# A Spatial Narrative of Alternative Fueled Vehicles in California: A GIS Story Map

by

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To my patient and loving husband, Larsson, who provided encouragement and support through this journey.

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# List of Abbreviations

| | |
|---|---|
| AB | Assembly Bill |
| ARB | California Air Resources Board |
| AGOL | ArcGIS Online |
| ARFVTP | Alternative and Renewable Fuel and Vehicle Technology Program |
| BEV | Battery electric vehicle |
| CalEPA | California Environmental Protection Agency |
| CEC | California Energy Commission |
| CPUC | California Public Utilities Commission |
| CVRP | Clean Vehicle Rebate Project |
| DAC | Disadvantaged community |
| DOE | Department of Energy |
| DMV | California Department of Motor Vehicles |
| EV | Electric vehicle |
| FCEV | Fuel cell electric vehicle |
| GIS | Geographic information system |
| GISci | Geographic information science |
| NOAA | National Oceanic and Atmospheric Administration |
| PEV | Plug-in electric vehicle |
| PHEV | Plug-in hybrid electric vehicle |
| PNG | Portable Network Graphics |
| SSI | Spatial Sciences Institute |
| USC | University of Southern California |

| | |
|---|---|
| USCB | United States Census Bureau |
| ZEV | Zero-emission vehicle |

# Abstract

Alternative fueled vehicles are positively shaping the environment, emissions, and social perceptions of vehicles. Several pieces of legislation and mandates have been passed in California to guide the state towards positive climate impact goals. Assembly Bill 118 and Executive Order B-16-2012 are notable pieces of legislation passed within the last decade that are driving California towards five million zero-emission vehicles by 2030. While these goals are aspirational, several state agencies have collaborated to create programs to accomplish this goal, including the Alternative and Renewable Fuel and Vehicle Technology Program. The California Energy Commission (CEC) has been tasked with implementing this program and releasing an annual Transportation Energy Demand Forecast. This report includes multiple charts and datasets, but no maps or visualizations to facilitate the public's understanding as to the progress of said goals or the ability to achieve the interim 1.5 million zero-emission vehicles by the 2025 target. Research has shown that maps enable data to be better understood by both professionals and the general public. The primary goal of this thesis was to create a Web GIS Story Map that visualizes the progress towards meeting California's alternatively fueled vehicle goals as a means of demonstrating the viability of Story Maps as a communication approach. The Story Map includes geographic representations of alternative fueled vehicles, spatial analysis of the demographic and economic adoptions throughout the state, and immersive multimedia to facilitate exploration of the alternative fueled vehicle program. This study evaluated the degree to which internal staff determined the Story Map useful versus approaches that are more traditional. Preliminary responses from internal staff showed that the Story Map was well organized and intuitive. This pilot project serves as a flagship Story Map that can be expanded upon and published by the CEC for the general public review in the near future.

# Chapter 1 Introduction

California leads the nation in reducing greenhouse gases (GHG) in part by increasing the number of alternative fuel vehicles. Since transportation related energy is the single largest source of the state's GHG emissions, state mandates and legislation have been passed to reduce GHG levels (California Energy Commission 2018b). In 2007, Assembly Bill 118 created the Alternative and Renewable Fuel and Vehicle Technology Program, which authorized the California Energy Commission (CEC) to develop and deploy alternative fueled vehicles to help attain the state's climate change goals. In 2012, Governor Brown issued executive order B-16-2012 to set a goal of 1.5 million zero-emission vehicles (ZEV) in California by 2025 (California Executive Order B-16-2012 2012). Since then, several mandates, incentives, and legislative bills have been passed increasing the use of ZEVs to reduce GHG emissions.

In an effort to facilitate public engagement with the progress towards these state mandates and goals, the CEC is tasked with reporting the trends and forecasts for transportation energy. Currently, this process is done through a *Transportation Energy Demand Forecast* and *Revised Transportation Energy Demand Forecast*, which is adopted on a sliding biannual scale through 2030. The 2017 report was revised for 2018 and adopted as the *Revised Transportation Energy Demand Forecast, 2018-2030*. While the report discusses economic and demographic data, there are no maps in the report (California Energy Commission 2018b). This is problematic because it has been shown that people can draw conclusions more effectively through maps rather than static tables of data (Paul 2018).

By displaying the number of vehicles registered since 2010, this project initiated a dialogue between the transportation staff and other CEC staff and management through a Story Map. This thesis created a smaller pilot project Story Map to allow internal CEC staff to view and test the Story Map for layout, content, and ease of use, while the future goal is to create a public-facing Web GIS Story Map. The Esri Story Map templates and designs for the creation of this project's Story Map were used because the interface allows for seamless integration with ArcGIS software and web-based display. Spatial analysis of the correlation between successful areas and the increase in a number of alternative fueled vehicles were performed to understand geographic regions that are adapting to registering more electric vehicles per population.

While the state goal is important, it is equally important to evaluate how each county is progressing and determine if there are gaps or areas of concern throughout the state. For example, according to the California Air Resources Board, there are no alternative fueled vehicle rebates claimed for Modoc County, as shown in Figure 1, which would imply that an entire county is not participating in the goal to a greener California (Center for Sustainable Energy 2018b). This statistic may not be completely accurate since there are other eligibility criteria for vehicle rebates. Due to these statistical complications, it is important to determine how the counties within the state are progressing towards the mandates as well as the correlations between the demographic and socioeconomic levels across the state.

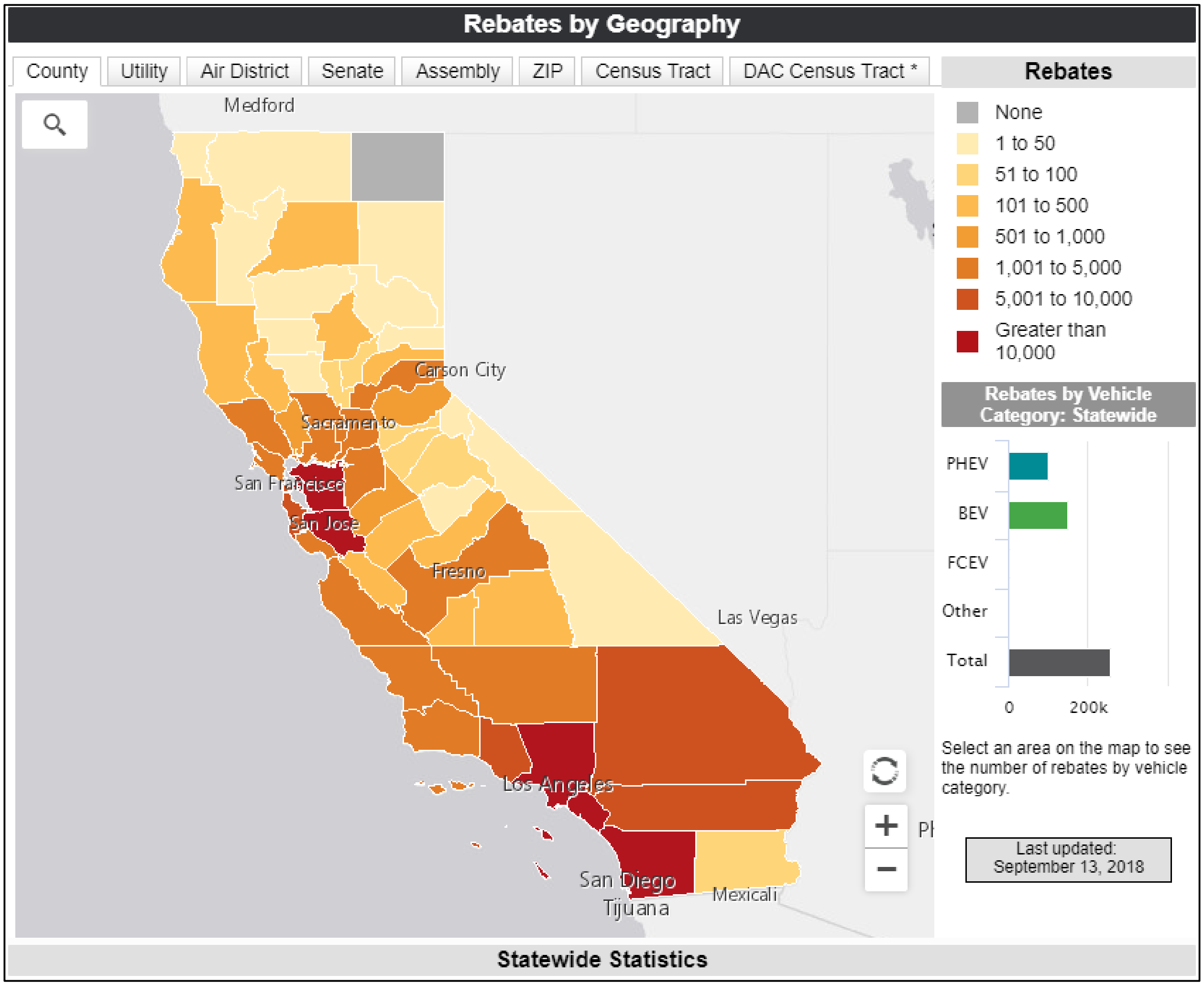


Figure 1 CVRP Rebate Map: Number of Rebates by County (Center for Sustainability, 2018b)

This project uses alternative fueled vehicle data to display the progress towards the state mandates and goals for alternative fueled vehicles between 2010 and 2017. This thesis lays the foundation to create a Story Map that includes the legislative history, programs, and major events that constitute the alternative fueled vehicles programs in California. The Story Map includes the incentives, pricing levels, car manufacturer changes, and successes and failures of the programs. This project utilizes data from the CEC, California Department of Motor Vehicles, United States Census Bureau, California Department of Finance, and other sources as needed. The second phase of this project will include enhancements to the Story Map and vetting by management before publishing this Web GIS Story Map to the public. The Story Map enhancements can be implemented to allow the general public to identify the progress towards the state mandates and goals, determine if any geographical barriers exist, and visualize the future trends that are identified in the transportation forecasts.

## 1.1. Motivation

As with most state agencies, information is shared with the public after rigorous reporting and data collection, analysis, findings, vetting, and finally a public adoption. By the time most reports are adopted, the data is at least six months old if not more. The status is no longer a real-time notification and instead is an archive of the degree of success. Reports are often adopted with confusing titles, dates, and minimal graphics or visualizations that baffle laypersons. Joint agency programs can lead to outdated or incorrect websites. GIS can add clarity with maps and visuals that inform the public without obscuring the data. This Web GIS Story Map is intended to be understandable, contain a simple and effective format, and maintain the attention of the user through interactive maps and visual graphics.

The California Energy Commission publishes a transportation forecast report biannually that describes the trends of vehicles, the forecast for the next ten years, and summarizes the previous years' datasets. While this is done biannually, the data is often a year old since it covers the previous complete year and requires time to perform the analysis, and is displayed in charts and tables that are unclear to the user as to their importance. By complementing this strategic report with a Web GIS Story Map that guides the user through data via maps, charts, and visual displays, the user can gain an understanding of the data within a spatial context. Visualization tools like maps are important mechanisms to inform the public on *where* things happen. In fact, the earliest cartographic maps were actually "story" maps (Paul 2018). To date, the California

Energy Commission has no Story Maps published, yet publishes over five reports a year that contain vast amounts of spatial data (CEC 2018a).

## 1.2. Alternative Fueled Vehicles

Alternative fueled vehicles have been widely called hybrid vehicles. The three main alternative fueled vehicles studied for this thesis are hybrid, battery-electric, fuel cell electric, and fossil fuel. The definitions of each vehicle fuel type are listed below as specified in the *Transportation Energy Demand Forecast.* In addition, the category "zero-emission vehicle" or ZEV refers to any vehicle that produces zero tailpipe emissions during operation (CEC 2018b).

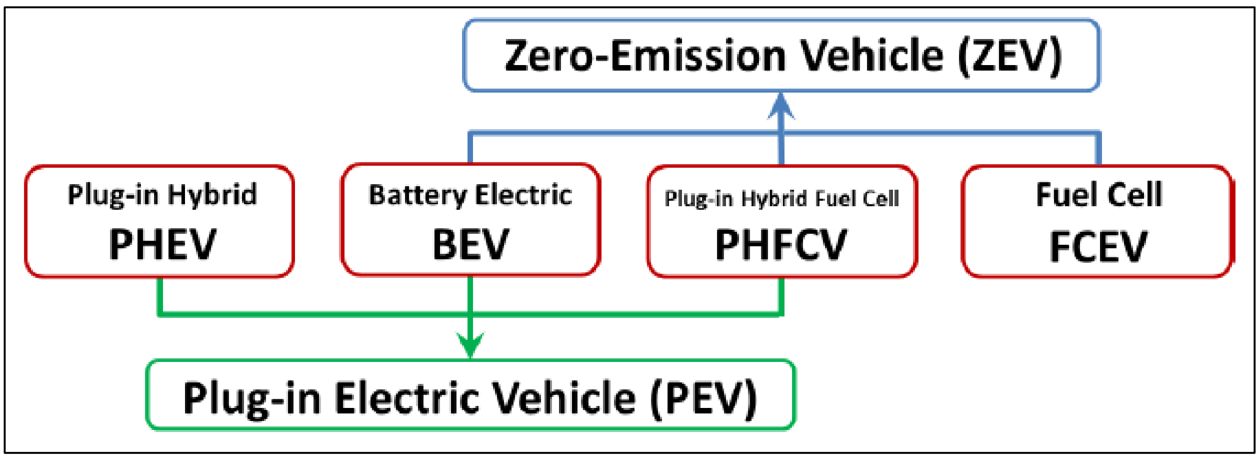


Figure 2 Types of Electric Vehicle Technologies (CEC 2018b)

### *1.2.1. Hybrid Vehicles*

A hybrid vehicle uses more than one type of energy and is typically a combination of fossil fuel and electric engine and a battery. The determination of a hybrid versus a plug-in hybrid electric is based on the battery charging. For this thesis, the term hybrid includes hybrid vehicles and plug-in hybrid electric vehicles (PHEV). The more well-known hybrids are Chevrolet Volt, Ford's C-MAX and Fusion Energi, and Toyota Prius, although there are several new models that have been released since 2016. In the dataset, these are labeled "PHEV."

### *1.2.2. Battery-electric Vehicles*

A battery-electric vehicle (BEV) contains an electric motor and is solely powered by batteries. The more well-known BEVs are BMW i3, Chevrolet Spark EV, Ford Focus Electric, Nissan LEAF, smart, and Tesla Model S; however, there are several other models available. In the dataset, these are labeled “Electric.”

### *1.2.3. Fuel Cell Electric Vehicles*

A hydrogen fuel cell electric vehicle (FCEV) contains a fuel cell, electric motor, and a battery. The determination of a FCEV versus a plug-in hybrid fuel cell vehicle (PHFCV) is based on the battery charging. For this thesis, the term fuel cell vehicles includes FCEV and PHFCV. For example, the Honda Clarity Fuel Cell, Hyundai Tucson Fuel Cell, or Toyota Mirai Fuel Cell vehicles. In the dataset, these are labeled “Hydrogen.”

### *1.2.4. Fossil Fuel Vehicles*

A fossil fuel vehicle is primarily an internal combustion engine that uses a variety of fossil-based fuels such as gasoline, diesel, natural gas, propane, and flex-fuel. Flex-fuel vehicles refer to a subset of gasoline blended fuel sources. For this thesis, the term fossil fuel includes all fossil fuel based fuel sources above and those that are not considered hybrid, BEV, or fuel cell.

## 1.3. Project Overview

This thesis created a pilot project for internal CEC staff to test a user-friendly Web GIS Story Map that bridges the gap between bureaucratic reporting and public transparency. Story Maps are a web-based application that can be updated with new data easily and has viewership information like most other websites and social media platforms. The simplicity of the design coupled with the considerable amount of information that can be displayed was key in choosing this format for communication. This project illustrates a story for the public as to how far California has come in reaching California's goals without the overly bureaucratic reports that readers bypass. Although the initial project is a small pilot project for internal CEC staff to use, the ultimate goal is to create a foundation to shape the process, creation, and deployment of Web GIS Story Maps for the future.

While there are many Esri Story Map templates, for this project the *Cascade* Story Map template was used to guide the user through the story and provide minimal distraction from required mouse-clicks or links that take the user away from the page. This template, as shown in Figure 3, uses full-page graphics and immersive sections. The immersive sections are full-page maps and infographics that click into place allowing the user to see the comment box narratives and view the entire map for the page as they continue to scroll. Additional information is embedded within the Story Map to provide context to the user, however the links offer supplemental data that is not required to understand the material contained within the Story Map. Several web maps were created in ArcGIS Online and used in the Story Map to create the immersive sections. Additional visualizations including infographics, charts, and mixed media were used to draw in the user and tie the narrative together. This process was done with the Esri Story Map template builder.

Figure 3 Esri Story Map Cascade template (Esri 2018b)

At the end of this thesis, the goal is to educate CEC staff on the effectiveness of conveying information to inform the public on the progress and future of alternative fueled vehicles in California in a Web GIS Story Map pilot project. CEC staff were asked to complete a survey about their experience viewing the Story Map, ease of use, comfort level while using the Story Map, and overall effectiveness to use the Story Map as an additive piece to supplement the transportation forecast report. As a method of viewership, the CEC tracks hits, likes, and views to determine user interaction.

# Chapter 2 Background

Cartography has been used for years to describe places. Cartography and GIS are also used in everyday life. Cartography and GIS should be used by public agencies to share valuable geospatial data with their customers – the public. Maps help create engagement with the public and provides visualizations that are more useful to convey information geographically (Paul 2018). While some federal public agencies are utilizing Esri Story Maps, most state agencies in California are not. The National Oceanic and Atmospheric Administration (NOAA), National Park Service, and U.S. Department of Agriculture have used Story Maps to display various themes and topics and educate the public on their projects. NOAA has several Story Maps in their gallery as shown below that illustrate the complexities of spatial data topics in an eloquent format that is easy to understand (NOAA 2018). Story Maps are an effective way to communicate with the public and should be used more widely by public agencies (Esri 2018c).

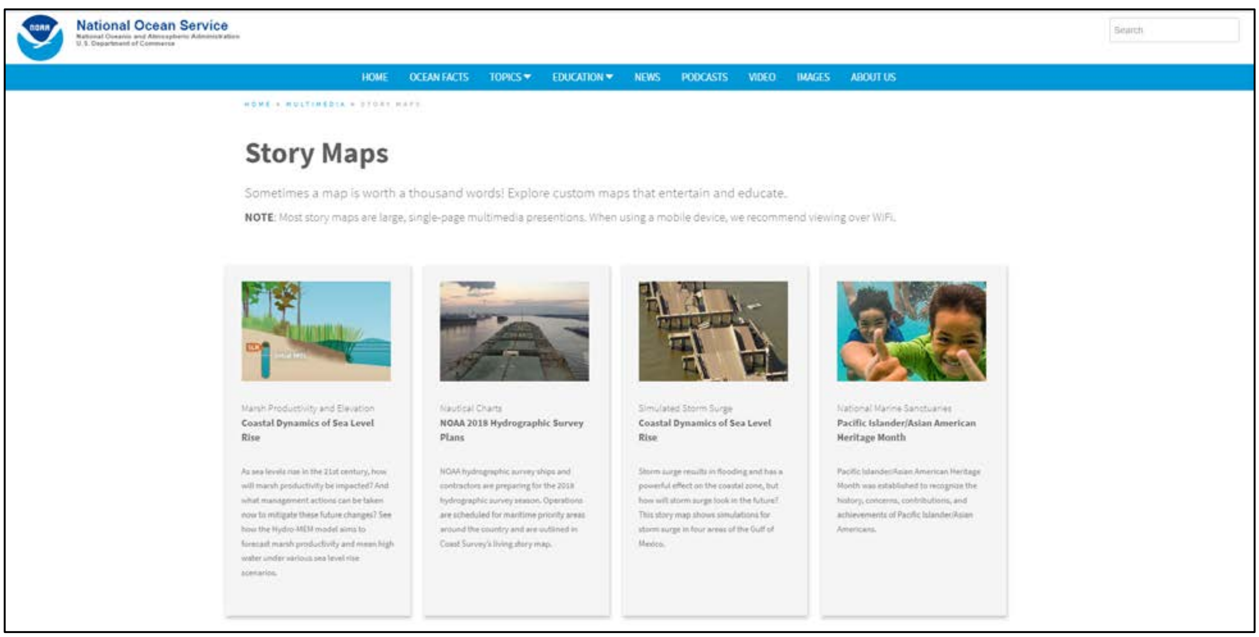


Figure 4 NOAA Story Maps web page (NOAA 2018)

## 2.1. Similar Web Applications

With the abundance of data the CEC collects, coupled with the vast amount of public data available, spatial data visualizations should be included in reports at a minimum. As Paul 2018 states, a static table tells us there is a problem, but not *where.* Adding supplemental maps inform the public on where things are happening, where the vehicles are located, where charging stations are, and where incentives are offered. Cartographic maps can also point out areas with higher concentrations that may not be visible in a table (Paul 2018). In the previous transportation report, only one map was provided, however, there were over thirty charts of data, and the sole map was not published by the CEC, it was added from the California High-Speed Rail Authority. This volume of information can be confusing to readers and should be displayed on maps that allow the reader to draw context to the datasets. GIS has the power to unite people through cartographic maps and web applications (Esri 2017a).

A Web GIS Story Map published by Esri tells the story of electricity in the United States. While this was not published by a government entity, it could be used as a framework and published by the CEC as an introduction to the state's electricity infrastructure, renewable energy goals and progress, and energy consumption. This example would be highly relevant to introduce the public to the purpose of the CEC, display information, and guide the user through the story. The immersive sections highlight the story, draw in the user to the interactive maps, and create powerful messages with the mixed media as shown below in Figure 5 and Figure 6 (Thomas 2012).

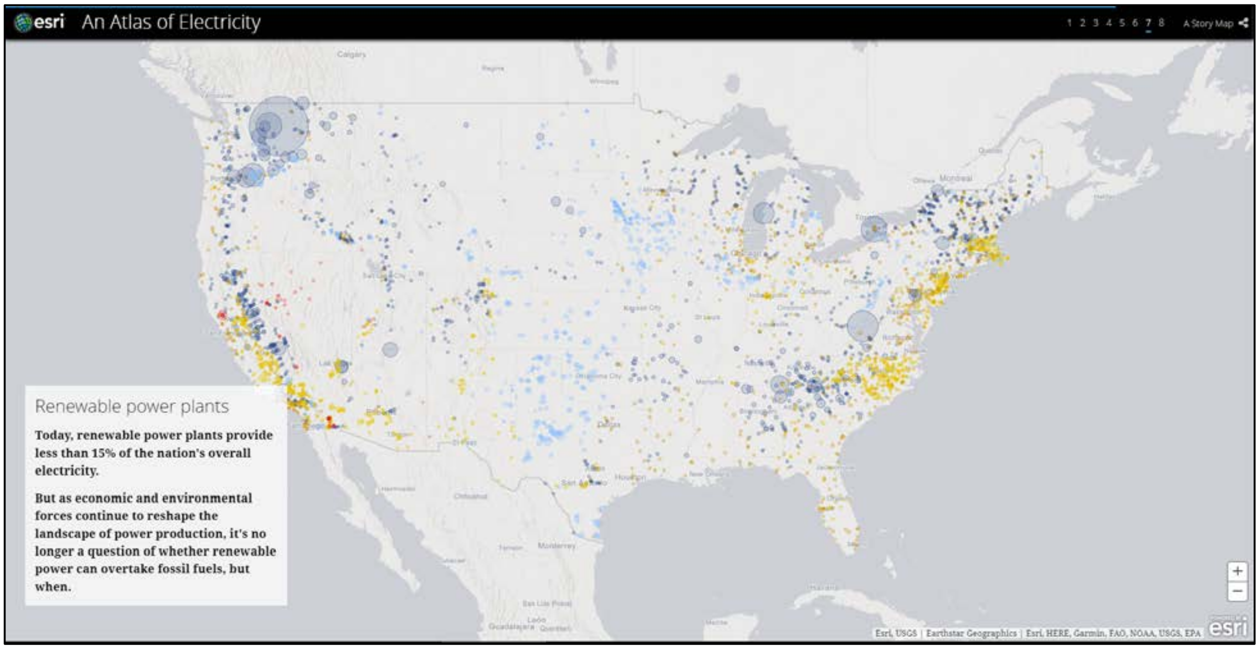


Figure 5 Esri An Atlas of Electricity Story Map – Immersive Web Map (Thomas 2012)


Figure 6 Esri An Atlas of Electricity Story Map – Immersive Mixed Media (Thomas 2012)

To date, the CEC does not have a Web GIS Story Map, and GIS is still in its infancy. Since this is the first Web GIS Story Map created for the CEC, this is aimed at a pilot project to engage staff with the concepts and visuals that are possible with a Web GIS Story Map and to gain traction from upper management on the process involved. As a state agency, the materials published on behalf of the CEC must meet certain requirements by the media and executive offices to establish the correct message and narrative of each item. This Web GIS Story Map introduces the internal staff to the layout, maps, legends, and narratives that can be utilized to accompany staff reports that are adopted across the commission.

## 2.2. Importance of Alternative Fueled Vehicles

GHG emissions are less in some parts of the United States, with California having a significantly lower amount than the rest of the United States in 2010 as shown in Table 1 below (Thomas 2012). However, even if all of the small-sized vehicles were replaced with battery electric vehicles, it would not be enough to reach the 1990 GHG levels as desired since the energy for charging the vehicles primarily comes from fossil fuel dependent power plants.

Table 1. Percentage of electricity generated in 2010 by fuel source in California compared to the entire US

| **Fuel Source** | **California** | **United States** |
|---|---|---|
| Coal | 8.1 % | 46.2 % |
| Oil | 0.0 % | 1.0 % |
| Natural Gas | 41.0 % | 20.3 % |
| Total Fossil Fuels | 49.1 % | 67.5 % |
| Nuclear | 23.1 % | 20.3 % |
| Renewables | 28.0 % | 9.4 % |

Source: Thomas 2012

### *2.2.1. Legislation and Mandates for California*

There are two main legislative pieces that drive the implementation of alternative fueled vehicles: Assembly Bill 118 and Executive Order B-16-2012.

Assembly Bill 118 (AB 118) was approved in 2007 and created the Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP) to be administered by the California Energy Commission. Under this bill, the CEC was required to establish and implement programs to reach the goal of reducing greenhouse gas emissions to 1990 levels by 2020. In addition, several programs and fees were established to support the reduction of transportation-related greenhouse gas emissions.

Executive Order B-16-2012 was signed in 2012 and requires several state agencies to work together to set benchmarks, goals, and programs in order to reach different goals for 2015, 2020, 2025, and 2050. By 2015, the California Air Resources Board (ARB), California Energy Commission (CEC), and California Public Utilities Commission (CPUC) are required to establish benchmarks to support metropolitan infrastructure, expand the manufacturing sector, and contribute to academic institutions' research to support zero-emission vehicles (ZEV). By 2020, the state infrastructure must support one million (ZEV), the cost of a ZEV must be competitive with conventional vehicles and widely available to consumers, public transportation must include ZEV, and the electric grid must support electric vehicle charging stations. By 2025, ZEV infrastructure will be provided for easy access and over 1.5 million ZEV will be on the roads. By 2050, the greenhouse gas emissions from the transportation sector will have eighty percent fewer emissions than 1990 levels. In addition, fleet purchased vehicles must rapidly increase to meet targets of ten percent by 2015 and twenty-five percent by 2020. Executive Order B-48-18 was signed in 2018 to increase the number of ZEVs to 5 million by 2030.

## 2.3. Barriers to Communicating Science to the Public

Communicating science to the public is a difficult task that requires the author to understand the intended audience. Displaying data accurately and correctly to direct the narrative of a story is one way GIScientists are using maps to communicate more effectively.

With the rate that electric vehicles are entering the market in California, the progress towards the state mandates should be known, however this number is unclear to most people.

Depending on when the information was posted and where the source of the information came from, the estimates are between 200,000 and over 400,000 ZEVs registered in California. The ARB released a fact sheet in 2018 stating since 2010, over 400,000 ZEV and plug-in hybrids have been registered in California, Next 10 stated in 2018 that by October 2017, 337,483 ZEVs have been sold in California, and the Union of Concerned Scientists stated in 2016 that more than 200,000 EVs had been sold in California to date (ARB 2018; Perry 2018; Reichmuth 2016). Each statement is different from the next, grouping ZEV and plug-in hybrids, only electric vehicles (EV), and ranging from 2015 statistics to 2017. This information is misleading to the public, and while all of these facts may have been correct at that time, it is confusing to know what is the most current information and the current progress on these goals.

While San Francisco and Los Angeles appear to be leaders for vehicle rebates, the population numbers are not factored into these accounts and are causing a disproportionate outcome for the rest of the state as seen in Figure 1 above (Center for Sustainable Energy 2018b). A map can contain correct and true data while falsely implying a narrative (Monmonier 1998). Clearly, communicating normalized data to the public must be done, and while it is difficult, with the assistance of GIS, this can be accomplished.

Creating an apples-to-apples comparison by normalizing the data onto a level platform, like population, allows the user to understand the value of vehicles per population rather than the overall number. It would not be surprising to see a higher number of vehicles in a highly populated place. However, a higher number of vehicles per population would be important to recognize and determine why the increased values exist. A classic example of this is vacant housing versus vacant housing per people. One would expect vacant houses around populated areas; however, a map showing vacant houses per population is more valuable and shows a different picture as seen below in Figure 7 and Figure 8 (Robinson 2019).

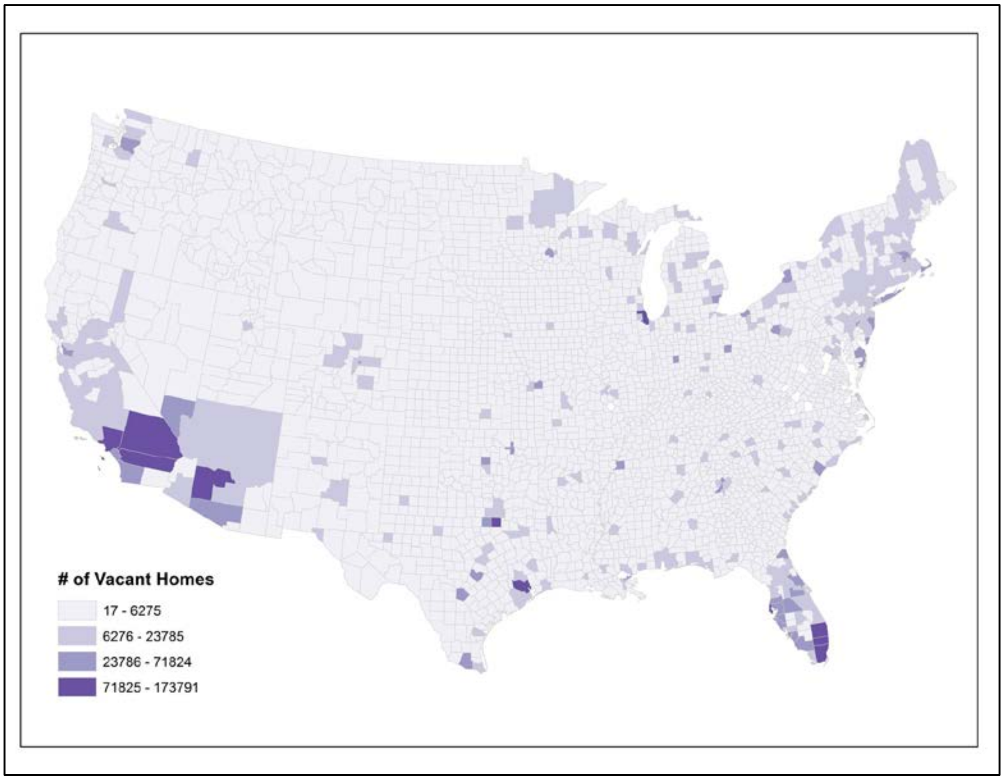


Figure 7 Unnormalized Map of Vacant Houses in the U.S. (Robinson 2019)

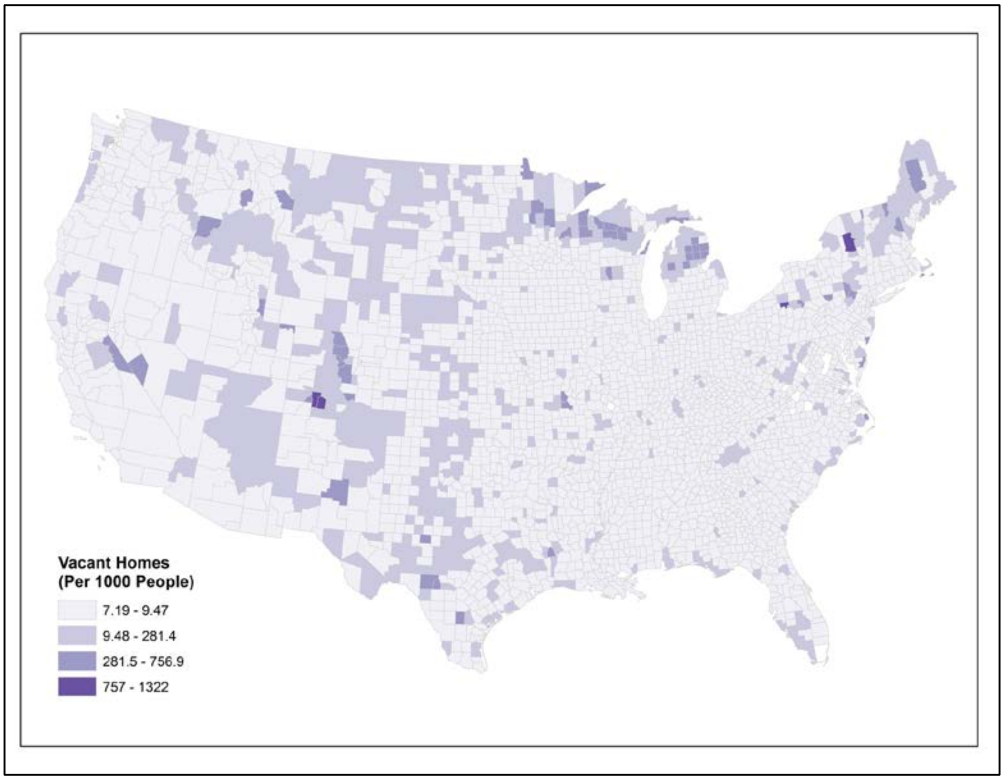


Figure 8 Normalized Map of Vacant Houses in the U.S. (Robinson 2019)

In addition, the statistical variations for data can also skew the overall narrative for the dataset as shown in Figure 9 below. The crude birth rate dataset is the same for each subfigure below however depending on the statistical data groupings the message is different. These statistical breaks are traditionally natural breaks, equal interval, and quantile. As shown below, the differences between the equal interval and quantile figures are drastically different and can swag the message while still using accurate data (Monmonier 1998). Using these communication techniques, maps can be used as an effective tool to inform the public about confusing datasets in a more logical format.

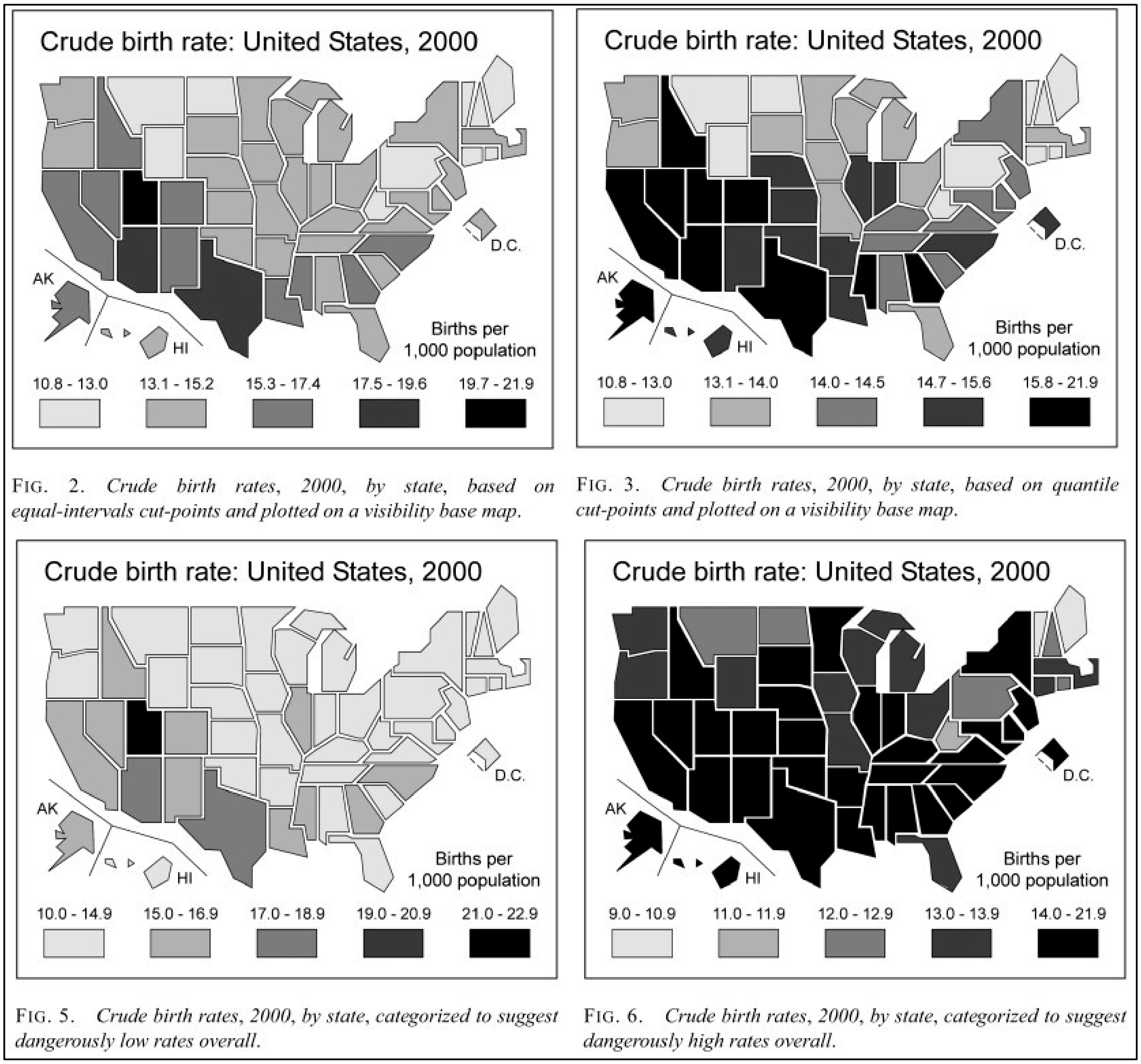


Figure 9 Monmonier's classic example of how to lie with maps (Monmonier 1998)

## 2.4. Social and Policy Impacts

In addition to biased datasets, social and policy impacts are designing the future for alternative fueled vehicles in the state. With aggressive statewide goals, some counties are being left behind due to non-connected roadways and disadvantaged communities. Non-connected roadways occur when the availability to charge an electric vehicle is too far away from the residence or workplace, leading to the inability to charge the vehicle. Disadvantaged communities often have lower income levels and face broader environmental and socioeconomic burdens like poverty, low birth weights, and lower education levels (CalEPA 2018). Several vehicle rebates are only offered for incomes less than $150,000 gross annually, however an additional rebate is offered to those within 300 percent of the federal poverty level at the time of purchase (Center for Sustainable Energy, 2018). Due to this distinction, it is important to determine if there is an increase in the number of vehicles in low-income areas and disadvantaged communities. Additionally, electric vehicles are becoming a status symbol as the middle class tries to keep up with the Joneses' (Axsen and Kurani 2013, Gordon-Bloomfied 2015) and consumer choice is driving car manufacturers towards greener cars. While the Toyota Prius has been around since 2000, Tesla was introduced in 2008 and is seen as a luxury car in comparison (Woody 2013). While the social constructs are beyond the scope of this project, it is important to keep in mind the additional factors beyond the income and price points of the vehicles. Even though most consumers are conscientious of the environmental impacts of driving (Breetz 2018), it may not be feasible to own an electric vehicle without a rebate, as forty-six percent of surveyors implied to the Center for Sustainability's question: "Would you have purchased or leased your PEV without the rebate?"

The trend for "green" vehicles and the environmental impacts are gaining support since the initial Prius hit the street, and scientists are gathering data to determine how well these alternative fueled vehicles are helping reduce greenhouse gas emissions (Thomas 2012). Although the goal is to add more alternative fueled vehicles to reduce greenhouse gas emissions, the effects may take years to fully understand. However, removing fossil-fueled vehicles from the road and replacing them with zero-emission is a step toward the greener future for California (CEC 2018b).

Nisbet (2009) discusses the *two Americas of climate perceptions* where one half is engaged and involved, and the other questions the ideology of climate change. Purchasing an electric vehicle has become a decision based on two trends; purchase an electric vehicle in order to address climate change and the other to purchase a status symbol. As with all policy issues, communication is key and can be used to frame an issue like a storyline. Since audiences rely on the framework to guide the issue, a Web GIS Story Map can be used in a similar fashion to guide the user to the policy issues and solutions (Nisbet 2009). Esri describes the best policy for readability and the attention span of users is simplicity. A user should be able to gather all of the necessary information in the current or next step rather than six steps later as the user will lose interest and the Story Map will not be as effective as shown in Figure 10 below (Esri 2018c).

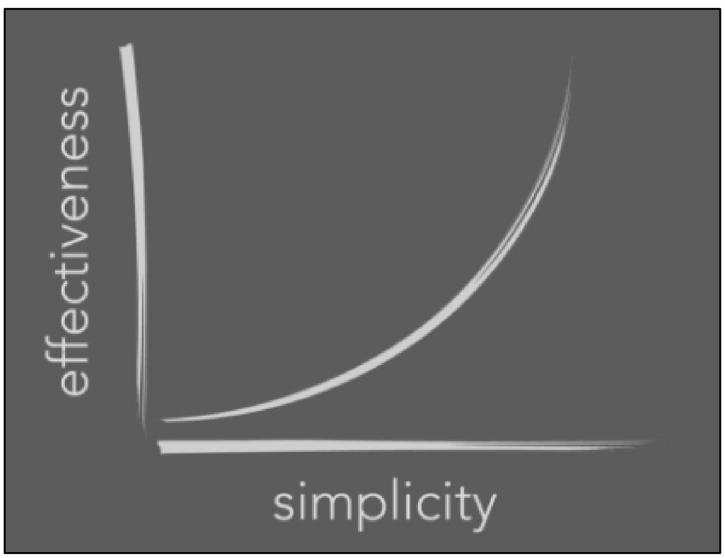


Figure 10 Esri Strive for simplicity (Esri 2018c)

Following Nisbet (2009) and Esri's recommendations, a catchy title and graphic displays must be used to engage the user to start the journey and continue along the pathway to the final destination. A title *The Transportation Outlook for the Suitability of the Alternative Fueled Vehicles in California* introduces a layer of confusion and boredom whereas *Driving California to a Greener Future* provides more context and vision. Both titles were considered for this Story

Map, however, after identifying the audience and conducting a short poll, it was determined the first was too similar to the transportation report that is not widely read outside of the primary stakeholders and partnering state agencies. The second title allows the user to feel involved with the change and part of the solution, which would reframe the perception to the user. Additional comments for the title poll were "too long, didn't read," "I stopped reading after Outlook," and "I want to read the shorter one." As shown in Figure 11 below, the immersive title section for the Cascade template draws in the user to the story.

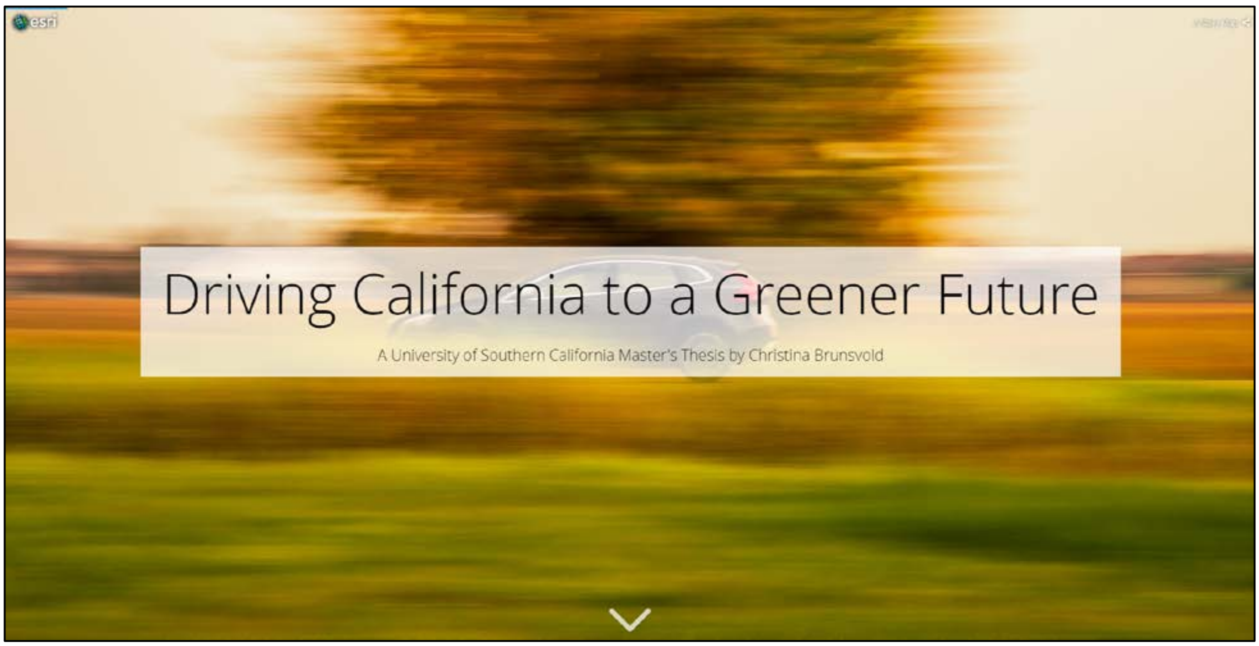


Figure 11 Story Map title page

## 2.5. Cartographic Design

Cartographic design techniques are important to provide context to map-readers and inform on the subject. Simple map characteristics like colors can play a big role in map perception. For example, the color red is often associated with crime and danger, so using red to associate a topic could introduce unwanted feelings and bias from the map-reader (Slocum

2009). Additional color schemes relating to color-blind people must be used to ensure that all map viewers can view and understand the maps without missing important color changes.

Symbology in maps can also provide context and distract the map-reader depending on the amount of detail contained on the map. While maps require minimal information to provide context like cities or counties, additional data can be distracting and deter the user from the original intent of the map. This cluttered information is called map noise and should be avoided. To avoid map noise, several maps in a series can be used to provide context and information to the map-reader without cluttering individual maps. In addition, web maps that incorporate symbology at different map scales allow the map-reader to view information necessary at that scale (Esri 2017a).

Static maps are also different from web maps as the map elements are no longer fixed within a single page. Map elements like labels, legends, scale, and pop-up boxes change the layout of the available space and alter the frame for users. Additionally, new hierarchies exist for web maps and fluid map layouts provide additional communication tools and parameters for creating web maps. The zoom level interface creates additional space on the page where labels and symbology can be applied at different zoom levels and allow more detailed information with less map noise (Muehlenhaus 2014).

## 2.6. Web GIS Story Maps

Esri Story Maps have been used to communicate policy with constituents through embedded maps and galleries on websites. A Web GIS Story Map, or simply a Story Map, combines illustrative maps with rich narrative and multi-media to engage the user into the story being told. Through the *Five Principles of Effective Storytelling*, a map or web application creator can harness the power of GIS to inform the public and stakeholders about policy issues (Esri 2018c).

With digital cartographic maps, the map-reader is now empowered with control over a map (Roth 2015). The Web GIS Story Map enables the map-reader to zoom in and out, focus on different areas, and dive into the narrative within the story. These Story Maps are a useful way to communicate data to the map user over geographical areas with a greater understanding. The public is most comfortable in their own geographical extent, understanding the roads, parks, schools, et cetera within their community. A statistic from a neighboring community might be understood, whereas a statistic from an unknown community may not. Enabling the map-reader to gain a glimpse of an understanding about these communities and cities provides geographical context to datasets that assist the map-reader to gain a better understanding (Esri 2017a).

# Chapter 3 Design and Development

This chapter describes the process of creating the pilot project Web GIS Story Map and the required spatial analysis and datasets. An initial review of the datasets determined the granularity that was used to display each dataset and spatial extent of the maps. Once the data was obtained, the datasets were analyzed spatially to determine any spatial correlations among the different indicators. This analysis was performed at the census level to determine if there are additional areas that should be disaggregated and evaluated. While the project aimed to capture the overall statewide progress towards the state mandates, the interdependencies of each census tract and county were evaluated to determine equitable adoption within the counties. The general process for obtaining and preparing the data is described in Figure 12 below.

## 3.1. Requirements

The Web GIS Story Map was created in ArcGIS Pro and ArcGIS Online and published on the CEC ArcGIS Online server.

To create a Web GIS Story Map that displays the spatial data and correlations among demographic and socioeconomic factors, several datasets were required. The primary dataset was the vehicle registrations for the state of California, which was provided by the California Department of Motor Vehicles (DMV) via the CEC. This dataset was "scrubbed" and partially processed for accuracy by CEC staff and includes the make, model, model year, fuel type, and vehicle registration address. Due to the large size of the dataset, it was obtained in a SAS format and needed to be integrated into ArcGIS. The dataset was geocoded to add the latitude and longitude to each address in the file. The secondary datasets to analyze included demographic, economic, and disadvantaged community areas. The demographic and economic datasets contained the population and income levels for the state of California per county and census tract. This dataset was provided by the US Census Bureau (USCB) and is downloaded annually. Once the datasets were converted to a spatial format, the evaluation of census level and county level aggregation were explored, and the findings determined that the granular data comparisons would be performed at the census tract level and the overall vehicle counts would be displayed at the county level. The disadvantaged community areas (DAC) are defined by the CalEnviroScreen3.0 from Senate Bill 535, which rates the census tracts amongst 20 environmental and socioeconomic factors (CalEPA 2018). A DAC is described as a census tract within the top 25% or top 10% of these barriers and is currently being evaluated by many state agencies for equitable program success due to Senate Bill 350 (CPUC 2018). Due to the increased attention to disadvantaged communities, management requested an analysis layer in the Story Map showing the correlation between DAC and ZEV locations. More information about the DAC areas can be found in 3.2.3.4 Disadvantaged Communities (DAC).

Supplemental datasets used to create detailed maps were the alternative fueled vehicle charging stations and fuel pumps, incentive-based data, and car manufacturer model price points for vehicles. The charging station dataset contains the locations of the different charging stations across the state of California. This includes electric vehicle charging stations, connector types and project status. This dataset is available for download from the Department of Energy. The incentive-based data includes the available monetary incentives as well as customer-based incentives offered by local utilities. The monetary incentives are determined by the vehicle model and are available from the Clean Vehicle Rebate Project. The customer-based incentives vary and are currently being researched, however, the Sacramento Municipal Utility District has one program listed, and similar programs are being researched for other utilities within the state.

The car manufacturer model price points dataset was researched and determined to be incomplete for this project.

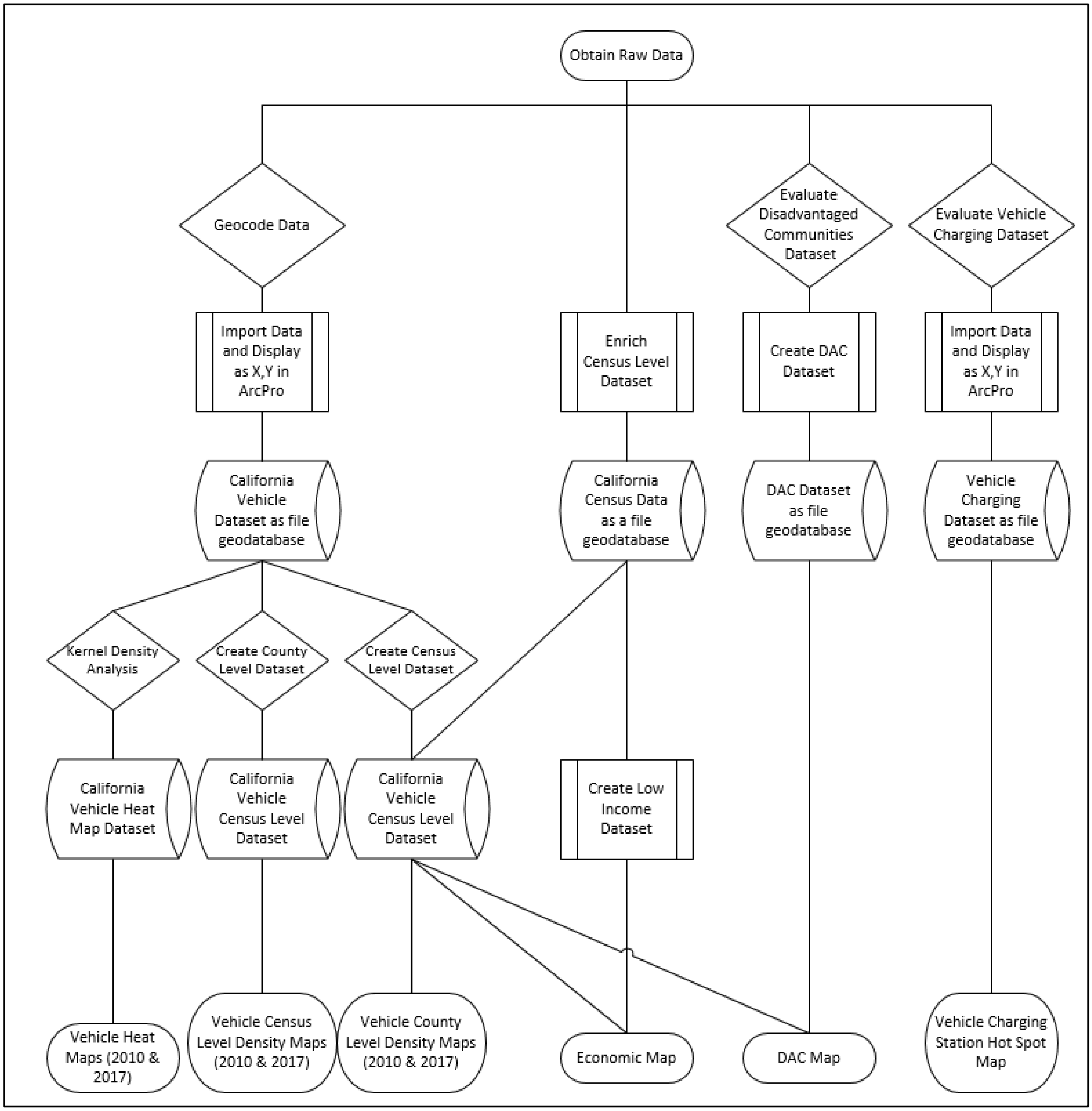


Figure 12 Methodology

### *3.1.1. Data Preparation*

Data obtained was prepared as spatial datasets in ArcGIS Pro. The datasets were converted to GIS tables, joined with existing spatial datasets, and geoprocessed to complete analysis necessary before map creation. Once the data was prepared, the datasets were shared as web layers and tile layers to ArcGIS Online (AGOL) as content. These datasets were used to create the various maps necessary in the Story Map.

For the Web GIS Story Map, there will be several web maps created by the various datasets. Due to the specific nature of the project, some maps will be fully immersive and interactive while others will be cast images of the maps. The intended datasets listed in Table 2 were used for these maps, infographics, and charts.

Table 2. Data Types

| **Data** | **Data Type** | **Source** | **Format** |
|---|---|---|---|
| California DMV vehicle stock database | Spatial* | California DMV via CEC | .csv<br>Shapefile* |
| Household Income | Spatial | US Census Bureau | Shapefile |
| Population | Spatial | US Census Bureau | Shapefile |
| Disadvantaged Communities+ | Spatial | CalEnviroScreen 3.0 | Shapefile |
| Alternative Fuel Charging Stations | Spatial | Department of Energy | Shapefile |

Note: * The DMV Dataset was geocoded to create the main spatial dataset.
+ Disadvantaged communities are defined by CalEnviroScreen 3.0, specifically in relation to Senate Bill 535.

*3.1.2. Applications Goals*

The goal of the project is twofold; first to pilot the creation of a Web GIS Story Map that can be expanded upon for future work and secondly to create an expanded public-facing Web GIS Story Map. This pilot will document the process to plan, develop, build, and display a Story Map. While several decisions have already been made, including the topic, datasets, level of granularity and enumeration unit, and Story Map template, there are several decisions that will be made with CEC staff to complete the Story Map. In order to facilitate these discussions, the pilot project will demonstrate the flow of the Story Map, the integration of mixed media, and the incorporation of immersive maps and legends. After the general understanding and presentation of the Story Map, discussions with CEC staff to expand the pilot into a public-facing Web GIS Story Map will begin and include discussions about the overall narrative portrayed, additional messages and maps, specific details and areas to highlight or focus on, and on-going maintenance and updates to the Story Map. Due to the robust review process, these discussions and implementation may take months to craft.

### *3.1.3. User requirements*

For the purposes of this thesis project, the users were internal CEC staff. The staff also functioned as the application test subject. Internal CEC staff will take a short survey after they have viewed the Story Map to provide feedback on the usefulness, ease of layout, and overall understanding of the information portrayed in the Story Map. Since most staff do not use or know about GIS daily, as with the general public, the Story Map will be constructed as simply as possible for maximum user interaction and satisfaction. It will be assumed that the knowledge level required would be zero so that the Story Map could be expanded in the future for a wider audience.

### *3.1.4. Functional requirements*

The Story Map will work on all internet platforms, mobile devices, and tablets. Users will be able to access the Story Map without needing an Esri account since the Story Map will be publicly available. However, the link will not be shared publicly until the narrative is vetted in the future. Users will be able to scroll through the story, click and drag maps and pop-up configuration boxes, and zoom to different areas on the maps.

3.1.4.1. Software

Due to the limited open source software and web application knowledge, this pilot project was created using Esri ArcGIS Pro 2.1, and ArcGIS Online. Supplemental infographics and media were created using Adobe Design suite including Adobe Illustrator. Analysis and supplemental charts were created in Microsoft Excel before converting to Adobe Illustrator. A GitHub Excel Hybrid Geocoder was used to geocode the DMV vehicle dataset (Github 2014).

3.1.4.2. Web Services

This pilot project Web GIS Story Map is hosted on the CEC ArcGIS Online account for internal staff viewing. Since the CEC already has an Esri account and is using ArcGIS Online, the potential costs are expected to be minimal and within the current scope of the project. Future costs for the expanded public-facing Story Map will be based on estimated credits for viewing and hosting as well as potential page views. This pilot project will provide detailed information about the Story Map hosting and viewing estimates for management consideration. Esri provides these analytics in the CEC administrator account to view the number of views.

*3.1.5. Design Principles and Choices*

The Story Map must be supported with existing CEC available software and will, therefore, be created using ArcGIS Pro and ArcGIS Online. The initial maps were created in ArcGIS Pro and symbolized using Color Brewer 2.0 recommendations. Once the layers were created, each layer was shared to AGOL as a web layer. The maps were created to provide easy user interaction, and therefore each map contained its own message and theme instead of a single map with multiple layers and content. The web layers were added to web maps and stylized with basemaps, transparency, and pop-up boxes before being saved and added to the Story Map. The design of the web maps was important because it sets the tone for the user experience. Having a visually pleasing, easy to use map not only enhances the mood of the map-user, but also enables the map-user to understand the map content (Roth 2017).

Using Color Brewer 2.0, recommended color schemes were chosen. Since electric vehicles do not have an associated color theme like green for money or red for crime, a neutral blue hue was chosen. In order to provide context, a green-blue hue was used which contained seven color variations. Darker colors are associated with more or higher values, and lighter colors are associated with less or lower values, so darker blue was associated with higher values, and lighter green-yellow was used to show lower values (Brewer 2004).

Specific maps were chosen to provide an accessible format without requiring mouse-clicks to add or remove layers. This required a separate map for each theme, creating a map for ZEV 2010, ZEV 2017, Electric Vehicle Charging Stations, Income, and Disadvantaged Communities. Each map was symbolized using the applicable color scheme and layout to show the entire state of California before zooming in to higher concentrated areas in Los Angeles and San Francisco. These designs were selected based on Esri's Five Principles of Effective Storytelling (Esri 2018c).

#### 3.1.5.1. Desired Maps and Infographics

- 2010 Vehicle Heat Spot Map – ZEV
- 2017 Vehicle Heat Spot Map – ZEV
- Comparison of 2010 - 2017 Vehicle Heat Spot Map (map slider)
- 2017 ZEV by Census Tract
- 2010 ZEV by Census Tract
- 2017 ZEV by County
- 2010 ZEV by County

- Guided map/infographic comparing Vehicle Counts by census level from 2010-2017.
- 2017 Vehicle Count by census level interactive map with 4 layers (each fuel type)
- Electric Vehicle Charging Station
- Disadvantaged Communities
- Household Income Level by Census Tract

## 3.2. Story Map Creation

The Esri Story Map Builder was used to create this pilot project Web GIS Story Map. The Cascade template was used for the Story Map that guides the user through the story. The Story Map contained several web maps including the primary maps for vehicle counts. Supporting maps displaying the ZEV 2010 and ZEV 2017 vehicle counts as heat maps were created to show the concentrations of ZEVs near urban areas and larger cities. In addition, the ZEV 2017 map was used to compare vehicle counts to disadvantaged communities and income levels as two additional maps. The electric vehicle (EV) charging stations were added as a separate map to illustrate the locations of chargers and establish a relationship between ZEV and EV charging stations.

To design the maps, Color Brewer 2.0 was used to determine the most suitable color schemes for the maps and ensure the public viewing ease. Since the optimal color ramp is no more than seven colors (Brewer 2004), the class ranks were set to seven. Additionally, using Color Brewer 2.0, the color-blind color sets were removed to reduce the public inability to see the color variations within the web maps. The Esri ArcGIS Pro color ramp Green-Blue 7 class was consistent with the Color Brewer 2.0 colors (Brewer 2004).

The ZEV 2010 and ZEV 2017 vehicle count by census tract and county level aggregation were created as the primary maps. These maps were normalized by population to show the number of vehicles relative to the population in each county and census tract.

While several maps were proposed, limitations occurred with the datasets and web acceptable formats that drove the decision to create the web maps. The proposed local incentives map was not created because the boundaries of the local areas overlapped and complete data was not available. Instead of a map, a simple graphic was created. Similarly, for the vehicle distribution, the vehicle types were not available as intended for map creation and would have caused more confusion than the graphic created to show the manufactures and available vehicle technology types.

*3.2.1. Cascade Template*

The Cascade Story Map template was chosen because of the ease of use, immersive sections, and guided path for users. While the Story Map Journal, Tabbed Layout, and Swipe were potential templates, each template lacked a vital component to drive the users toward the message. The Story Map Journal template provided a similar layout as Cascade; however, the clunky bar of information caused excessive scrolling for long narrative sections. The Tabbed Layout had a useful past, present, and future sectional feel. However, the user must click and navigate through each tab, which may leave some tabs undiscovered. The Swipe template was also a promising choice to display the past and present comparisons, however like the tabbed layout; it lacked direction for the users to explore the other swipe maps. The Cascade template combined the positives from each of these templates into one, allowing the user to explore larger sections of text, compare past and present maps and graphics, and guides the user through the story without missing information.

The immersive section capabilities in the Cascade template were the original reason this format was chosen. After viewing several Story Map examples, Lutz's *Oceanic Blue Carbon* Story Map showed the ability to utilize the immersive section and scrolling legend to draw in the user to understand each section of the infographic in detail allowed. This functionality could be used to highlight sections of the alternative fueled vehicles progress infographic in the Story Map to guide the user. In the figures below, Lutz described different sections of the infographic while greying out other areas so the user could focus on one specific item at a time. This will help guide the user through more challenging areas that could have distractions from the linear flow intended in the narrative.

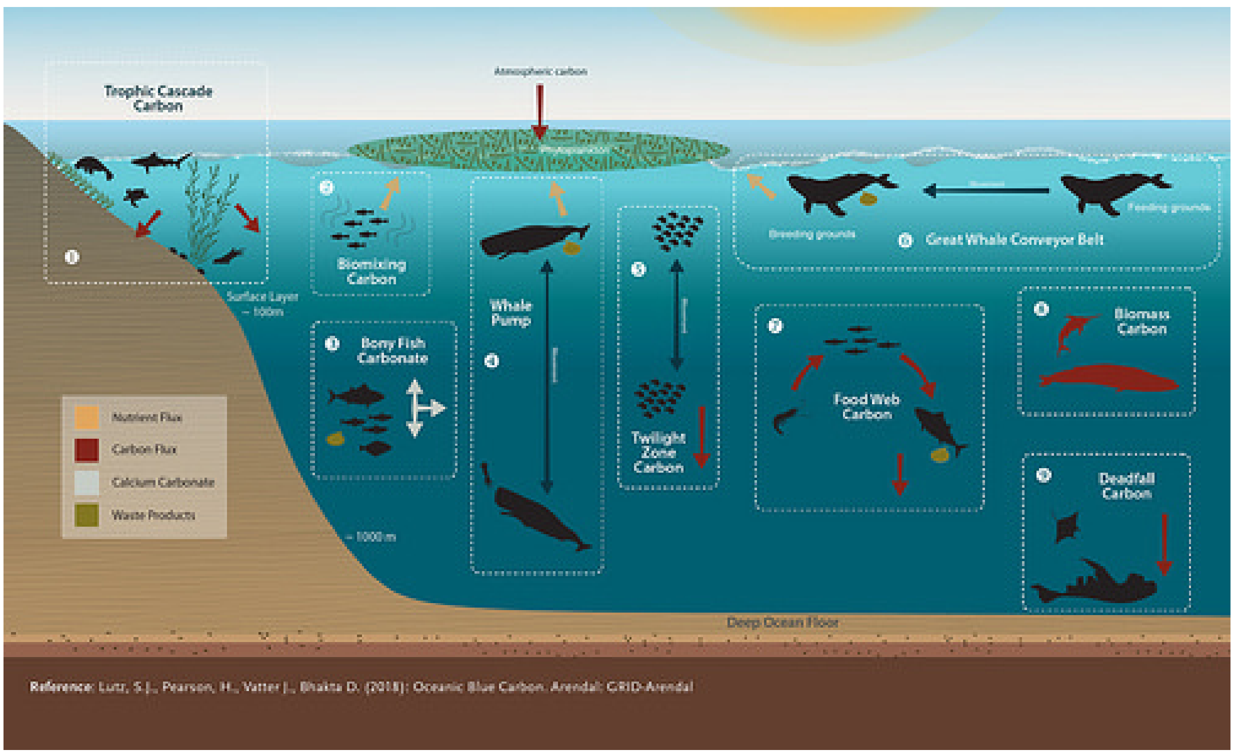


Figure 13 Lutz *Oceanic Blue Carbon* Immersive Infographic (Lutz 2018)

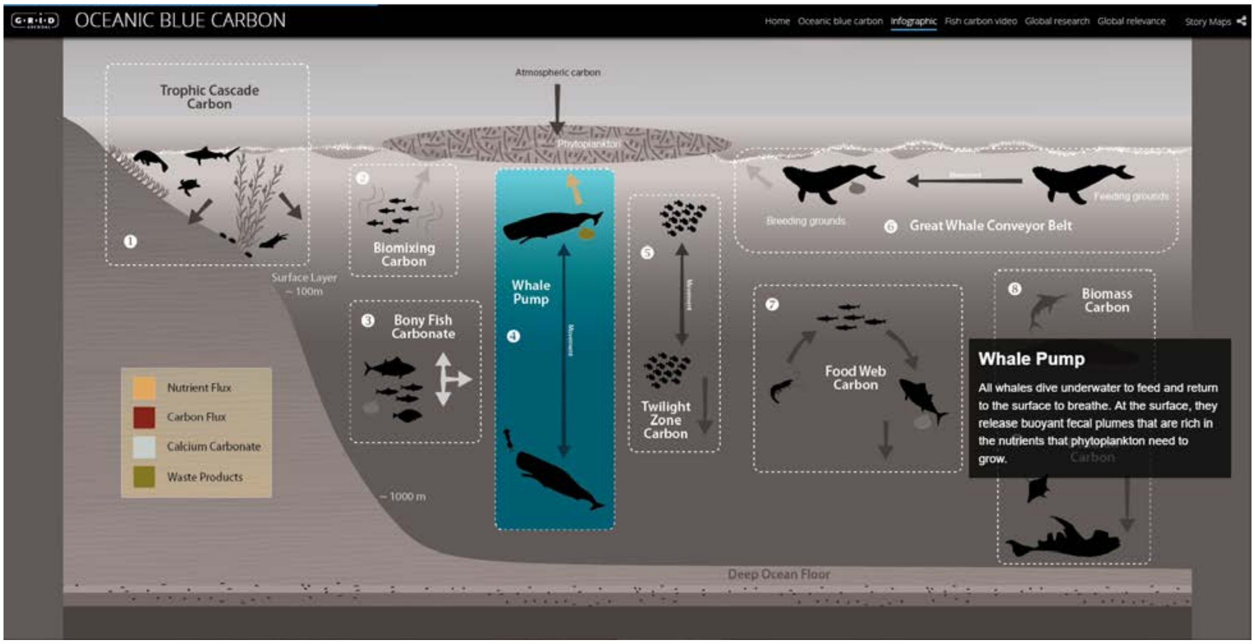


Figure 14 Lutz *Oceanic Blue Carbon* Infographic with Legend (Lutz 2018)

*3.2.2. Development*

The Story Map creation process comprised three main components: web maps, narrative, and infographics. The web maps were created as six individual sections to the viewer while actually comprising nine maps. The maps were inserted into the Story Map as immersive sections, which “locked in” the maps to a full page and allowed the user to scroll while having a narrative box scroll with the mouse. This allowed for additional map views to be added for the Los Angeles and San Francisco areas while the user continued to scroll without requiring map movement on the user. The design principles were implemented on the maps, infographics, and narrative, maintaining the same color scheme throughout.

The Story Map was created with a past, present, and future layout. This allowed the user an introduction to the subject, given a brief overview of the history, an understanding of the current progress, and the outlook for the future. Each section was a new topic that had an associated map or infographic, which allowed the user to finish each thought before moving to the next one. A simple process showing the steps taken is provided in Figure 15 below.

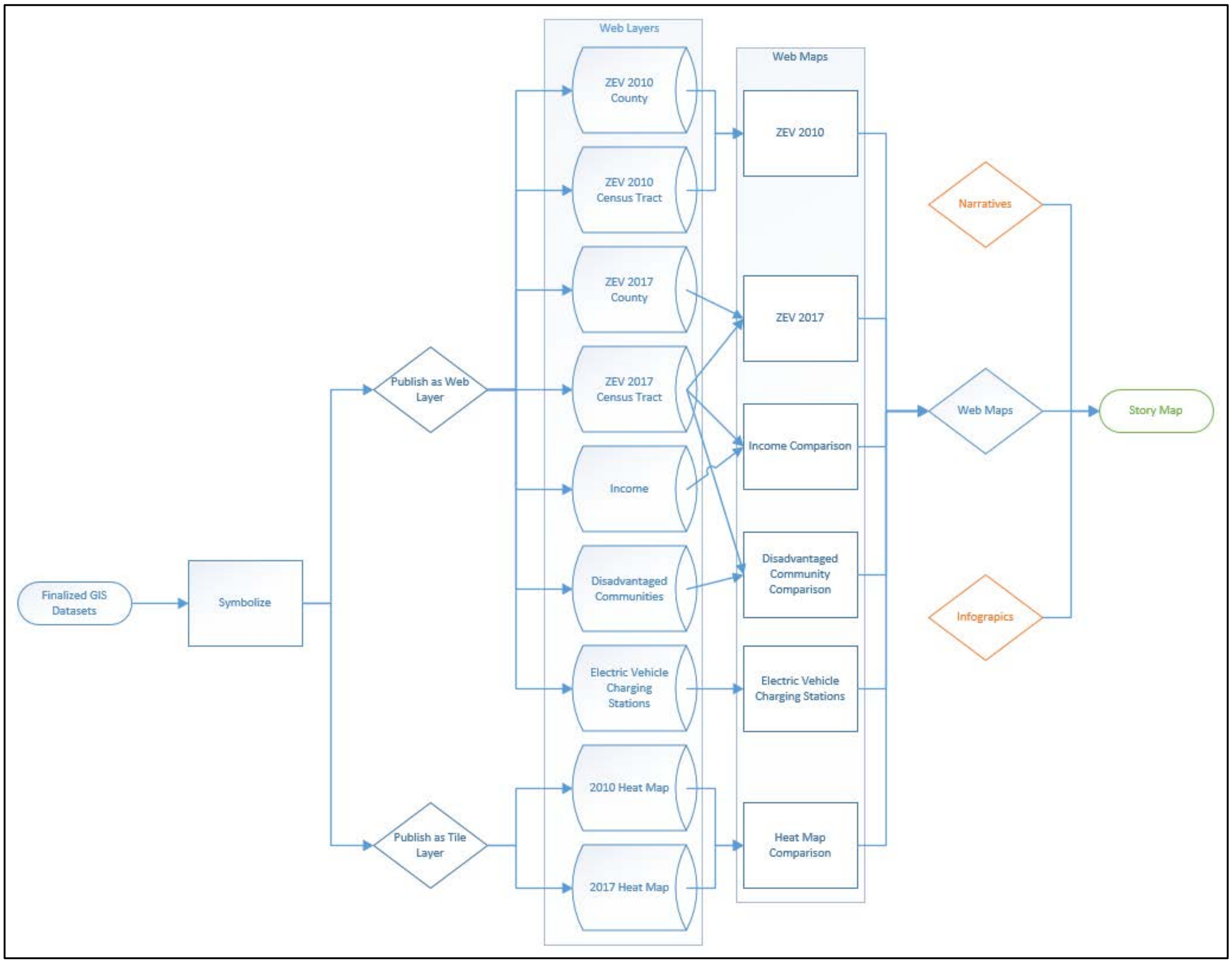


Figure 15 Story Map Creation Process

### *3.2.3. Data*

Several datasets were created in order to create the web maps. The primary dataset was the DMV vehicle stock dataset, and the supporting datasets were the electric vehicle charging stations, household income, and disadvantaged communities. Each dataset required different processes to convert the data to spatial data and prepare the data for integration into ArcGIS Online for web map creation.

3.2.3.1. Department of Motor Vehicles (DMV) Data

The primary dataset was the DMV vehicle stock data, which contained the vehicle address, fuel type, manufacturer, model, and model year. This data was provided in a .csv file format with the full address, city, state, and zip code. In order to convert the dataset for GIS, the dataset was geocoded using an Excel Hybrid Geocoder from Github. This produced the GPS coordinates for each vehicle along with a confidence level. The confidence level was associated with how accurate the algorithm thought the location was. Once the DMV vehicle stock data was geocoded, this table was imported to ArcGIS Pro and converted to a GIS table. This process was completed for the 2010 and 2017 datasets. Once imported, the datasets were displayed as X, Y data and the locations of vehicles were displayed as points on the map. Points that were located outside of California were evaluated for accuracy, and many were removed due to old addresses that were not within the state. Other addresses that were not accurate were moved to the correct location, and those with registrations outside of California were removed. This provided 762 and 332,506 vehicles in California for 2010 and 2017 respectively.

To create the choropleth maps, the dataset was summarized by county and census tract for 2010 and 2017 to provide boundary layers with vehicle counts. Then the data was normalized by population counts to show the number of vehicles per population in each county and census tract. These datasets were the foundational datasets for this project and used in conjunction with other datasets to create the maps.

To create the heat maps, the point dataset of vehicles were used with the Kernel Density geoprocessing tool. The Kernel Density tool calculates the distance of neighboring points and produces a raster cell for the count of points. The default settings for cell size, output radius, and area units were used. The 2017 dataset contained more points and provided a smoother transition showing peak areas of San Francisco, Los Angeles, San Diego, Sacramento, and Fresno. The symbology was set to stretch with three standard deviations. The same process was performed for 2010. However, due to the limited number of data points, the transition was rough and called out San Francisco and Los Angeles areas generically. In order to evaluate the heap map trends between the two years, the same color ramp was used by applying the symbology from the 2017 ZEV Heat Map layer with the Apply Symbology from Layer tool.

#### 3.2.3.2. Electric Vehicle Charging Station

The 2019 electric vehicle (EV) charging station dataset was obtained from the Department of Energy website and downloaded as a .csv file. This dataset provided the charging station location, name, descriptive address, city, charger connector type, and operational date among other fields. Since the dataset contained the location as both the address and GPS coordinates, it was ready to be imported to ArcGIS Pro. Once the dataset was imported and displayed as X, Y, the locations of each EV charging station were shown. In order to correlate the number of vehicles and the availability and number of EV chargers, the dataset was displayed as a point dataset showing each location.

#### 3.2.3.3. Income

Income data was obtained from the US Census Bureau and was provided per census tract. This dataset contained the American Community Survey (ACS) 5-year estimates for 2013-2017. This dataset was already prepared for GIS as a shapefile by the CEC, whom joined the median household income data with the respective census tract. This was added to ArcGIS Pro and used as a file geodatabase to be joined with the census tract level ZEV 2017 dataset.

3.2.3.4. Disadvantaged Communities (DAC)

The DAC dataset was a shapefile downloaded from CalEnviroScreen 3.0 and contained data fields by census tract. A DAC is defined as the top twenty-five percent scoring from the CalEnviroScreen. The CalEnviroScreen dataset is the output of a model created from twenty statewide indicators for pollution burden and population characteristics. Each census tract receives a score for each indicator, which are ranked from highest to lowest. The population characteristic score for sensitive populations and socioeconomic factors are averaged. The pollution burden score contains the average of exposures and one-half of the average of environmental effects because the environmental effects make a smaller contribution to the pollution burden. The formula multiplies the pollution burden by the population characteristic to create the CalEnviroScreen score (CalEPA 2018).


Figure 16 CalEnviroScreen 3.0 Scoring and Model (CalEPA 2018)

This data was added to ArcGIS Pro and used as a file geodatabase, which was paired with the census tract level ZEV 2017 dataset as two layers on the same map. Each layer displayed the respective information for 2017 ZEV and DAC areas. The 2017 ZEV layer was made transparent and is the top layer while the DAC layer is a full-colored bottom layer.

## 3.3. Intended Users

The intention of this thesis was to create a pilot project for a Web GIS Story Map that can be used to understand the progress towards the state mandates and goals for alternative fueled vehicles. The initial Story Map was created and tested by internal CEC staff to determine the usefulness of using a Story Map as a communication tool with the public. In addition to introducing staff to Story Maps and creating a dialogue for enhancements of the current Story Map was started. This second phase will include additional maps and narrative for the future audience. This unique group of future users will range from the general public and stakeholders to other state agencies and car manufacturers as the Story Map will be publicly available on the CEC's website and linked from the transportation forecast page. These users will have the ability to see a glimpse of the information within the 117-page report and selected historical background concerning alternative fueled vehicles without needing to go to several locations.

Once the Story Map pilot project was completed, internal staff were given a timeframe to view the Web GIS Story Map, interact with the maps and images, and then asked to take a survey on their experience. The survey asked their name, previous knowledge of alternative fuels and the state goals and mandates, the user experience viewing the Story Map, and whether they learned anything new or relearned something after viewing the application. A sample survey is included below in Table 3. A minimum of 10 staff and a maximum of 25 staff will take the survey.

## 3.4. Application Evaluation

### *3.4.1. Subjects*

The intended users for this pilot project are internal CEC staff, namely the staff within the Energy Assessments Division that focuses on the Transportation Energy Demand Forecast. These subject matter experts develop the transportation forecast report and have key knowledge about the public message surrounding the alternative fueled vehicles progress and future. These staff were identified as the survey subjects to view this Story Map and provide feedback based on the ease of use, optimal flow of the narrative, and overall layout and understanding of the

Story Map. Sixteen staff members were asked to complete the survey. Staff had a range of knowledge and skills about the transportation report, Web GIS Story Maps, and changing technologies. These staff were identified as test subjects based on their length of experience; obtaining a wide range of subjects. One test subject performs the duties of the lead role while another subject is a student. This range of knowledge and skills provided an overview of the different levels of knowledge that may be seen in the public for the future users.

### *3.4.2. Design of survey*

The survey was designed in Google forms as a simple ranking and binary survey that users will fill out after viewing the Story Map. The purpose was to gather feedback on the Story Map ease of use, flow, and overall organizational layout. Any comments and edits made will be implemented before presenting the Story Map to other CEC staff and management. The results of this survey are included as percentages to show the overall user experience.

Table 3. Survey Form Layout

| **Survey Question** | | **Possible Answers** |
|---|---|---|
| Before using this Web GIS map, what was your familiarity with the following? | | No knowledge<br>A small amount of knowledge<br>A moderate amount of knowledge<br>A significant amount of knowledge<br>A great deal of expertise |
| | Alternative fueled vehicles generally | |
| | Alternative fueled vehicle mandates in California | |
| | Alternative fueled vehicle California state goals | |
| | Web-based Story maps | |
| In general, how comfortable do you feel with new technology? | | Very comfortable<br>Somewhat comfortable<br>Neither comfortable or uncomfortable<br>Somewhat uncomfortable<br>Very uncomfortable |
| How well do the following terms describe this Story Map? | | Very well<br>Somewhat well<br>Neither well or poorly<br>Somewhat poorly<br>Very poorly |
| | Intuitive | |
| | Clear | |
| | Confusing | |
| | Disorganized | |
| | Engaging | |
| How appropriate do you think this Web GIS Story Map is for the following audiences? | | Not at all appropriate<br>Somewhat appropriate<br>Very appropriate |
| | The general public | |
| | Laypeople who understand the basics of alternative fueled vehicles | |
| | Policymakers and Legislators | |
| | Stakeholders | |
| | Other State Agencies (ex. CPUC and ARB) | |
| As a tool for communicating with the following groups, how do you think this Web GIS Story map compares to the Transportation Energy Demand Forecast Report? | | Much better<br>Somewhat better<br>Neither better or worse<br>Somewhat worse<br>Much worse<br>N/A – I am unfamiliar with the report |
| | The general public | |
| | Laypeople who understand the basics of alternative fueled vehicles | |
| | Policymakers and Legislators | |
| | Stakeholders | |
| | Other State Agencies (ex. CPUC and ARB) | |
| **Demographics** | | **Possible Answer** |
| What is your age | | 0-18<br>19-24<br>25-34<br>35-44<br>45-54<br>55-64<br>65+ |

| | |
|---|---|
| Gender | Female<br>Male<br>Prefer not to say<br>Other |
| What is your race/ethnicity (select all that apply)? | White/Caucasian<br>Hispanic/Latino<br>Black/African American<br>Asian<br>Prefer not to say<br>Other |
| What is your highest level of education? | High school or less<br>Vocational/trade school<br>Some college<br>Bachelor’s Degree<br>Masters/JD<br>PhD<br>Prefer not to say |
| What is your profession | Open-ended answer text box |
| Email address (note- this will only be used for personal communication and will not be shared with any 3rd parties) | Open-ended answer text box |

### *3.4.3. Time involved in testing*

Users had access to the Story Map to view the narrative, maps, and infographics. The entire survey testing took approximately two weeks to select internal staff for the survey, view the Web GIS Story Map, conduct the survey, and compile the results. The Cascade template provides a logical flow to the story to guide the users throughout the storyline as intended. The users were instructed to follow the original flow of the story and provide feedback with their experience. The Story Map took on average fifteen minutes to scroll through, and staff were asked to spend approximately fifteen to thirty minutes reviewing the Story Map before completing the survey.

# Chapter 4 Results

## 4.1. Overview

The pilot Story Map was created using ArcGIS Pro, ArcGIS Online, and Esri Story Map Builder. Several datasets were used to create file geodatabases and web layers in ArcGIS Pro for publishing to ArcGIS Online. Once the maps were created, they were integrated into the Story Map web application and paired with narratives and supporting infographics and charts.

## 4.2. Maps

As mentioned before, several maps were created to illustrate the story of the alternative fueled vehicles. The ZEV datasets were used as the foundation to create the maps and serve as the supporting layer for the DAC and income level maps.

The maps were constructed by creating the layers in ArcGIS Pro. The datasets were symbolized and then shared as web GIS layers to ArcGIS Online (AGOL). Once the layers were added to AGOL, the layers were added to maps and the individual maps were created. Each layer was re-symbolized for the online environment including selecting the appropriate basemap, setting zoom levels and transparency, and creating pop-up boxes. Each layer had its own pop-up box that contained detailed information within the layer specific for the purpose of that map.

### *4.2.1. ZEV 2010*

This map was created as two maps, one for the county and one for the census tract level. The ZEV 2010 County layer was added to the map, symbolized as a choropleth map with natural breaks classification, and then the pop-up was configured to show the county name and the vehicle count. The census tract maps were created in the same manner, by adding the 2010 ZEV Census Tract layer, symbolizing the layer, and configuring the pop-up to display the census tract name and vehicle count. For each of these layers, the counties and census tracts without a vehicle were omitted or greyed out. This helped illustrate the lack of vehicles in those areas of California. The mouse scroll function was used to move from the county level to census tract level map. To guide the user to the important areas, copies of the map were created in the immersive section to show the user the concentrated areas of vehicles in Los Angeles and San Francisco. The narrative boxes were added to provide context to the user as shown in Figure 17 below and described the map content.

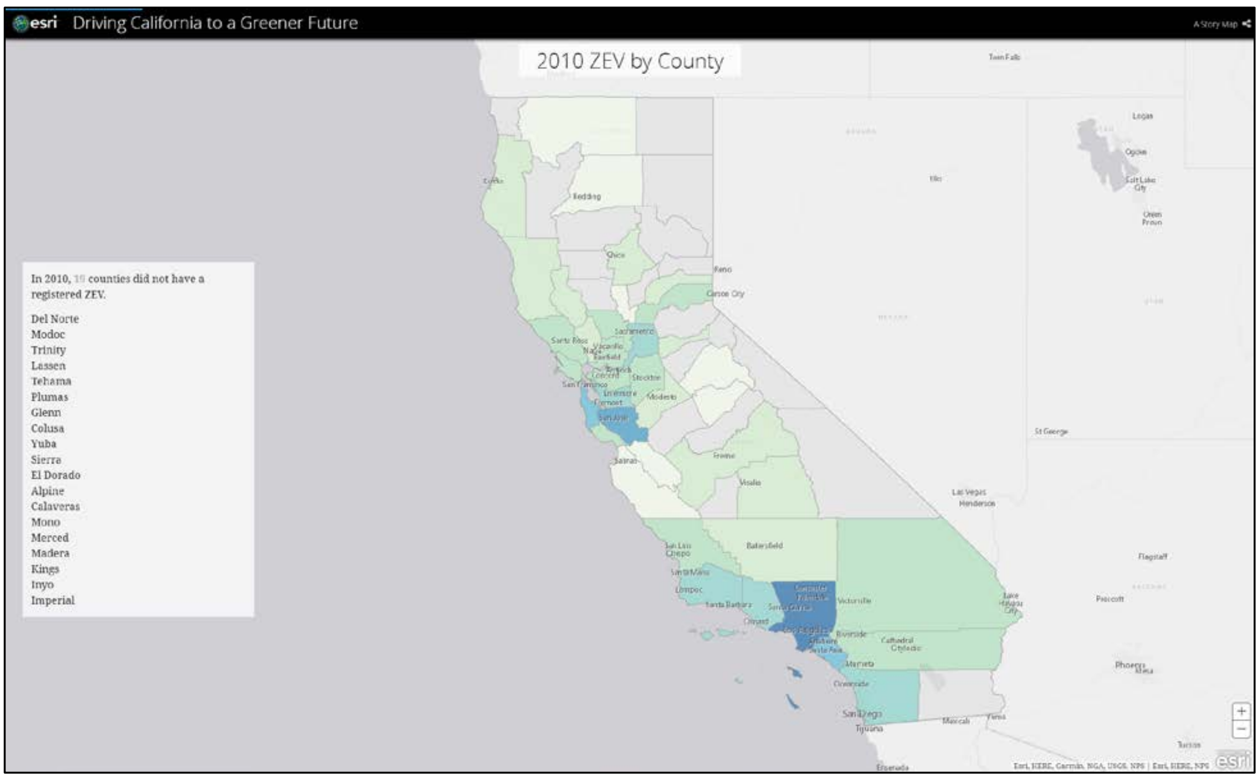


Figure 17 ZEV 2010 Immersive Map and Narrative Box

*4.2.2. ZEV 2017*

This map was created as two maps, one for the county and one for the census tract level. The ZEV 2017 County layer was added to the map, symbolized as a choropleth map with natural breaks classification, and then the pop-up was configured to show the county name and the vehicle count. The census tracts that did not have a vehicle were omitted similar to the 2010 map. The mouse scroll function was also used to move from the county to census tract map. To guide the user, copies of the maps were created to build the immersive section that showed the user where the concentrated vehicles were. The narrative box and colors were used instead of traditional map legends to focus the user on the main point for the map. As shown in Figure 18 below, the focus was a large number of ZEV registrations as displayed with the dark blue text. By applying the colors to the text, the user can gain the information necessary to draw conclusions without distracting from the map content (Esri 2017).

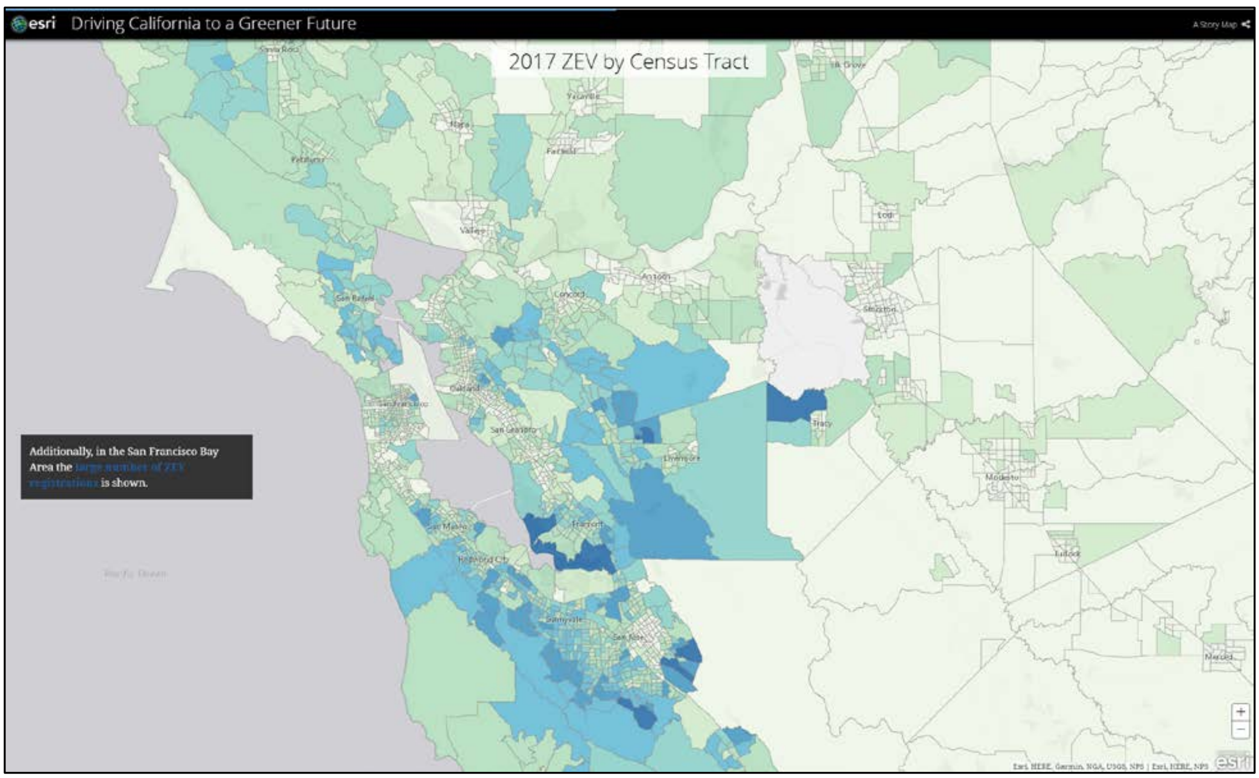


Figure 18 ZEV 2017 Immersive Map with Narrative Box

*4.2.3. Heat Map*

The 2010 normalized heat map tile web layer was added to a map with the basemap. Since this dataset was normalized to the same scale as the 2017 dataset, the blue variation was shown on the map as a single color. The 2017 heat map showed the typical heat map. The “slider” function was used to horizontally swipe between the 2010 and 2017 maps to really show the differences. Narrative boxes were used to highlight the increase of ZEVs between 2010 and 2017 using the colored text to describe the concentrated areas.

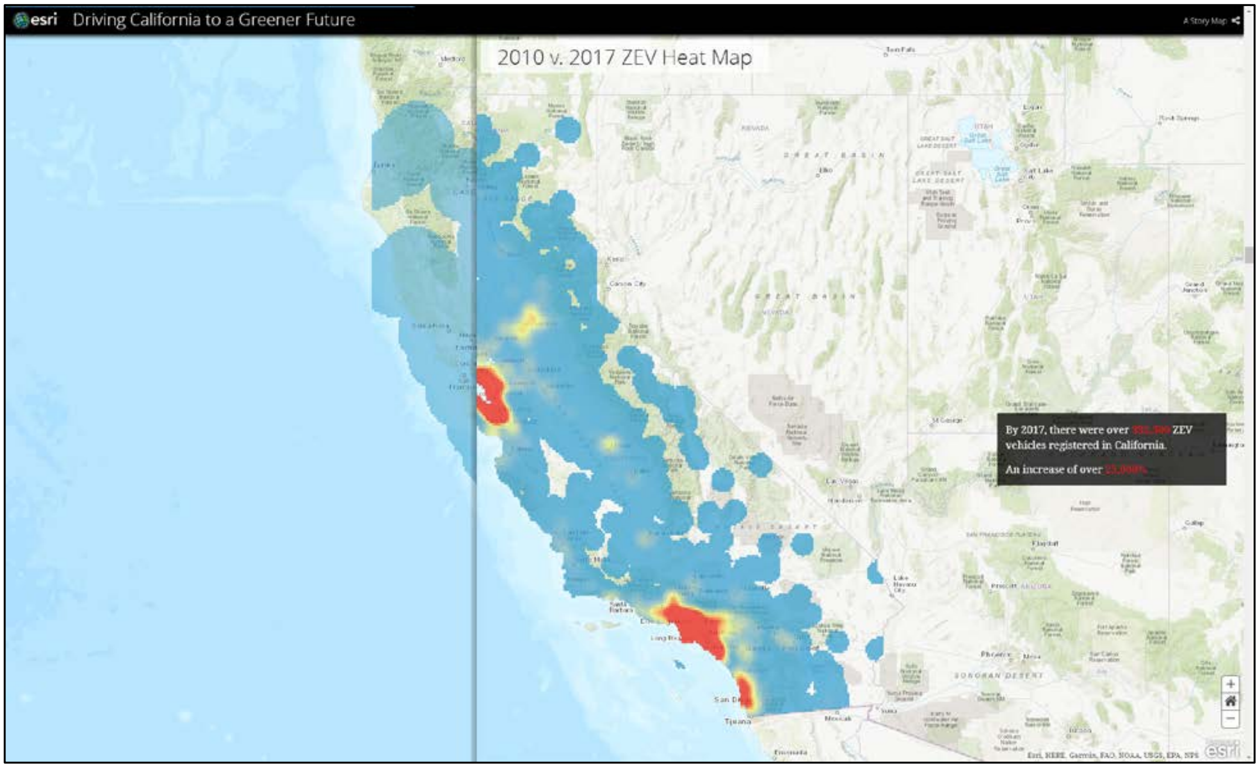


Figure 19 Heat Map Slider View

*4.2.4. EV Charging Stations*

The EV charging stations web layer were added to the map, and the appropriate basemap was selected. The comparison of streets and roads were the priority for this map, so the basemap containing roadways was used to illustrate the locations of EV chargers near major cities and along the major roads in California. The narrative box and colored text were used to inform the user that the purple dots on the map were electric vehicle chargers and provide context. Additional concentration level maps were used to show the areas of Los Angeles and San Francisco when the user continued to scroll. The pop-up box was configured to show the user the location name and charger type when selected.

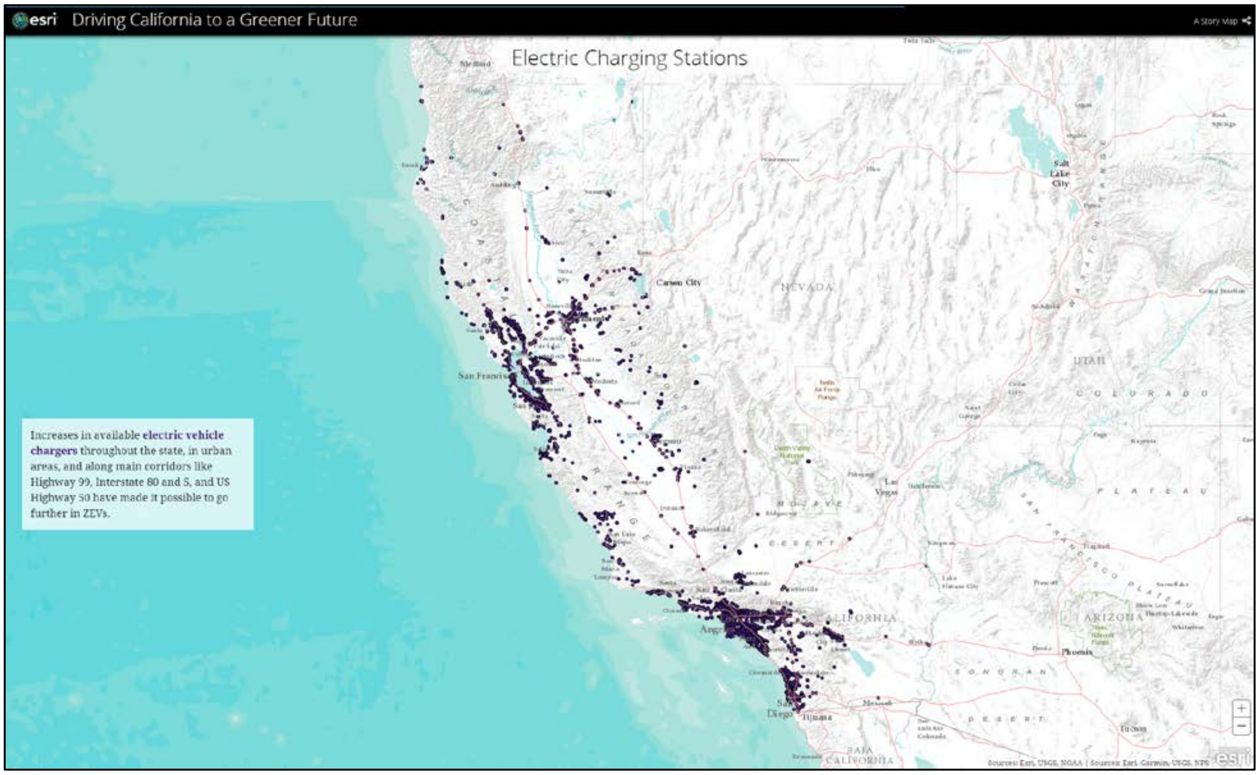


Figure 20 Electric Vehicle Charging Stations Immersive Map

*4.2.5. Low Income ZEV*

The ZEV income layer was added along with the low-income layer. The ZEV layer was symbolized as a choropleth map with natural breaks classification and a pop-up that contained the census tract number, the vehicle count, income for that census tract, and the statewide median household income percentage for the census tract. A separate layer, Low income, was added and symbolized to show the census tracts that were under eighty percent of the statewide median income. This layer was not selectable and was used as a supporting layer since the data was joined to the ZEV layer.

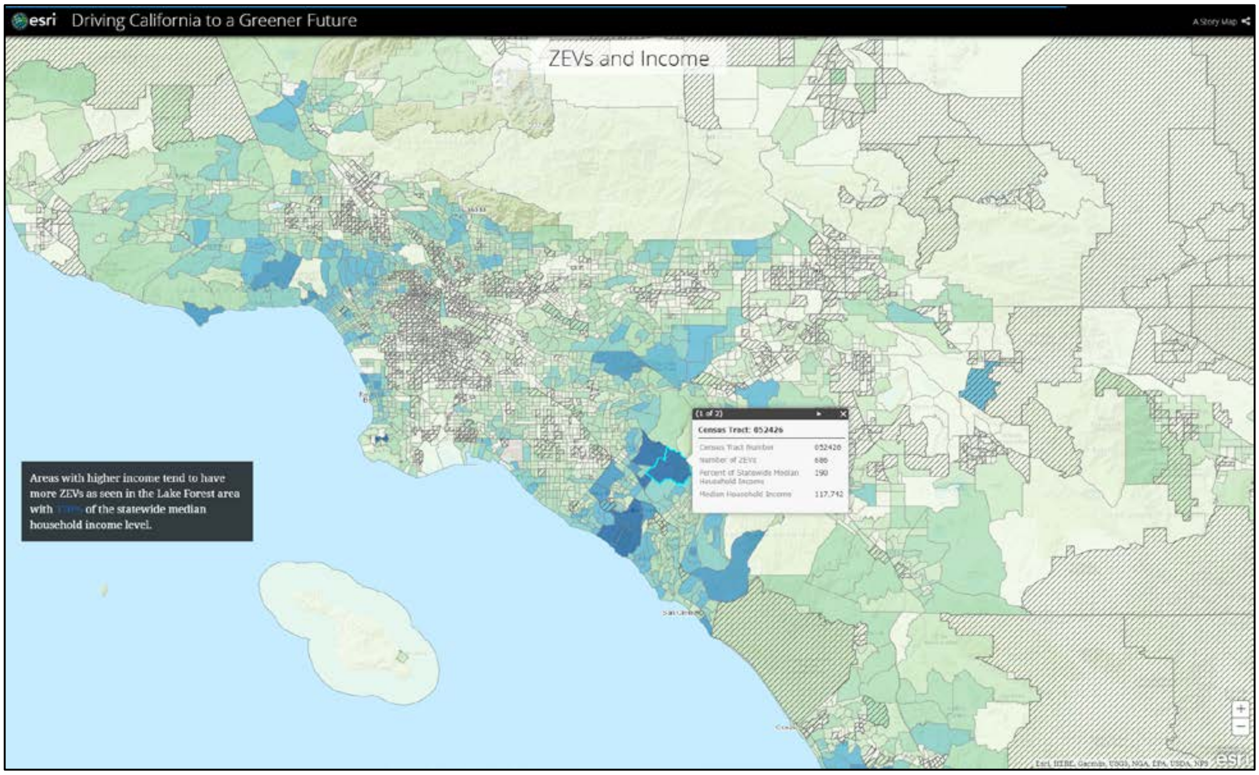


Figure 21 ZEV and Income Immersive Map

### *4.2.6. DAC ZEV*

The DAC and ZEV 2017 web layers were added to a map. The DAC layer was the bottom layer, and the ZEV 2017 layer was made transparent and placed on top. The DAC layer was symbolized as a choropleth map with an equal interval classification for ten-percent of the DAC score. Due to the two color ramps, green-blue for the ZEV 2017 and a red-green for the DAC layers, the transparency allowed the color concentrations to highlight the extremes of the map. A bold, dark green highlighted the lower DAC and higher ZEV areas. Conversely, the high DAC and low or no ZEV concentrated areas were bright red since the ZEV layer that did not contain vehicles was not colored, and the low areas were light yellow/green in color. The pop-up was configured to show the census tract name, vehicle count, and CalEnviroScreen score.

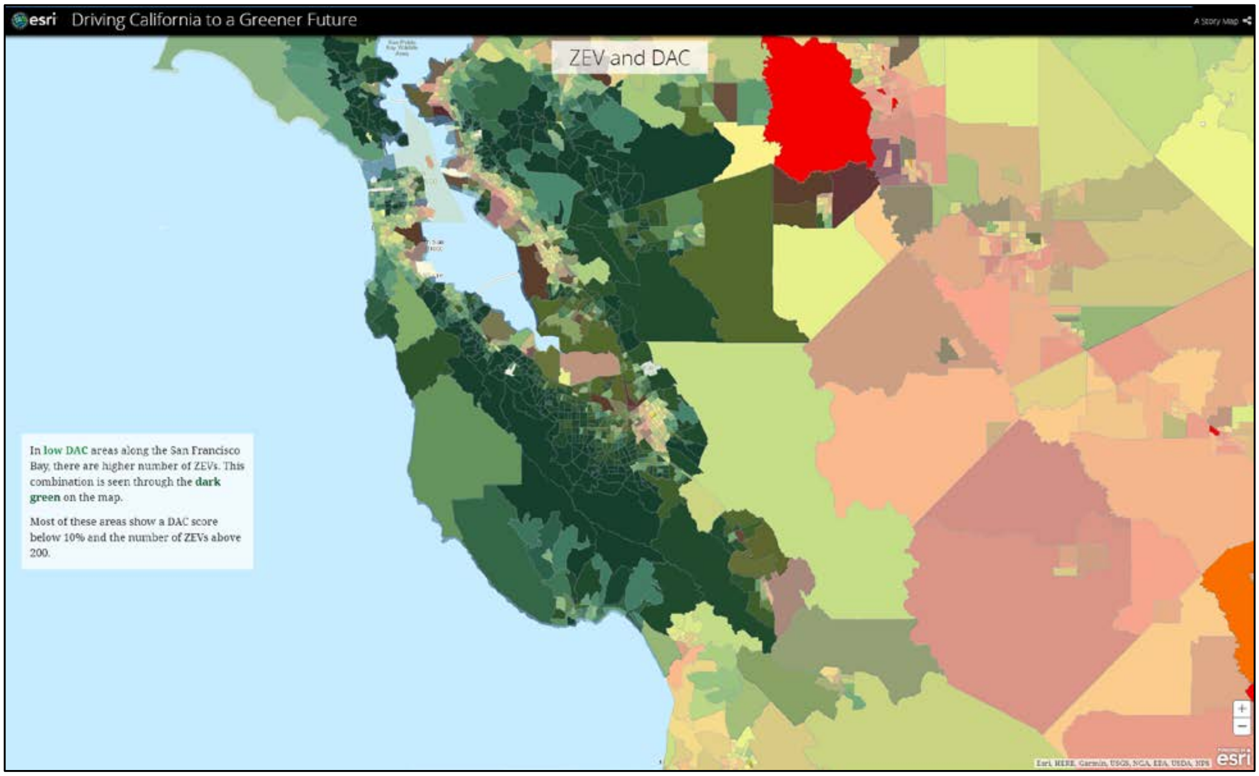


Figure 22 ZEV 2017 and DAC Immersive Map

## 4.3. Infographics

Several infographics were created to pair with the immersive section maps and narrative text in the Story Map. These infographics were created in Adobe Illustrator from a starter file downloaded from Freepik. The colors used were the color scheme from the CEC with blue, green, and orange as the primary colors. This provided a cohesive look across the Story Map and a smooth transition from narrative text, immersive sections, and infographics. Once created, these infographics were added to the Story Map through the Esri Story Map Builder as .png files.

### *4.3.1. Main infographic*

The main infographic for the Story Map details the summary statistics, and major points about the alternative fueled vehicles. The sections relevant to each major point were highlighted, and the remaining infographic was greyed out to emphasize the point being made similar to

Lutz's Oceanic Blue Carbon infographics. These graphics were then used in the Story Map as an immersive feature in which the user scrolls through and the graphic changes with each point. Each section was created as a separate .png file to be added to the immersive section. This allowed the new infographic highlighted area to appear and the narrative box to scroll with the mouse scroll.

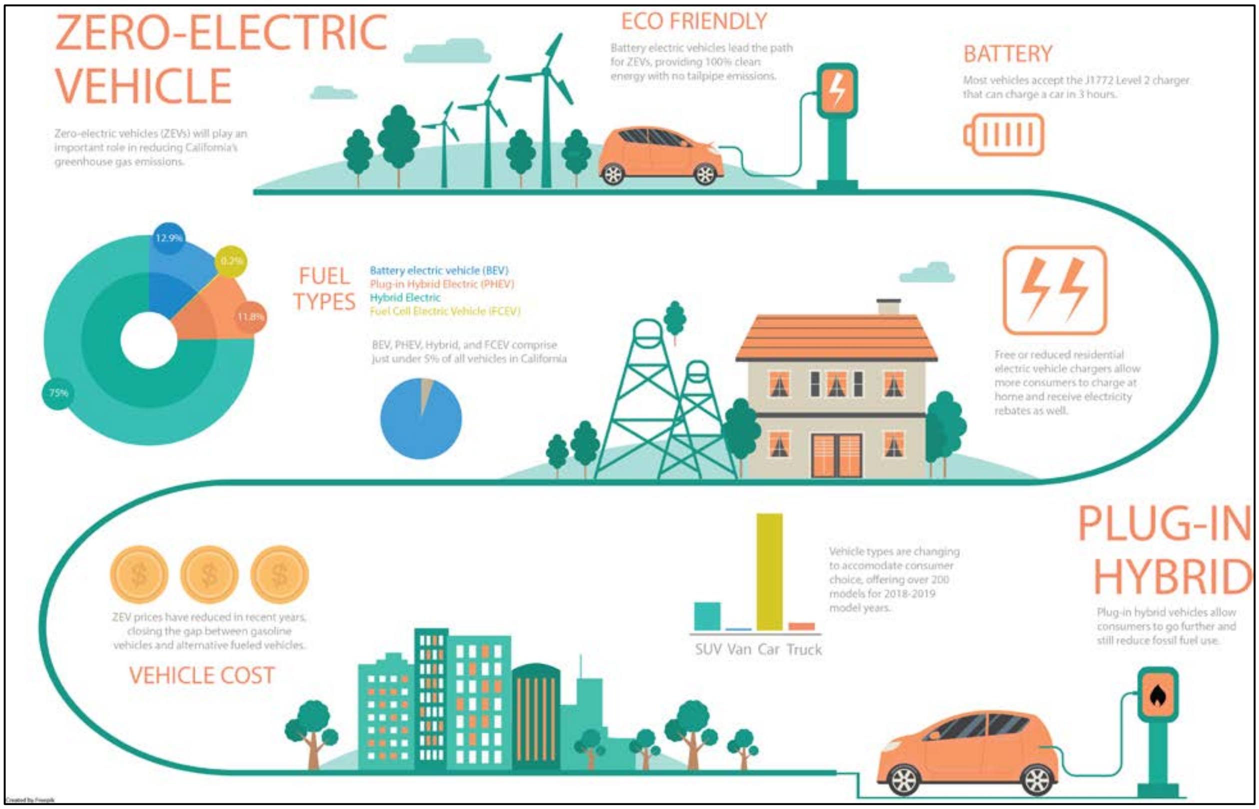


Figure 23 Story Map Infographic


Figure 24 Story Map Infographic Highlighted Area

*4.3.2. Supporting Infographics*

The other infographics, comparison of vehicle counts (Figure 25) and the vehicle manufacturer fuel types (Figure 26). These were added within the text line of the narrative sections, as they did not need to be full-page immersive sections.

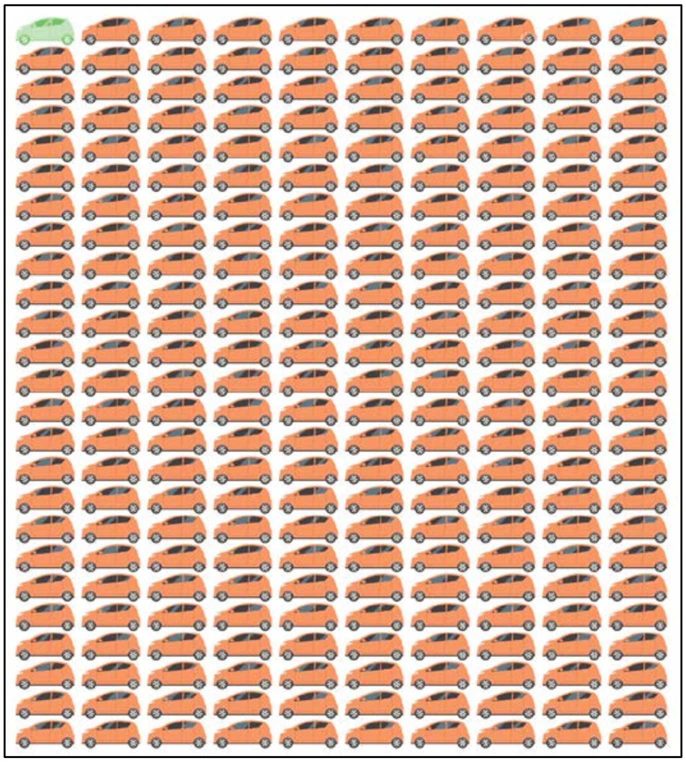

Figure 25 Vehicle Comparison Between 2010 and 2017

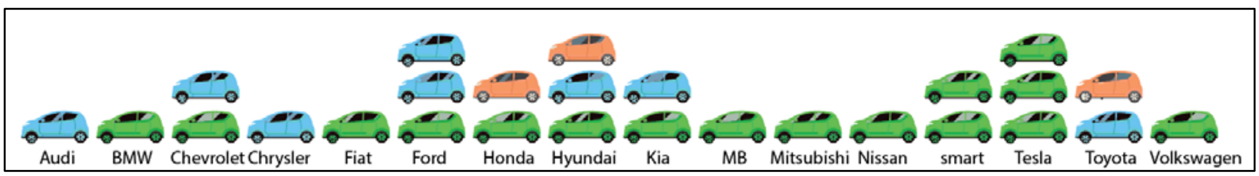


Figure 26 Vehicle Manufacturer Fuel Type Infographic

## 4.4. Supporting Documentation

Since the pilot project Story Map purpose is to guide internal staff along the narrative of alternative fueled vehicles, additional links were imbedded for further reading and understanding of the complex programs, mandates, and legislation. Once this Story Map is published for the public, they will be able to access these supporting links to gain access for legislative guides, programs with funding and charging station information, as well as incentives and local programs.

## 4.5. Survey Results

The results showed most users felt the Story Map was intuitive, clear, and organized. Users were engaged with the map and agreed that the Story Map was a good tool for communicating with the general public, laypersons, policy makers, and legislators, and stakeholders. Additionally, users liked maps and infographics that drew attention to sections of the Story Map. The overall feedback was positive, and users recognized the value to adding the Story Map as a complimentary component to the Transportation Energy Demand Forecast. The additional survey questions and results can be found in Appendix B Survey Results.

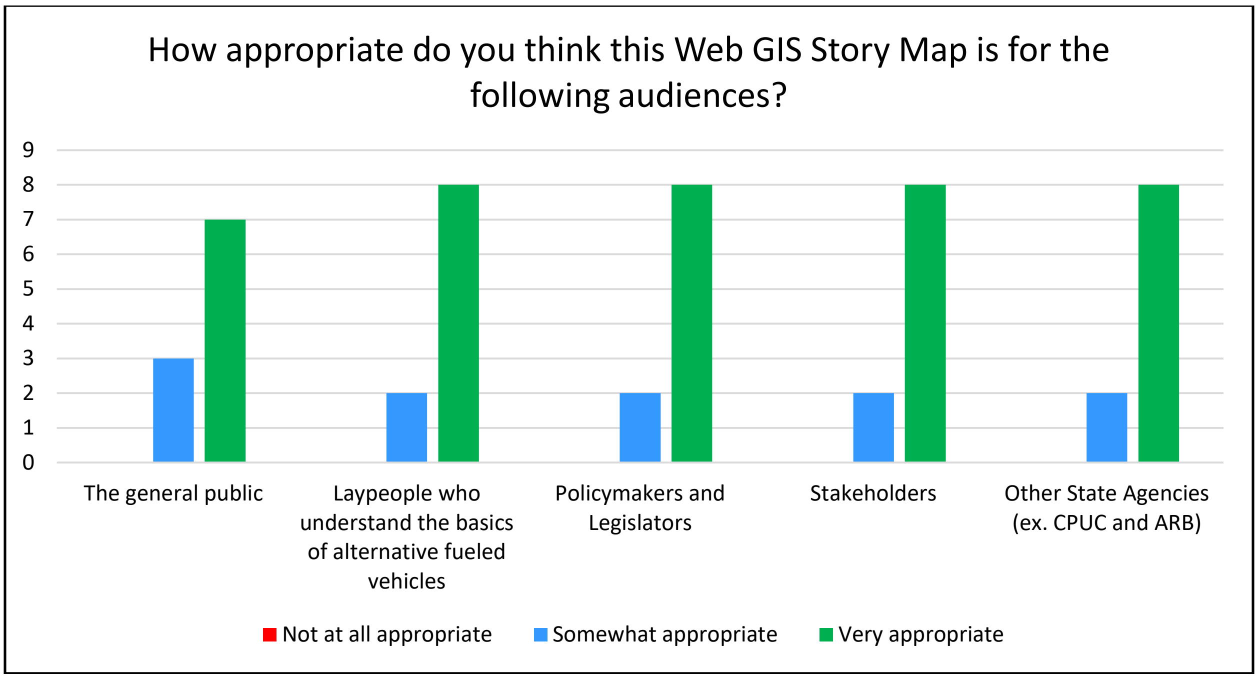


Figure 27 Survey Results

# Chapter 5 Discussion and Conclusion

## 5.1. Summary Description

The Story Map created was a well-organized, functioning Story Map that engaged CEC internal staff and introduced a new tool that could be used with the traditional reports. Staff agreed that the Story Map was easy to use and were excited for the final version to be deployed along with the Transportation Energy Demand Report in the near future.

## 5.2. Challenges in Development

While the initial goal was to create a Story Map for the general public, the timeframe limitations for the thesis project and the internal review process did not align. This thesis project was shifted to provide the first of two phases: phase one as the internal CEC staff introduction to Story Maps and review of the Story Map process, creation, and possibilities and phase two as the fully published, publicly available Story Map. In addition to the timeframe restrictions, ad hoc requests to add data layers, maps, infographics, and additional narrative sections were outside of the initial scope of the project. These additional pieces, however, can be added to phase two in the near future.

## 5.3. Limitations of the Project

The main limitation of this project was the confidentiality of the DMV dataset since it contains personally identifiable information (PII) and must remain confidential. This was noted, and the datasets were carefully managed to ensure proper data confidentiality occurred, and aggregation standards were met. An original goal of the project was to provide more granular, detailed information about the locations of alternative fueled vehicles. Since the exact locations were not allowed to be shared, census tract level grouping were made, however these enumeration units also provided vague ambiguity.

Another limitation was the availability of several datasets, including the statewide incentives for each utility, county, and city. This dataset does not exist and requires additional staff expertise to gather the information for the incentives and the jurisdictional boundaries for each component. This can be added as a phase two addition. The other main dataset was the manufacturer specific registrations. The intent was to analyze the locations of manufacturer and model specific vehicle locations; however, the registration database limited the vehicle fuel-type options, which limited this analysis. This can be evaluated for a future project.

## 5.4. Future Expansion and Full Deployment of the Application

This Story Map includes data and maps for 2010 as the base year and 2017 as the most current complete year at the time of this thesis start date (Fall 2018). Since 2018 was not yet completed, that year's dataset was not yet available. Each compete year's dataset can be added and updated in the spring of the following year to continue the narrative and provide the progress towards reaching the alternative fueled vehicle goals. In the enhanced phase of this project, a closer look into the spatial correlations of alternative fueled vehicles and poverty levels, demographic associations for race, and income inequality can be evaluated. Creating a baseline of data for 2010 allows the creation of 2011 through 2016 datasets to be compared as well as future datasets from 2018 to 2030. This detailed analysis will uncover the geographical links and discover new solutions for providing alternative fueled vehicles in California.

In addition, this Story Map will be used as a guideline for the creation of new Story Maps to support other reports. The design elements, techniques, and fundamental choices can be used as a framework to implement the creation of Story Maps for public facing reports and updates.

This will cut down on a considerable amount of time to create this process and insure that the GIS techniques are implemented accordingly to communicate science with the public.

## 5.5. Conclusion

The initial goal of this thesis project was to complete a Story Map for internal CEC staff and was successful. This introduction to web GIS Story Maps has provided staff with a new vision to create complimentary Story Maps to inform the public on the progress made on several state mandates and goals. The functionality of the Story Map was intuitive, easy to use, and provided a natural flow to the users. The ability to edit and update the maps when new data becomes available is also key since this will reduce staff time to create new Story Maps from scratch. This template can also be used to create Story Maps for other reports and content by the CEC in the future. The Story Map also provides historical context for the baseline years and the progress made to date and shows the historical trends.

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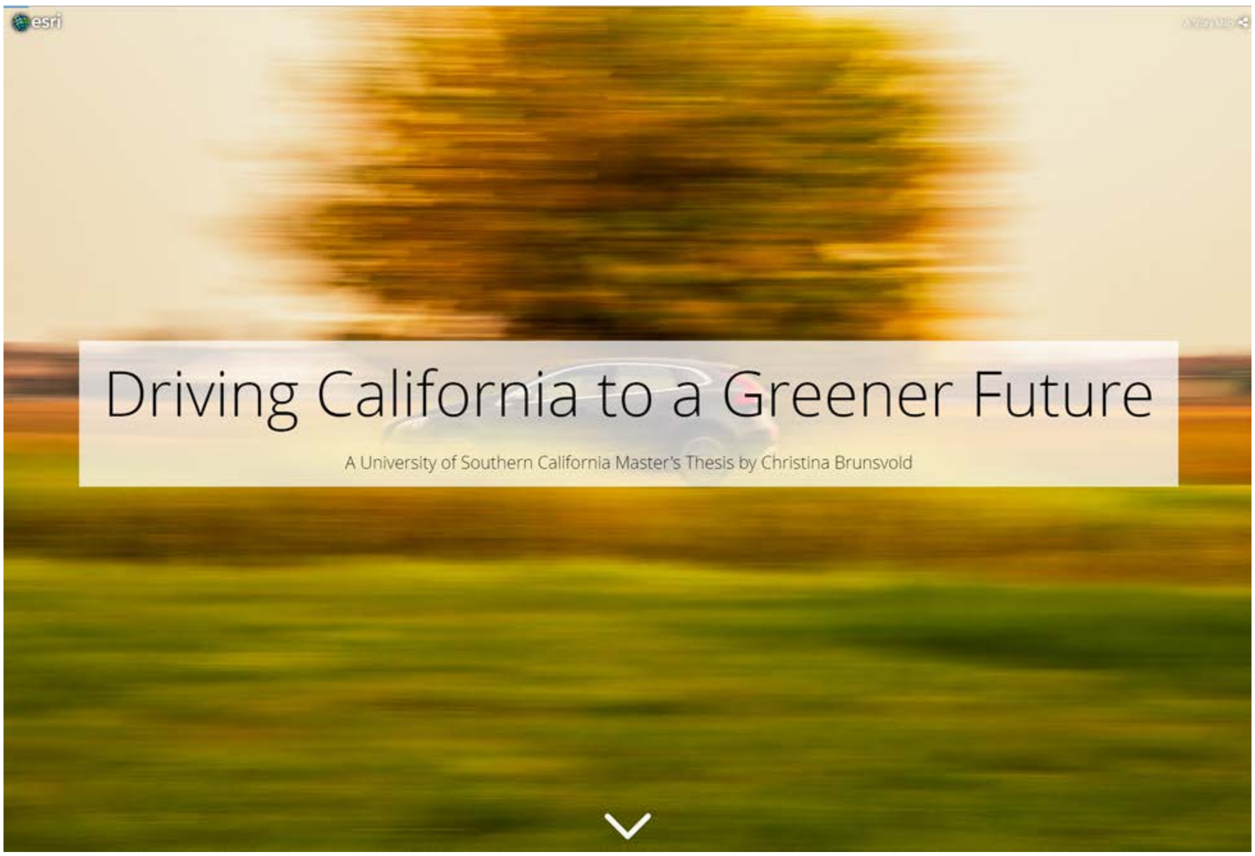
# Appendix A Story Map

The graphics and illustrations provided in this appendix are intended to provide context to the content within the Web GIS Story Map. The purpose of this section is to show the layout, narrative, infographics, and interactive web maps. Each web map contains pop-up boxes, interactive map functions, and map scales that allow the user to visualize the content within the Story Map.



## Overview of the project

California is leading the nation to reduce greenhouse gases (GHG) by increasing the number of alternative fueled vehicles. Since transportation-related energy is the single largest source of the state's GHG emissions, state mandates and legislation have been passes to reduce GHG levels.

In 2007, Assembly Bill 118 created the Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP) to develop and deploy alternative fueled vehicles to attain the state's climate change goals.

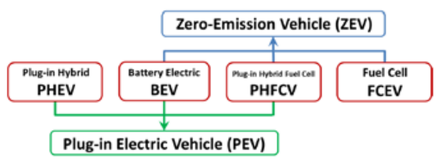
In 2012, Governor Brown issued executive order B-16-2012 to set a goal of 1.5 million zero-emission vehicles (ZEV) in California by 2025. In 2018, that goal increased to 5 million ZEVs by 2030 with executive order B-48-18.

In this thesis project, we will explore the use of an Esri Story Map to communicate the progress made towards these state mandates and goals and the future of alternative fueled vehicles in California. This Story Map will be used by internal California Energy Commission (CEC) staff. Once this project is completed, the Story Map can be enhanced to allow the public to identify the progress towards the state mandates and goals, determine if any geographical barriers exist, and visualize the future trends that are identified in the transportation forecasts.

Each section will guide you through the history of alternative fueled vehicles, and includes geographic representations of the alternative fueled vehicles, spatial analysis of the demographic and economic adoptions throughout the state, and immersive multimedia to narrate the status of the alternative fueled vehicle program. Click on each map to move the maps, click for more information, and dig deeper into the details.

## Alternative Fueled Vehicles

Alternative fueled vehicles have widely been called hybrid vehicles. While there are several alternatives to gasoline, the three main alternative fueled vehicles are hybrid, battery electric, and fuel cell electric. These vehicles are commonly referred to as zero-emission vehicles (ZEV).




Throughout this story map, we will refer to alternative fueled vehicles as ZEVs. For this thesis, the term hybrid will include hybrid vehicles and plug-in hybrid electric vehicles (PHEV).


## Historical Overview

Historically, most consumers drove gasoline powered vehicles. As vehicle choices have increased from the original manufacturers, the consumers have driven model choices, seating capacities, additional options, and fuel types.




Photo by Unsplash

With the introduction of Assembly Bill 118, the Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP) was created with the purpose of implementing programs that would reduce greenhouse gas emissions. This started the shift towards alternative fueled vehicles in the state for mass consumer use.

In 2010 there were just 3 models of ZEVs sold: the Toyota Rav4, Toyota Prius, and Tesla Roadster. The price for these vehicles was much higher than other gasoline based cars at the time, on average over $15,000.

In 2010, there were only 113 charging stations across the state. While this number may seem adequate for the 762 vehicles, it left more to be desired. People didn't want to be confined to their neighborhoods and worried about driving across the state in their vehicles without proper charging stations.

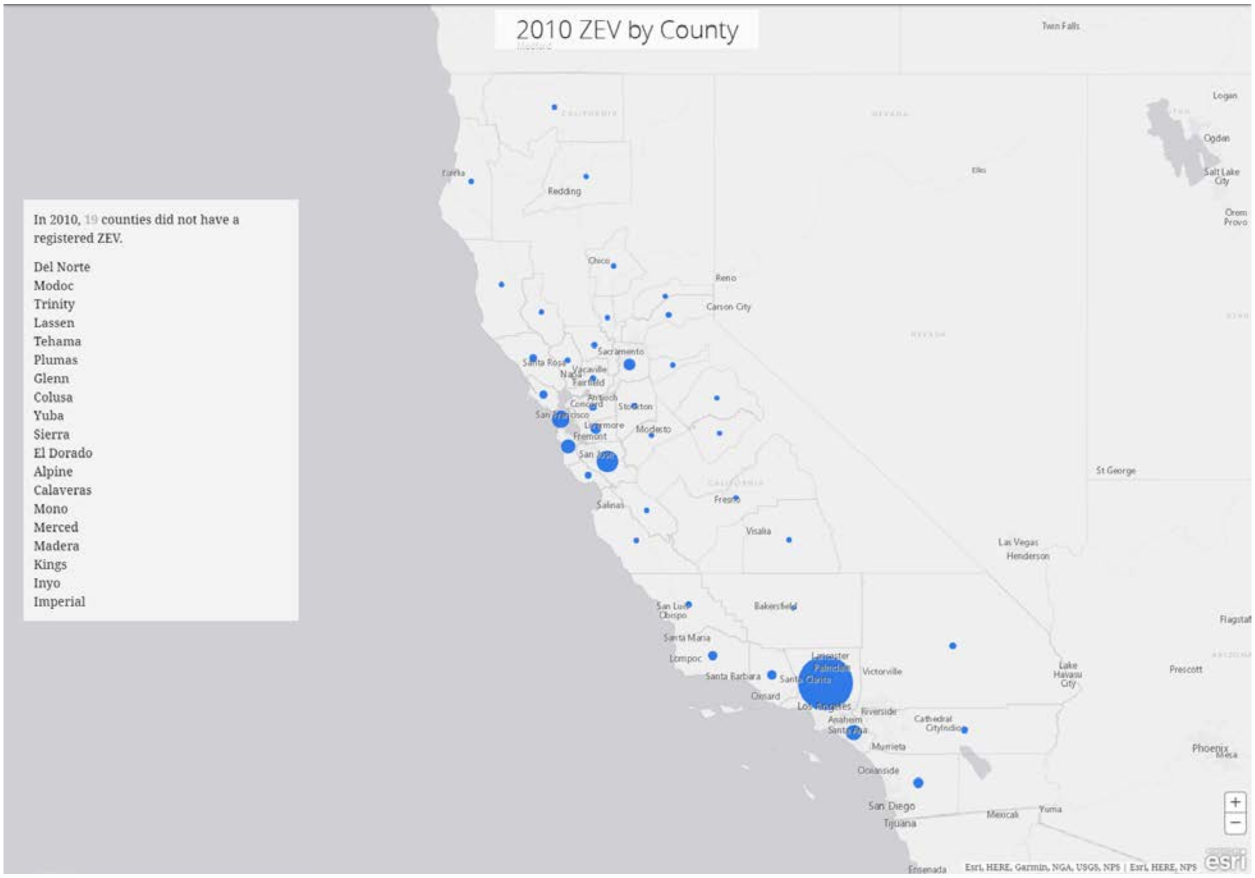
## Executive Order B-16-2012

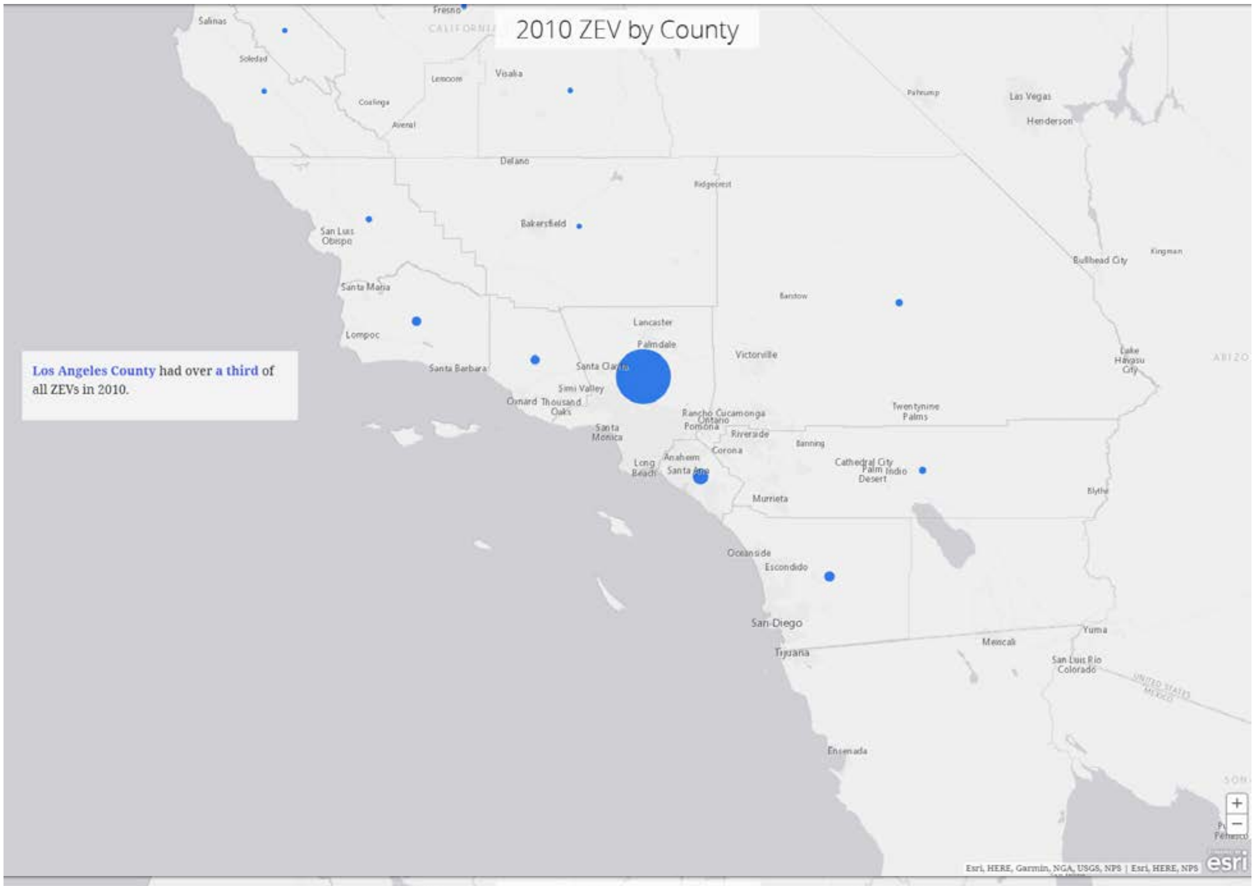
Following these great first steps, Governor Brown signed Executive Order B-16-2012 in 2012 which required several state agencies to set benchmarks, goals, and programs.

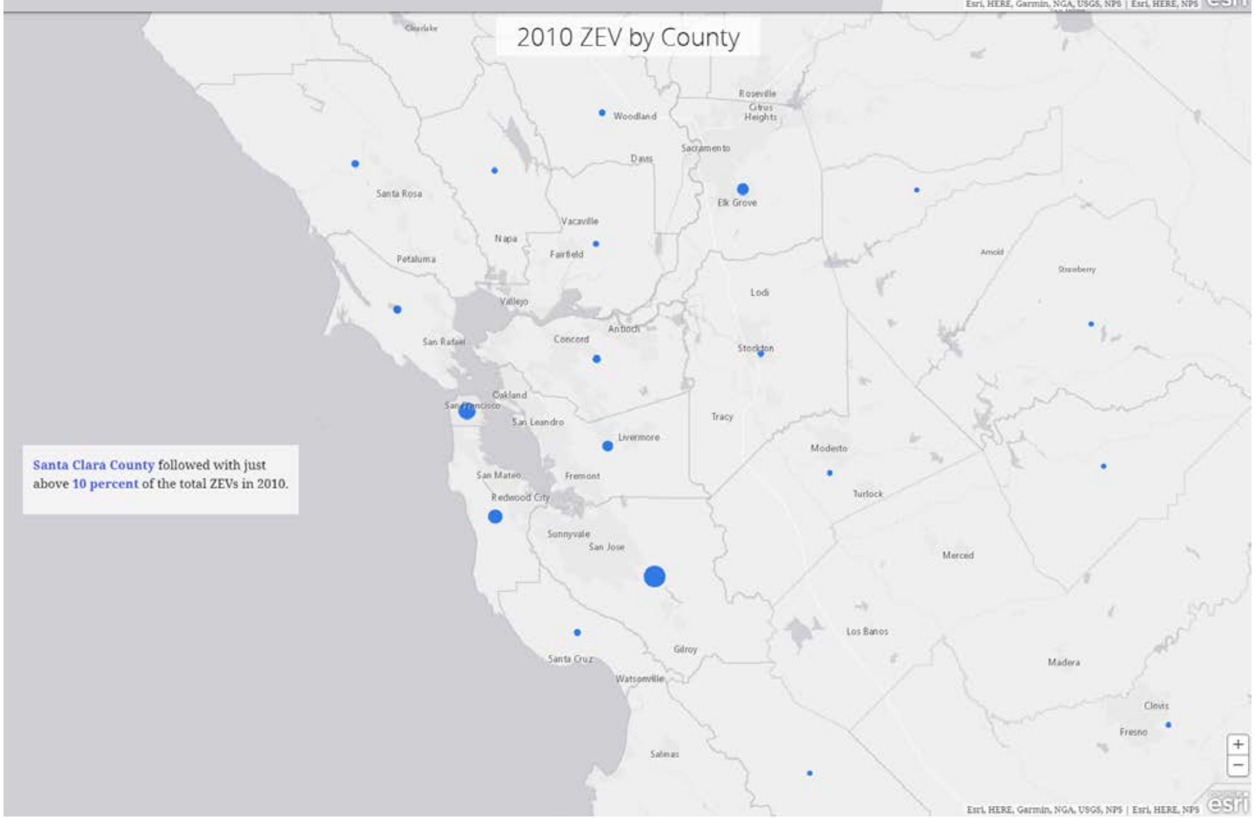
By 2015, the California Energy Commission (CEC), California Air Resources Board (ARB), and California Public Utilities Commission (CPUC) were required to expand the manufacturing sector, support metropolitan infrastructure, and contribute to academic institutions' research to support one million ZEVs.

By 2020, the state infrastructure must support one million ZEVs, the cost of a ZEV must be competitive with conventional vehicles, and the electric grid must support electric vehicle charging stations.

By 2025, infrastructure must support 1.5 million ZEVs.

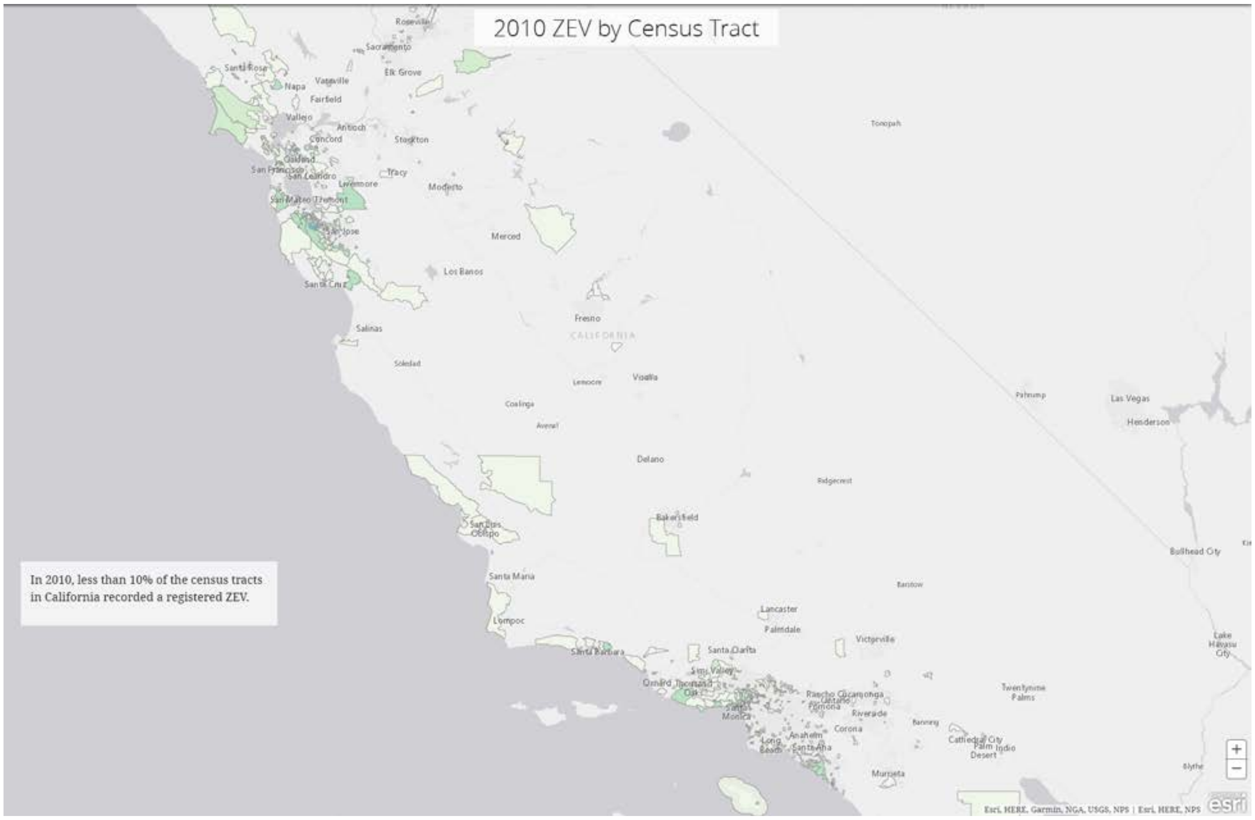

2010 ZEV by County
In 2010, 19 counties did not have a registered ZEV.
Del Norte
Modoc
Trinity
Lassen
Tehama
Plumas
Glenn
Colusa
Yuba
Sierra
El Dorado
Alpine
Calaveras
Mono
Merced
Madera
Kings
Inyo
Imperial
Redding
Chico
Reno
Carson City
Sacramento
Stockton
Modesto
Fresno
Visalia
Bakersfield
Salinas
Santa Maria
Lompoc
Santa Barbara
Oxnard
Victorville
Riverside
Murrieta
Oceanside
San Diego
Tijuana
Mexicali
Yuma
Las Vegas
Henderson
St George
Prescott
Phoenix
Logan
Ogden
Twin Falls
Esri, HERE, Garmin, NGA, USGS, NPS | Esri, HERE, NPS

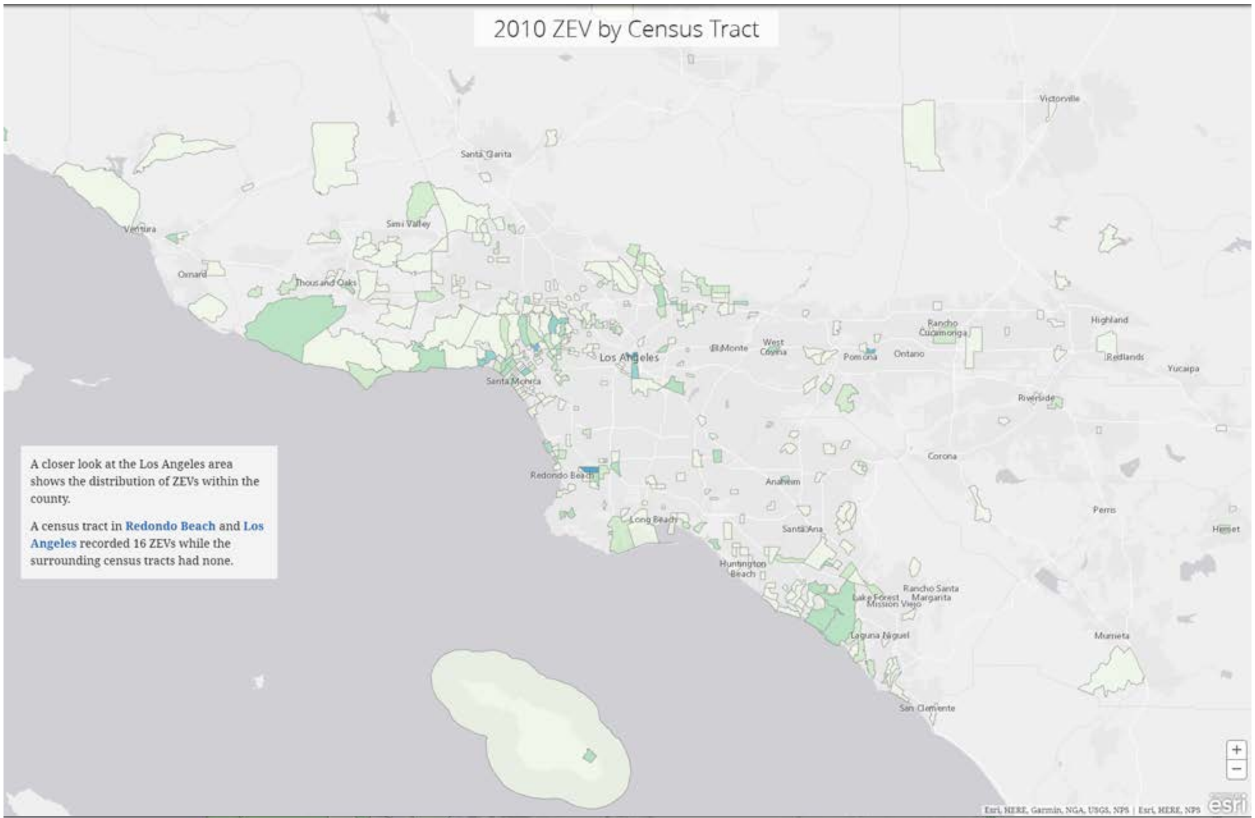

2010 ZEV by County
Los Angeles County had over a third of all ZEVs in 2010.
Esri, HERE, Garmin, NGA, USGS, NPS | Esri, HERE, NPS


2010 ZEV by County
Santa Clara County followed with just above 10 percent of the total ZEVs in 2010.
Esri, HERE, Garmin, NGA, USGS, NPS | Esri, HERE, NPS

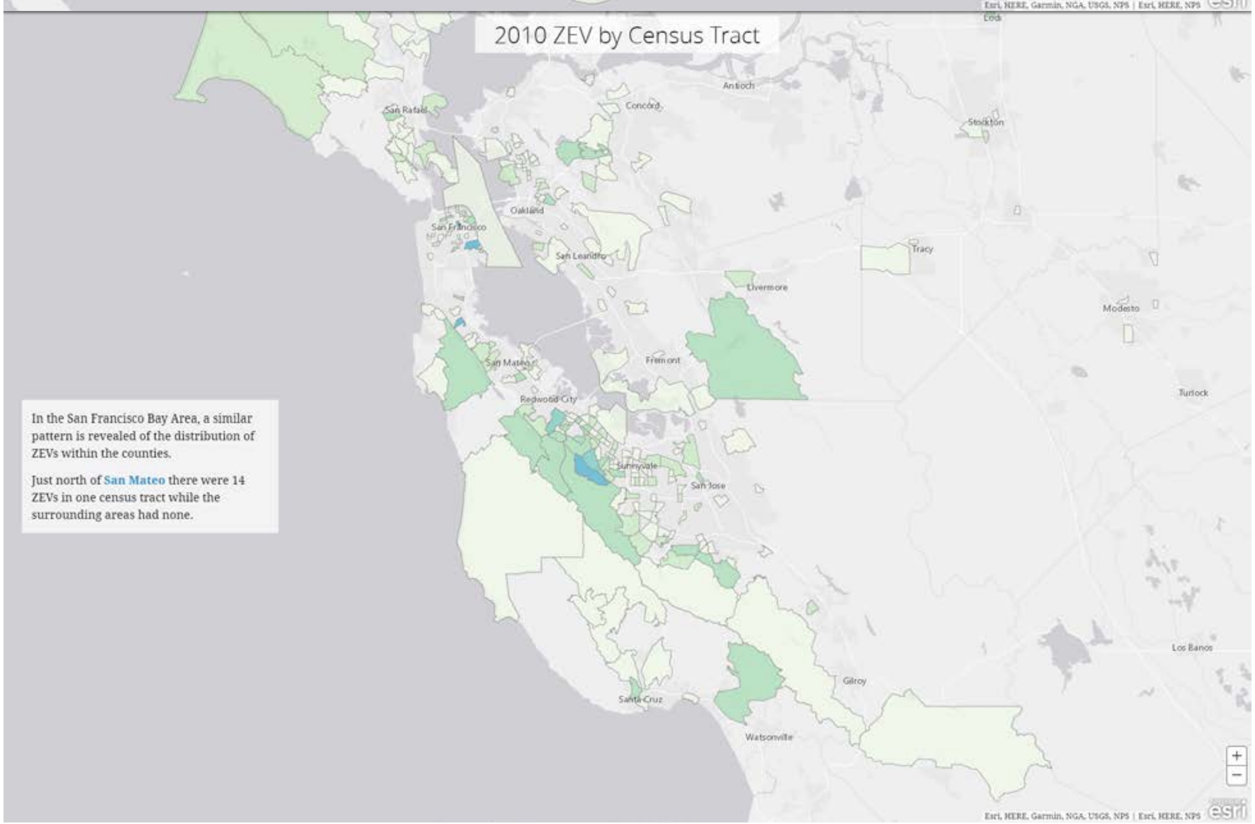
## A deeper look

While the overall goal is to support ZEV growth across the state, a more granular look into each county to show the growth within each census tracts provides a clearer picture.





2010 ZEV by Census Tract
A closer look at the Los Angeles area shows the distribution of ZEVs within the county.
A census tract in Redondo Beach and Los Angeles recorded 16 ZEVs while the surrounding census tracts had none.
Los Angeles
Santa Monica
Redondo Beach
Long Beach
Anaheim
Santa Ana
Huntington Beach
Ventura
Oxnard
Thousand Oaks
Simi Valley
Santa Clarita
Pomona
Ontario
Riverside
Corona
San Clemente
Victorville
Esri, HERE, Garmin, NGA, USGS, NPS | Esri, HERE, NPS

2010 ZEV by Census Tract
In the San Francisco Bay Area, a similar pattern is revealed of the distribution of ZEVs within the counties.
Just north of San Mateo there were 14 ZEVs in one census tract while the surrounding areas had none.
San Francisco
Oakland
San Rafael
Concord
Antioch
Stockton
San Leandro
Livermore
Tracy
Modesto
San Mateo
Fremont
Redwood City
Sunnyvale
San Jose
Santa Cruz
Watsonville
Gilroy
Turlock
Los Banos
Esri, HERE, Garmin, NGA, USGS, NPS | Esri, HERE, NPS

## Comparing 2010 to 2017

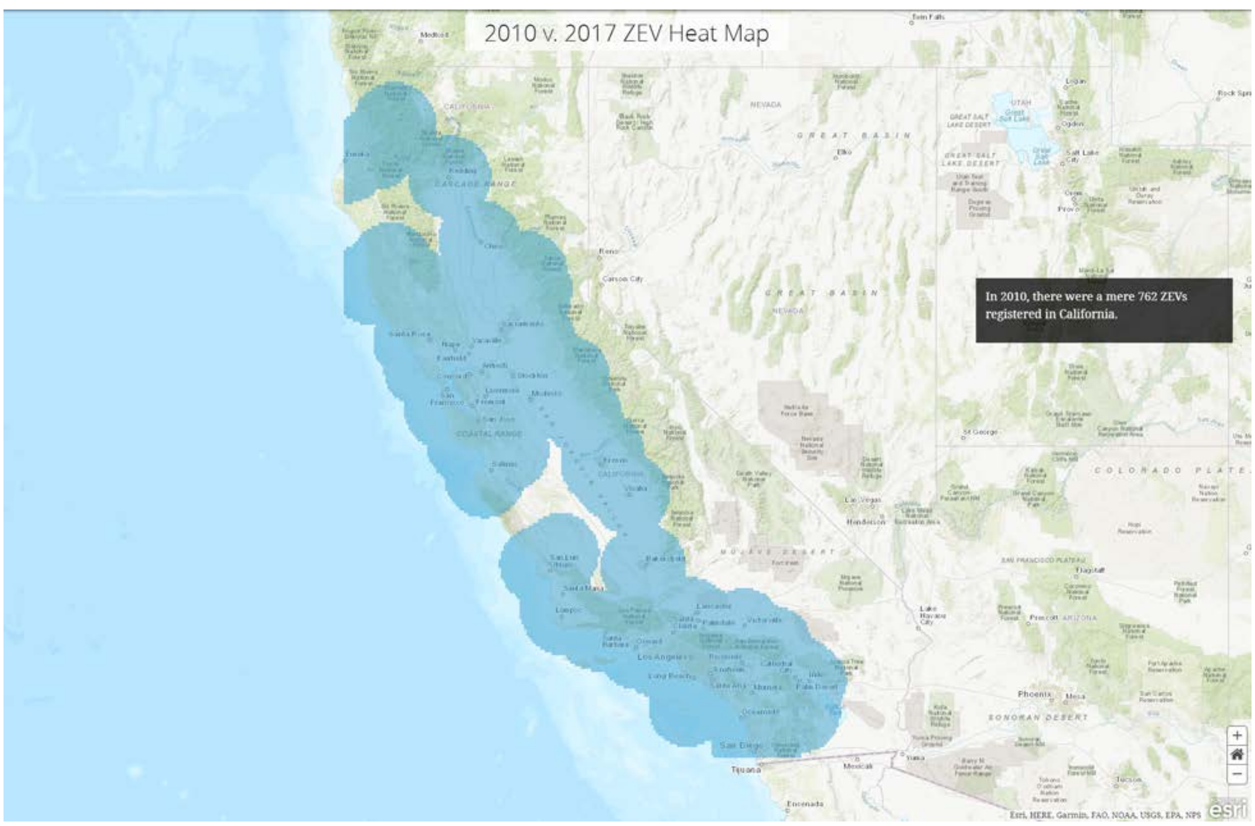
In 2010, there were only **113 charging stations** across the state. By contrast, at the end of 2017, there were over **5,100** charging stations across the state. This effort provided consumers with the option to drive along the major corridors and travel to new locations in their ZEVs.

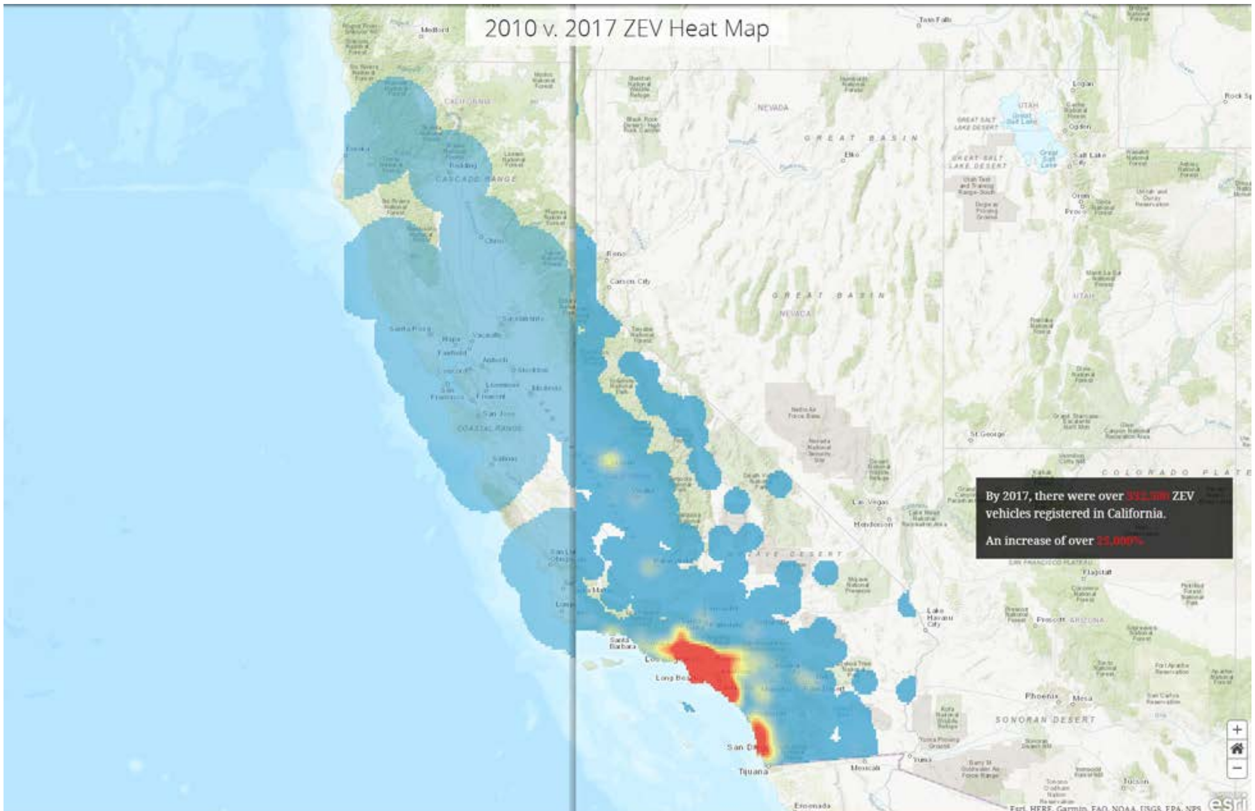
In addition to the increase in electric charging stations, there was a vast increase in the available models and manufacturers, which allowed for an increase in ZEVs. The availability of consumer choice, new vehicle styles, lower cost, and incentives have all played a role in the increase of ZEVs in California.

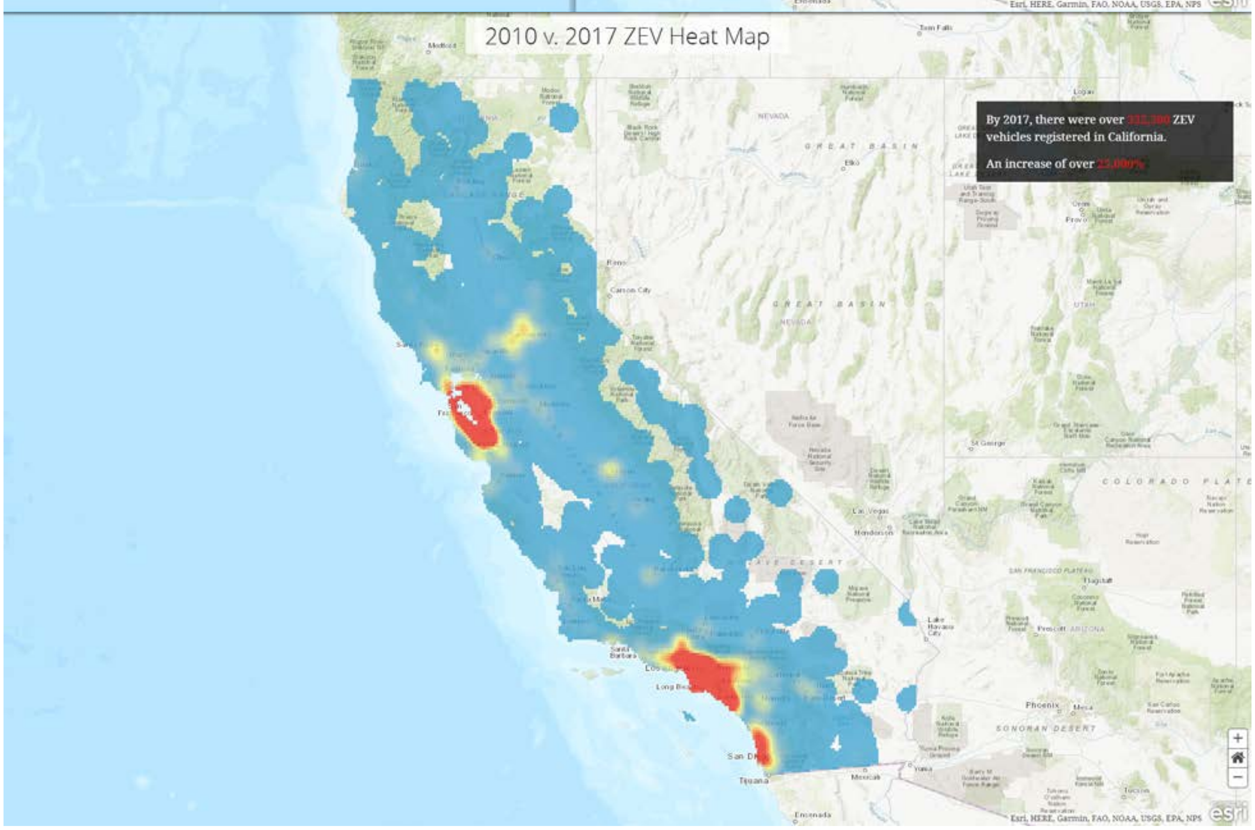
For comparison, the green car represents each vehicle registered in 2010, while the orange cars represent the vehicles registered in 2017. The explosion of growth can easily be seen here.

A comparison between 2010 and 2017 ZEV in California

A staggering comparison between 2010 and 2017 shows the large increase in registered ZEVs in California. Similarly though, we see the same concentrations in the Los Angeles and San Francisco areas.




2010 v. 2017 ZEV Heat Map
By 2017, there were over
ZEV vehicles registered in California.
An increase of over
Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS


2010 v. 2017 ZEV Heat Map
By 2017, there were over
ZEV vehicles registered in California.
An increase of over
Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS


## Current Trends

Historically, most consumers drove gasoline powered vehicles. As vehicle choices have increased from the original manufacturers, the consumers have driven model choices, seating capacities, additional options, and fuel types.

Photos by Unsplash

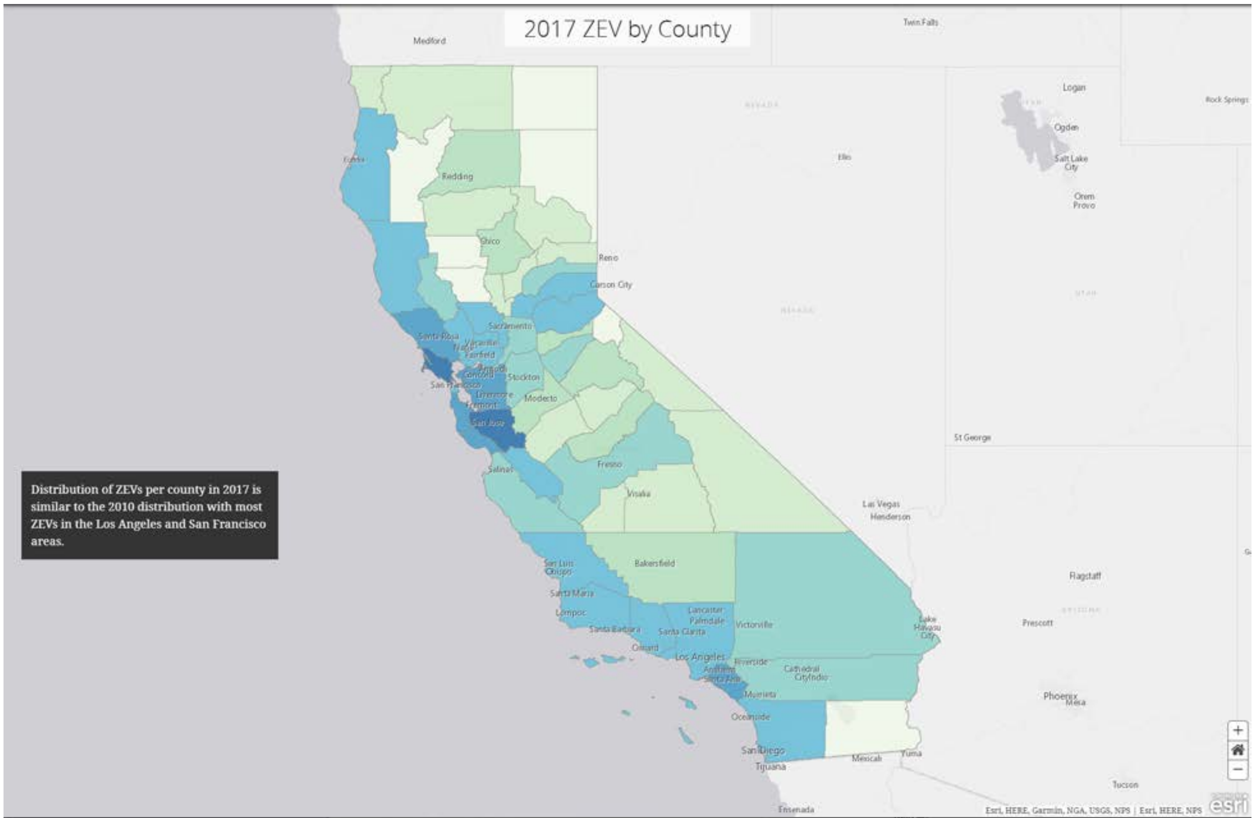
Currently, there are several state and local programs to promote ZEVs. Across the state, the California Vehicle Rebate Project (CVRP) is providing information about the eligible rebates for ZEVs. Locally, some cities and counties are providing additional incentives and resources to encourage consumers to purchase ZEVs.

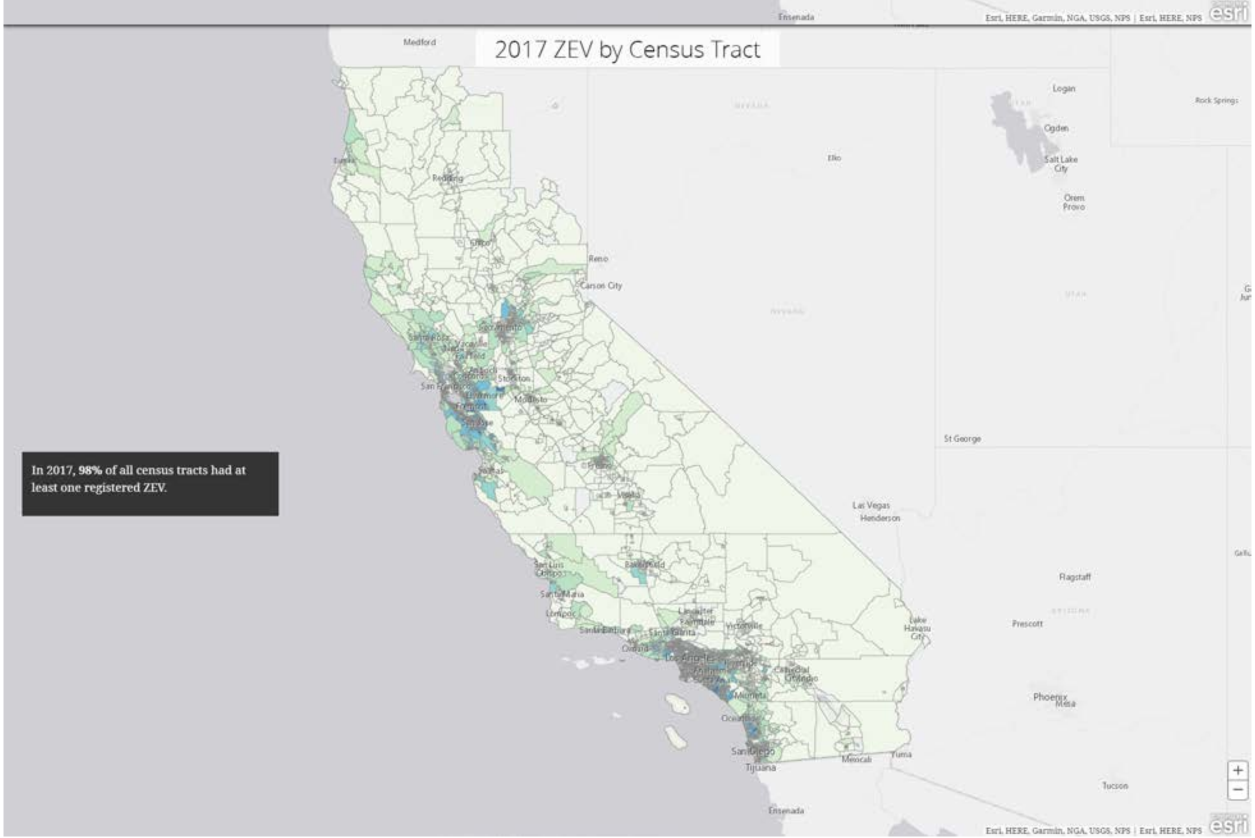
These efforts have produced enormous results - with **over 332,500 ZEVs** registered in California by 2017. The average consumer is more aware of the available incentives and rebates for ZEVs along with additional charging incentives from utilities and shopping centers.

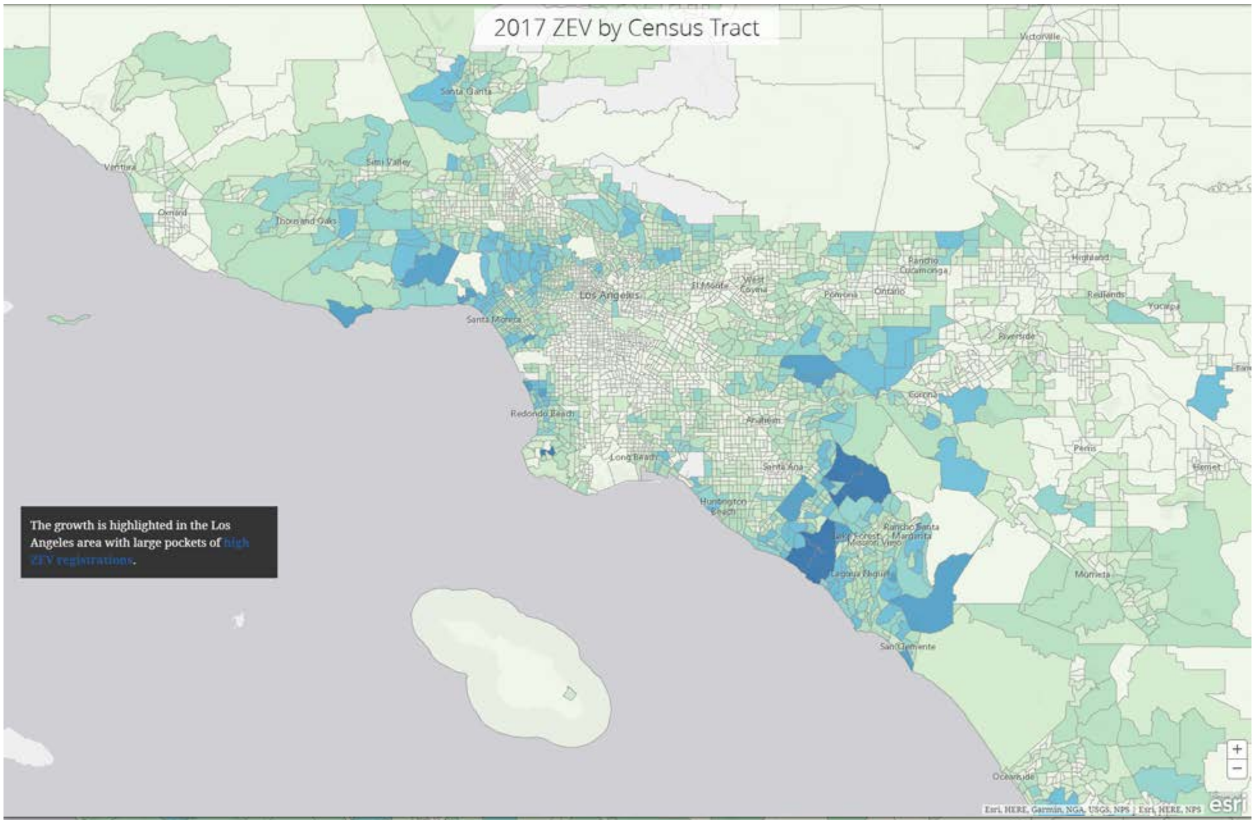
Vehicle price for ZEVs has also closed the gap between traditional gasoline vehicles since 2010, with the price difference at roughly $200 between a hybrid and gasoline vehicle. Several rebates are still available to bring the price down further. There are **27 models** available for the California rebate, and of those, 24 are available for an additional federal tax rebate.

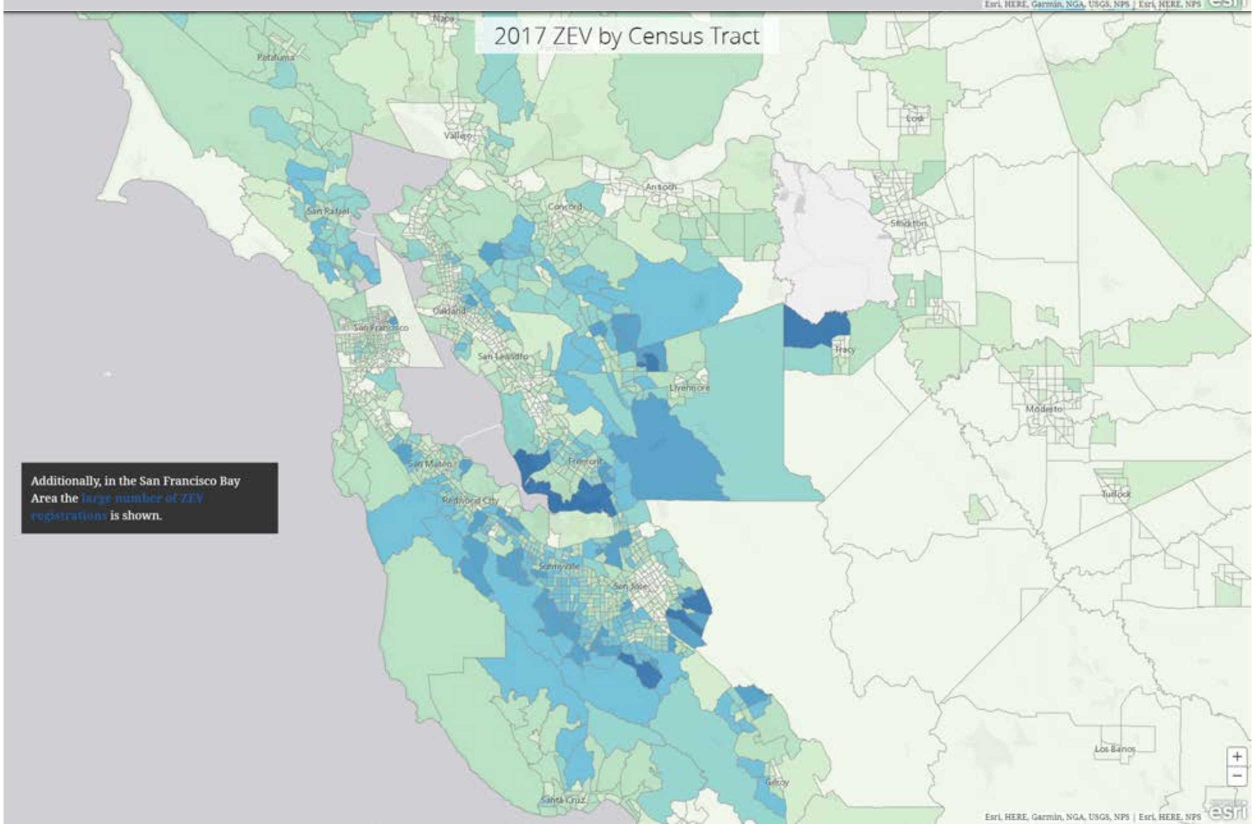

2017 models available for battery electric, plug in hybrid, and fuel cell vehicles.

The distribution of ZEVs across the state shows the increase of ZEVs in more populated counties like Los Angeles and Santa Clara, however all counties have at least one ZEV registered.


2017 ZEV by County
Distribution of ZEVs per county in 2017 is similar to the 2010 distribution with most ZEVs in the Los Angeles and San Francisco areas.
Esri, HERE, Garmin, NGA, USGS, NPS | Esri, HERE, NPS


2017 ZEV by Census Tract
In 2017, 98% of all census tracts had at least one registered ZEV.
Esri, HERE, Garmin, NGA, USGS, NPS | Esri, HERE, NPS

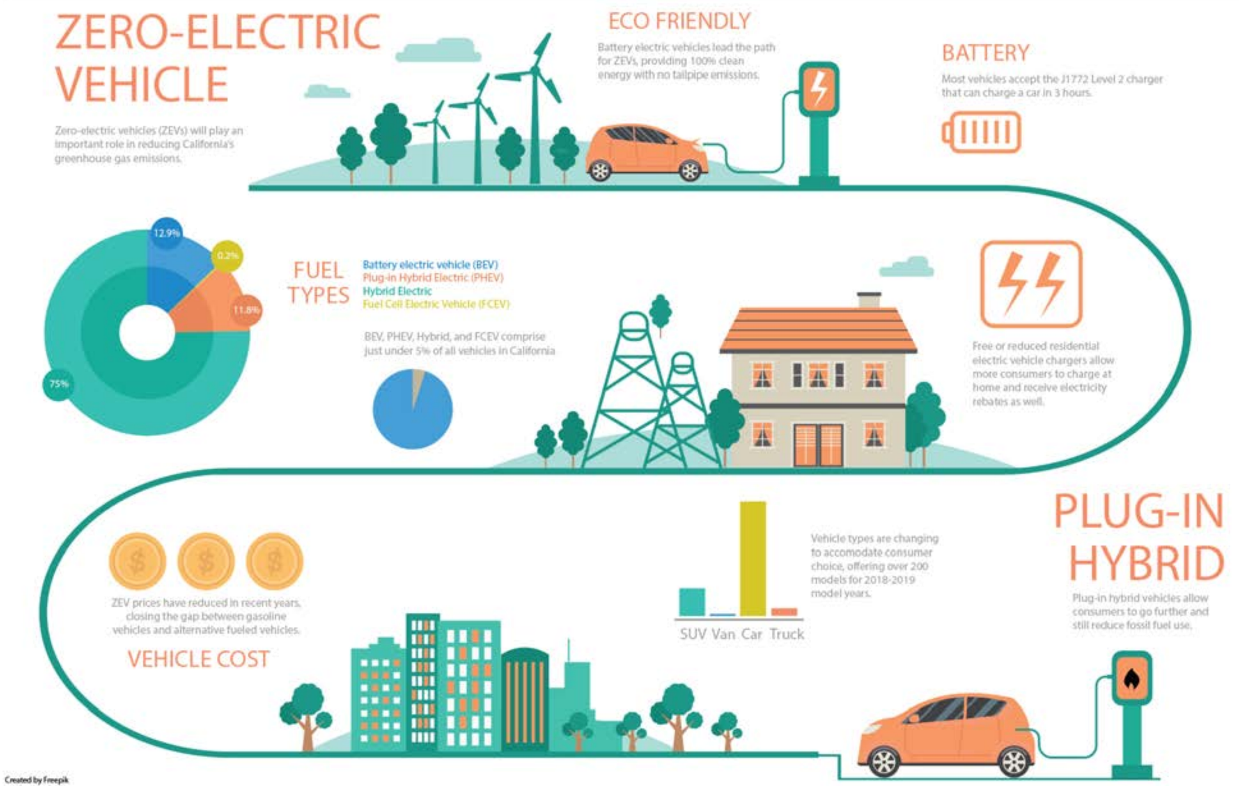

2017 ZEV by Census Tract
The growth is highlighted in the Los Angeles area with large pockets of high ZEV registrations.
Santa Clarita
Simi Valley
Ventura
Oxnard
Thousand Oaks
Los Angeles
Santa Monica
El Monte
Pomona
Ontario
Redlands
Riverside
Corona
Redondo Beach
Anaheim
Long Beach
Santa Ana
Huntington Beach
Perris
Hemet
Murrieta
San Clemente
Oceanside
Esri, HERE, Garmin, NGA, USGS, NPS | Esri, HERE, NPS


2017 ZEV by Census Tract
Additionally, in the San Francisco Bay Area the large number of ZEV registrations is shown.
Napa
Petaluma
Vallejo
Lodi
San Rafael
Concord
Antioch
Stockton
Oakland
San Francisco
San Leandro
Tracy
Livermore
Modesto
San Mateo
Fremont
Redwood City
Turlock
Sunnyvale
San Jose
Los Banos
Gilroy
Santa Cruz
Esri, HERE, Garmin, NGA, USGS, NPS | Esri, HERE, NPS

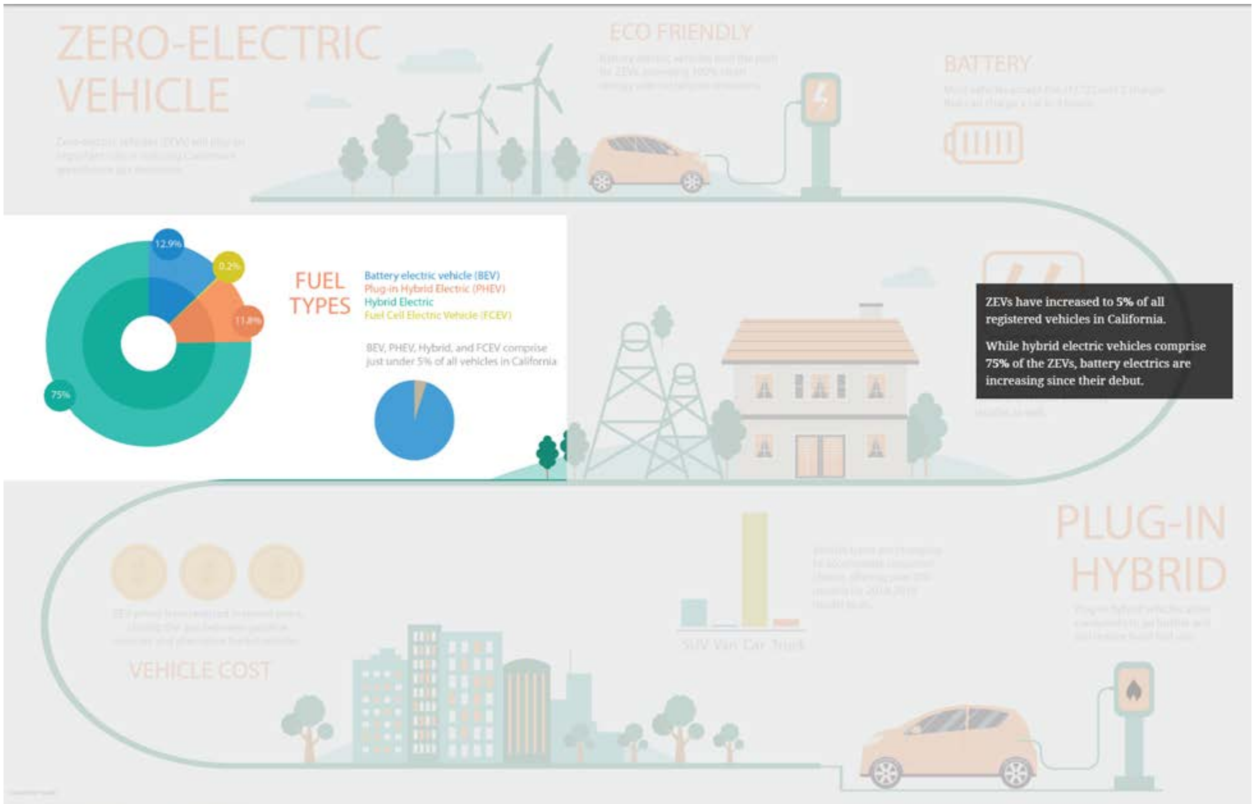
## A new outlook

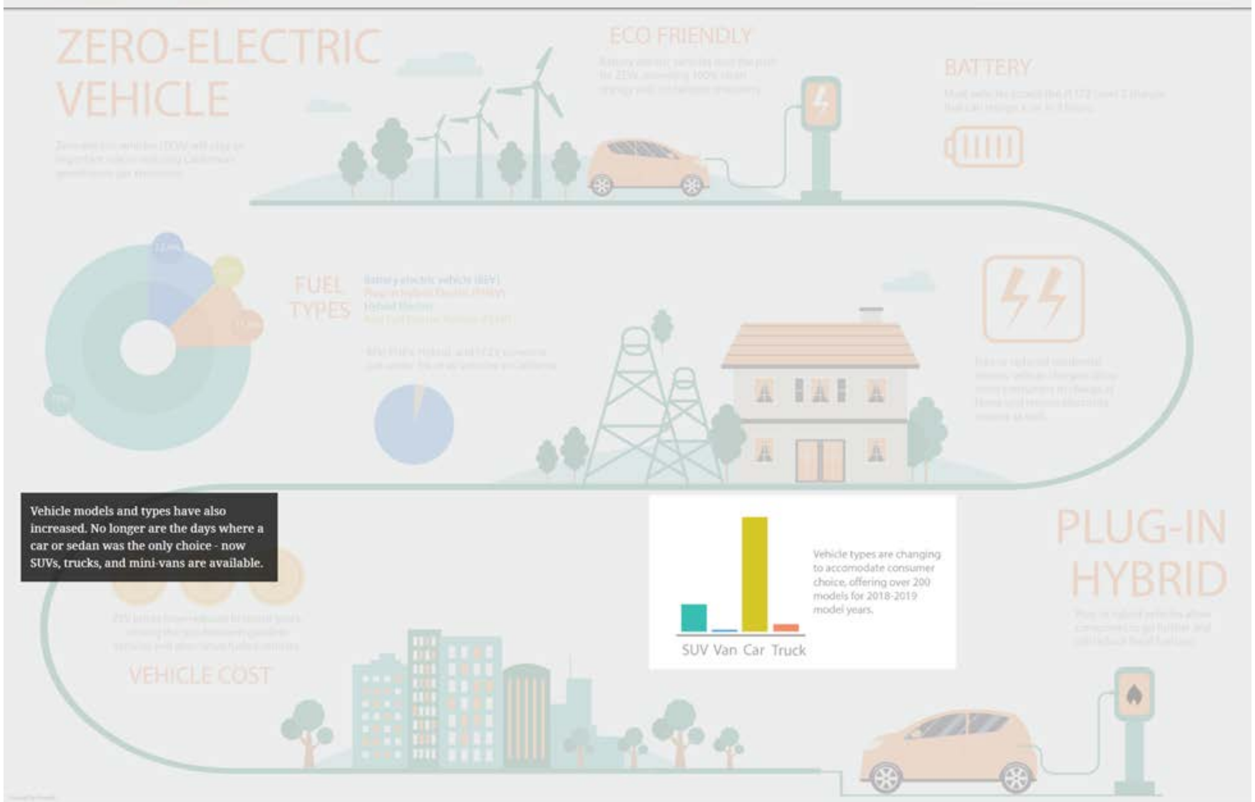
By 2017, there were over 100 models available and 27 were included in the incentive rebates. This increase in consumer choice and vehicle types provided new options that were not previously available. For the first time, a SUV, mini-van, and truck were available.

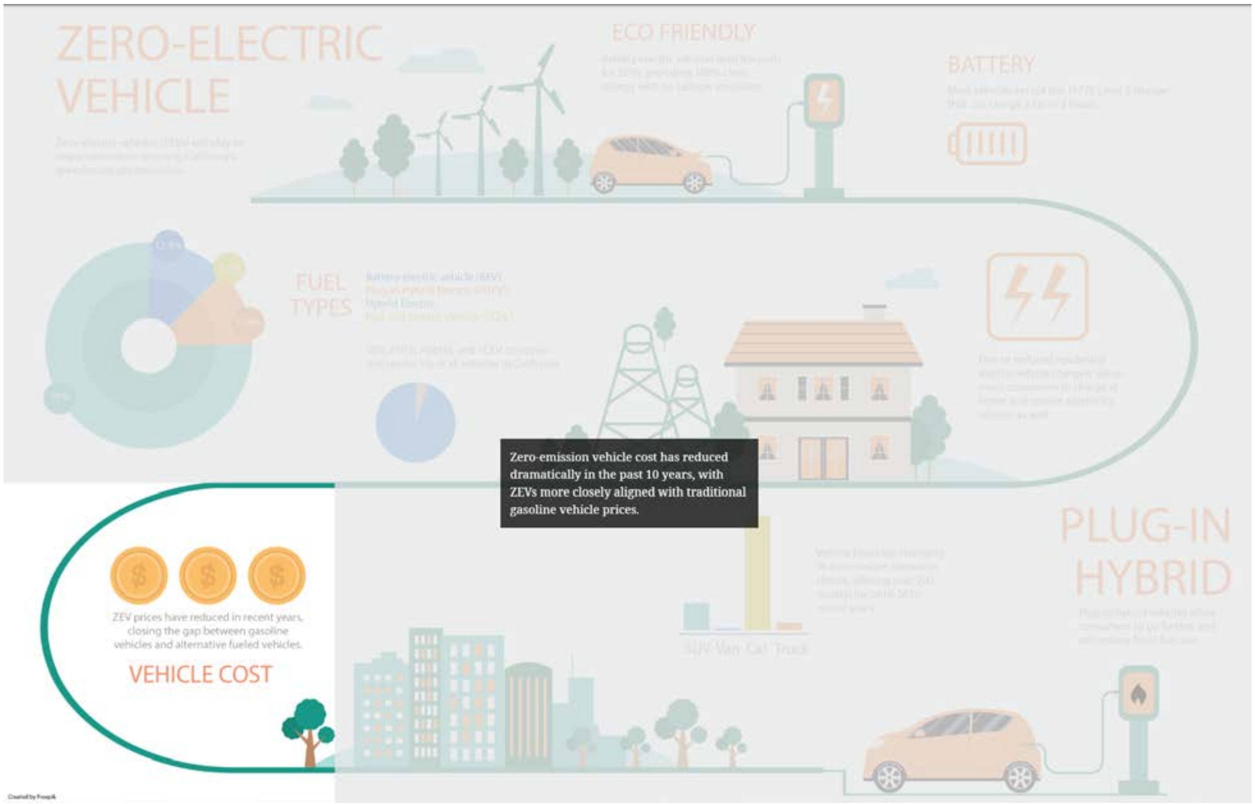
While the 25,000% increase of ZEVs is impressive, the count is still only 2% of the total number of vehicles registered in California and only 22% of the goal to reach 1.5 million ZEVs by 2025.



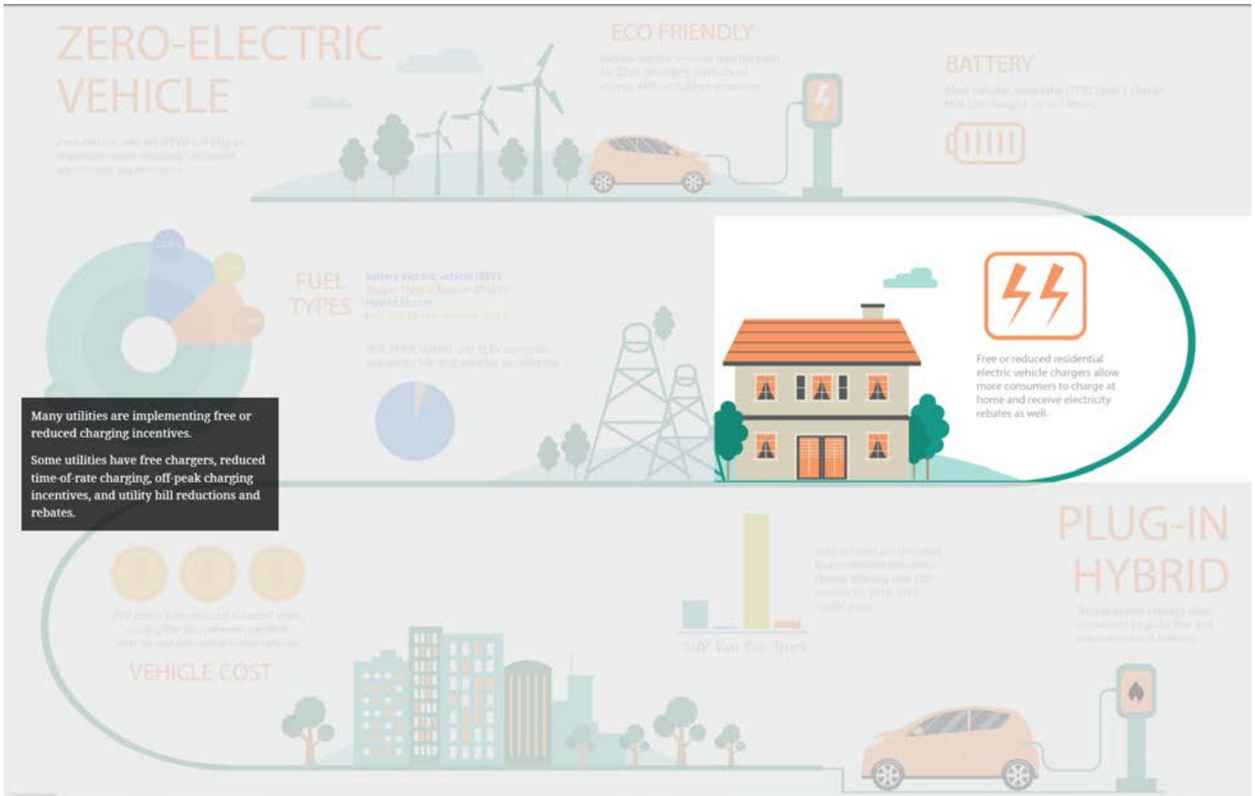

Created by Freepik


ZERO-ELECTRIC
VEHICLE
ECO FRIENDLY
BATTERY
12.9%
0.2%
11.8%
75%
FUEL
TYPES
Battery electric vehicle (BEV)
Plug-in Hybrid Electric (PHEV)
Hybrid Electric
Fuel Cell Electric Vehicle (FCEV)
BEV, PHEV, Hybrid, and FCEV comprise just under 5% of all vehicles in California
ZEVs have increased to 5% of all registered vehicles in California.
While hybrid electric vehicles comprise 75% of the ZEVs, battery electrics are increasing since their debut.
PLUG-IN
HYBRID
SUV Van Car Truck
VEHICLE COST


ZERO-ELECTRIC
VEHICLE
ECO FRIENDLY
BATTERY
FUEL
TYPES
Vehicle models and types have also increased. No longer are the days where a car or sedan was the only choice - now SUVs, trucks, and mini-vans are available.
Vehicle types are changing to accomodate consumer choice, offering over 200 models for 2018-2019 model years.
SUV Van Car Truck
PLUG-IN
HYBRID
VEHICLE COST


ZERO-ELECTRIC VEHICLE
ECO FRIENDLY
BATTERY
FUEL TYPES
Zero-emission vehicle cost has reduced dramatically in the past 10 years, with ZEVs more closely aligned with traditional gasoline vehicle prices.
PLUG-IN HYBRID
ZEV prices have reduced in recent years, closing the gap between gasoline vehicles and alternative fueled vehicles.
VEHICLE COST
SUV Van Car Truck

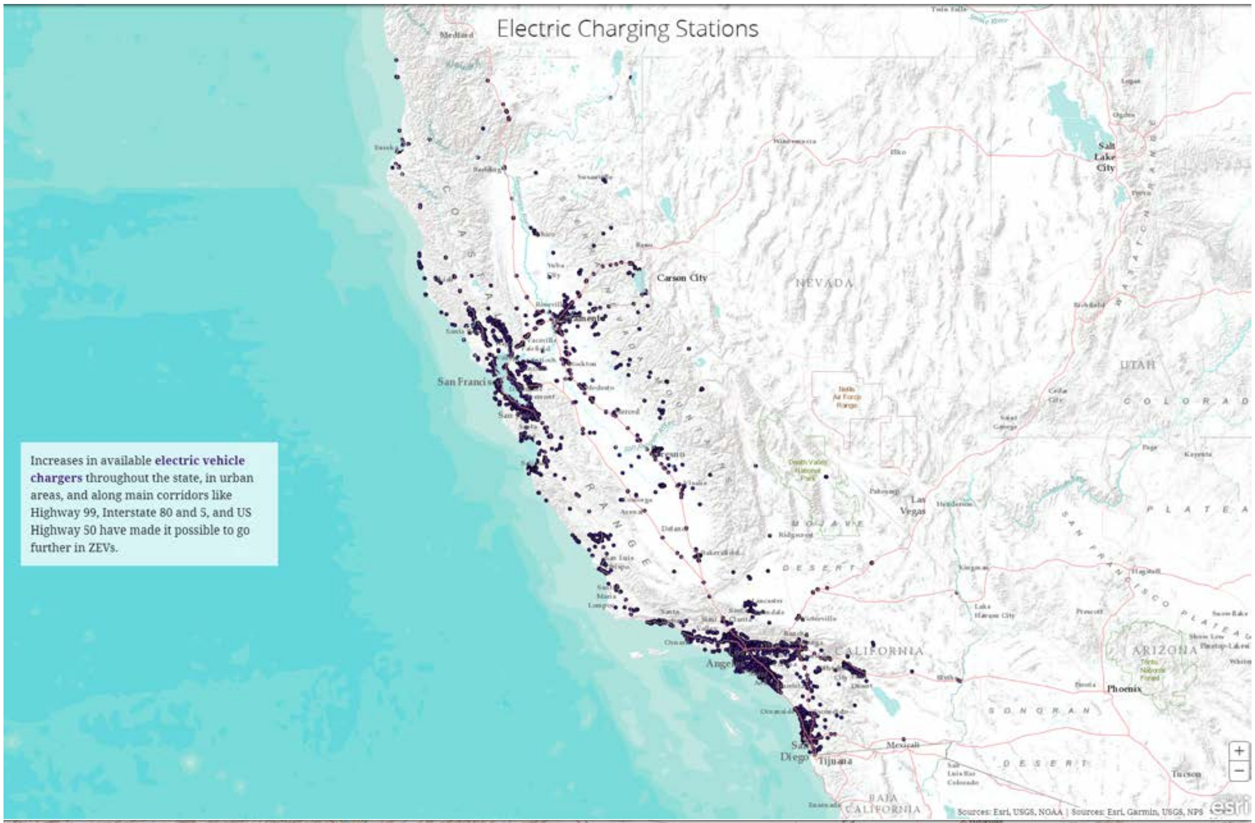

ZERO-ELECTRIC VEHICLE
ECO FRIENDLY
BATTERY
Most vehicles accept the J1772 Level 2 charger that can charge a car in 3 hours.
FUEL TYPES
Electric vehicle chargers are more widely accessible and many cars share the same charger types. The three main charger types are J1772, SAE Combo, and CHAdeMO.
Tesla vehicles have manufacturer specific chargers.
PLUG-IN HYBRID
VEHICLE COST
SUV Van Car Truck

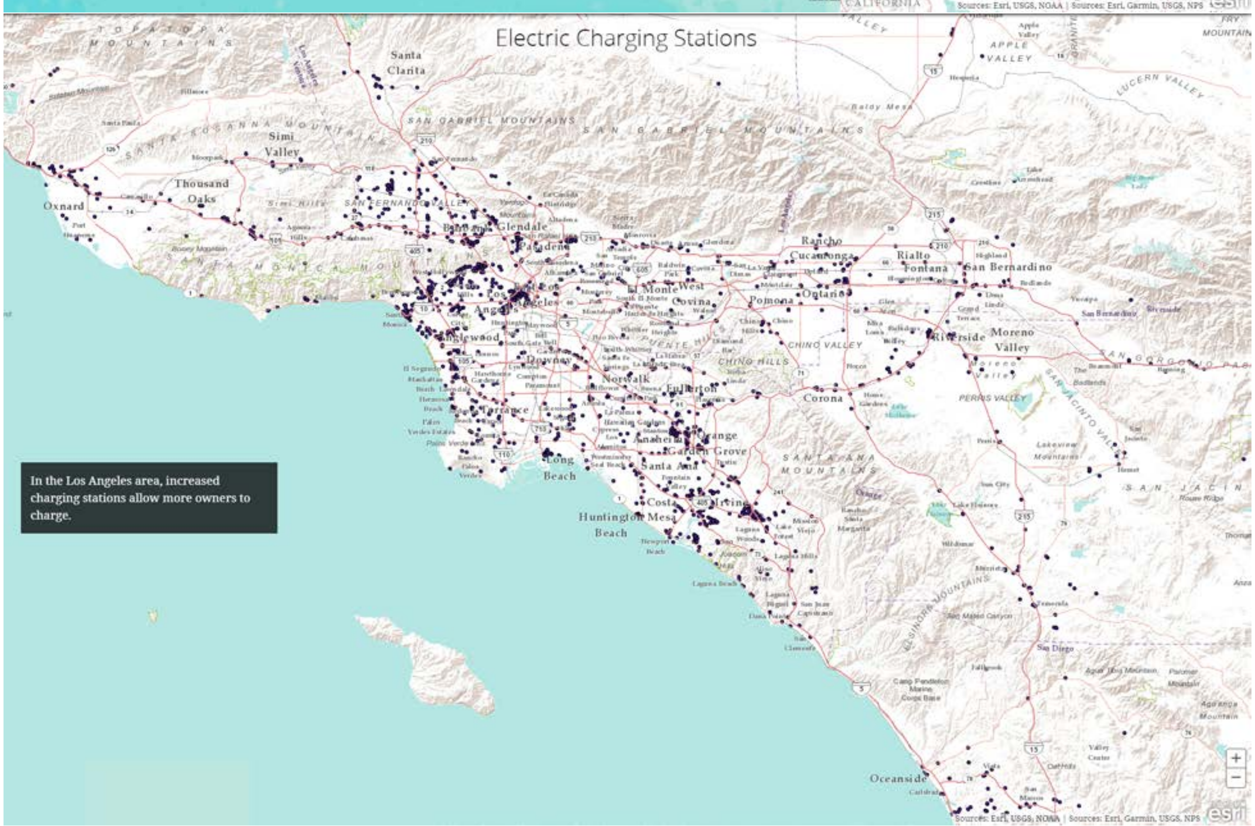


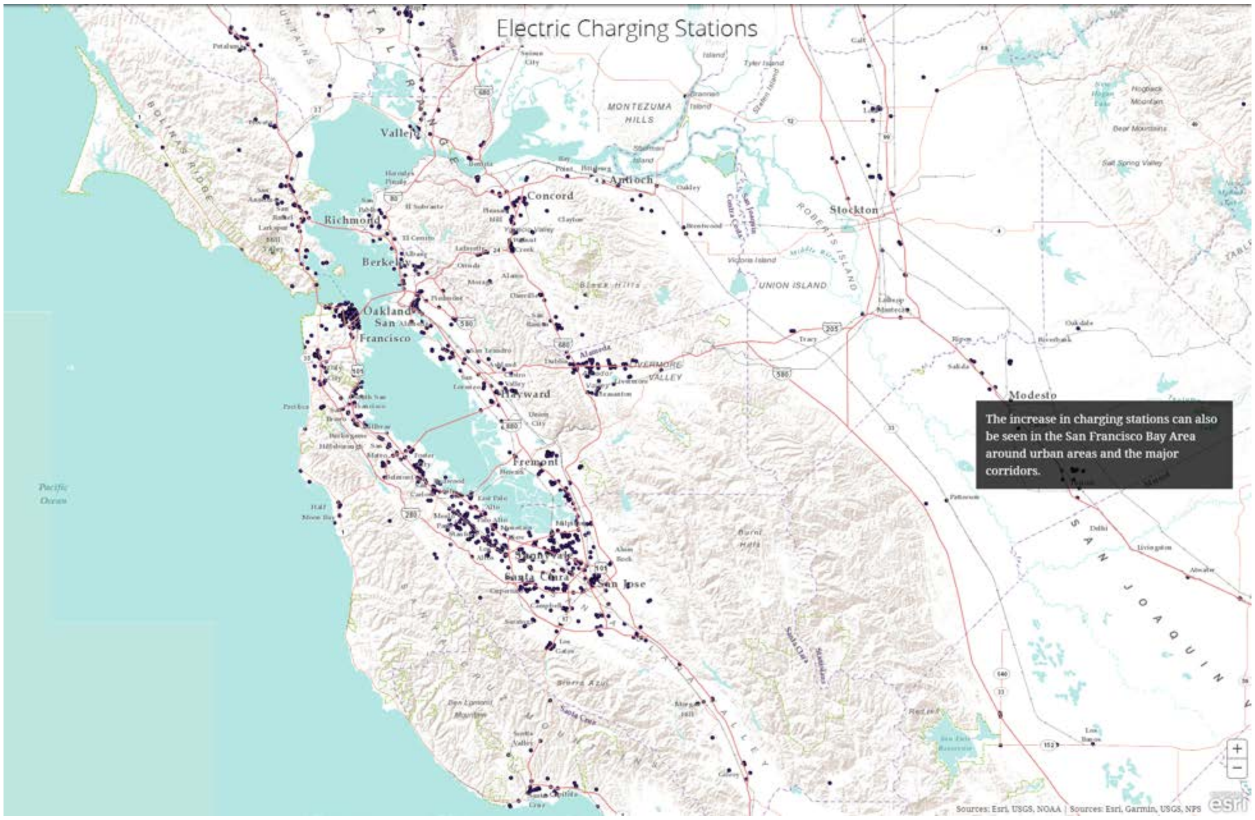

## Charging for ZEVs

There are 3 levels for vehicle charges, Level 1, Level 2, and Level 3, which have their own power rating (kW) and charge times. Level 1 contains the lowest power and slowest charge while Level 3 has the highest power and is considered a "fast charger." The most common connector is the Level 2 J1772 which is used in most public charging stations since all vehicles can use this in California.

Photo by John Cameron on Unsplash


Electric Charging Stations
Increases in available electric vehicle chargers throughout the state, in urban areas, and along main corridors like Highway 99, Interstate 80 and 5, and US Highway 50 have made it possible to go further in ZEVs.
Sources: Esri, USGS, NOAA | Sources: Esri, Garmin, USGS, NPS


Electric Charging Stations
In the Los Angeles area, increased charging stations allow more owners to charge.
Sources: Esri, USGS, NOAA | Sources: Esri, Garmin, USGS, NPS




## Income and Incentives

With the cost of ZEVs dropping significantly over the last decade, consumers are now faced with a comparable price point. The Toyota Prius and Toyota Camry are **within 1% of the same cost.**

In addition to the cost of ZEVs becoming more affordable, state and federal incentives are available to most consumers. Most ZEVs in California are eligible for $1,500 - $5,000 state incentive and up to $7,500 federal incentive based on the battery size of the vehicle.

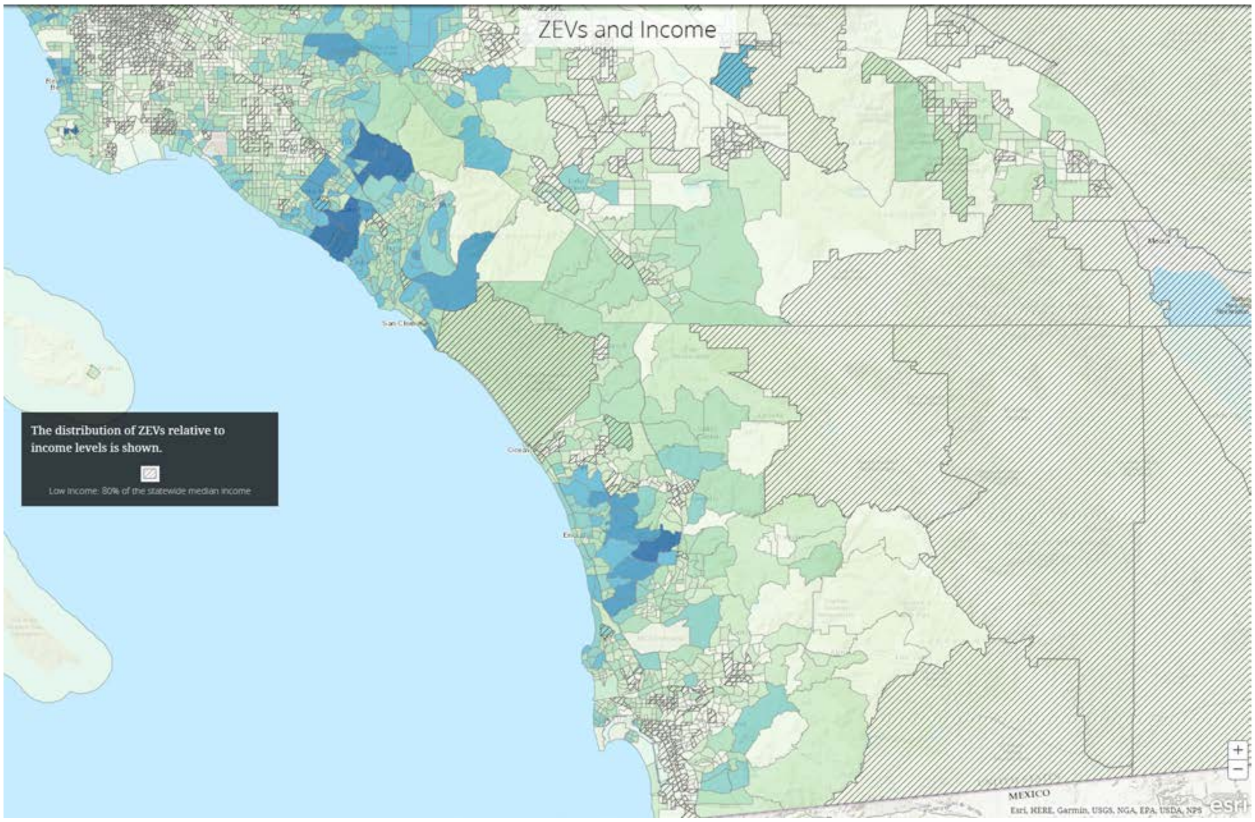
| Fuel Type | Manufacturer | Model | State Rebate | Federal Rebate |
|---|---|---|---|---|
| Fuel Cell | Honda | Clarity | $5,000 | None |
| | Hyundai | Tuscon | | |
| | Toyota | Mirai | | |
| Plug In Hybrid | Ford | C-MAX Energi | $1,500 | $4,007 |
| | Ford | Fusion Energi | | |
| | Audi | A3 e-tron | | $4,502 |
| | Toyota | Prius Prime | | |
| | Hyundai | Sonata | | $4,919 |
| | Kia | Optima | | |
| | Chevrolet | Volt | | $7,500 |
| | Chrysler | Pacifica | | |
| Battery Electric | BMW | i3 | $2,500 | $7,500 *Tesla will phase out in 2019 |
| | Chevrolet | Bolt | | |
| | Fiat | 500e | | |
| | Ford | Focus | | |
| | Honda | Clarity | | |
| | Hyuandai | Ioniq | | |
| | Kia | Soul | | |
| | Mercedes-Benz | B250e | | |
| | Mitsubishi | i-MiEV | | |
| | Nissan | LEAF | | |
| | smart | Electric Fortwo Cabriolet | | |
| | smart | Electric Fortwo Coupe | | |
| | Tesla | Model 3 | | |
| | Tesla | Model S | | |
| | Tesla | Model X | | |
| | Volksuwagen | e-Golf | | |

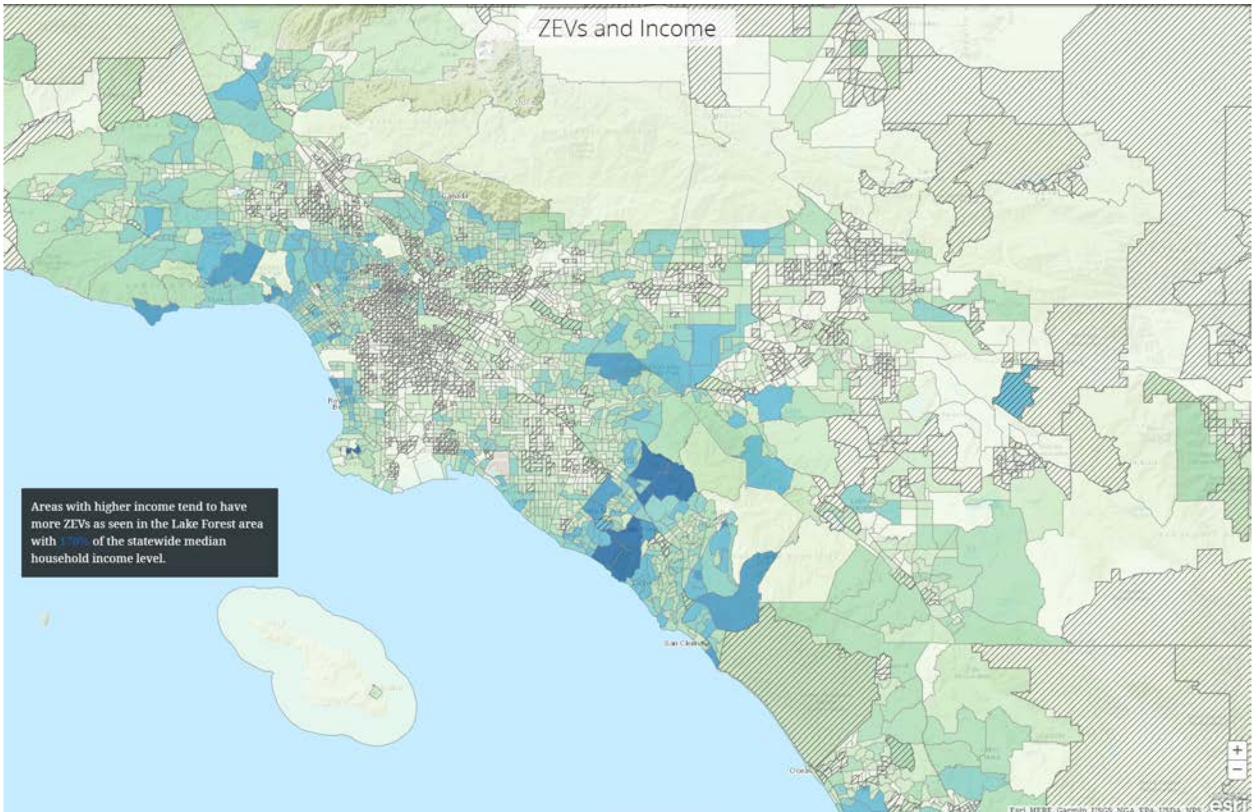
Vehicle Rebates

Based on the median household incomes per census tract, we can draw conclusions that places with higher incomes had a higher number of ZEVs and places with lower incomes had fewer ZEVs. Additionally, in most low income areas, there were fewer ZEVs overall. This conclusion leads to the theory that while the costs of ZEVs are reducing, they are still not purchased as frequently as vehicles in other census tracts.

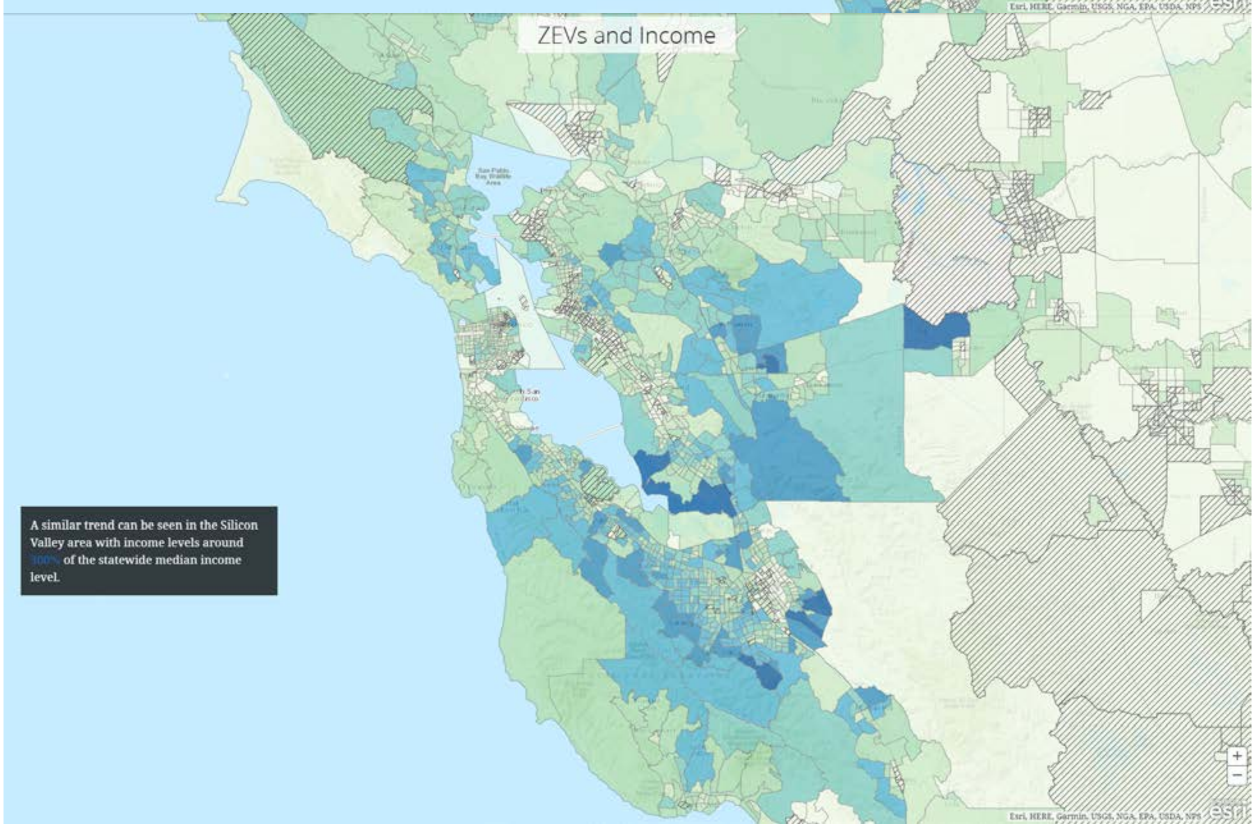
Most large utilities in California provide an incentive, credit, or rebate to their customers for charging electric vehicles. PG&E, SCE, LADWP, and SMUD have a plug-in electric vehicle charge rate reduction or rebate ranging from a $500 rebate to a free Level 2 charger. In addition, several utilities offer a discounted price for charging during off-peak times. These combinations are providing upfront cost savings and charging savings over time that may bring the costs of an alternative fueled vehicle in reach for consumers.

In addition to monetary incentives, the biggest non-monetary contributor is the High Occupancy Vehicle (HOV) sticker that allows single-occupancy vehicles to use the HOV lanes. This perk has been well received in California and offers many drivers in congested areas like Los Angeles and the San Francisco Bay Area and alternative to sitting in traffic.





ZEVs and Income
Areas with higher income tend to have more ZEVs as seen in the Lake Forest area with 170% of the statewide median household income level.
Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS

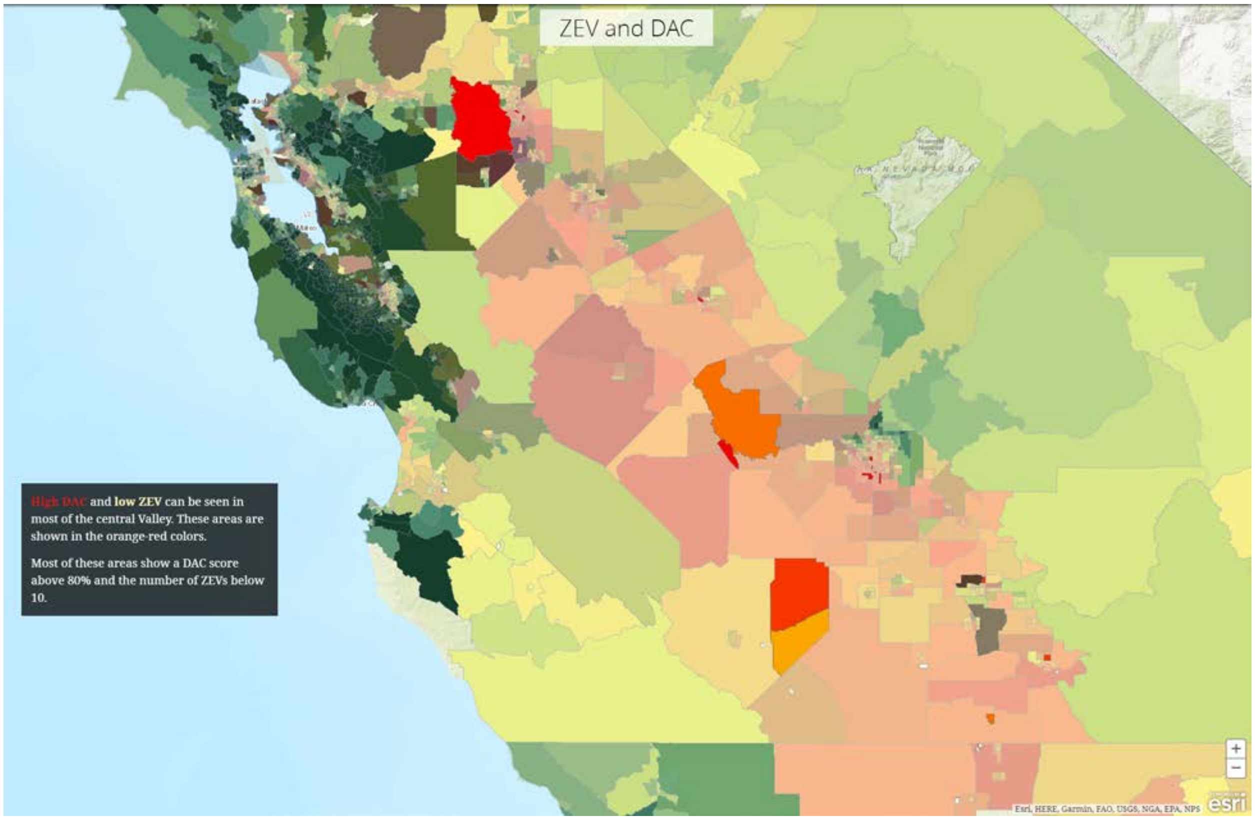



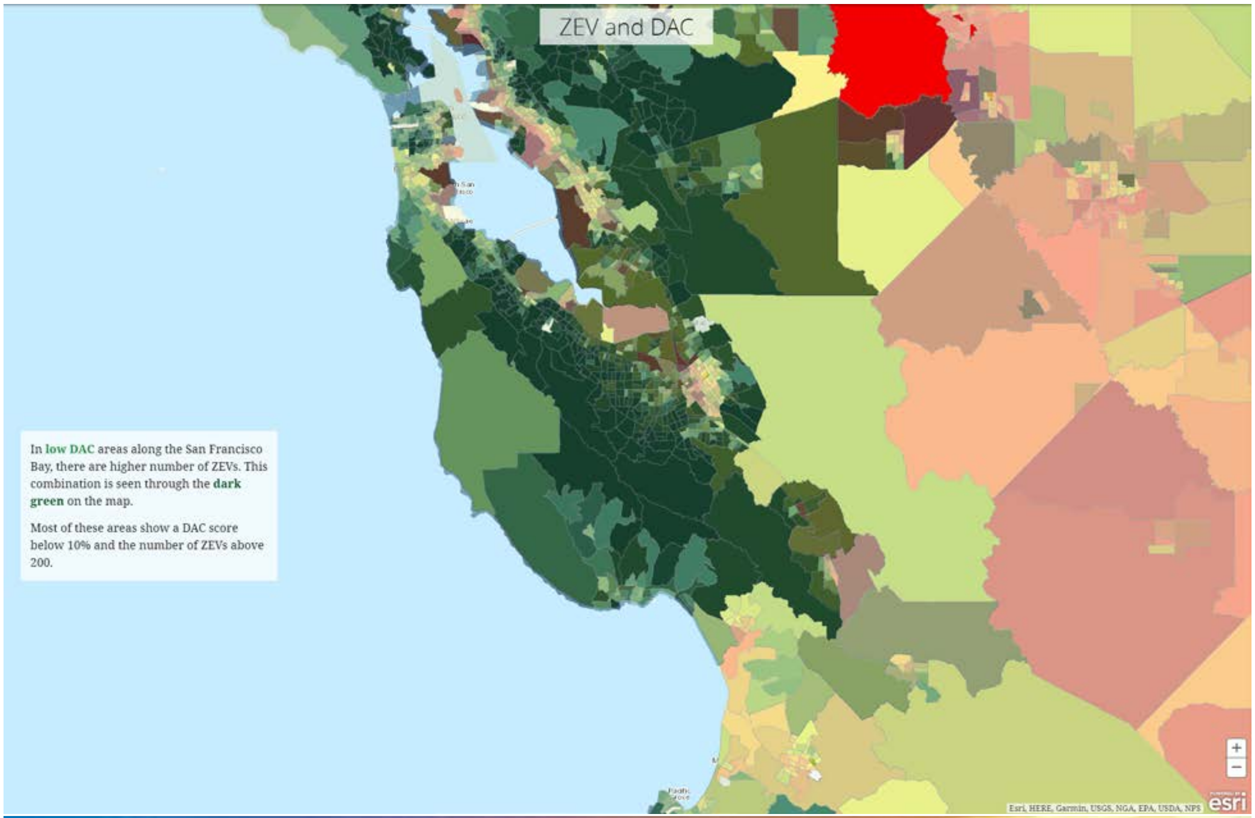
ZEVs and Income
A similar trend can be seen in the Silicon Valley area with income levels around 300% of the statewide median income level.
Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS

### Disadvantaged Communities

Disadvantaged communities (DAC) are assessed based on several socioeconomic challenges and environmental pollution. CalEnviroScreen 3.0 is a tool that calculates the burden for each census tract throughout the state based on 22 factors, and ranks each area accordingly. This tool is used to assist California communities, local government, and leaders to provide resources for the revitalization of disadvantaged communities.

By comparing the location of ZEVs to the DAC areas, the correlation between low DAC (or less disadvantaged) and high number of ZEVs can be seen. Conversely, the higher the DAC, the lower the ZEV count.



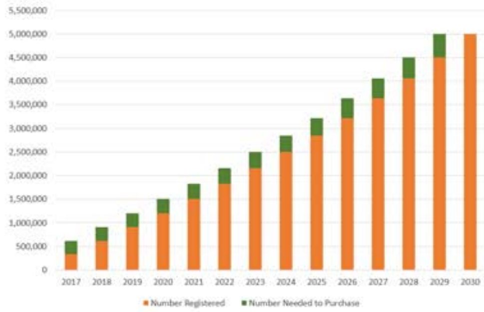




The progress towards alternative fueled vehicles has been swift, increasing over 25,000% in a short seven years. The uptake of ZEVs can be attributed towards lower upfront vehicle costs, increased incentives, rebates, and charging, and consumer influence, selection, and buying power. In 2010, 3 commercially available models were being sold, in 2017 over 100 models are available, and in the 2019 model-year line up there are more vehicles being announced.

With the current rate of ZEVs being purchased, if consumers continue to purchase at roughly 330,000 ZEVs per year, the goal of 1.5 million ZEVs by 2025 will be reached easily, with approximately 2,972,500 ZEVs in California. Along these line, the goal of 5 million ZEVs by 2030 will be just shy, at approximately 4,922,500 ZEVs. In order to reach the goal of 5 million ZEVs, consumers would need to purchase 360,000 ZEVs per year.

While the number of available vehicles needed to purchase each year may not be currently available, an increased approach to reach 5 million ZEVs may be more realistic. Starting the number of ZEVs needed to purchase each year at 280,000 and increasing each year to 500,000 ZEVs will allow California to reach the goal of 5 million ZEVs by 2030.




A hypothetical ramp of vehicles required to reach the 2030 ZEV goal

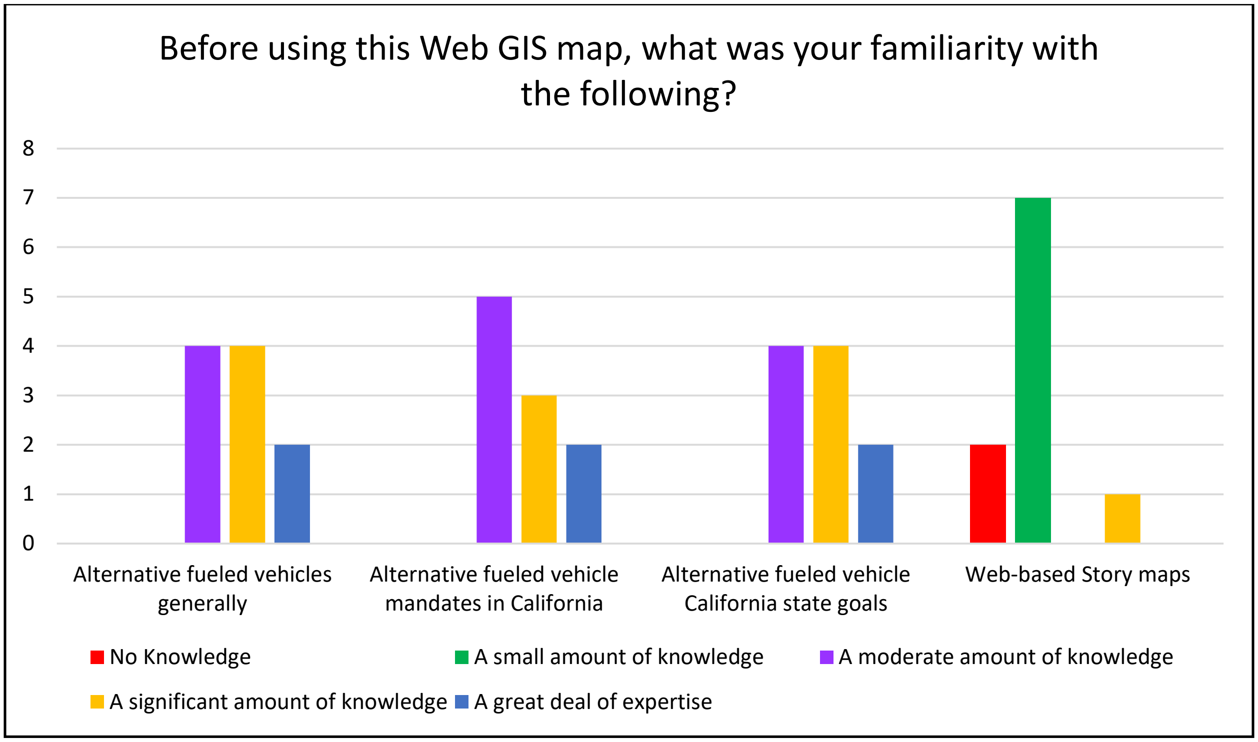
In addition to the mandates and legislation passed, new and updated mandates are being passed to increase the number of electric vehicle charging stations, continue the vehicle rebates, and create new programs with utilities for reduced energy rates for vehicle charging. California continues to drive forward towards 5 million ZEVs and reducing greenhouse gas emissions.

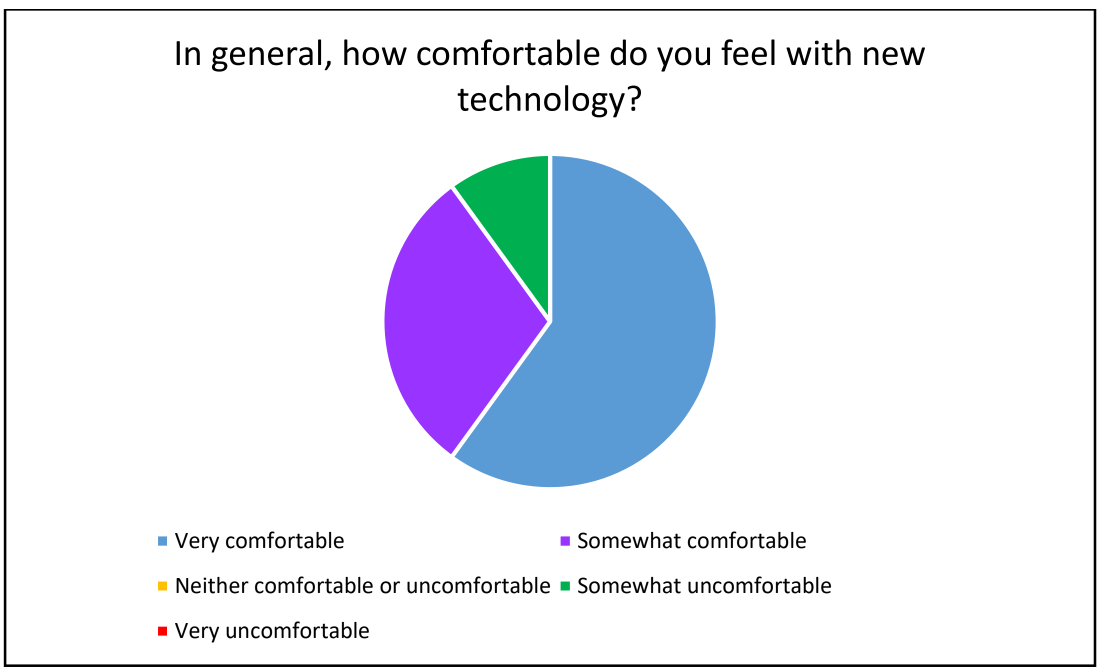
Credits

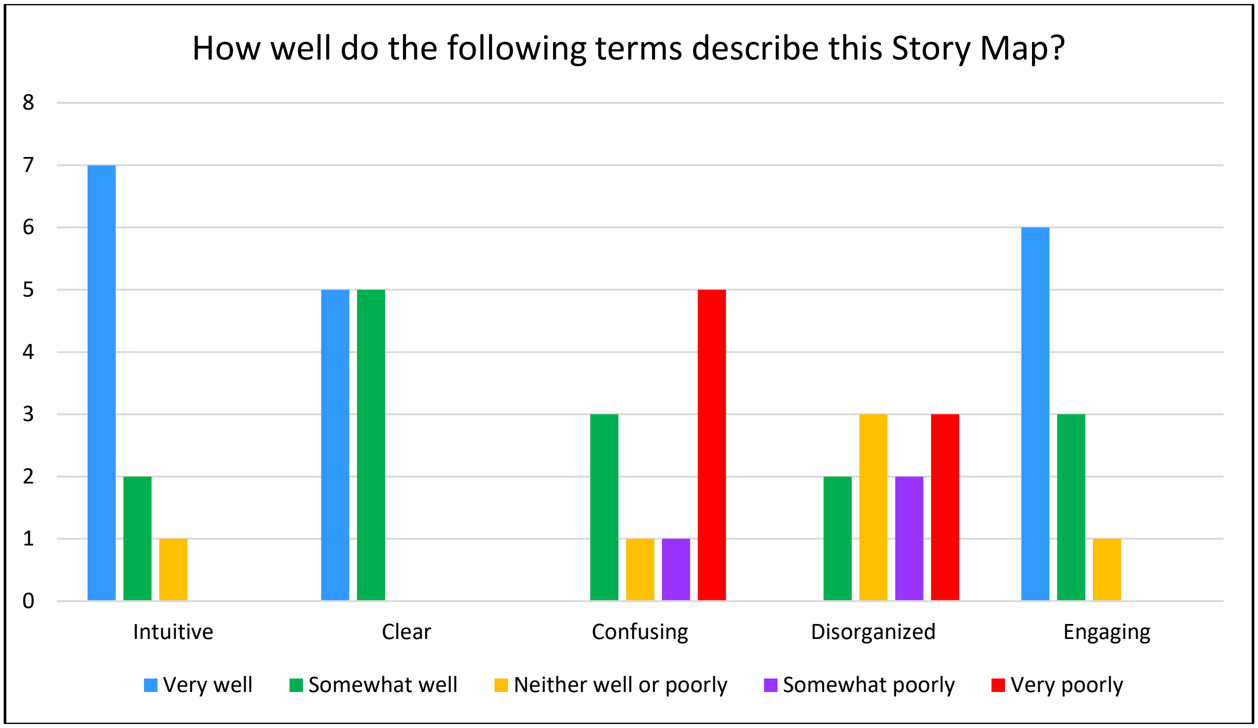
| | |
|---|---|
| Christina Brunsvold | USC GIST Master's Candidate 2019 |
| California Energy Commission | https://www.energy.ca.gov/ |
| CalEPA - OEHHA | CalEnviroScreen 3.0 |
| Center for Sustainability | Clean Vehicle Rebate Project |
| US Department of Energy | Electric Vehicles |

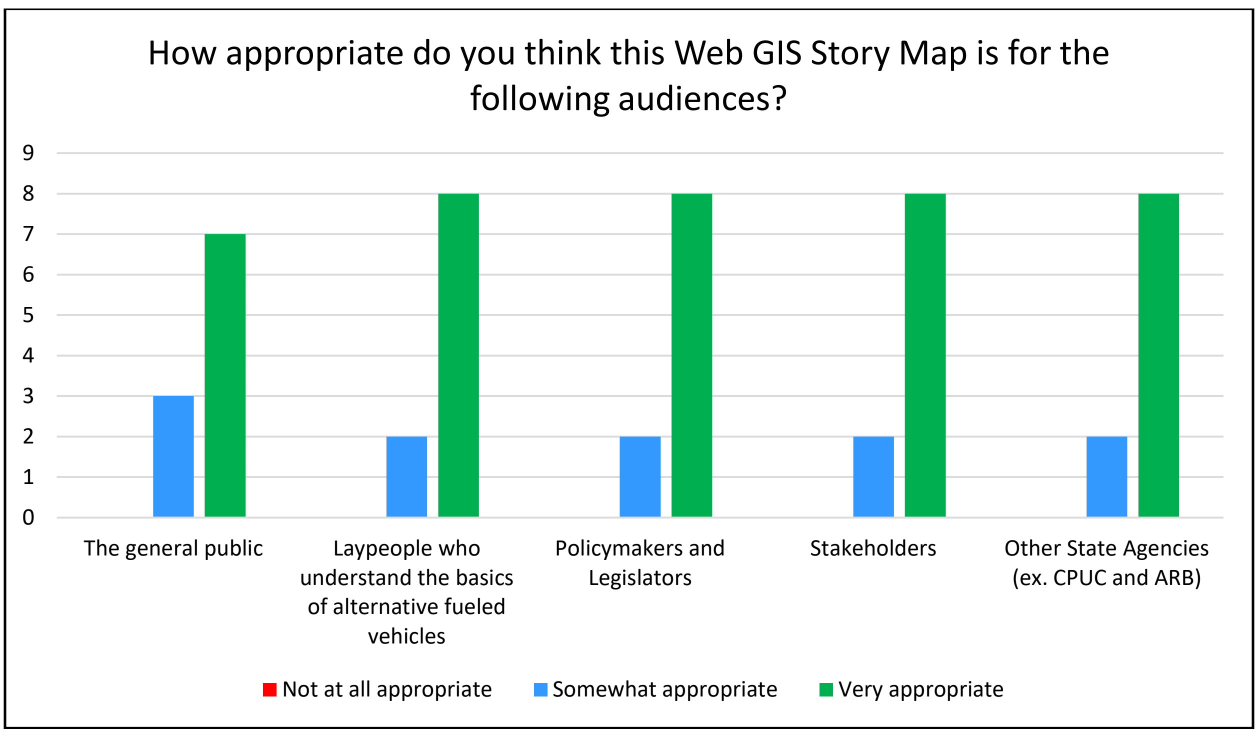
# Appendix B Survey Results

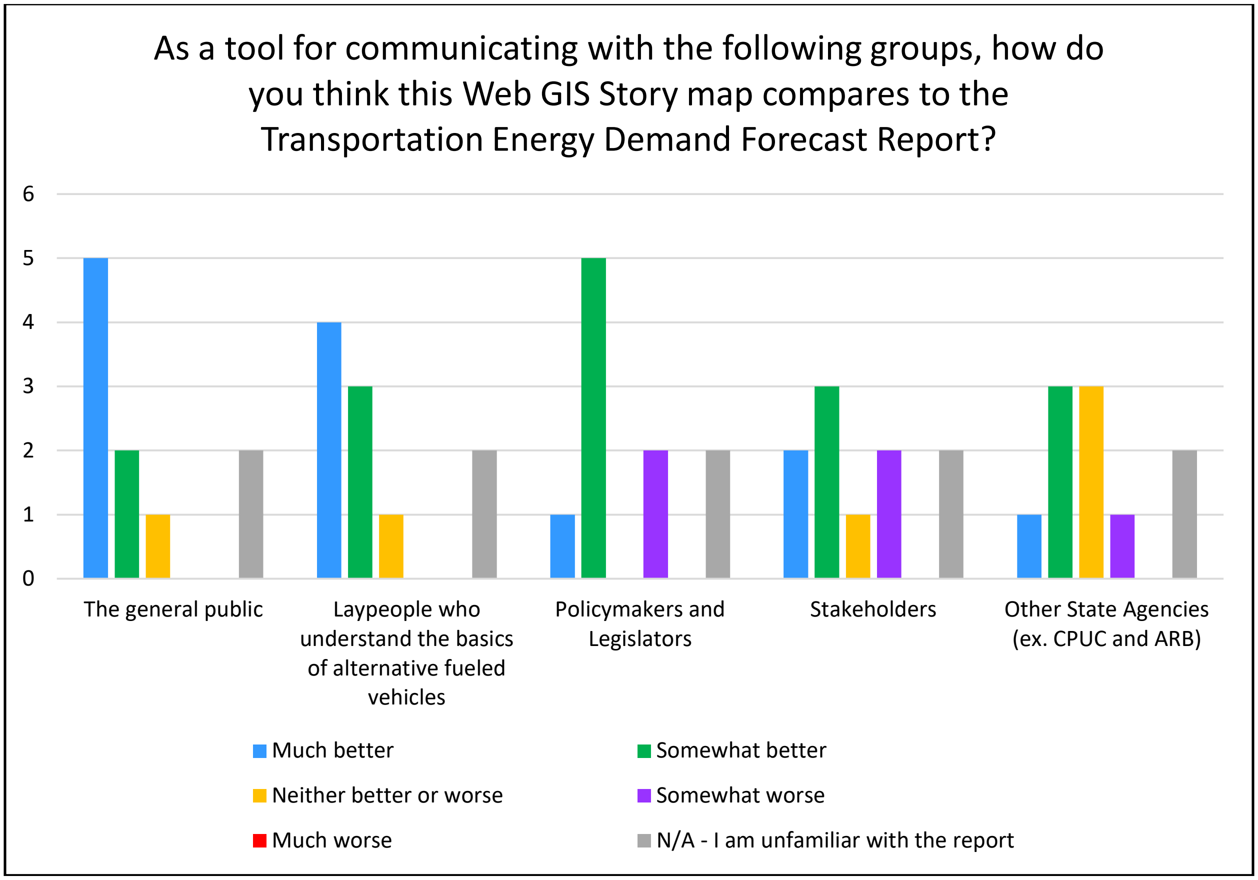
This section shows the survey that was provided to internal CEC staff and the summarized responses from the survey.




How well do the following terms describe this Story Map?
8
7
6
5
4
3
2
1
0
Intuitive
Clear
Confusing
Disorganized
Engaging
Very well
Somewhat well
Neither well or poorly
Somewhat poorly
Very poorly


How appropriate do you think this Web GIS Story Map is for the following audiences?
9
8
7
6
5
4
3
2
1
0
The general public
Laypeople who understand the basics of alternative fueled vehicles
Policymakers and Legislators
Stakeholders
Other State Agencies (ex. CPUC and ARB)
Not at all appropriate
Somewhat appropriate
Very appropriate


As a tool for communicating with the following groups, how do you think this Web GIS Story map compares to the Transportation Energy Demand Forecast Report?
6
5
4
3
2
1
0
The general public
Laypeople who understand the basics of alternative fueled vehicles
Policymakers and Legislators
Stakeholders
Other State Agencies (ex. CPUC and ARB)
Much better
Somewhat better
Neither better or worse
Somewhat worse
Much worse
N/A - I am unfamiliar with the report