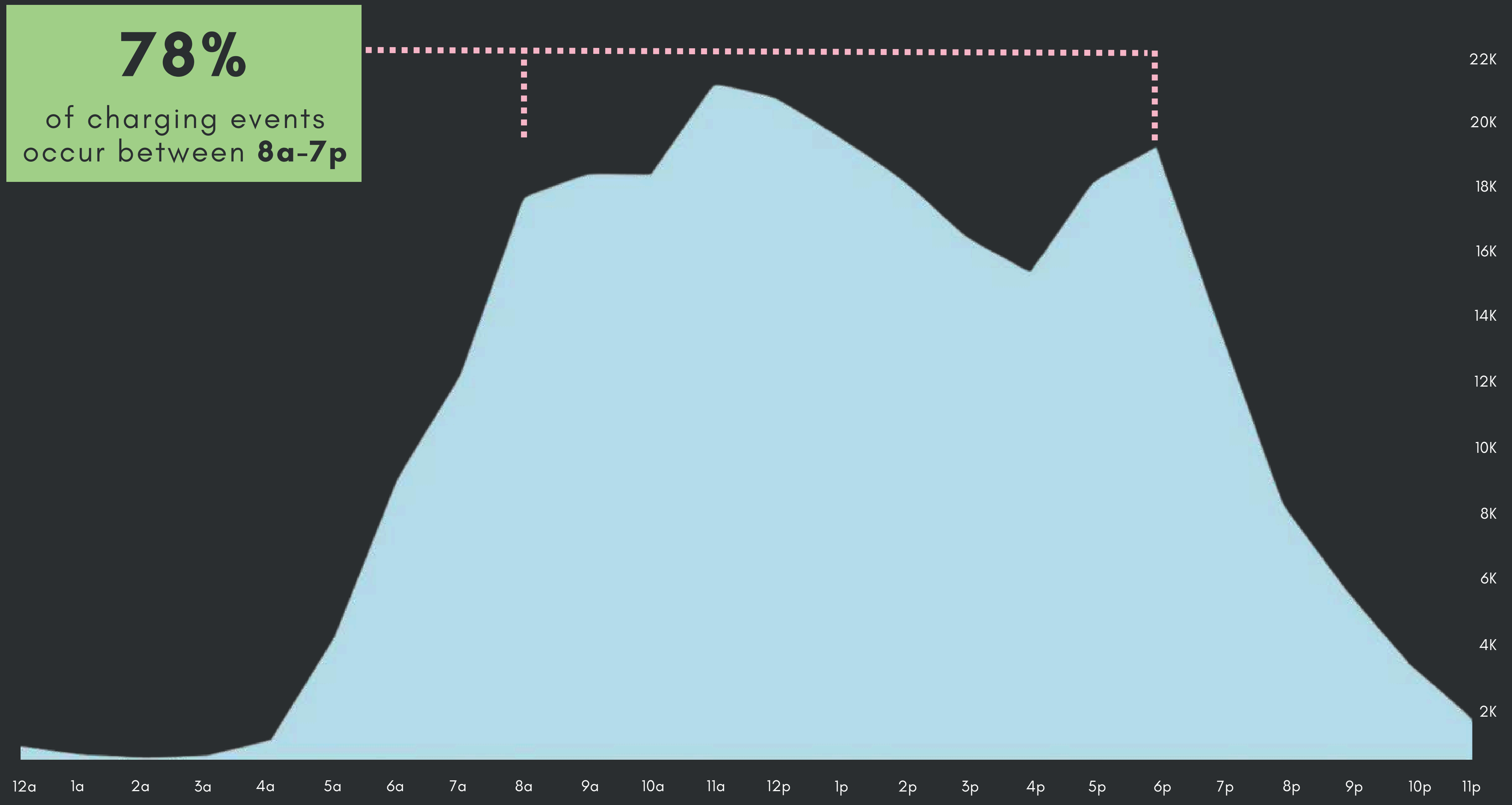
Station use was at its peak between 2016 and 2019, likely curtailed by the COVID-19 shelter in place mandate. Tuesday through Friday were the most popular times to charge a vehicle.

Time-based Charging

At what hours do most charging events occur?
What is the most popular level of charging used?

Total Charging Hours by Station and Port Type





Total Charging Hours by Transaction Hour