Making Electric Vehicles Accessible: A Program Evaluation of California's Clean Vehicle Assistance Program

by

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Abstract

Transportation contributes approximately 41 percent of California's greenhouse gas emissions and 27 percent of national greenhouse gas emissions (CARB, 2019, EPA, 2017). In response to climate change concerns, stakeholders have encouraged the use of electric and hybrid vehicles through tax credits, rebates, and education campaigns. Environmental and transportation justice groups have raised concerns about increasing access to clean transportation, especially for disadvantaged communities who are often disproportionately impacted by climate change and receive fewer mobility options than higher income households. California has become a leader in encouraging the adoption of clean vehicles, especially for disadvantaged communities, by implementing various incentive programs including the Clean Vehicle Assistance Program (CVA Program). This program provides grants to low-to-moderate income Californian's for the purchase of a new or used clean vehicle. Participants are required to complete a financial literacy course, are limited to loans that are under 16 percent interest, and must come from an authorized dealership. This study aims to evaluate how the CVA Program has incorporated equity into the program design and implementation. This research will utilize the Greenlining Institutes Operationalizing Equity Framework to analyze program reports, the program implementation manual, and interviews with program staff. This research will also be supplemented with an analysis of how the CVA Program addresses key electric vehicle adoption barriers. Results from this paper will provide policy recommendations for electric vehicle incentive programs and state level policy recommendations to improve electric vehicle program creation. This research will aid in providing an equity lens evaluation of electric vehicle incentive programs and provide insight for other states that are considering implementing similar policies.

Introduction

Concerns over climate change and rising greenhouse gas emissions have driven state and federal governments to incentivize the purchase of clean vehicles. Transportation is one of the leading sectors contributing to greenhouse emissions and is one of the many ways that can help meet climate change goals. Transportation electrification is not only seen as a short term solution to climate issues, but also as part of a larger conversation on how transportation is changing and the opportunity to create more livable urban areas globally (Fulton et al., 2017). There are many synergies between the future of mobility, particularly automation and electrification, which will increase efficiency and meet transportation demand affordably (Fulton et al., 2017). Governments have begun prioritizing incentivizing the purchase of clean vehicles due to slow adoption rates that can be attributed to several key barriers, including high vehicle costs, limited battery range, and limited charging infrastructure.

Electric vehicle adoption has primarily consisted of affluent consumers who are considered early adopters. To meet climate goals, it will be necessary to have a majority of the population transition to alternative modes of transportation, especially clean vehicles. Prioritizing low-income households and communities of color in adopting electric vehicles is critical and can help address other inequities marginalized populations face. Disadvantaged and low-income communities are often disproportionately impacted by air pollution and therefore suffer from air pollution related illnesses (US Department of Transportation, n.d.). Additionally, disadvantaged and low-income communities pay higher proportions of their income on transportation, the second highest household expense, which is important considering transportation commute time also is a factor limiting economic upward mobility (Surface Transportation Policy Project, 2003, Chetty et al., 2014).

California has been a leader in establishing electric vehicle incentive programs and allocating funding for disadvantaged communities to benefit from these programs. This report aims to evaluate how the Clean Vehicle Assistance Program (CVA Program) in California has incorporated and operationalized equity into the program design and implementation. The research will use the Greenlining Institutes Operationalizing Equity Framework to analyze the CVA Program grant solicitation and description, program implementation manual, California Air Resources Board reports, and interviews with program staff. The essay will provide an introduction to electric vehicles in California, and a literature review highlighting previous research on electric vehicle adoption, an explanation of methods for this research, and findings. The essay will conclude with a discussion on how the CVA Program has incorporated equity into the program, how key electric vehicle barriers are addressed, and program recommendations.

History of Electric Vehicles

The first electric vehicle was developed in 1890 in Des Moines, Iowa. The invention led to different automakers developing their own version of electric vehicles throughout the country. In the early 1900s, Ford mass-produced the internal combustion engine (ICE) vehicle the Model T at an affordable price that began the rise of gasoline-powered vehicles over electric and steam powered vehicles (Department of Energy, 2014). Electric and hybrid vehicles reemerged as an alternative to gasoline-powered vehicles in the 1970s as oil and gasoline shortages encouraged Congress to pass the Electric Hybrid Vehicle Research Development and Demonstration Act of 1976. In the 1990s, more stringent transportation emission regulations and research incentives set by the California Air Resources Board, the 1990 Clean Air Act Amendment, and the 1992

Energy Policy Act encouraged development of electric vehicles. Today, almost all major automobile manufacturers offer a battery electric vehicle or plug-in hybrid electric vehicle option. Automakers, governments, utilities, and other stakeholders are also developing charging infrastructure throughout the country to support adoption of electric vehicles as a transportation option. The US Department of Energy has invested more than $115 million in developing charging infrastructure and battery technology research (Department of Energy, 2014).
The US Department of Energy recognizes biodiesel, electricity, ethanol, hydrogen, natural gas, and propane as alternative fuel options for vehicles, which compromise a small percentage of vehicles sold (AFDC, n.d.). The most popular of the alternative fuel options are the different types of electric vehicles. Battery electric vehicles (BEV), such as the Nissan Leaf or Chevy Bolt, use electricity to store and power the battery. BEVs are also called zero-emission vehicles (ZEV) because they do not emit tailpipe emissions due to the use of electricity and regenerative braking for energy. Plug-In hybrid electric vehicles (PHEV), such as the Honda Clarity PHEV and Ford Fusion Energi, are like BEVs because they can also gather electricity from the grid and through regenerative braking but differ by also utilizing a gasoline-powered engine. Hybrid electric vehicles (HEVs) also use both electricity and gasoline but are not able to access electricity directly. Examples of HEVs include Toyota Prius Hybrid and Honda Civic Hybrid (AFDC, n.d.). This research will also use the term clean vehicle to discuss both battery electric and plug-in hybrid electrics.

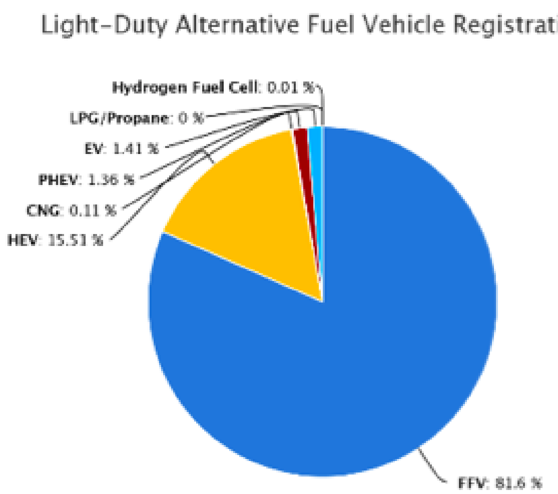


Figure 1: Flexible Fuel Vehicles (FFVs) primarily consists of gasoline-powered vehicles. This figure identifies hybrids as either Hybrid Electric Vehicles (HEV) or Plug-In Hybrid Electric Vehicles (PHEV). Source: https://afdc.energy.gov/data/10861

Transportation Equity, Electric Vehicles, and Barriers to Adoption

According to the US Department of Transportation (USDOT), transportation equity is a public health issue that is caused by inadequate transportation infrastructure affecting low-income and minority communities (US Department of Transportation, n.d.). Further, these communities are prevented from participating in active transportation and have reduced air quality, causing negative impacts, due to close proximity to highways or congested streets (US Department of Transportation, n.d.). Due to the relatively higher costs of electric vehicles compared to gasoline vehicles and a limited used electric vehicle market, lower-income populations are not able to purchase or use clean vehicles at the same rate as higher-income populations and therefore having limited access to clean vehicle technology.

The California Environmental Protection Agency (CALEPA) has created mechanisms to determine priority populations, for the purpose of allocating funding to those most impacted by pollution and other environmental problems. In California priority populations are categorized as low-income communities or households and disadvantaged communities. Low-income communities, determined by census tracts, and low-income households are at or below 80 percent of the statewide median income. Disadvantaged communities are identified as the top 25 percent most impacted census tracts from the CalEnviroScreen, as seen in figure 4. CalEnviroScreen is a publicly available tool to identify communities in California that are disproportionately impacted by pollution (CARB, 2018). CalEnviroScreen takes into account both environmental burden and population burden to determine impact in communities. Population characteristics include measuring the sensitivity of the population, which are biological traits that make a population vulnerable, and socioeconomic factors, which are community characteristics like poverty and educational attainment, that could increase vulnerability (Rodriguez and Zeise, 2017). This tool allows policies and programs to allocate funding and to target areas with the most burdens to potentially make the most positive impact.

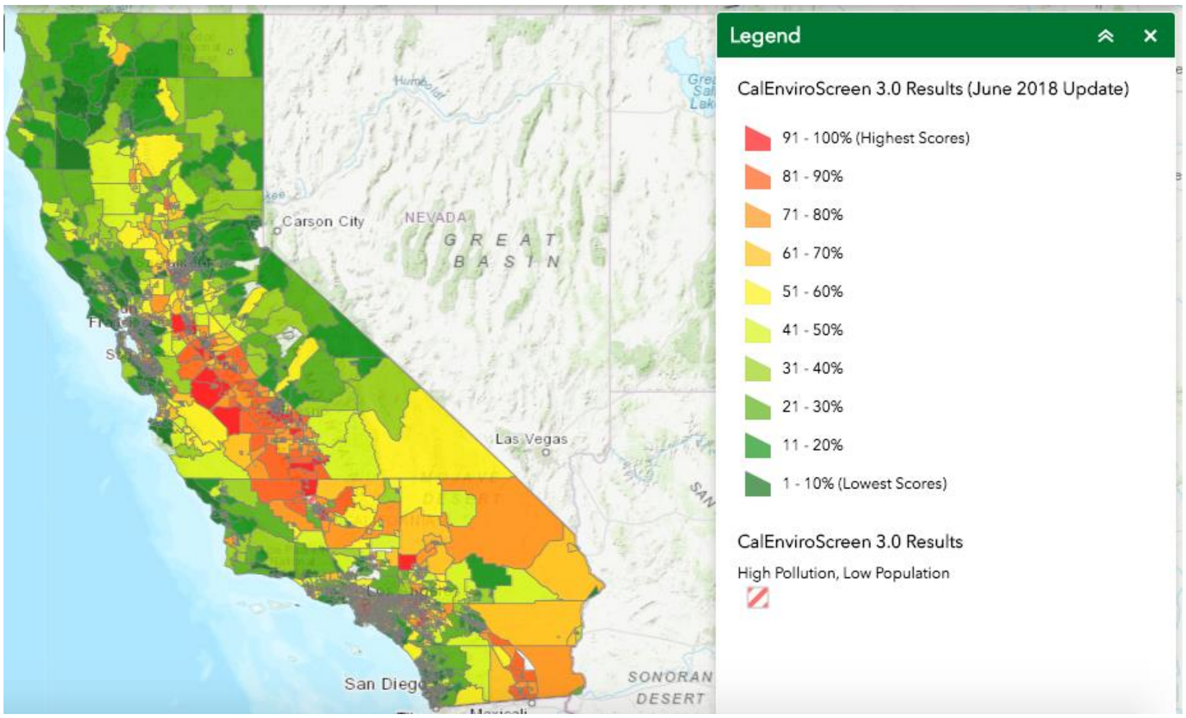


Figure 4 is an image of CalEnviroScreen. The darker red areas are the most burdened areas in the state. Source: https://oehha.ca.gov/calenviroscreen/report/calenviroscreen-30

More broadly, equity is an important factor in evaluating transportation because of the role it plays in being able to access necessities and opportunities. Transportation equity is the ability to access to safe, reliable, affordable and clean transportation regardless of race, ethnicity, gender, socioeconomic status or any other characteristic. This report and much of the California Air Resources Board's (CARB) focus on creating transportation options that will help meet climate goals and reduce greenhouse gas emissions, however, transportation equity goes beyond environmental justice. Chetty et al. demonstrated that segregation can limit upward economic mobility by analyzing commute time and rates of upward economic mobility. The research showed that areas with less sprawl, and therefore less commute time, have higher rates of upward economic mobility (Chetty et al., 2013). While there are many factors that can attribute to remaining in poverty, longer commutes can be associated with lack of opportunity to access higher paying jobs and fewer opportunities for higher education, which can lead to cyclical effects for youth not being able to move out of generational poverty. For this report, equity is including the statewide determinants of priority populations, which are low-income and disadvantaged communities, and expanding on that by including communities of color. Race is being considered in this lens of equity because of America's history on using race to discriminate against specific populations, especially black and African American populations, and because race compounded by other social determinants can lead to even more disproportionate burdens.

California African American, Latino, and Asian households are more exposed to particulate matter from vehicles compared to white Californian's (Union of Concerned Scientists). Further, the lowest-income households in the state have 10 percent higher exposure to particulate matter than the most wealthy (Reichmuth, 2019). While electric vehicle sales are increasing both nationally and internationally, there are barriers to adoption that have continued to slow adoption of this transportation option. According to the National Research Energy Laboratory (NREL), the most significant barriers to electric vehicle adoption are electric vehicle range, awareness of charging infrastructure, and electric vehicle price. NREL found in their study that a majority of respondents expected to pay $30,000 or less on their next vehicle, which is lower than most new electric vehicles on the market. Prices for electric vehicles are often more expensive than comparable gasoline vehicles due to the newer technology, but this is changing with the implementation of financial incentives and technology improvements (Singer, 2017). Furthermore, the City of Seattle identified information barriers due to limited education on electric vehicles. The report states that consumers often overestimate how many miles they drive per day, leading to the belief that many electric vehicles don't have sufficient range for their daily needs. Another significant barrier to electric vehicle adoption is access and perceived access to charging. Although charging infrastructure is increasing nationally, the visibility of charging stations is not as prevalent compared to gasoline stations. Residential charging is not always possible for consumers who don't have access to an electrical outlet, such as those in multi-unit dwellings or those with street parking, and therefore must rely on public charging (Seattle Office of Sustainability and Environment, 2014).

EV Charging

Improving electric vehicle charging infrastructure has been a priority for federal and state governments, utility companies, automakers, and other stakeholders to increase electric vehicle adoption. Thousands of charging stations are available publicly, however, most electric vehicle owners charge their vehicles at home because it's convenient and cost effective. Electric vehicle charging stations are available in three levels of charging, as seen in the chart below. Charging connectors and compatibility are not universal. For example, not all electric vehicles are compatible with DC Fast Chargers, which have two different charging connector standards, SAE Combo CCS and CHAdeMO. Many newer DC Fast Chargers are now equipped with both standards to accommodate more vehicles (Department of Energy, n.d.). Finally, Tesla has its own charging system that is not available with other automobile manufacturers.

Charging Stations

	Voltage	Standards	Time to 80% Charge
Level 1	120 volt	SAE J1772	8-12 hours
Level 2	240 volt	SAE J1772	4-8 hours
Level 3 (DC Fast Charging)	480 volt	SAE Combo CCS, CHAdeMO	30min-1 hour
Tesla HPWC	208-250 volt	Tesla	4-8 hours https://www.tesla.com/support/home-charging-installation/wall-connector
Tesla Supercharger	480 volt	Tesla	30 min-1.5 hours https://www.tesla.com/supercharger

Figure 2 shows the different levels and standards of electric vehicle charging. Source: https://chargehub.com/en/electric-car-charging-guide.html

Electric vehicle charging price depends on several factors such as the location of the charging station, the amount of kilowatt hours (kWh), and the price of electricity. While these factors can make it difficult to know exactly how much it will cost to charge an electric vehicle, electricity is often less expensive and more stable than gasoline (Department of Energy, n.d.). An example of regional partnerships to advance charging infrastructure is the West Coast Electric Highway, where California, Oregon, Washington, British Columbia, Canada, and Baja California, Mexico have partnered to establish a charging corridor. The West Coast Electric Highway is an initiative to lower greenhouse gas emissions by providing electric vehicle charging stations approximately every 20-50 miles along Interstate 5 spanning from Baja California, Mexico to British Columbia, Canada. Various stakeholders such as state agencies, utility companies, and interest groups are continuously collaborating to increase adoption of electric vehicles by building charging infrastructure (FHWA, 2012).

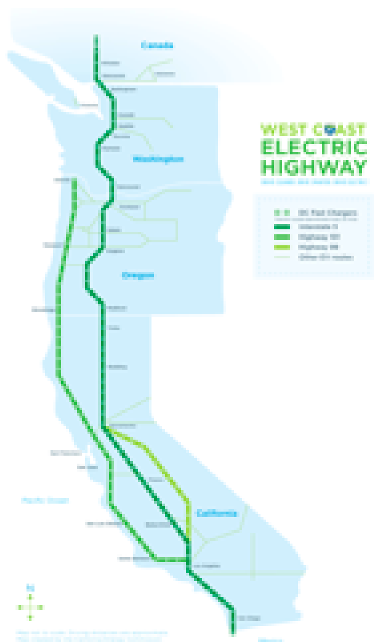


Figure 3: West Coast Electric Highway. Source:
http://www.westcoastgreenhighway.com/electrichighway.htm

Sustainability

In California, transportation contributes approximately 41 percent of total greenhouse gas emissions (CARB, 2019). Transportation electrification is considered a tool for lowering greenhouse gas emissions and meeting global climate change goals because battery electric vehicles and plug-in hybrid vehicles produce lower local emissions. Battery electric and plug-in hybrid electric vehicles produce lower amounts of tailpipe emissions compared to gasoline-powered vehicles, such as nitrogen oxides and carbon dioxides, that lead to public health and environmental concerns (Department of Energy, n.d.). An important factor in determining the sustainability of electric vehicles is how the electricity is sourced. In California, approximately 32 percent of electricity is from renewable sources and only 0.15 percent is generated from coal (CEC, 2018). As electricity continues to be generated from renewable sources, the sustainability of electric vehicles will continue to improve.

Life cycle emissions analysis is a more comprehensive review of the impact that electric vehicles have on greenhouse gas emissions. This analysis typically includes emissions from production, distribution, use, and disposal. Emissions analysis considers both the fuel and vehicle contribution, making the emissions impact variable dependent on how electricity is sourced (Department of Energy, n.d.). Studies have shown differences in emissions and environmental impact during different stages of the life of a vehicle. The electric vehicle production stage has been found to be more intensive than gasoline powered cars, however, depending on the source of electricity, the usage phase of electric vehicles can make the technology less environmentally intensive over the lifespan of the vehicle (Hawkins et al., 2013). Electric vehicle production is more intensive because of the sourcing of the lithium batteries that power the vehicles and the additional use of copper in the production and manufacturing stage (Hawkins et al., 2013). More research is being done on the environmental impact of electric vehicles and gasoline powered vehicles as the technology continues to improve and the demand grows.

Incentives

Federal and state governments provide incentives for consumers to encourage the use of alternative fuel vehicles. The primary federal incentive is the federal income tax credit that applies to battery electric vehicles and plug-in hybrid electric vehicles. The US Department of Energy administers the federal income tax credit for battery electric and plug-in hybrid electric vehicles with batteries with at least 5 kilowatt hours of capacity that were purchased in or after 2010 (IRS, n.d.). The federal income tax credit ranges from a minimum of $2,500 to a maximum of $7,500 depending on the battery capacity (AFDC, n.d.). The tax credit is phased out for each automobile manufacturer in the second quarter after the auto-manufacturer reaches 200,000 battery electric vehicles and plug-in hybrid electric vehicles sold (AFDC, n.d.). Several auto-manufacturers are expected to reach 200,000 sales in the next 5 years as plug-in vehicle sales are anticipated to increase.

At the state and local level, there's a range of incentive options. The most common incentive is a financial rebate that can be offered as either at the point of purchase or mail in for qualified vehicles. States offering rebates issue varying rebate amounts depending on battery size, vehicle price, and consumer income. State and local governments also can incentivize the use of alternative fuel vehicles by providing parking privileges and high occupancy vehicle (HOV) access. Charging infrastructure is also incentivized through rebates to increase infrastructure development and overall adoption (AFDC, n.d.).

California was the first state to develop a rebate and is the leader in electric vehicle adoption in the country. California's Clean Vehicle Rebate Project (CVRP) provides up to $7,000 for eligible vehicles and has issued over 270,000 rebates since 2010 (CVRP, n.d.). CVRP is funded through California Climate Investments that utilizes Cap-and-Trade revenue. Similarly, both Massachusetts and Connecticut offer rebates of up to $1,500 and $5,000 for eligible vehicles, respectively (MOR-EV, n.d., Department of Energy and Environmental Protection, n.d.).

California EV Strategy and California Policies

California's ambitious goals to reduce greenhouse gasses (GHG) emissions and accelerate the adoption of clean vehicles have been shaped by various federal and state policies. The Clean Air Act of 1970 authorized the federal government and the State of California to establish regulations to reduce vehicle pollution (US EPA, 2017). California policy pushed even further to reduce the environmental impact of vehicles by establishing Zero Emission Vehicle (ZEV) regulation in 1990 that required large automobile manufacturers to sell ZEVs in the state (CARB, n.d.). Assembly Bill 32, also known as the Global Warming Act of 2006, was a starting point in California transitioning to a low-carbon future by requiring the state to lower greenhouse gas emissions to 1990 levels by 2020 (CARB, 2014). There has been significant focus on providing financial incentives to encourage the adoption of electric vehicles. In 2007, Assembly Bill 119 established the incentive program to fund clean vehicle projects, among other projects, which is now known as the Clean Vehicle Rebate Project (CSE, 2019). Funding for clean vehicle programs increased with the creation of the Greenhouse Gas Reduction Emission Fund from Cap-and-Trade proceeds. In 2012 funding for the Greenhouse Gas Reduction Emission Fund was established by Assembly Bill 1532, Senate Bill 535, and Senate Bill 1018 (BSF, 2018). Senate Bill 535 and Assembly Bill 1550 allocated a portion of the funding to directly be invested in and benefit disadvantaged communities. Finally, in 2015 Senate Bill 1275 established the Charge

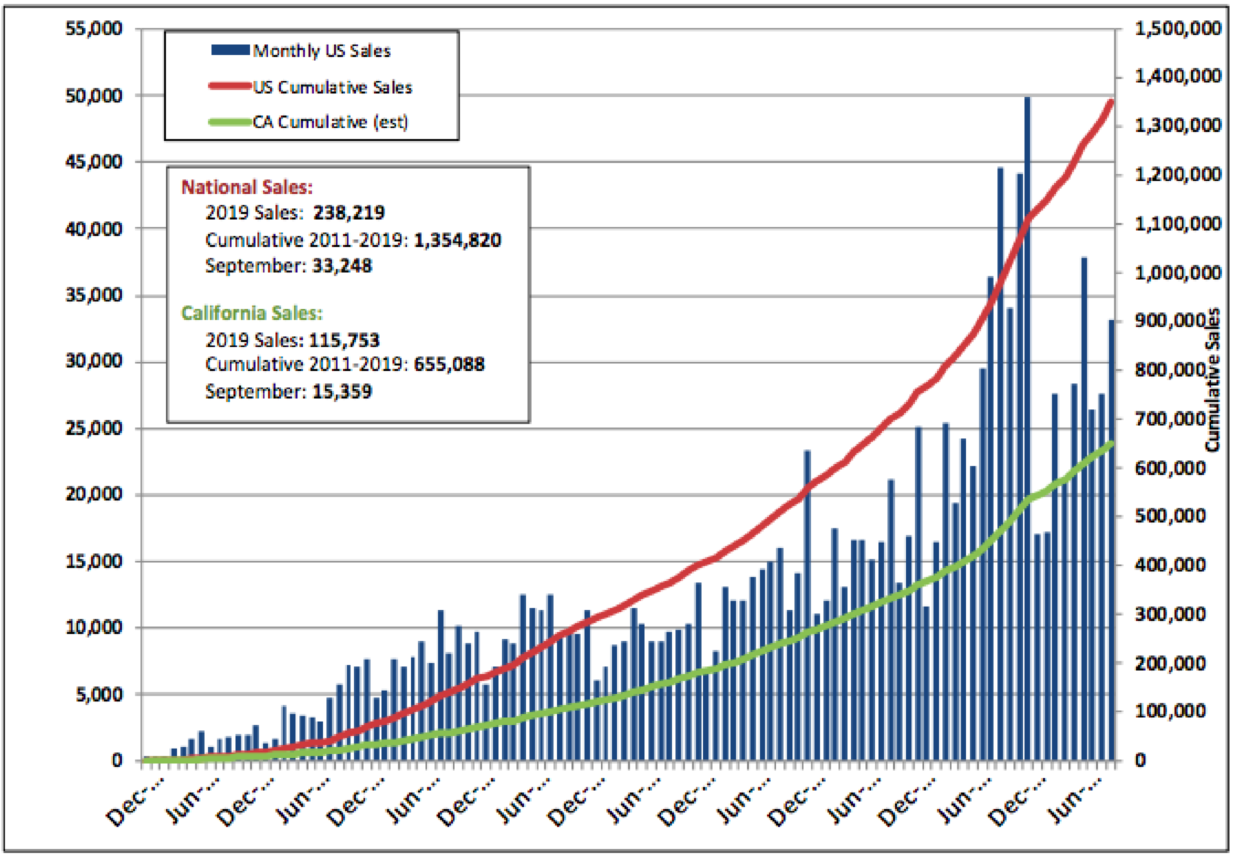
Ahead California Initiative, which establishes the goal to have at least 1 million ZEVs on the road by 2023 and specifies increased access for disadvantaged and low-income communities (De Leon, 2014). These policies have helped shape California's clean vehicle movement by setting the foundation for advancing ZEV technology and setting priority to allocate funds to benefit disadvantaged communities.

Senate Bill 350, the Clean Energy and Pollution Reduction Act of 2015, directed the California Air Resources Board to report on the barriers and opportunities to increase access to clean vehicles for low-income and disadvantaged communities in California. From this report, CARB held a public process to receive direct information from low-income communities in California to determine barriers and recommendations. Five themes emerged in the research on barriers including access and reliability, convenience of services, safety, community demographics, and investments for infrastructure. From these barriers, CARB provided six short-term recommendations, such as expanding funding to meet the needs of low-income communities, developing regional one-stop-shop programs to assist with consumer awareness, and conduct assessments of low-income transportation needs that can be used as feedback for land-use planning (California Air Resources Air Board, 2018).

In 2013, 8 states established the Multi-State Zero Emission Vehicle (ZEV) task force to collaborate on supporting state ZEV program implementation. These states recognized light-duty vehicles as the single largest contributor to greenhouse gas emissions and a significant source of pollutants impacting public health (CARB, n.d.). The first Multi-State ZEV Action Plan from 2014 to 2017 focused on supporting the electric vehicle market through financial incentives, education, and consumer outreach efforts. States also adopted California's more stringent vehicle emission standards and adopted California's Advanced Clean Cars Program (CARB, n.d.). In 2018, the Multi-State ZEV Action Plan for 2018-2021 outlined the new initiatives to increase electric vehicle adoption. These initiatives include increasing consumer education and outreach, investing in charging and hydrogen fueling infrastructure, providing consumer purchase incentives, promoting light-duty fleets, and supporting dealerships to improve electric vehicle sales (CARB, n.d.).

Current Landscape of EVs

National and California sales of clean vehicles have continued to grow since 2011, as shown in figure 5. As of September 2019, there have been 1,354,820 national electric car sales and 655,088 California electric car sales since 2011 (Veloz, 2019). California has been a leader in accelerating the adoption of electric vehicles and currently comprises approximately half of all sales in the country.



Note: Approximation assumes CA sales are 46% of national sales.
Reference: www.hybridcars.com and www.insideevs.com

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Figure 5 demonstrates clean vehicle sales in the United States and California. Source: https://www.veloz.org/sales-dashboard/

Programs such as Clean Vehicle Rebate Project (CVRP), Clean Vehicle Assistance Program (CVA Program), and Enhanced Fleet Modernization Project (EFMP Plus Up), now called Clean Cars for All, have incentivized the purchase or lease of clean vehicles, ranging from battery electric to hybrid vehicles, for low-income and disadvantaged communities. In November 2016, CVRP began issuing increased rebates for low-income communities and disadvantaged communities, which has resulted in 11,405 rebates being issued to disadvantaged communities (CVRP, n.d.). More than 16,000 incentives have been issued from CVRP, CVA Program, and EFMP Plus Up; promoting the purchase of clean vehicles in California. This number is a rough and conservative estimate of the number of clean vehicles that have been made accessible to disadvantaged and low-income communities but does show that these communities are only a small fraction of total number of vehicles sold (CVRP, n.d.). In order to increase mobility and meet climate goals, there will need to be a continued effort to target these communities in the clean vehicle movement.

The incentives listed above are only three of the 60 California Climate Investment programs that are being implemented. These programs are funded by Cap-and-Trade auction proceeds, which are distributed to programs with goals to reduce greenhouse gas emissions and promote public health, environmental benefits, and economic benefits. As required by the California legislature, at least 35 percent of investments are to be benefited in disadvantaged and low-income communities. In 2018, 57 percent of investments were cumulatively benefiting these priority populations. Investment programs are also expected to reduce greenhouse gas emissions by almost 37 million metric tons of carbon dioxide over time. As of May 2019, more than $11 billion dollars have been appropriated for greenhouse gas emission reduction programs (CCI, 2019).

California Climate Investment programs are categorized into three priority areas; which are Transportation and Sustainable Communities, Clean Energy and Energy Efficiency, and Natural Resources and Waste Division. Programs promoting incentives for clean vehicles are categorized under Low Carbon Transportation, which is in the Transportation and Sustainable Communities priority area. Other programs in this category include Clean Mobility Options for Disadvantaged Communities, Rural School Bus Pilot Projects, Zero and Near Zero-Emission Freight Facilities, and Agricultural Worker Vanpools (CCI, 2019). The Transportation and Sustainable Communities section receives continuous appropriations of 60 percent of Greenhouse Gas Reduction Fund specifically for programs on high-speed rail, public transit and affordable housing. The Low Carbon Transportation programs also receive annual appropriations.

This research will focus on one of the newer California incentive programs, the Clean Vehicle Assistance Program (CVA Program). This program is funded through the Greenhouse Gas Reduction Fund and is one of the California Climate Investment Programs, which is overseen by the California Air Resources Board (CARB). The CVA Program is a grant-based program that is administered by Beneficial State Foundation in collaboration with the Center for Sustainable Energy and Grid Alternatives (BSF, 2018). This program provides grants of $5,000 for electric and plug-in hybrid vehicles and $2,500 for hybrid vehicles. Participants are eligible if they meet income criteria based off 400 percent of the Federal Poverty level and take the required financial literacy course provided by Beneficial State Foundation. Once approved, participants can go to CVA Program network dealership and purchase a new or used clean vehicle. Beneficial State Foundation does limit the loan interest maximum at 16 percent (CVA Program, n.d.). After a vehicle has been purchased, the dealership receives the grant amount within 10 business days. More details and analysis of this program can be found in the findings section.

Literature Review

Electric Vehicle Adoption

Electric vehicle research has focused on the adoption of the technology and the ways in which the government has encouraged the transition to transportation electrification. Policymakers have incentivized the adoption of clean vehicle technology for environmental and sustainability benefits. Electric vehicles are typically viewed as more sustainable options to ICE vehicles because of fewer local tailpipe emissions. However, electric vehicles also have been associated with negative environmental impacts because of fossil fuels that are used at the power plant (Egbue and Long, 2012). The sustainability of electric vehicles is dependent on how the electricity is generated. Vehicles powered by electricity generated by coal produce similar emissions as ICE vehicles (van Viet et, al, 2011). As more electric vehicles enter the market, it will be important for the government and industry to transition to renewable forms of electricity generation.

Governments at various levels have pursued incentivizing electric vehicle adoption through rebates and other financial methods to lower the costs. Financial incentives are important tools in helping increase adoption of clean vehicles. Studies looking at incentives data prior to 2010, show that federal and state government financial incentives such as sales tax waivers and income tax credits showed positive adoption rates among hybrid electric vehicles (Jenn et al., 2013; Gallagher et al., 2011; Tseng et al., 2013). Internationally, many countries have developed their own types of financial incentives that can help reduce costs. In the Netherlands, stakeholders noted 10 different policy measures that could assist with electric vehicle adoption. These measures include support for infrastructure, on street parking for electric vehicles, education and outreach, and exemption from tolls (Bakker and Tripp, 2013). Incentives that decrease the costs of electric vehicle use, such as free parking and free charging, are the most important policies to influence electric vehicle use and hav positive correlation with electric vehicle adoption (Langbroek et al., 2016, Sierzchula et al., 2014). However, while some countries like Norway have seen increased adoption of electric vehicles by implementing incentives other countries like Denmark and Belgium have seen lower levels of utilization (Sierzchula et al, 2014).

In a study on the impacts of hybrid incentives in different states, Diamond saw that financial incentives may disproportionately benefit higher-income consumers who would likely be able to purchase the hybrid without the financial incentive (2009). The higher upfront costs can be a barrier for lower-income consumers. The study also found a stronger relationship between increasing gasoline prices motivating hybrid sales than financial incentives (Diamond, 2009). There is growing literature on the impact rebate programs and tax incentives have on electric vehicle adoption. Deshazo et al.'s simulation of the impact of the California electric vehicle rebate found that lower-income consumers were more responsive to rebates and led to a 7 percent increase in plug-in vehicle sales (2017). The research also found that by setting an income cap, making higher income consumers ineligible for the rebate, while also increasing rebate levels could increase the number of vehicles sold and increase the equity of the program, but this approach does increase the costs of the program (DeShazo et al., 2017). In Chandra et al. analysis of cost-effectiveness of tax rebates for hybrid vehicles, results showed that rebates did have a significant effect on hybrid vehicle sales and rebates subsidize consumers who would have purchased a hybrid regardless of incentive (2010).

Barriers to Adoption

Despite cost effectiveness and sustainability benefits, there are many barriers that can prohibit transitioning to electric vehicles. A barrier on the production side is that producers choose not to invest in new technology, which can slow down the progression of electric vehicles (Sierzchula et al., 2014). There are several barriers for consumers, especially lower-income consumers, in purchasing or leasing an electric vehicle. Non-purchasing motives of electric cars have been identified as battery range, price, charging infrastructure, and others (Priessner et al., 2017).

Upfront electric vehicle and hybrid vehicle costs are higher than the comparable gasoline vehicle. Due to the higher upfront costs of electric vehicles, it’s not surprising that early adopters tend to have a high income, are highly-educated, and are multi-car households (Hardman et al., 2016, Priessner et al., 2017). A justification used for higher costs of clean vehicles are the user costs, such as lifetime energy costs and maintenance costs, are generally lower for electric vehicles compared to gasoline fueled vehicles. One study found that the overall lifetime consumer ownership costs are still higher for PHEVs and BEVs (Tseng et al., 2013). Federal tax incentives can help lower ownership costs of clean vehicles to make them comparable to gasoline-fueled vehicles (Tseng et al., 2013). The lifetime costs of electric vehicles are lowering as technology continues to improve, therefore lowering the upfront costs of vehicles, and gas prices are unpredictable causing ICE vehicle fueling to rise.

Clean vehicle technology, specifically charging the electric battery and battery range, is a barrier for adoption of clean vehicles (Egbue and Long, 2012). Krupa et al. found that survey respondents were concerned with battery replacement costs and the possibility of being stranded due to a dead battery (Krupa et al., 2014). A study in the United Kingdom found that drivers who had a BEV for a week were concerned with accurately determining the amount of battery they had left and if they would be able to make it to their destination or to recharge (Graham-Rowe et al, 2012). This fear is known as range anxiety is a deterrent for new and potential EV buyers. Technology has improved since the onset of the electric vehicles on the vehicle market, however, there is still a difference between the range of a traditional ICE vehicle and electric vehicle. There also is a gap in expectations between the miles people typically drive in a day and what they perceive they need in terms of range (Egbue and Long, 2012). Barriers to electric batteries include more than range anxiety and replacing the battery. These barriers can include accessibility of charging if living in an apartment building, variable battery charging time, and technical difficulties integrating with the electric grid (Steinhilber et al., 2013). All of these concerns can result in drivers feeling that they would not be able to adapt to constraints associated with electric vehicles (Graham-Rowe et al., 2014).

Electric Vehicle Preferences

Perceptions and preferences for electric vehicles have impacted the growth of the technology in the United States vehicle market. Positive preferences towards clean vehicles often comes from consumers who are early adopters, a group that often is described as having more education and identifies as male (Egbue and Long, 2012). These user groups are important, however, to achieve higher adoption rates electric vehicles will need to appeal and be accessible to other users. Hidrue et al. found in a nationwide survey that main concerns with electric vehicle are range anxiety, charging time, and higher price of the vehicle (2011). The study also found that a person is more likely to purchase an electric vehicle if they are younger, have higher education, and have access to installing a charging station in their home (Hidrue et al., 2011). Krause et al. found that BEV consumers were more likely to be younger, have a higher education, and were male (2013). Results for PHEV were similar with the exception of gender (Krause et al., 2013).

Krupa et al. found that vehicle price, MPG, and vehicle performance were important factors in future vehicle purchasing decisions and that consumers found financial and battery factors as more important than environmental factors when considering PHEV adoption (Krupa et al., 2014). The study also found that consumers considered a tax rebate to be an important factor in purchasing a PHEV, which could help lower the higher initial costs of the vehicle (Krupa et al., 2014). Kraus et al. used a survey to determine preferences for plug in vehicles and found that over 70% of respondents were not aware of the potential fuel savings and 60% were not aware of the correct maintenance costs of owning a plug-in vehicle, which are lower than a gasoline vehicle (2013). The study also found that respondents would be more interested in purchasing a BEV and PHEV if incentives were available, however, most respondents who had access to state and local incentives were not aware of them (Krause et al., 2013).

Transportation Equity

Transportation equity is having all users, especially low-income and communities of color, be able to access safe, reliable, and clean transportation. In a British study analyzing social exclusion among lower-income demographics, researchers found that lowering transportation costs and encouraging land use planning with more accessibility can help lower social exclusion (Preston and Rajé, 2007). Barriers to transportation can depend on cultural and language factors that prevent certain groups from participating even if mobility options are available (Preston and Rajé, 2007, Sanchez and Wolf, 2005). Language barriers can restrict minorities from receiving a driver's license or using public transit (Sanchez and Wolf, 2005). One cause of reduced access to mobility is the rising cost associated with car ownership that can impact minorities, elderly, and lower-income populations (Sanchez and Wolf, 2005). Impacts of transportation have also been studied to illustrate how transportation can affect health in communities. Transportation studies have shown that some underserved communities live in areas with higher traffic areas and with higher rates of pollution that have been correlated with illnesses such as asthma (Sanchez and Wolf, 2005).

Increased mobility can help with accessing food and other necessities. Low-income households can face food insecurity due to a lack of mobility access. In general, underserved communities often spend more of their incomes on transportation and have longer travel times because they rely on slower forms of transportation (Clifton, 2004). Increased travel costs and travel time can limit options as a consumer and therefore options for necessities such as food (Clifton, 2004). In Austin, Texas, interviews with low-income residents found that a primary transportation strategy for purchasing food was by driving a car because of its reliability, reduced time, and ability to go to several locations (Clifton, 2004). However, purchasing a car was seen as an investment for the family because of the high purchasing and maintenance costs (Clifton, 2004). For some who did not have access to a personal car, receiving rides from peers allowed benefits such as shopping at different stores that are farther distances but required reliance on others that could lead to fewer shopping opportunities (Clifton, 2004). In a study seeking to understand the role of owning a vehicle and housing vouchers, the study found that households with access to the car felt safer in their neighborhoods, over time experienced less exposure to poverty, and felt they had access to live in areas with higher school performance (Pendal et al, 2014).

Transportation policy and planning literature in the 20th century was characterized by a focus on mobility, which included congestion, safety, and reduction in travel time (Manaugh et al., 2015; Hananel and Berechman, 2016). In a study reviewing equity in transportation planning of major metropolitan areas in North America, Manaugh et al. found that it is important to include measures and goals that captures the complexity of social equity (2016). Incorporating social equity into transportation can be challenging as diverse groups have different needs for transportation and prior methods of quantifying demand for transportation services can exclude disadvantaged communities (Manaugh et al., 2016). Hananel and Berechman, applied the capabilities approach to evaluate King County's transportation policy to demonstrate how the theory can be used in real projects (2016). Highlights from the application showed King County policies on transportation equity addressed disadvantaged communities and provides an alternative method to evaluating equity in transportation projects (Hananel and Berechman, 2009).

Much of the transportation equity focused research has been focused on larger metropolitan areas in North America. While this is important, many disadvantaged communities live in smaller areas with transportation options that are not as well funded. Karner's assessment on environmental justice and equity in smaller metropolitan planning organizations (MPOs) in the San Joaquin Valley of California found that definitions of environmental justice communities were outlined by many of the MPOs, which is important because different abilities to use transportation investments is dependent on mode choice, such as car owners use the highway, and therefore a higher percentage of transportation spending than transit dependent individuals (2016).

Methods

For the quantitative analysis of this research, data was used from the 2015-2017 California Vehicle Survey (CVS) that is administered by the California Energy Commission. The purpose of the survey aims to gain information on the decision factors of vehicle owners on vehicle ownership and gauge interest in alternative fuel vehicles. This survey is one source of data for the California Energy Commission's report and forecast of transportation fuel demand and the potential shift in vehicle and fuel trends (Fowler et al., 2018). CVS has been conducted over the past 20 years and can show shifts in vehicle owner preferences. The 2015-2017 CVS builds on questions that were asked in the past and also includes more questions on evolving transportation technology, including plug-in hybrid electric vehicles and battery-electric vehicles. This research will focus on light-duty vehicles and on California consumers.

The 2015-2017 CVS was created in three phases, including reviewing previous surveys, hosting nine focus group sessions, and conducting survey pretests, all influencing revisions until the final survey design was completed. The final version includes add on questions for plug-in vehicle owners to reveal owner behavior around this vehicle technology and demographic information such as age, gender, education, and transportation behavior. The survey was conducted using both address-based sampling and online-address based sampling in six different regions of California. 3,164 residential survey responses were collected, with 600 completed plug-in vehicle owner surveys completed. The survey questionnaire took an average of 30 minutes to complete, which could have deterred respondents from completing the survey (Fowler et al., 2018).

To run the analysis of the data, respondents were separated by those who would qualify for the CVA Program to analyze if there were any potential differences in responses based on program eligibility. These responses were not directly linked to the CVA Program when administered. The CVA Program income requirements are based on 400% of the 2018 Federal Poverty Level (CVA Program, n.d.). The 2015-2017 CVS survey asked respondents to give their household income based on income ranges provided in the survey questionnaire. These income ranges did not match the income amounts of the CVA Program, therefore the analysis gives an estimate of survey respondents who qualified based on reported income range and household size. Figure 6, shows the CVA Program income amounts and the 2015-2017 CVS Survey income amounts. Income amounts were chosen to include the highest amount for people who qualify, but may include those who are over the income amount or exclude those who could qualify. While race and ethnicity are important in determining how a program is reaching disadvantaged communities, race and ethnicity was not included in the sample because the program cannot use race and ethnicity for grant eligibility. The program also has not published any data on participant race and ethnicity.

Family Size	CVA Program Maximum Income	CSV Survey Income
1	$48,560	$49,999
2	$65,840	$49,999
3	$83,120	$74,999
4	$100,400	$99,999
5	$117,680	$99,999
6	$134,960	$149,999
7	$152,240	$149,999
8	$169,520	$199,999

Figure 6 shows income differences between 2015-2017 CSV Survey income and CVA Program maximum income.

A chi-squared analysis was completed to understand if there was significance in the relationship between qualifying for programs and concerns of electric vehicle barriers. The survey questions were chosen based on if they addressed the three electric vehicle adoption barriers, which were costs of vehicles, charging, and range. These questions included options for both battery electric vehicles and plug-in hybrid electric vehicles. Survey questions were framed to allow survey respondents to choose top concerns for each vehicle type. Survey respondents didn't rank concerns but only marked if they were a concern.

Program Evaluation

The quantitative analysis used from the 2015-2017 CVS will compliment the main part of this research, which is a program evaluation of California's incentive program CVA Program. This program aims to increase access to clean vehicles, especially for disadvantaged and low-income communities. This report will utilize a framework designed to assist with creating mobility equity pilot programs from the Greenlining Institute. The Greenlining Institute is a policy, research, and advocacy organization that focuses on racial and economic justice. The institute has established itself as a leader in electric vehicle advocacy since highlighting barriers in 2011 and leading the Charge Ahead Coalition. The Greenlining Institute's Environmental Equity team focuses on electric vehicles because of the intersection between transportation and environmental justice. Some of their electric vehicle work includes best practices in creating equitable mobility projects that can serve disadvantaged communities (Greenlining Institute, 2019).

Greenlining's Operationalizing Equity Framework has been widely received and used in California and other states in developing mobility pilot programs. Stakeholders have used this framework as they consider designing mobility programs and policies. The Operationalizing Equity Framework is a product of previous research the Greenlining Institute did on transportation equity, including bringing electric vehicles to low-income communities of color. The institute has also helped influence policies that have allocated funding at the state level for programs, such as EV incentive programs, for disadvantaged communities. Their expertise in mobility equity influenced the framework, which has four categories for creating and operationalizing equitable mobility pilot projects. The first section is to evaluate if the program embeds equity into its vision or mission. Second, creating a process that not only includes and benefits communities of color and low-income communities, but also partners with organizations that serve them. Next, implementing a program that incorporates other forms of benefits to disadvantaged communities beyond mobility access. Finally, measuring and analyzing the outcomes of the program to ensure that equity is result and that it's communicated to stakeholders. The framework provides guiding questions for each section that can be used to consider how equity is being incorporated into the program (Greenlining Institute, 2019).

The Operationalizing Equity Framework will be used while analyzing the CVA Program to find different themes for equity considerations within the program. To get an in-depth analysis of the CVA Program, multiple data sources will be used such as documents, website analysis, program reports, and interviews with program administrators (Creswell and Poth, 2018; Bowen, 2009). Documents include grant solicitation and summary of applicants, program implementation manual, review of administering organizations, and reports to the California Air Resources Board. To conduct the document analysis and context analysis, documents will be reviewed in an iterative process to extract information into categories based on the mobility equity framework (Bowen, 2009). For the evaluation, data is all publicly available.

The program evaluation also will include interviews with program staff including the Program Director, Operations Director, Data and Impact Manager, and Community Engagement Manager. These stakeholders were interviewed because of their experience and knowledge of different parts of the program. Interviews took place over the phone and between November 2019 and December 2019. Interview questions were specific to each interviewee based on their role at the CVA Program and ability to speak on different program functions. Questions were based on either specific program details or Greenlining's equity framework.

This research combines two methods to determine how equity is being implemented in the CVA Program. First, survey respondents who do qualify for the program are compared to those who don't qualify for the program based on income eligibility to determine if there is a difference in concerns of clean vehicle adoption barriers. Second, a program evaluation utilizing an equity framework is used to look at the program as a whole. Finally, using the equity framework as a reference, analysis is done on how the program addresses these barriers to adoption. This approach was done for several reasons. Electric vehicle adoption barriers have been widely researched but have not been researched in the context of this specific EV incentive program. Further, not as much research has been done to evaluate programs from an equity lens. This report contributes to the growing research on electric vehicle adoption by using an equity perspective on a new EV incentive program.

Potential bias of this research is the researchers previous work experience with the Greenlining Institute and Beneficial State Foundation. A limitation of this study is that publicly available data can be limited to what the organizations are required to share publicly. Further, the CVA Program has also only been through one phase of the program and therefore has limited data. Another limitation of the research is that the California Air Resources Board changes program requirements each fiscal year and therefore there may not be consistent program implementation practices.

Findings

There are several barriers to adoption of electric vehicles that have made uptake slow. For electric vehicle incentive programs to be accessible to disadvantaged communities, program administrators need to not only understand how barriers to adoption may be worse for lower-income consumers but also address barriers through program design. This research focuses on three key barriers to electric vehicle adoption, which are costs of vehicles, range, and charging. Following the barriers, there is a program evaluation of how the CVA Program has incorporated equity into its program by using the Greenlining Institute's Operationalizing Equity Framework.

<u>Cost of Electric Vehicle Concerns</u>

Concern for BEV Cost	Does not Qualify- CVA Program	Does Qualify- CVA Program	Total
Not selected	1,369	621	1,990
Selected	1,001	623	1,624
Total	2,370	1,244	3,614
	65.58	34.42	100.00

Pearson chi2(1) = 20.2863 Pr = 0.000

Table 1 shows concerns associated with costs of battery electric vehicles.

Concern for PHEV Cost	Does not Qualify- CVA Program	Does Qualify- CVA Program	Total
Not selected	1,362	647	2,009
Selected	1,008	597	1,605
Total	2,370	1,244	3,614
	65.58	34.42	100.00

Pearson chi2(1) = 9.8465 Pr = 0.002

Table 2 shows concerns associated plug-in hybrid electric vehicle costs.

Cost as Top Attribute	Does not Qualify- CVA Program	Does Qualify- CVA Program	Total
Not selected	673	279	952
Selected	1,697	965	2,662
Total	2,370	1,244	3,614
	65.58	34.42	100.00

Pearson chi2(1) = 14.9800 Pr = 0.000

Table 3 shows cost as a top attribute when considering vehicle purchase. This is regardless of vehicle technology.

As previously mentioned, transportation is the second highest cost for households behind housing. Lower-income families often pay a higher percentage of their income on transportation compared to higher income households (Surface Transportation Policy Project, 2003). BEV's and PHEV's upfront costs are higher than the internal combustion engine (ICE) alternative making it difficult for lower-income consumers to purchase an electric vehicle.

Based on the chi-squared independence tests, the findings show that CVA Program qualification and cost concerns are dependent of each other. In tables 1 and 2, a majority of respondents selected that cost of BEVs and PHEVs is not a concern. However, as shown in table 3, a majority of respondents did select cost as a top attribute when considering purchasing a vehicle regardless of technology. This could suggest that respondents may not be considering clean vehicle technology due to high costs and therefore are not concerned with the costs of BEVs and PHEVs.

Range Concerns

BEV Battery having Limited Range	Does not Qualify- CVA Program	Does Qualify- CVA Program	Total
Not selected	810	605	1,415
Selected	1,560	639	2,199
Total	2,370	1,244	3,614
	65.58	34.42	100.00

Pearson chi2(1) = 71.5624 Pr = 0.000

Table 4 shows concern for limited battery range for BEVs.

PHEV Battery having Limited Range	Does not Qualify- CVA Program	Does Qualify- CVA Program	Total
Not selected	1,154	672	1,826
Selected	1,216	572	1,788
Total	2,370	1,244	3,614
	65.58	34.42	100.00

Pearson chi2(1) = 9.2620 Pr = 0.002

Table 5 illustrated concern for limited battery range for PHEVs.

The lower range of BEVs compared to ICE vehicles is a barrier to adoption that has been improving as battery technology has advanced. Range anxiety is the fear that one will not be able to get to their destination in a BEV and may even get stranded due to the battery losing power. While this fear is valid, especially for lower range vehicles, there is a common misconception that people drive further than they actually do.

Based on the chi-squared tests for concerns on limited range, findings show that qualifications for the CVA Program and range concerns are dependent of each other. In tables 4, the test shows that a majority of respondents did select BEVs having limited batter range as a concern. Results for table 5, which showed concerns for PHEVs, were not as significant as BEVs. This suggests that range anxiety is a concern for respondents regardless of qualification into the CVA Program and there is greater concern for BEV technology.

Charging Concerns

BEV Concern for Limited Charging Options	Does not Qualify- CVA Program	Does Qualify- CVA Program	Total
Not selected	866	539	1,405
Selected	1,504	705	2,209
Total	2,370	1,244	3,614
	65.58	34.42	100.00

Pearson chi2(1) = 15.8181 Pr = 0.000

Table 6 demonstrates concern of limited vehicle charging options for BEVs.

PHEV Concern for Limited Charging Options	Does not Qualify- CVA Program	Does Qualify- CVA Program	Total
Not selected	1,153	645	1,798
Selected	1,217	599	1,816
Total	2,370	1,244	3,614
	65.58	34.42	100.00

Pearson chi2(1) = 3.3397 Pr = 0.068

Table 7 shows concerns for limited vehicle charging options for PHEVs.

BEV Concern for Charging Time	Does not Qualify- CVA Program	Does Qualify- CVA Program	Total
Not selected	1,252	766	2,018
Selected	1,118	478	1,596
Total	2,370	1,244	3,614
	65.58	34.42	100.00

Pearson chi2(1) = 25.3207 Pr = 0.000

Table 8 shows respondents concerns with time required to charge a BEV.

PHEV Concern for Charging Time	Does not Qualify- CVA Program	Does Qualify- CVA Program	Total
Not selected	1,328	723	2,051
Selected	1,042	521	1,563
Total	2,370	1,244	3,614
	65.58	34.42	100.00

Pearson chi2(1) = 1.4452 Pr = 0.229

Table 9 demonstrates respondents concerns with time required to charge a PHEV.

Charging is a barrier to electric vehicle adoption because of the lack of public infrastructure, varying fees for public charging, length of time to charge, and potential inability to install a charging unit at home. The chi-squared tests for charging concerns were significant for BEV charging and not significant for PHEV charging. Concerns for charging include both having limited charging options and amount of time to charge the vehicle. This could suggest that respondents have more concerns for BEVs compared to PHEVs because BEVs require more charging than PHEVs, which can rely on a gasoline engine if the battery is depleted.

CVA Program Equity Program Evaluation

Mission, Vision, Values of the Program

The CVA Program embeds equity through its main mission by directly stating the goal of the program is for disadvantaged and low-to-moderate income Californian's to access clean vehicles (BSF, 2018). Interviews with CVA Program staff, all explained that the main goal of their work, and by extension the program, is to increase access for low-income and disadvantaged communities. The grant solicitation directly identified that low-income and disadvantaged communities must benefit from this financial assistance program (CARB, 2017). Direction from grant funders is a critical step in ensuring that programs have funding set aside to benefit communities of concern.

The CVA Program is administered by organizations that focus on equity throughout their work. The program is administered by Beneficial State Foundation, who partners with Grid Alternatives and the Center for Sustainable Energy to run the statewide program. All three organizations identify creating opportunities and serving traditionally underserved communities. Grid Alternatives is a clean energy organization and assists in installing charging stations for CVA Program participants (Grid Alternatives, n.d.). The Center for Sustainable Energy is a leader in clean vehicle incentive programs and runs the Clean Vehicle Rebate Program in California and similar programs in other states (CSE, n.d.). Jhana Valentine, Program Director of the CVA Program, explained that the Center for Sustainable Energy also helps the CVA program by providing a third party evaluation and by sharing lessons learned from CVRP (2019).

Creating an Equitable Program Process

The Operationalizing Equity Framework outlines that to have an equitable process there needs to be community engagement, assured benefits for the population the program serving, and understanding of possible impacts or burdens (Greenlining Institute, 2019). Ideally, community engagement will bring in disadvantaged communities in a culturally appropriate way and that empowers communities (Greenlining Institute, 2019). Adrian Gomez, the Community Engagement Coordinator, explained that during the first round of the program they focused on trying to reach as many people as possible to advertise the program (2019). The program had more success than anticipated, partially because of partnering with Grid Alternatives to reach their large community network, and was forced to stop accepting applications due to the volume of grant applications reaching the funding limit.

During the second phase of the program, Beneficial State Foundation plans on using data to identify communities that are lower-income and who live in more pollution burden areas for community engagement efforts (Adrian Gomez, Joe Jackson, Rodrigo Sandoval, 2019). This change is taking place because they found that in the first phase of the program many of the recipients weren't necessarily their target communities because they were on the higher end of the income requirements. To do this work, the team plans to use a community burden map of California to find communities to engage with (Adrian Gomez, 2019). In this work the CVA Program partners with CBOs who are directly engrained in the community to do outreach (Adrian Gomez, 2019). It is generally best practice in community engagement to partner with local CBOs who already have relationships within the community and can lead to better outreach outcomes. For the second phase of the program one community they want to focus on is Native American community (Rodrigo Sandoval, 2019). However, they've found that this work is especially difficult because those on tribal land often don't have the financial means to purchase an electric vehicle (Adrian Gomez, 2019).

To have a program design that embeds equity, it's important to consider the benefits and the potential burdens it can have on communities. For the CVA Program the benefits are obvious, mainly access to a clean vehicle, however the burdens are not as obvious. Rodrigo Sandoval, the Operations Director, explained that a concern with incentives programs is the potential to put someone in a financial situation that they won't be able to support (2019). Internally the team strategizes on how to best mitigate this for their program participants. Joe Jackson, the Data and Impact Manager, is concerned with low-income participants may get a vehicle with technology that is not suitable for their lifestyle (2019). Jackson explains that for low-income people losing wages due to electric vehicle range not reaching their workplace can be a significant burden and the program could benefit from having a set of screening questions to ensure that participants can be better informed on the technology that will work for best for them (2019).

Implementation of the Program

The implementation of the program is an opportunity to provide benefits to target communities and also increase economic opportunity beyond program participants (Greenlining Institute, 2019). An equitable program will have multiple benefits for the community it's serving, such as health and economic opportunities (Greenlining Institute, 2019). As a California Climate Initiative, the CVA Program aims to help lower greenhouse gas emissions and air pollution by putting more electric vehicles on the road and potentially removing older more polluting vehicles (CARB, 2017). This in turn can provide long term health benefits such as reduced asthma and lung related conditions.

The CVA Program is structured to provide benefits beyond transportation, particularly economic benefits. In this program, all participants have to participate in an online financial literacy course that provides lessons such as budgeting. Further, the program tries to prevent participants from receiving a subprime or predatory loan by requiring that loans be a maximum 16 percent interest. The CVA Program also recommends that participants receive a loan with Beneficial State Bank, because they will work with subprime applicants, although there are restrictions (CVA Program, n.d.). The program's structure of being a grant versus a rebate allows participants to receive a lower loan amount and lower out-of-pocket down payment because the grant is available at the time of purchase. This is a benefit of having a grant program over a rebate program, which typically applies after the purchase of the vehicle and therefore cannot be used as a down payment.

The program incorporates equity into the implementation of the program directly addressing key barriers disadvantaged and lower-income communities have. First, the program is designed to serve many Californians' by setting the income eligibility at 400 percent of the 2018

Federal Poverty Level (CVA Program, n.d.). Charging can be difficult for low-income participants who don't have access to charging because they live in an apartment or don't have access to a garage to charge. The CVA Program is addressing this in the second phase by offering portable Level 1 and Level 2 chargers (Adrian Gomez, 2019). Gomez explains that offering a portable charger allows them to increase equity in the program because it's creating more access to charging infrastructure (2019). The California Air Resources Board has also designated funding to incentive BEVs and PHEVs by providing higher grants for this technology compared to HEVs (Rodrigo Sandoval, 2019). Sandoval explained that in the 450 grants that were issued, participants favored BEVs and PHEVs because they were given a higher grant (2019). The CVA Program also offers grants for both new and used vehicles, which makes this grant program accessible to low-income consumers (CVA Program, n.d.). Even with a grant, a new electric vehicle may still be too expensive for most low-income consumers. Used electric vehicles are significantly less expensive than new electric vehicles, allowing lower-income participants to receive a lower loan amount and participate in the program.

Internally, equity is being prioritized through hiring of program staff and location of program operations. Most of the program staff is located in Fresno, California at a Beneficial State Bank branch. This is significant because Fresno, like much of Central California, has high percentages of air pollution and percentage of disadvantaged communities (OEHHA, 2018). Jackson described that many of the program staff are representative of the communities that the program serves. Further, the program is internally giving access to fairer incomes to staff who are representative of the communities they serve (Joe Jackson, 2019).

Analysis and Evaluation of the Program

An important aspect of creating a program that incorporates equity is to establish mechanisms to measure, analyze, and evaluate the program (Greenlining Institute, 2019). By having these mechanisms, the program can be held accountable that it's making a positive impact, instead of creating harm, and also ensures that progress is being communicated. Climate Investments programs require program administrators to report on a quarterly basis and CARB publishes an annual report compiling all program data. The quarterly reports require programs to report on funding expenditures, vehicles funded, outreach efforts, implementation challenges and achievements. A final report includes the previous requirements and recommended potential program improvements (CARB, 2017). The CVA Program requires participants to complete an adoption survey and an ownership survey. However, the CVA Program does not explicitly state how they will evaluate the impact of the program or who is involved in determining the metric selection, data collection, or review (BSF, 2018).

The CVA Program is a product of using evaluation of a different program to create a better one. Before the statewide program, a smaller local program was piloted in northern California. The program aimed to help lower-income Californians in the area receive financial assistance to purchase an electric vehicle. Valentine explained that this program provided significant lessons learned for the CVA Program due to the restrictions that the pilot had in its design (2019). For example, the program provided $5,000 grants, capped the loan amount at about $10,000, and limited loans to having a maximum 8 percent interest. Participants found that it was difficult to find an eligible vehicle that they could afford without also using savings. The program became inaccessible to people who did not have savings to contribute to a vehicle. Although the pilot program initially had created this design to ensure that people didn't enter into a situation that they wouldn't be able to financially maintain, it severely restricted who could participate. The lessons learned from the pilot helped influence the CVA Program by not creating a loan cap, increasing eligibility to 400 percent2 of the Federal Poverty Level, and not geographically restricting the program (Jhana Valentine, 2019).

In 2019, the CVA Program expanded its capacity by hiring a Data and Impact Manager, Joe Jackson, to lead reporting to CARB and managing program data. Jackson explained that he found that CVA Program didn't have a program evaluation plan or logic model before he started, which made it difficult to know if they were collecting the right information (2019). They are now in the process of creating these plans and models, which will help guide them as they continue in future phases of the program. Specifically, the program model will help create a reporting structure to determine when and how reporting is structured. Jackson explained that evaluation is an opportunity for learning how the process is working and what the outcomes are (2019). It will help better serve the team, funders, stakeholders, and others who are looking to do this work. He envisions that they will have a monitoring report that will likely be pulled once a month for the team to internally evaluate their progress and then publish an annual report on learnings, partnerships, and requirements (Joe Jackson, 2019).

In the meantime, Jackson explained how data is currently used to improve the CVA Program. Jackson explained that they use publicly available data because the program data is so small that it doesn't give a sense of impact. The program has released 450 grants, which is not large enough to show the impact of electric vehicles. The CVA Program also can't use race and ethnicity as a determining factor for the program so they are required to rely on income. However, it's a goal to use data to show that race is a factor for many inequities. When race is compounded with income, the burden is worse for communities. Jackson's work has helped the team prepare for the second phase of the program by using data to determine where to focus engagement. The team is targeting areas with higher proportions of low-income and people of to allocate resources and build relationships in this area (Joe Jackson, 2019).

Discussion

To incorporate equity, a program needs to be designed intentionally with equity as a focus and a deep understanding of the barriers that cause the need for the program. The CVA Program has created a program that incorporates equity into an electric vehicle incentive program and has taken steps to reduce barriers to electric vehicle adoption. The findings section highlighted differences of concern for three barriers to electric vehicle adoption and evaluated the CVA Programs using Greenlining's Operationalization Equity framework. The discussion section aims to connect these barriers and the evaluation.

Costs

To help meet climate goals, electric vehicle adoption will need to be widespread. Low-income communities and disadvantaged communities will need extra assistance due to the high upfront cost of clean vehicles. One report found that electric vehicles won't reach cost parity to ICE vehicle equivalents until 2025 (Soulopoulos, 2017). Further, the Bloomberg report estimates that electric vehicles may be up to 15 percent cheaper than ICE vehicles by 2030 (Soulopoulos, 2017). In the survey, respondents described that vehicle price was a top attribute when considering purchasing a vehicle. Since electric vehicles are more expensive than ICE vehicles, this could lead to prospective buyers not considering them due to their higher price point.

The CVA Program aims to make electric vehicles accessible and affordable for low-income communities, by addressing two of the biggest issues associated with acquiring a clean vehicle. First, the program aids in the upfront costs by providing a grant that can be applied directly during the purchase and therefore lowering the amount needed compared to a rebate program. The program also encourages and requires that participants don't fall subject to subprime loans by capping loan interest amounts. Second, the program allows used clean vehicles to be eligible, which allows lower-income consumers to participate and receive a smaller loan than if they were to purchase a new clean vehicle. The CVA Program, along with other electric vehicle incentive programs, helps increase adoption and address affordability, however, there also needs to be action in the industry. Having an incentive program will not alone be able to make electric vehicles affordable. At the federal level, there needs to be support to continue progressing battery technology that will aid in lowering the costs of electric vehicles. Further, adding more electric vehicle options, increasing electric vehicle advertisement, and encouraging dealerships to sell electric vehicles may help increase demand of clean vehicles.

Range

The range of an electric vehicle may be one of the biggest misperceptions that is deterring mass adoption. Electric vehicles that are more affordable often have lower range, which could be a barrier for those who live further from work or who work multiple jobs. Further, many people perceive that they drive more than they do on a normal day and would actually be able to benefit from a BEV. In the survey, range concerns were significant for respondents and therefore indicate that the limited driving range of battery technology can be prohibitive for adoption.

The CVA Program addresses these issues by including PHEV and HEV in the program design. Participants who need a vehicle with further range can still benefit from a clean vehicle. Although these vehicles are not zero emission, including them is important because they still reduce local air pollutants and potentially help get older and more polluting vehicles off the road. An important aspect of understanding the difference between each type of clean vehicle is the education and outreach piece. It's important for electric vehicle programs to clearly explain and teach participants about the different types of clean vehicles and also encourage participants to purchase a vehicle that will actually meet their needs.

Charging

Charging infrastructure is a barrier to electric vehicle adoption because charging infrastructure is still expanding across the state and country. Survey responses for charging were significant for concerns with limited charging options for BEVs, which a well know barrier to adoption. Even though there have been efforts at the local and state level to increase charging stations, there is still a lack of charging options, especially for consumers who do not own their home. This becomes a more significant issue when clean vehicle owners can't charge their vehicles at home because they don't have access to a parking spot and an electrical outlet.

The CVA Program addresses concerns with charging infrastructure by including partnering with Grid Alternatives to provide charging stations and funding for installation. The program has also adapted from the first phase to now include portable charging options for those who are unable to install charging infrastructure. This is a great example of how to improve a program and make it more accessible. It is important to note that in order for charging infrastructure to meet the growing demand, there will need to be investments from multiple stakeholders. These stakeholders include government, utility companies, and private industry, such as automobile manufacturers.

CVA Program

The CVA Program is one of several stakeholders who are trying to make electric vehicles more accessible. As a newer program, the CVA Program had an opportunity to incorporate equity through its design and implementation. Beyond directly addressing cost, charging infrastructure, and range, the CVA Program has embedded equity that will help create a change that goes beyond providing access to clean vehicles.

The transportation system has failed people of color and low-income communities for decades. From not investing in public transit in areas where these communities live to building highways next to or in low-income communities, the transportation system has been built to not adequately serve all. Today transportation is the second largest expense for low-income households and the leading factor in greenhouse gas emissions in California (Surface Transportation Policy Project, 2003, CARB, 2019). The CVA Program is one of many programs and stakeholders aiming to reduce both the historical and current disparities that low-income households and communities of color experience. The program is directly reducing the cost of transportation and making clean vehicles more accessible, while also setting a precedent that clean vehicles don't only serve more affluent communities.

While this program is still relatively small compared to larger programs, such as the Clean Vehicle Rebate Project, the impact is quite large. CVRP has provided thousands of rebates to Californian's to purchase clean vehicles, while CVA Program has granted approximately 450 grants for clean vehicles. However, the CVA Program goes beyond providing grants to clean vehicles and addresses equity in other ways. Internally, the CVA Program has created economic opportunities for people living in one of the more air-polluted areas in California. The program staff diversity helps create representation in the transportation field and aids them in better serving program participants. Finally, the financial piece of the CVA Program is an opportunity for Californian's to not only purchase a clean vehicle, but also improve their credit score and financial health that can lead to more opportunities outside of transportation in the future.

Policy Recommendations and Conclusion

EV Incentive Program and CVA Program Recommendations

Expand Metrics

All EV incentive programs that are funded by California Climate Investments and overseen by CARB are required to report on a quarterly and annual basis. A recommendation for EV incentive programs is to establish metrics that go beyond CARBs required reporting metrics. The CVA Program is rooted in strong components of financial and transportation equity, therefore metrics should reflect this. Reporting on financial and transportation equity metrics can be difficult and time consuming, however, it can help set precedent for other programs and begin to build a data set that can help improve systems beyond the program. Measuring financial benefits, or burdens, of the CVA Program could include tracking if loan payments for the vehicle were met, change in credit score, and ability to receive future loans that are not subprime.

Measuring transportation equity would aim to understand what are the mobility burdens that program participants have and how owning a clean vehicle has helped reduce these burdens. Metrics could include asking participants what appointments they have missed due to transportation barriers and are now able to make, household transportation expenses, commute time before and after purchasing a clean vehicle, and new employment opportunities. This work is being done in other areas in the country and with different types of mobility. A report on emerging mobility in Minnesota outlined metrics to be tracked for equitable shared mobility options. These metrics include monthly household spending on transportation, electrification of the sector, jobs accessed due to new shared transportation services, measurements of coverage area, and affordable housing units with shared mobility services (Randal, 2017). Data that is tracked for Los Angeles, California Electric Vehicle Carsharing Pilot Project includes categories like trip types, neighborhood, automobile ownership, race, and income (Randal, 2017).

Ideally metrics and evaluation planning would occur during program design and includes diverse stakeholders to identify metrics of success. The CVA Program added a Data and Impact Coordinator after the first phase of the program. In hiring this position, the program was able to more effectively evaluate the impact of their program and make changes as necessary. Programs should prioritize having at least one person dedicated to measuring impact. Additionally, it's important to create mechanisms within the program that will allow flexibility in program design to change as necessary.

EV Incentive programs have the opportunity to conduct data collection that can help lead to bigger systems change because they have a captive audience to collect from. Data has become ever increasingly important to evaluate how bigger systems are working for disadvantaged and low-income communities. In this context, data needs to be collected to be determining what is the broad impact of these programs and how other programs or stakeholders are using this data to improve their work. Finally, it's important to include metrics on race to determine who is benefiting from these programs.

Broaden Partnerships

To create a more equitable transportation system, there will need to be strong partnerships from different types of stakeholders. The CVA Program has benefited from strong partnerships with Grid Alternatives and the Center for Sustainable Energy in designing and implementing the program. The program also partners with local based organizations to help in expanding outreach and community engagement efforts. Other partnerships that could expand the programs reach and impact include partnering directly with electric utilities, municipalities, interest groups, and even private companies.

In California and other parts of the country, such as Colorado and Sonoma County, there have been electric utilities, municipalities, and interest groups that have coordinated electric vehicle group-buys (Berman, 2016, Sonoma Clean Power, 2020). In these programs, a stakeholder negotiates with a dealership or automobile manufacturer to receive a special discount for a large group of customers. The dealerships or automobile manufacturers benefits by selling a large quantity of vehicles in a short time and the consumers benefit from getting a special discount to incentivize the purchase of the clean vehicle. The CVA Program and other electric vehicle incentive programs can take advantage of these group buys by partnering with group buy hosts and encouraging them to advertise the incentive program. This could help lower-income program participants purchase a newer vehicle that they wouldn't have been able to access prior to the combination of the group-buy discount and incentive.

Over the past several years, foundations and big donors have been funding cities to create equitable change to meet progressive climate change or other societal goals. Collaborating directly with these cities can help the EV incentive programs expand their reach. For example, three cities in California are participating in the Bloomberg American Cities Climate Challenge where they receive resources to make innovative changes to help meet climate change (Bloomberg Philanthropies, 2018). By working directly with San Jose, Los Angeles, and San Diego, EV incentive programs can reach a higher number of people, including disadvantaged communities, and potentially lower the cost of EVs even further. The CVA Program also has the opportunity to help increase the role of equity in the American Cities Climate Challenge work by working with the participating cities to reach their more underserved communities.

State Specific Recommendations

Continue to build systems that allow EV incentive programs to be easily understood and combined

In California, EV incentives funded through California Climate Investments cannot be combined. These programs include the Clean Vehicle Rebate Program, Rebate Now, Tune In Tune Up, and Replace Your Ride (CVA Program, n.d.). However, it could further help lower-income participants purchase an electric vehicle, especially a newer electric vehicle with higher range, such as a Chevy Bolt or a 2019 Nissan Leaf Plus, that may still be out of the price range without a second incentive. Having access to an electric vehicle with higher range, compared to older used models or lower range models, can help encourage consumers who drive further.

It's important for consumers to understand the differences between all of the EV incentive programs so they are able to determine which program is better for them. Differences that distinguish the various programs include varying levels of income eligibility, when the incentive amount is released, the incentive amount, and vehicle eligibility among other factors. The ecosystem of EV incentive programs can be difficult for consumers to understand, mainly because of the different rules, but there is an opportunity for programs to not be siloed and create a more equitable EV ecosystem. One way this is being done is through CARB's One-Stop-Shop Pilot where participants can use one application to apply and qualify for CARBS Low Carbon Transportation Equity Projects, including the CVA Program, CVRP, and EFMP-Plus Up (California Air Resources Board, 2018). Pilots like these are important to help streamline the process for applying for grants and understanding what are the best options for participant needs. The pilot has goals to increase beyond transportation to also include clean energy and housing programs administered through CARB as well (California Air Resources Board, 2018).

A benefit of administering multiple programs is a coordination of data and reporting. The state of California recently released an open data portal that can be accessed by the public demonstrating the importance of increasing access to data. However, this portal doesn't address environmental or transportation justice issues (State of California, 2020). CARB requires each program to report on specific metrics quarterly and annually. This is an opportunity to build data that can be used to determine the impact of clean vehicles for low-income and disadvantaged communities. California could benefit from going beyond collecting data on climate change goals, demographics, and grant specific metrics, by including reporting guidelines on prior transportation challenges and the impact of acquiring a clean vehicle on access to healthcare, education, and employment. These metrics are often more difficult to calculate but can provide more insight on the success of these programs in terms of equity.

Build Capacity by Compensating CBOs

An important aspect of building relationships with disadvantaged communities and the local community-based organizations (CBOs) that support them is to partner with CBOs to conduct outreach and community engagement. Partnerships should include compensation to help build capacity within the organization and within the community. When partnerships are not adequately funding smaller community-based organizations, especially organizations that focus on equity, they are continuously not able to grow their organization and better serve the community. The Financial Assistance for Low Income Consumers grant solicitation requires outreach in DACs and to provide a strategy to support organizations that represent DACS. However, the grant does not explicitly state that the organizations need to be financially compensated for their work. For statewide programs it's critical to partner with local organizations to reach target demographics, however, they need to be compensated to help build capacity and be more effective in their outreach. Grant solicitations should specifically state that partner organizations are compensated and that grantees outline an estimate of how much of their budget will be used to compensate partner organizations.

Go Beyond Transportation Equity

Addressing and increasing equity for low-income and communities of color has to happen at different levels and therefore requires programs to be done holistically. While transportation is a high cost burden for low-income communities and communities of color, it's important to understand the intersectionality that transportation has to other inequities. Also, many of the root causes that have caused inequities in transportation are deeply rooted systemic issues that are causing other forms of inequities for low-income households and communities of color. EV Incentive programs can help address some of the results from these root causes by increasing access to transportation and meet climate goals.

EV incentive programs can go beyond meeting climate change goals by creating programs that include other assured benefits such as access to employment, healthcare, and education. This can begin to address other effects from deeply rooted systemic causes of inequity. The CVA Program is a great example of how a program can provide other benefits, mainly through the financing aspect of the program, to help create more opportunities for disadvantaged communities to build financial health.

Increase Public Input in Program Design

Before a grant solicitation is released, CARB hosts workshops and other opportunities for public input on the program. This input has been an opportunity for CBOs and interest groups to provide information that can help create better programs. For the CVA Program, groups like Beneficial State Foundation and the Greenlining Institute provided suggestions to help shape the Clean Vehicle Assistance Program grant solicitation. Many of the suggestions came from lessons learned from previous programs and helped create a more equitable program.

Another way to create more equitable programs is to provide opportunities where consumers or potential program participants not only share feedback but also show that they have decision-making power in these programs. This should happen at both the grant solicitation level and at the program design level once a program administrator has been decided. While it may not be feasible to have every single potential participant provide input, at least reaching target groups can begin to create opportunities for more diverse input that will help create programs that actually address the needs of people. Funding for more local programs can also help allow communities to have decision-making power to have programs that can better serve them. Compared to large statewide programs, local programs can be more targeted to address the needs of the community.

Conclusion

This research focuses on equity in the CVA Program by determining how equity has been embedded into the program and how it addresses electric vehicle adoption barriers. The term transportation equity references the concept that access to safe, affordable, and reliable transportation should occur regardless of income, race, ethnicity, gender, or ability. Transportation planning has had a history of creating systems that disproportionally impacted marginalized communities. A significant impact from transportation on many low-income and disadvantaged communities is higher exposure to vehicle air pollution. In response to the environmental and public health impacts from transportation, many have encouraged the transition to electric vehicles. However, due to higher upfront costs, range concerns, and limited charging opportunities, higher-income consumers have primarily used and benefited from electric vehicles.

California has encouraged transportation electric electrification through financial incentive programs, such as the CVA Program. This report evaluated the CVA Program using the Greenlining Institute's Operationalizing Equity Framework, specifically designed for practitioners to use for mobility pilots, programs, and policy. From an equity lens, the CVA Program has designed a statewide program that increases access to clean vehicles for low-and-moderate-income households and disadvantaged communities. This program has implemented equity by allowing increasing vehicle eligibility to include used vehicles and different technologies, provides grants to lower the upfront costs, and partnering with local community-based organizations. To make this program more equitable, the CVA Program is currently working with their Data and Impact Manager to be intentional in their evaluation mechanisms and has already seen benefits by targeting specific groups in community engagement.

While the CVA Program has created and implemented a program that embeds equity, this program is only one step towards making clean transportation more accessible. For many, a new electric vehicle will still not be accessible with a grant and lower interest automobile loan. As the used vehicle market becomes more robust and battery prices decrease, there will be greater access to clean vehicle technology for low- to- moderate-income households. Other states can benefit from creating similar clean vehicle incentive programs and better serve their communities by embedding equity into the design and implementation of their program.

There are many opportunities to expand this research to build on evaluating programs using an equity lens. Future research could focus on comparing multiple electric vehicle incentive programs; compare different states efforts on incentive programs with an equity lens, and including participant perspective on electric vehicle incentive programs. Finally, taking a federal level perspective on policies and programs associated with electric vehicles could aid in understanding and evaluating electric vehicle equity on a larger scale.

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