Spring 5-2020

The Adoption of Zero-Emissions Vehicles by Low-Income Consumers in California: An Outcome Evaluation of the Clean Vehicle Rebate Project

Julie Nguyen
San Jose State University

Follow this and additional works at: https://scholarworks.sjsu.edu/etd_projects

Part of the [Energy Policy Commons](#), [Environmental Policy Commons](#), [Health Policy Commons](#), [Policy Design, Analysis, and Evaluation Commons](#), [Public Administration Commons](#), and the [Transportation Commons](#)

Recommended Citation

Nguyen, Julie, "The Adoption of Zero-Emissions Vehicles by Low-Income Consumers in California: An Outcome Evaluation of the Clean Vehicle Rebate Project" (2020). *Master's Projects*. 947.
DOI: <https://doi.org/10.31979/etd.n6a2-y5cp>
https://scholarworks.sjsu.edu/etd_projects/947

This Master's Project is brought to you for free and open access by the Master's Theses and Graduate Research at SJSU ScholarWorks. It has been accepted for inclusion in Master's Projects by an authorized administrator of SJSU ScholarWorks. For more information, please contact scholarworks@sjsu.edu.

The Adoption of Zero-Emissions Vehicles by Low-Income Consumers in California:
An Outcome Evaluation of the Clean Vehicle Rebate Project

by

Julie Nguyen

A Thesis Quality Research Paper

Submitted in Partial Fulfillment of the

Requirements for the

Master's Degree in

PUBLIC ADMINISTRATION

Professor Frances L. Edwards, Ph.D.

Adviser

The Graduate School

San José State University

May, 2020

TABLE OF CONTENTS

LIST OF TABLES	4
LIST OF FIGURES	5
LIST OF ABBREVIATIONS.....	7
BACKGROUND	8
Problem	8
Research Question and Purpose.....	8
Solution	10
LITERATURE REVIEW	15
Internal Combustion Engine Vehicles (ICEVs) vs. Zero-Emission Vehicles (ZEVs)	15
History of Government Incentives for Electric Vehicles in the U.S.....	15
The Effect of Financial Incentives on the Adoption of Electric Vehicles	17
Socioeconomic Characteristics of Incentive Program Recipients	19
Perceived Higher Costs of Adopting and Operating ZEVs	21
Other Barriers to the Adoption of ZEVs.....	24
METHODOLOGY	27
FINDINGS AND DESCRIPTIVE STATISTICS	31
Findings on Vehicle Registrations in California.....	31
Findings on Overall CVRP Rebates	33
Findings on CVRP Rebates Issued to Consumers in Low-Income Communities	38
Findings on CVRP Rebates Issued to Low-Income Consumers	42
Findings on CVRP Consumer Survey 2013-2017	47
Findings on GHG Emissions in California	51

Comparison of ZEV and ICEV Operating Costs and Emissions.....	52
ANALYSIS.....	53
Analysis of Measures and Outcomes.....	53
Limitations.....	65
Future Areas of Research.....	66
Conclusion.....	67
REFERENCES.....	68

LIST OF TABLES

Table 1: CVRP Rebates According to ZEV Type and Rebate Amount	14
Table 2: Logic Model: Outcome Evaluation of CVRP.....	29
Table 3: Registrations of Vehicles in California 2018-2019	31
Table 4: Registrations of New Vehicles in California 2016-2018.....	32
Table 5: CVRP Rebates Issued, March 2010-November 2019	33
Table 6: CVRP Rebates Issued by ZEV Type, March 2010-November 2019	34
Table 7: CVRP Rebates Issued to Consumers in Low-Income Communities, March 2010- November 2019.....	38
Table 8: CVRP Rebates Issued to Recipients in Low-Income Communities by ZEV Type, March 2010-November 2019	39
Table 9: CVRP Rebates Issued to Low-Income Consumers, March 2016-November 2019.....	42
Table 10: CVRP Rebates Issued to Low-Income Consumers by ZEV Type, March 2016- November 2019.....	43
Table 11: Rebate Importance: CVRP Consumer Survey 2013-17	47
Table 12: Rebate Essentiality: CVRP Consumer Survey 2013-17.....	49
Table 13: PEV Interest: CVRP Consumer Survey 2013-17	50
Table 14: Total GHG Emissions of Light-Duty Vehicles in California 2010-2017.....	51
Table 15: Comparing Percentage Change of CVRP Rebates Issued, Percentage Change of CVRP Rebates Issued to Consumers in Low-Income Communities, and Percentage Change of CVRP Rebates Issued to Low-Income Consumer.....	52

LIST OF FIGURES

Figure 1: Map of Disadvantaged Communities and Low-Income Communities in California.....	13
Figure 2: SPSS Output of CVRP Rebates Issued, March 2010-November 2019.....	33
Figure 3: CVRP Rebates Issued by ZEV Type, March 2010-November 2019	34
Figure 4: CVRP Rebates Issued by Vehicle Manufacturer, March 2010-November 2010.....	35
Figure 5: CVRP Rebates Issued by Air District, March 2010-November 2019.....	36
Figure 6: CVRP Rebates Issued by Amount, March 2010-November 2019	37
Figure 7: SPSS Output of CVRP Rebates Issued to Consumers in Low-Income Communities, March 2010-November 2019	38
Figure 8: CVRP Rebates Issued to Consumers in Low-Income Communities by ZEV Type, March 2010-November 2019	39
Figure 9: CVRP Rebates Issued to Consumers in Low-Income Communities by Vehicle Manufacturer, March 2010-November 2019	40
Figure 10: CVRP Rebates Issued to Consumers in Low-Income Communities by Amount, March 2010-November 2019	41
Figure 11: SPSS Output of CVRP Rebates Issued to Low-Income Consumers, March 2016- November 2019.....	42
Figure 12: CVRP Rebates Issued to Low-Income Consumers by ZEV Type, March 2016- November 2019.....	43
Figure 13: CVRP Rebates Issued to Low-Income Consumers by Vehicle Manufacturer, March 2016-November 2019	44
Figure 14: CVRP Rebates Issued to Low-Income Consumers by Vehicle by Amount, March 2016-November 2019	45
Figure 15: SPSS Output of Correlation Between CVRP Rebate Recipients Residing in Low-Income Communities and CVRP Low-Income Rebate Recipients	46
Figure 16: Rebate Importance: CVRP Consumer Survey 2013-17	48
Figure 17: Rebate Essentiality: CVRP Consumer Survey 2013-17.....	49
Figure 18: PEV Interest: CVRP Consumer Survey 2013-17	50

Figure 19: Calculation of Annual Operating Cost and Emissions of ZEV Compared to ICEV51

Figure 20: SPSS Output of Relationship Between Rebate Essentiality, Rebate Importance,
and PEV Interest52

LIST OF ABBREVIATIONS

Assembly Bill	AB
All-Battery Electric Vehicle	BEV
California Air Resources Board	CARB
California Electric Vehicle Infrastructure Project	CALeVIP
California New Car Dealers Association	CNCDA
Clean Vehicle Rebate Project	CVRP
U.S. Department of Energy	DOE
California Department of Motor Vehicles	DMV
U.S. Energy Information Administration	EIA
Electric Vehicle	EV
Executive Order	EO
Plug-In Electric Drive Vehicle Credit	PEDVC
Hybrid Electric Vehicle	HEVs
Hydrogen Fuel-Cell Electric Vehicle	FCEV
Greenhouse Gas	GHG
Internal Combustion Engine Vehicle	ICEV
Plug-In Electric Vehicle	PEV
Plug-in Hybrid Electric Vehicle	PHEV
Senate Bill	SB
Zero-Emissions Vehicle	ZEV

BACKGROUND

Problem

Air pollution is harmful to all living things and the environment. In California, there are over 39 million people generating unhealthy amounts of air pollution. The state's rugged topography (the physical shape of the land) and its warm, sunny climate are perfect for collecting and forming air pollutants. Greenhouse gases (GHGs) are air pollutants that trap heat in the atmosphere, contributing to global warming and climate change (CARB, 2019a). Since 1990, the American Lung Association (ALA) has reported on air quality in the United States (U.S.). For 19 out of the 20 years, California has been rated as the state with the worst air quality (ALA, 2020). ALA revealed that over 90% of Californians live in areas affected by unhealthy air (ALA, 2020). To reduce GHGs and improve air quality, California created the Clean Vehicle Rebate Project (CVRP) to promote the purchase or lease of Zero-Emissions Vehicles (ZEVs) by offering rebates aimed at low- and moderate-income consumers.

Research Question and Purpose

How effective is the Clean Vehicle Rebate Project (CVRP) in promoting the adoption of Zero-Emissions Vehicles (ZEVs) by low-income consumers in California?

Consumers face a difficult choice when deciding if the next new vehicle they purchase or lease will be a ZEV or a non-ZEV, hereinafter referred to as an Internal Combustion Engine Vehicle (ICEV). The adoption and operating costs of ZEVs are perceived to be higher than ICEVs. However, the rebates offered by CVRP make it more compelling and financially feasible to even consider adopting a ZEV. It would be useful to evaluate what kind of effect CVRP rebates have on consumers when they make a decision on what type of vehicle to get.

CVRP has a large annual budget—for fiscal year (FY) 2019-20, it is \$238 million (CARB, 2019c, p. iv). Since that much funding is allocated to CVRP, it would be beneficial to

assess whether the program is effective in meeting its legislative intent of reducing GHGs by putting more ZEVs on the road. It would be valuable to explore whether CVRP is actually accelerating the adoption of ZEVs in California, whether consumers are deciding to adopt ZEVs because of the rebates, and whether the program has an effect on low-income groups. This research is valuable for California legislators and taxpayers who would like to know whether the funding allotted for CVRP is prudent, and whether disadvantaged communities have equal access to public resources, for prospective consumers interested in the rebates who would like to know if ZEVs are cost-efficient, and for the CVRP program as well as vehicle manufacturers, which would both like more information on public attitudes and preferences related to ZEVs.

The California Global Warming Solutions Act of 2006 (Assembly Bill [AB] 32) was signed into law by Governor Arnold Schwarzenegger, setting an ambitious goal for the drastic reduction of statewide GHG emissions to 1990 levels by 2020 (CARB, 2014). This landmark legislation was California's first comprehensive and long-term operation to fight climate change. It gave the California Air Resources Board (CARB) authority to regulate sources of GHG emissions. According to CARB, 70% of California's GHG emissions originate in the transportation sector, and within that, light-duty vehicles (cars and trucks weighing 8,500 pounds or less) account for 28% of total GHG emissions (LAO, 2018, p. 8). Pursuant to AB 32, CARB has been assigned the responsibility of "protecting the public from the harmful effects of air pollution and developing programs and actions to fight climate change" (CARB, 2019a).

The California Alternative and Renewable Fuel, Vehicle Technology, Clean Air, and Carbon Reduction Act of 2007 (AB 118, Statutes of 2007, Chapter 750) was signed into law by Governor Schwarzenegger the following year, instituting the Air Quality Improvement Program

(AQIP), which is administered by CARB and provides funding for new alternative fuel and air quality incentive programs (CVRP, 2019f, p. 1).

In 2012, Governor Jerry Brown signed into law three bills, AB 1532 (California Global Warming Solutions Act of 2006: Greenhouse Gas Reduction Fund), Senate Bill (SB) 535 (Disadvantaged Communities), and SB 1018 (Public Resources), which together created the Greenhouse Gas Reduction Fund to receive Cap-and-Trade auction proceeds and to establish the basis for how the auction proceeds will be directed to fulfill the mission of AB 32 (CVRP, 2019f, p. 1). Billions of dollars from Cap-and-Trade auction proceeds have been appropriated to CARB for Low Carbon Transportation Investment projects that reduce GHG emissions, particularly ones that benefit the most underprivileged communities in California (CVRP, 2019f, p. 1). Disadvantaged populations are particularly vulnerable to the effects of climate change. These projects are intended to advance public health, the quality of life, and economic opportunity for these communities, while also reducing the air pollution that leads to climate change (CalEPA, 2019).

Solution

Each year, the legislature authorizes funding to CARB through the Low Carbon Transportation Investments and the Air Quality Improvement Program to support incentive projects aimed at reducing GHG emissions caused by light-duty vehicles (CVRP, 2019f, p. 2). One such innovative measure taken by CARB was launching CVRP in 2010 to “promote clean vehicle adoption by offering rebates...for the purchase or lease of new, eligible zero-emission vehicles (ZEVs), including electric, plug-in hybrid electric and fuel cell” (CVRP, 2019a) vehicles. The vehicle must be new, and may not be purchased, leased, or delivered from out of state (CVRP, 2019d). The intent of the program is to partially offset the higher initial cost of adopting a ZEV

by providing rebates, mostly to low- and moderate-income consumers, to overcome the cost barrier of purchasing or leasing ZEVs (CVRP, 2019f). The program makes adopting a ZEV more accessible to a greater number of drivers across income levels.

CVRP offers rebates for the purchase or lease of four types of ZEVs: hydrogen fuel-cell electric vehicles (FCEVs), all-battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), and zero-emission motorcycles (ZEMs) (CVRP, 2019b). ZEMs will not be included in this research as these are not considered passenger vehicles (they do not have four wheels) and not all of the types of CVRP rebates are offered for the purchase or lease of them. The three types of ZEVs that will be discussed are distinguished by where the electricity to power them is derived from. First, there are FCEVs, which use a fuel cell instead of a battery to generate electricity by combining hydrogen fuel and oxygen (CEC, 2015). Then, there are Plug-In Electric Vehicles (PEVs), which use a battery to store electricity from the electrical grid by charging at home or at charging stations (CEC, 2015). PEV is an umbrella term that refers to two distinct types of vehicles: BEVs and PHEVs. BEVs run exclusively on batteries (CEC, 2015). In 2015, most BEVs had a range of 50-100 miles on a single charge (CEC, 2015), but they have vastly improved, now averaging a range of 220 miles, so most drivers can go days without recharging (EV Adoption, 2019b). PHEVs are powered by a battery and an internal combustion engine, usually fueled by gasoline. Like BEVs, PHEVs plug into the electrical grid to recharge the battery, but they also have a refillable gasoline tank so they can be refueled at gas stations, similarly to ICEVs. PHEVs operate in battery-powered electric mode for an average of 21 miles (EV Adoption, 2019a), but their overall driving range is 250-400 miles (CEC, 2015). PHEVs can be attractive to drivers who mostly travel short distances covered by battery power, but who also want the full driving range of the internal combustion engine (CEC, 2015).

It is apparent that California's long-term transportation strategy is to boost the adoption of ZEVs. In January 2018, Governor Brown signed Executive Order (EO) B-48-18, launching an eight-year, \$2.5 billion initiative to fund CVRP rebates and to build more infrastructure, including 250,000 PEV charging stations and 200 hydrogen fueling stations by 2025. It also set a goal of 1.5 million ZEVs in California by 2025 and five million by 2030 (California Office of the Governor, 2018). In June 2018, the California Legislature approved \$200 million in Cap-and-Trade auction proceeds for CVRP (CVRP, 2019f, p. 1). Of the \$200 million, CARB apportioned \$60 million to cover the rest of the FY 2017-18 rebates, and the remaining \$140 million was for the FY 2018-19 rebates (CVRP, 2019f, p. 1).

Some populations are particularly vulnerable to the effects of climate change. In June 2019, the California Legislature approved the FY 2019-20 budget of \$238 million for CVRP, which includes \$213 million for standard rebates and \$25 million for low-income rebates, "to ensure the equity element of CVRP continues to grow and that rebates are prioritized for lower income applicants" (CARB, 2019c, p. iv-v). SB 535 identified that disadvantaged communities are "areas disproportionately affected by environmental pollution and other hazards that can lead to negative public health effects, exposure, or environmental degradation" (CalEPA, 2017, p. 1). Many residents of these communities live near busy roads with heavy pollution, magnifying their risks for GHG emissions-related health problems like cancer, respiratory diseases, cardiovascular diseases, pregnancy disorders, and inhibited child development (DEC, 2019). SB 535 demanded that 25% of the proceeds from the Greenhouse Gas Reduction Fund go to projects that benefit disadvantaged communities (CalEPA, 2019). SB 535 also required that 10% of CVRP funds be distributed to disadvantaged communities (Rubin & St-Louis, 2016, p. 67). AB 1550 (Low-Income Communities) passed in 2016, revising that now 35% of the proceeds from the

Greenhouse Gas Reduction Fund must be directed towards “priority populations,” which includes disadvantaged communities, low-income communities, and low-income households (CARB, 2018). AB 1550 specified that low-income communities are “census tracts that are either at or below 80% of the statewide median income, or at or below the threshold designated as low-income by the California Department of Housing and Community Development's 2016 State Income Limits” (CARB, 2018). Figure 1 is a map of SB 535 designated disadvantaged communities and AB 1550 designated low-income communities.

Figure 1: Map of Disadvantaged Communities and Low-Income Communities in California

Source: CARB, 2018

In 2014, SB 1275 (Charge Ahead California) was passed, establishing household income caps in order to be eligible for CVRP rebates. It also increased rebate amounts for low- and moderate-income consumers starting in March 2016 (CARB, 2016). Higher-income consumers are those with annual incomes greater than the following limits: \$150,000 for single filers, \$204,000 for head-of-household filers, and \$300,000 for joint filers. These higher-income consumers can only receive rebates for FCEVs, and not for BEVs and PHEVs (CVRP, 2019f, p. 9-10). The standard rebate applies to moderate-income households with incomes from equal to or below 300% of the federal poverty level (FPL) to the higher-income limits stated above. The standard rebate amount for FCEVs is \$5,000, for BEVs is \$2,500, and for PHEVs is \$1,500 as shown in Table 1 (CARB, 2019b). The CVRP rebate amounts are higher for low-income consumers in order to make ZEVs accessible to more drivers, particularly those in communities greatly affected by air pollution (CARB, 2016). These supplementary rebates are to reduce the upfront financial impact of adopting ZEVs over lower-cost ICEVs. Rebate amounts are increased by \$2,000 for consumers with household incomes less than or equal to 300% of the FPL, which is categorized as low-income. The low-income rebate amount for FCEVs is \$7,000, for BEVs is \$4,500, and for PHEVs is \$3,500 as shown in Table 1 (CARB, 2019b). The varying rebate amounts for different income levels raises the question of how they affect consumers' decisions to adopt ZEVs.

Table 1: CVRP Rebates by ZEV Type and Rebate Amount

ZEV Type	Higher-Income Rebate Amount	Standard Rebate Amount	Low-Income Rebate Amount
FCEV	\$5,000	\$5,000	\$7,000
BEV	None	\$2,500	\$4,500
PHEV	None	\$1,500	\$3,500

Source: CARB, 2019b

LITERATURE REVIEW

Internal Combustion Engine Vehicles (ICEVs) vs. Zero-Emission Vehicles (ZEVs)

Internal combustion engines are the most common as they are found in more than 250 million vehicles in the U.S. (DOE, 2013). The majority of Internal Combustion Engine Vehicles (ICEVs) are fueled by gasoline, followed by diesel, but they can also use renewable or alternative fuels, such as natural gas, propane, biodiesel, or ethanol (DOE, 2013). Combustion is the chemical process of releasing energy from a fuel and air mixture. The products of combustion serve as the working fluids of the engine, activating the system of gears in the powertrain, which drives a vehicle's wheels (DOE, 2013). When fuel burns in an internal combustion engine, the vehicle's exhaust system releases GHGs, primarily carbon dioxide, through the tailpipe, which can cause global warming and climate change (DEC, 2019). GHG emissions can also damage human lung tissue, and can lead to or exacerbate respiratory and cardiovascular diseases (DEC, 2019). This is in contrast to ZEVs, which emit minimal to no exhaust gas (and thus, minimal GHGs) due to having mainly or solely electricity as the onboard source of power (LAO, 2018, p. 9).

History of Government Incentives for Electric Vehicles in the U.S.

The adoption of electric vehicles (EVs) is one innovation to help address environmental concerns, such as GHG emission levels. However, trends have demonstrated that EV adoption often demands "stimulation from external factors such as stringent emissions regulations, rising fuel prices, or financial incentives" (Sierzchula, Bakker, Maat, & Van Wee, 2014, p. 183). Out of those factors, financial incentives for consumers have been found to be the most crucial for EVs to reach a mass market. To encourage the adoption of EVs, financial incentives for their purchase or lease have been established by federal, state, and local governments. These

incentives include purchase/lease rebates, tax exemptions, tax credits, access to bus lanes, and waivers on fees for parking, tolls, charging, and other services (Jenn, Springel, & Gopal, 2018, p. 349). The incentive amount usually depends on the type of EV being purchased or leased.

The U.S. Energy Policy Act of 2005 introduced a federal income tax credit of up to \$3,400 for the purchase or lease of new hybrid electric vehicles (HEVs) (IRS, 2005, p. 2). HEVs are powered by both a gasoline-fueled internal combustion engine and a rechargeable battery, though the battery does not have the ability to be plugged in to recharge (IRS, 2005, p. 2). HEVs were the precursor to and are different from ZEVs, which emit minimal to no emissions. The tax credit was limited to the first 60,000 vehicles per vehicle manufacturer and has since ended (IRS, 2005, p. 2).

The Energy Improvement and Extension Act of 2008 was the first U.S. law to grant a tax credit for new PHEVs (IRS, 2009). It enacted Internal Revenue Code Section 30D, offering the Plug-In Electric Drive Vehicle Credit (PEDVC) of \$2,500 to \$7,500 for the purchase or lease of PHEVs (IRS, 2019). This credit is subtracted from a purchaser's total federal tax liability. When a manufacturer's vehicle reaches 200,000 in qualifying sales, the credit begins to phase out and vehicles by that manufacturer are not eligible for a credit if obtained after the phase-out period (IRS, 2019).

The Car Allowance Rebate System (CARS), commonly known as "Cash-For-Clunkers," allowed consumers to trade in an older, less fuel-efficient vehicle for a voucher to be used on the purchase of a newer, more fuel-efficient vehicle (Gayer & Parker, 2013, p. 1). The federal CARS program began on July 1, 2009 and ended on August 24, 2009, as the appropriated funds were quickly depleted (Gayer & Parker, 2013, p. 1). The program had two objectives: the first was to temporarily stimulate the economy (which was experiencing a recession at the time) by boosting

vehicle sales. The second objective was to put more fuel-efficient vehicles on the roads and reduce emissions. According to an evaluation performed by Gayer and Parker, CARS provided a small and short-lived spur in vehicle sales of about 380,000 vehicles, which were pulled forward (or borrowed) from sales that would have occurred in subsequent months in the absence of the program (Gayer & Parker, 2013, p. 6). The environmental impact of CARS in reducing emissions was marginal since it ran for less than two months and the nearly 700,000 vehicles purchased under the program made up less than one percent of the total vehicles in the U.S. (Gayer & Parker, 2013, p. 10). The program resulted in a minor reduction of gasoline usage, equal to about 2.4 to 7.9 days' worth of current usage (Gayer & Parker, 2013, p. 11).

Many states are also taking action to reduce GHG emissions through the deployment of EVs. As of July 2017, “forty-five states and the District of Columbia provide an incentive for certain hybrid and/or electric vehicles, either through a specific utility operating in the state or through state legislation” (NCSL, 2017). This means that only five states do not have any incentives in place. Furthermore, in October 2013, the governors of eight states, including California, (and joined by a ninth in May 2018), signed a plan to commit to “coordinated action to ensure the successful implementation of their state zero-emission vehicle (ZEV) programs” (ZEV Task Force, 2019) by offering financial incentives, providing access to high-occupancy vehicle (HOV) lane access, and building more charging stations. Together, these states pledged to have at least 3.3 million ZEVs on their roads by 2025 (ZEV Task Force, 2019).

The Effect of Financial Incentives on the Adoption of Electric Vehicles

Chandra, Gulati, and Kandlikar examined the effect of tax rebates on the sales of HEVs in Canada (Chandra et al, 2010, p. 79). This study found that a \$1,000 increase in the tax rebate raises the market share of HEVs by 31 to 38% (Chandra et al, 2010, p. 79). However, it was also

observed that only 26% of HEVs sold can be attributed to the rebate (Chandra et al, 2010, p. 79). This indicates that 74% of HEVs sold were not due to the rebate. In addition, it was concluded that tax rebate programs mostly subsidize consumers who would have purchased HEVs in any case, not just due to the rebate (Chandra et al, 2010, p. 92).

Gallagher and Muehlegger studied the effectiveness of incentives, including state sales tax waivers, income tax credits, and non-tax incentives, on the adoption of HEVs in the U.S. (Gallagher & Muehlegger, 2011, p. 1). The inquiry found that even though state sales tax waivers tend to be less than state income tax credits, sales tax waivers were linked to more than a ten-fold growth in the sales of HEVs in comparison to income tax credits, for a number of reasons (Gallagher & Muehlegger, 2011, p. 1). First, a sales tax waiver is automatic, while an income tax credit requires a consumer to apply for it the following year (Gallagher & Muehlegger, 2011, p. 9). Secondly, a sales tax waiver is immediate, while an income tax credit must be claimed on a future return. Lastly, the value of a sales tax waiver is easily understood, while an income tax credit may fluctuate based on a consumer's tax liability (Gallagher & Muehlegger, 2011, p. 9).

Tal and Nicholas explored the impact of the PEDVC on the PEV market by studying the preference surveys of more than 2,882 PEV owners in 11 states (Tal & Nicholas, 2016, p. 95). The findings were that 28.5% of PEV sales were due to this federal tax credit (Tal & Nicholas, 2016, p. 99). The incentive increased the sales of PEVs by 32.5% between 2010 and 2014 (Tal & Nicholas, 2016, p. 101).

Jenn, Springel, and Gopal collected a dataset of 198 financial and non-financial incentives to study their effects on the adoption of EVs in the U.S. Since the CVRP program being evaluated in this research offers a cash rebate, financial incentives were of particular

interest to study. The research indicates that financial incentives (which are the most common incentive) have a positive effect on the adoption of EVs—every \$1,000 offered as a rebate or tax credit raises the average sales of EVs by 2.6% (Jenn et al, 2018, p. 354).

Johnson and Williams looked at the influence of CVRP's cash rebates on the purchase or lease of ZEVs by consumers. Using a voluntary CVRP Consumer Survey administered to rebate recipients, this study assessed the relationship between consumer factors (such as transaction, household, and demographic characteristics, reasons for PEV adoption, and measures of experience with PEVs) and the impact of CVRP rebates on consumers' adoption decisions (Johnson & Williams, 2017, p. 23). The results were that some factors are correlated with a greater likelihood that a consumer would regard the rebate to be crucial. These factors include “having lower household income, being younger, adopting less-expensive vehicles, being more motivated to adopt a PEV by a desire to save money, being less motivated to adopt a PEV by a desire to reduce environmental impact, and reporting a lower initial interest level in adopting a PEV” (Johnson & Williams, 2017, p. 23). Identifying consumers most influenced by incentives is critical so that a program like CVRP knows who to focus its attention on through education activities, targeted outreach, and strategic marketing (Johnson & Williams, 2017, p. 29).

Socioeconomic Characteristics of Incentive Program Recipients

Households in the U.S. have received \$18.1 billion “in federal income tax credits for weatherizing their homes, installing solar panels, buying hybrid and electric vehicles, and other ‘clean energy’ investments” (Borenstein & Davis, 2015, p. 1). Borenstein and Davis utilized tax return data to study the socioeconomic characteristics of recipients of these federal income tax credits. This analysis separated taxpayers into five income groups (quintiles). It determined that between 2006 and 2012, higher-income taxpayers have received a large amount of the tax

credits—the top income quintile received about 90% of all credits, while the bottom three quintiles received about 10% of all credits. The most severe disparity was in the distribution of the PEDVC, as the top income quintile received about 90% of all credits (Borenstein & Davis, 2015, p. 1). The evidence shows that the “distributional pattern is similar across years and reflects that higher-income taxpayers are much more likely to claim credits and for significantly larger credit amounts” (Borenstein & Davis, 2015, p. 1). Consumers of ZEVs tend to have higher incomes and more educations than the general population and ICEV consumers (Tal & Nicholas, 2016, p. 95).

Rubin and St-Louis analyzed the distribution of CVRP rebates across recipient characteristics, including census tract, race-ethnicity, income, and socioeconomic status (Rubin & St-Louis, 2016, p. 67). The inquiry found that between 2010 and 2015, rebates were not equitably dispersed across households with different socioeconomic statuses with higher-income groups more likely to receive rebates (Rubin & St-Louis, 2016, p. 73). Eighty-three percent of rebate recipients had annual incomes higher than \$100,000 (Rubin & St-Louis, 2016, p. 67). Nearly 90% of the rebates were issued to only three of California’s 35 air districts: the San Francisco Bay Area, the Los Angeles Metropolitan area, and the San Diego Metropolitan area, which are the regions with the state’s highest populations (Rubin & St-Louis, 2016, p. 67). In addition, “census tracts with lower median household incomes and higher proportions of people of color received fewer clean vehicle rebates (Rubin & St-Louis, 2016, p. 68). The biggest obstacle for low-income households to purchasing or leasing a ZEV is obtaining the upfront capital to do so and qualifying for such a large auto loan (Rubin & St-Louis, 2016, p. 73).

A report by the UC Davis Policy Institute for Energy, Environment, and the Economy concluded that ZEV purchase incentives are largely concentrated among higher-income

consumers, highlighting concerns about inequitable incentive distribution among income groups. Moreover, this raises the issue of whether these incentives are cost-effective, since higher-income consumers are more likely to have adopted a ZEV in the absence of a rebate (UC Davis, 2019b, p. 4). This is in contrast to how a rebate is a substantial factor in the purchasing decisions of low-income consumers, since ZEVs are more costly than ICEVs.

Gallagher and Muehlegger observed that consumers with social preferences for environmental quality and energy security cited those as notable reasons for the adoption of HEVs (Gallagher & Muehlegger, 2011, p. 13). Egbue and Long's survey collected data from a sample population largely composed of current owners of ICEVs in order to gain insight on the opinions, perceptions, and attitudes of potential ZEV buyers. The study found that 83% of respondents were somewhat familiar with the topic of sustainability, which most of the respondents associated with product/resource longevity, resource conservation, and protecting the environment (Egbue & Long, 2012, p. 723). More respondents who were working towards, or who had completed a graduate degree were acquainted with the concept of sustainability than those who were working towards, or who had completed an undergraduate degree (Egbue & Long, 2012, p. 723). In addition, respondents in the 18-24 age range were less likely to be aware of the concept than those ages 25 and up (Egbue & Long, 2012, p. 723).

Perceived Higher Costs of Adopting and Operating ZEVs

There is a widely held belief that compared to ICEVs, ZEVs have higher initial costs to purchase or lease, and also higher costs of operation afterward. Compared to ICEVs, there are higher costs to manufacture ZEVs that are passed onto consumers. The most expensive component of a ZEV is the battery (Next 10, 2018, p. 3). Research has found that the purchase price of a ZEV is approximately \$10,000 more than a comparable ICEV (Sierzchula et al, 2014, p. 185). In

addition, the larger the size of a ZEV battery, the greater its driving range is, but also the higher the cost to purchase or lease the ZEV (Sierzechula et al, 2014, p. 185). However, the cost of batteries is rapidly declining, and it is predicted that ZEV battery cost will decrease by almost 10% until 2025, “when ZEVs will reach price parity with ICEVs” (Next 10, 2018, p. 19), even without incentives and subsidies. This development in battery technology is enabling vehicle manufacturers to produce ZEVs with greater driving range and better performance at lower prices.

When the term ZEV is brought up, the Tesla brand often comes to mind. But Tesla is just one of 22 vehicle manufacturers producing CVRP-approved ZEVs (CVRP, 2019b). While some ZEVs are considered luxury vehicles, there are more affordable options. There are five-passenger PHEVs, such as the Hyundai Ioniq Plug-in Hybrid, Toyota Prius Prime Plug-in Hybrid, and Kia Niro Plug-in Hybrid, which all start at \$28,500 or under (PluginCars, 2019). There are five-passenger BEVs, such as the Nissan LEAF, Hyundai Ioniq Electric, and Volkswagen E-Golf, which all start at \$31,300 or under (PluginCars, 2019). FCEVs were recently introduced in the U.S. at the end of 2015. Currently, there are three FCEVs on the market and they are only sold in California and Hawaii—the Hyundai NEXO (starts at \$53,300), the Toyota Mirai (starts at \$53,500), and the Honda Clarity Fuel Cell (can only be leased for \$379/month for 36 months) (Kaslikowski, 2019). The prices of PHEVs and BEVs can be considerably lower than FCEVs, and the models available are numerous and diverse.

California consumers have access to financial incentives that can help to offset the higher cost to purchase or lease a ZEV. As previously discussed, CVRP offers rebate amounts ranging from \$1,500 to \$7,000, depending on the ZEV type and consumer income level. In addition, the federal government still offers the PEDVC of \$2,500 to \$7,500 for the purchase or lease of BEVs

and PHEVs, although FCEVs do not qualify for this credit. All BEVs qualify for the full \$7,500, while PHEVs qualify for a reduced amount (CVRP, 2019i).

Another factor influencing consumer adoption of ZEVs is the cost to operate them. The nonpartisan organization Next 10 found that while the initial costs for ZEVs are higher than their ICEV equivalents, life cycle fuel and maintenance costs are lower. An analysis of 17 popular ZEV models produced in 2017 determined that many can be price competitive with ICEVs, even without government financial incentives (Next 10, 2018, p. 4).

However, the general public is not yet knowledgeable about the cost to charge a ZEV, and how the cost compares to fueling an ICEV with gasoline. The cost to charge a BEV or PHEV at home depends on the vehicle's battery size and the price of electricity set by the utility provider (CVRP, 2019c). Most of them offer time-of-use (TOU) rates that significantly reduce costs by charging during off-peak hours (CVRP, 2019c). Electricity costs vary throughout California, but the average cost of electricity in the state is 15¢ per kilowatt hour (kWh)² (CVRP, 2019i). "At this price point, charging a 40-kWh battery with a 150-mile range would cost about 4¢ per mile (or about \$6 to fully charge). Meanwhile, fueling a 25-mpg gas vehicle at California's average gas price of \$3.53 per gallon would cost about 14¢ per mile (or about \$21 for enough gas to drive approximately 150 miles)" (CVRP, 2019c), thus, it costs less to charge a ZEV than to fuel an ICEV enough to drive 150 miles. ZEVs can also be charged at public charging stations, which "can be free, pay-as-you-go, or subscription-based, and prices are set by networks or property owners. Some vehicle manufacturers, such as Hyundai, Nissan and Tesla also provide complimentary public charging. One popular public charging network charges members \$1.50 per hour to charge on Level 2, and 15¢ per minute for DC fast charging...At these rates, charging a 40-kWh battery with a 150-mile range would cost about 6¢ per mile on

Level 2, and 7¢ per mile for DC fast charging” (CVRP, 2019c). Some employers, both in the public and private sectors, have built worksite charging stations for their employees.

Many California utility providers and air districts issue rebates to install Level 2 charging stations in the home. The rebate amounts vary throughout the state but can range in dollar amount from \$500 to \$5,000 per Level 2 charger, all the way to covering 100% of the cost of equipment and installation (CVRP, 2019c). Additionally, a number of utilities have programs to issue rebates to customers who drive BEVs and PHEVs as a reward for their use of electricity as a clean transportation fuel: Pacific Gas and Electric Company (PG&E) Clean Fuel Rebate, San Diego Gas & Electric (SDG&E) Electric Vehicle Climate Credit, and Southern California Edison (SCE) Clean Fuel Rewards (CPUC, 2019).

As part of its analysis of ZEV operation costs, Next 10 evaluated maintenance expenses. Each ZEV has about 20 moving parts, which is decidedly less than the 1,980 moving parts of an ICEV (Next 10, 2018, p. 26). As a result, ZEVs have fewer maintenance issues, visits, and costs than ICEVs. The small number of parts and a less complex propulsion system make ZEV assembly and part-replacement more simple and less expensive. BEVs do not need most maintenance services standard to ICEVs, including oil changes, tune-ups, and pump and filter replacements (Krause, Carley, Lane, & Graham, 2013, p. 436). PHEVs still need these maintenance procedures, although less frequently than ICEVs do (Krause et al, 2013, p. 436).

Other Barriers to the Adoption of ZEVs

Another factor influencing consumer adoption of ZEVs is performance characteristics, such as driving range and charging time. As previously discussed, the driving range of ZEVs has increased in recent years, with FCEVs averaging 300 miles (DOE, 2019a), BEVs averaging 220

miles (EV Adoption, 2019b), and PHEVs averaging 21 miles on battery power and 325 miles overall (EV Adoption, 2019a), which are all in line with comparable ICEVs.

Charging time and charging availability are concerns for prospective ZEV consumers. FCEVs can be charged in under five minutes (DOE, 2019a), but this can only be done at hydrogen stations. The infrastructure for them is still lacking, with only 40 hydrogen stations throughout California. However, it is promising that 24 hydrogen stations are at some point in the permit, planning, construction and commissioning process (Wardlaw, 2019). Most ICEVs are able to refuel in about four minutes, but most methods to charge PEVs (BEVs and PHEVs) take much longer (Sierchula et al, 2014, p. 185). Level 1 charging uses a standard 120-volt outlet, which requires no equipment installation in the home. It is the slowest charging method, but it is sufficient for drivers who charge overnight and travel 30–40 miles per day (CVRP, 2019c). Level 2 charging uses a 220-volt outlet, which drivers need to have installed in the home at a cost, although many California utility providers and air districts issue rebates to offset the cost of installation (CVRP, 2019c). DC fast charging, also known as quick charging or supercharging, is the fastest charging method. It requires a 480-volt connection, which cannot be installed in the home so stations are usually located in shopping centers and along major travel corridors (CVRP, 2019c). This charging method only works on BEVs and not on PHEVs (CVRP, 2019c).

For most drivers, the most convenient and inexpensive way of charging PEVs is to do it at home with Level 1 or Level 2 chargers. But this method usually requires a driver to reside in a single-family home with a garage where they can plug in their vehicle. Home charging is not a viable option if a driver resides in a multi-unit dwelling without their own garage. In California's costly housing market, low-income households are 2.3 times more likely to rent than moderate- to higher-income households and often, they rent a unit rather than a single-family home

(Brinklow, 2017). Public charging stations exist as an alternative to home charging, but the stations may not be widespread, convenient, or affordable enough to appeal to potential consumers.

To address gaps in charging infrastructure, the California Energy Commission (CEC) created the California Electric Vehicle Infrastructure Project (CALeVIP) to incentivize the installation of Level 2 and DC fast chargers for PEVs at publicly accessible locations throughout the state (CEC, 2018, p. 9-10). The aim of CALeVIP is to support regions in their plans to install charging stations to meet current and future needs. Ideally, PEV drivers will have reliable access to chargers and the availability of them will encourage more Californians to adopt PEVs. CALeVIP's first regional project, the Fresno County Incentive Project, was inaugurated in December 2017, providing rebates of up to \$7,000 for Level 2 chargers (CEC, 2018, p. 10). The Southern California Incentive Project began in August 2018, providing up to \$80,000 for the installation of DC fast chargers in Los Angeles, Orange, Riverside and San Bernardino Counties. This project also requires that 25% of its funding be directed to projects in disadvantaged communities (CEC, 2018, p. 10). Now, there are a total of six regional projects. In addition to the first two mentioned, there are four other projects: San Joaquin Valley Incentive Project, Central Coast Incentive Project, Northern California Incentive Project, and Sacramento County Incentive Project (CEC, 2018).

METHODOLOGY

Data

This research follows Sylvia & Sylvia's Outcome Evaluation model consisting of an explanation of the approach and the component parts of the CVRP program: the theoretical goal, program goals, program functions, proximate indicators, measures, and anticipated outcomes (Sylvia & Sylvia, 2012, p. 115-138). An outcome evaluation was conducted by studying publicly available data to determine whether CVRP is increasing ZEV adoption, particularly by low-income consumers in California. An outcome evaluation focused on the activities from 2010 to the present. An analysis of the outcomes recorded measured whether CVRP is meeting its stated goals and anticipated outcomes.

Vehicle registration data was gathered from the California Department of Motor Vehicles (DMV) website (DMV, 2018), (DMV, 2019). This data included the total number of vehicle registrations and ZEV registrations in California in 2018 and 2019. It was used to calculate the percentage of ZEVs registrations compared to ICEVs registrations, the net percentage changes of ZEVs registrations, and the net percentage changes of ICEVs registrations, to see whether these numbers are increasing. The California New Car Dealers Association's (CNCDA) Green Vehicle Reports publish data on the registration of all new vehicles in California from 2016 to 2018, and break it down to the specific numbers of registrations of new ZEVs and new ICEVs (CNCDC, 2019). This data was used to calculate the percentage of new ZEVs registrations compared to new ICEVs registrations, the net percentage changes of new ZEVs registrations, and the net percentage changes of new ICEVs registrations, to see whether these numbers are increasing.

Data was gathered from CVRP Rebate Statistics to compute the total number of rebates issued annually from 2010 to 2019, categorized by ZEV type, vehicle manufacturer, air district,

rebate amount, and if the rebate recipient resides in a low-income community (CVRP, 2019h). In 2016, CVRP began implementing the supplementary low-income level rebate so the total number of rebates issued was compared to the number of rebates issued to low-income consumers annually from 2016 to 2019. This data was used to see whether the number of rebates is increasing and whether the change in the number of rebates is different in low-income consumers compared to moderate- and higher-income consumers.

The CVRP Consumer Survey 2013-17 is a dataset collected October 2013 to August 2017 from 40,028 voluntary respondents who received CVRP rebates (CVRP, 2019k). The survey examines the CVRP “program impacts, consumer demographics and housing characteristics, purchase/lease motivations, decision-making processes” (CVRP, 2019k). Data regarding the responses to three survey questions were inputted into SPSS to find statistical significance and to see whether the rebates offered are persuading consumers to adopt ZEVs.

The operating costs of ZEVs are often perceived to be more than ICEVs. The U.S. Energy Information Administration (EIA) provides updated retail electricity and gasoline prices in California (EIA, 2020a), (EIA, 2020b). The U.S. Department of Energy (DOE) website has a Vehicle Cost Calculator tool to compare the operating costs of a ZEV to a similar gasoline-fueled ICEV, holding all driving conditions constant (DOE, 2019b). This tool was used to compare the annual cost of electricity of a ZEV, the annual cost of gasoline of an ICEV, and the overall annual operating costs for both types of vehicles. It also assessed the amount of carbon dioxide (which is a GHG) that a ZEV emits compared to an ICEV.

Table 2: Logic Model: Outcome Evaluation of CVRP

Theoretical Goal	Program Goals	Program Functions	Proximate Indicators	Measures	Anticipated Outcomes
T1: To promote and accelerate ZEV adoption in California by issuing rebates to low-income consumers	G1: Increase the total number of ZEVs in California year after year (T1)	F1: Allocate funding from CARB annually for CVRP rebates. Higher-income consumers are only eligible for FCEV rebates so the two main rebate options are: standard rebates for moderate-income consumers and additional rebates for low-income consumers (G1-G3)	I1: Total number of ZEVs in California (F1)	M1: Track total number of ZEV registrations in California (I1-I2)	AO1: Total number of ZEV registrations should increase in California (M1)
	G2: Increase the percentage of ZEVs compared to ICEVs year after year (T1)		I2: Percentage of ZEVs compared to ICEVs in California (F1)	M2: Track percentage of registration changes of ZEVs compared to ICEVs in California (I1-I2)	AO2: Percentage of ZEV registrations compared to ICEV registrations in California should increase (M2)
	G3: Increase the total number of rebates issued, particularly in low-income consumers year after year (T1)	F2: Provide the following rebate amounts for three types of ZEVs: up to \$7,000 for FCEVs, up to \$4,500 for BEVs, and up to \$3,500 for PHEVs, based on annual program budget (G1-G3)	I3: Total number of rebates issued (F1-F2)	M3: Track total number of CVRP rebates issued annually (I3-I4)	AO3: Total number of rebates issued should increase (M3)
		F3: Collect rebate data and income indicators on new claims to forecast future program budget (G3)	I4: Percentage change in rebates issued based on income indicators of consumers residing in low-income communities and low-income consumers (F1-F3)	M4: Track percentage change in rebates issued to consumers residing in low-income communities and to low-income consumers (I3-I4)	AO4: Total number of rebates issued to consumers residing in low-income communities and to low-income consumers should increase year after year (M4)
					AO5: The percentage of rebates issued to consumers residing in low-income communities and the percentage of rebates issued to low-income consumers should increase at greater rates than overall rebates issued (M4)

The aforementioned data will be used to measure if CVRP is meeting its anticipated outcomes. After the outcome evaluation is complete, the findings will substantiate whether CVRP is effective in promoting the adoption of ZEVs by disadvantaged populations in California using two income indicators: 1) consumers of residing in low-income communities (as designated by AB 1550) and 2) low-income consumers (consumers with household incomes less than or equal to 300% of the FPL, the designation used by CVRP to determine eligibility for supplementary low-income rebates). The assessment will present the income and geographical distribution of the CVRP rebates. It will also uncover the numbers of the three types of ZEVs being adopted as well which ZEV manufacturers are the most popular. Furthermore, the CVRP program will be evaluated from a multi-faceted approach instead of just the singular approach of finding the number of rebates dispersed. Is CVRP making a difference and beneficial in other ways than just providing a rebate check? Is CVRP stimulating ZEV adoption enough to have an effect on the reduction of GHG emissions in California?

FINDINGS AND DESCRIPTIVE STATISTICS

Findings on Vehicle Registrations in California

Table 3: Registrations of Vehicles in California 2018-2019

Year	Total Registrations of Vehicles	Registrations of ICEVs	Registrations of ZEVs	Percentage of Registrations of ZEVs out of Total Registrations of Vehicles
2018	30,581,168	30,235,929	345,239	1.13%
2019	32,034,413	31,554,871	479,542	1.50%

Source: DMV, 2018 & DMV, 2019

The DMV lists registration data from 2018 and 2019 for all registered vehicles (both new and used) in California and consolidated them into two main categories: ZEVs (FCEVs, BEVs, PHEVs) and ICEVs (all other vehicle types) as reflected in Table 3 (DMV, 2018), (DMV, 2019). The data was consolidated into two main categories: ZEVs (FCEVs, BEVs, PHEVs) and ICEVs (all other vehicle types). In 2018, there were 30,581,168 total registrations of vehicles in California. Of those, 30,235,929 were registrations of ICEVs and 34,5239 were registrations of ZEVs. Out of the total registrations, 1.13% were ZEVs. In 2019, there were 32,034,413 total registrations of vehicles in California. Of those, 31,554,871 were registrations of ICEVs and 47,9542 were registrations of ZEVs. Out of the total registrations, 1.50% were ZEVs.

Table 4: Registrations of New Vehicles in California 2016-2018

Year	Total Registrations of New Vehicles	Registrations of New ICEVs	Registrations of New ZEVs	Percentage of Registrations of New ZEVs out of Total Registrations of New Vehicles
2016	2,013,831	1,938,757	75,074	3.73%
2017	1,949,123	1,850,661	98,462	5.05%
2018	1,844,336	1,686,677	157,659	8.55%

Source: CNCDC, 2019

CNCDA's Green Vehicle Reports deliver data on the registration of new vehicles in California from 2016 to 2018 as presented in Table 4 (CNCDC, 2019). In 2016, there were 2,013,831 total registrations of new vehicles in California. Of those, 1,938,757 were registrations of new ICEVs and 75,074 were registrations of new ZEVs. Out of the total new registrations, 3.73% were ZEVs. In 2017, there were 1,949,123 total registrations of new vehicles in California. Of those, 1,850,661 were registrations of new ICEVs and 98,462 were registrations of new ZEVs. Out of the total new registrations, 5.05% were ZEVs. In 2018, there were 1,844,336 total registrations of new vehicles in California. Of those, 1,686,677 were registrations of new ICEVs and 157,659 were registrations of new ZEVs. Out of the total new registrations, 8.55% were ZEVs.

Findings on Overall CVRP Rebates

Table 5: CVRP Rebates Issued, March 2010-November 2019

Year	Total CVRP Rebates Issued
2010	135
2011	4,521
2012	11,219
2013	29,152
2014	43,702
2015	46,543
2016	44,455
2017	47,758
2018	73,380
2019	65,099
Total 2010-2019	365,964

Source: CVRP, 2019h

Figure 2: SPSS Output of CVRP Rebates Issued, March 2010-November 2019

	N	Sum	Mean
Total CVRP Rebates March 2010- November 2019	365,964	\$838,695,276	\$2291.74

Source: CVRP, 2019h

The CVRP website provides the numbers of rebates issued for the purchase or lease of a ZEV from when the program began in March 2010 through November 2019, which is the most recent month listed (CVRP, 2019h). As shown in Table 5, during that period of time, a total of 365,964 CVRP rebates have been issued. Figure 2 is an output from SPSS, detailing that the total amount of CVRP rebates issued is \$838,695,276, and the average rebate amount issued is \$2,291.74.

Table 6: CVRP Rebates Issued by ZEV Type, March 2010-November 2019

ZEV Type	CVRP Rebates Issued	Percentage of Total CVRP Rebates Issued
Other	1,061	0.3%
FCEV	6,904	1.9%
PHEV	130,884	35.8%
BEV	227,115	62.1%
Total of all ZEV Types	365,964	100.0%

Source: CVRP, 2019h

Figure 3: CVRP Rebates Issued by ZEV Type, March 2010-November 2019

Source: CVRP, 2019h

Table 6 and Figure 3 are two different formats depicting the same data: the overall numbers of the CVRP rebates issued from March 2010 to November 2019, sorted by ZEV type (CVRP, 2019h). BEVs are the ZEV type that rebates were issued for most with 227,115, which accounts for 62.1% of total rebates issued, followed by PHEVs with 35.8%, and then by FCEVs with 1.9%.

Figure 4: CVRP Rebates Issued by Vehicle Manufacturer, March 2010-November 2019

Source: CVRP, 2019h

Figure 4 illustrates the overall numbers of CVRP rebates issued, sorted by vehicle manufacturer, from March 2010 to November 2019 (CVRP, 2019h). The vehicle manufacturer for which the greatest number of rebates were issued for is Tesla, which accounts for 27.6% of total rebates issued, followed by Chevrolet with 19.6%, Toyota with 11.1%, Nissan with 11.0%, and Ford with 7.9% (CVRP, 2019h).

Figure 5: CVRP Rebates Issued by Air District, March 2010-November 2019

Source: CVRP, 2019h

Figure 5 shows overall CVRP rebates issued, sorted by the California air district the recipients reside in, with data from March 2010 to November 2019 (CVRP, 2019h). California’s 35 local air districts are responsible for the regulation and monitoring of regional air quality, implementation of air improvement programs, and reporting of information to CARB (CARB, 2020a). The air district with the most amount of rebates issued is the South Coast Air Quality Management District (AQMD), which “includes Los Angeles County except for areas covered by the Antelope Valley AQMD, Orange County, and the western portion of San Bernardino and Riverside counties” (CARB, 2020a), accounting for 44.0% of total rebates issued, followed by Bay Area AQMD with 34.4%, San Diego County Air Pollution Control District (APCD) with 8.2%, San Joaquin Valley APCD with 3.2%, and Sacramento Metro AQMD with 2.2% (CVRP, 2019h).

Figure 6: CVRP Rebates Issued by Amount, March 2010-November 2019

Source: CVRP, 2019h

Figure 6 displays overall CVRP rebates issued, sorted by amount, from March 2010 to November 2019 (CVRP, 2019h). The rebate amount issued most often is \$2,500, which accounts for 58.5% of total rebates issued. Table 1 indicates that this is the “standard” rebate amount issued to moderate-income consumers who adopt BEVs. Following that, the second rebate amount issued most often is \$1,500 with 33.6% of total rebates issued. This is the “standard” rebate amount issued to moderate-income consumers who adopt PHEVs. Following that, the third rebate amount issued most often is \$4,500 with 2.4% of total rebates issued. This is the rebate amount issued to low-income consumers who adopt BEVs. Following that, the fourth rebate amount issued most often is \$5,000 with 2.2% of total rebates issued. This is the rebate amount issued to moderate- and higher-income consumers who adopt FCEVs. Following that, the fifth rebate amount issued most often is \$3,500 with 1.9% of total rebates issued. This is the rebate amount issued to low-income consumers who adopt PHEVs (CVRP, 2019h).

Findings on CVRP Rebates Issued to Consumers in Low-Income Communities

Table 7: CVRP Rebates Issued to Consumers in Low-Income Communities, March 2010-November 2019

Year	Total CVRP Rebates Issued	CVRP Rebates Issued to Consumers in Low-Income Communities	Percentage of Total CVRP Rebates Issued
2010	135	23	17.04%
2011	4,521	856	18.93%
2012	11,219	1,645	14.66%
2013	29,152	4,175	14.32%
2014	43,702	7,121	16.29%
2015	46,543	7,461	16.03%
2016	44,455	7,785	17.51%
2017	47,758	9,488	19.87%
2018	73,380	14,426	19.66%
2019	65,099	13,889	21.34%
Total 2010-2019	365,964	66,869	Average 2010-2019: 18.3%

Source: CVRP, 2019h

Figure 7: SPSS Output of CVRP Rebates Issued to Consumers in Low-Income Communities, March 2010-November 2019

	N	Sum	Mean
Total CVRP Rebates Issued to Consumers in Low-Income Communities March 2010- November 2019	66,869	\$156,613,698	\$2,342.10

Source: CVRP, 2019h

Table 7 displays the number of overall CVRP rebates compared to the number of CVRP rebates issued to consumers residing in low-income communities (as designated by AB 1550), and the percentage of the CVRP rebates issued to recipients in low-income communities of overall CVRP rebates from March 2010 through November 2019 (CVRP, 2019h). During this period of time, a total of 66,869 CVRP rebates were issued to consumers residing in low-income communities, accounting for 18.3% of total rebates issued. Figure 7 is an output from SPSS, detailing that the total amount of CVRP rebates issued to consumers residing in low-income communities is \$156,613,698, and the average rebate amount issued is \$2,342.10.

Table 8: CVRP Rebates Issued to Recipients in Low-Income Communities by ZEV Type, March 2010-November 2019

ZEV Type	CVRP Rebates Issued to Consumers in Low-Income Communities	Percentage of Total CVRP Rebates Issued
Other	330	0.5%
FCEV	1,289	1.9%
PHEV	26,560	39.7%
BEV	38,690	57.9%
Total of all ZEV Types	66,869	100.0%

Source: CVRP, 2019h

Figure 8: CVRP Rebates Issued to Consumers in Low-Income Communities by ZEV Type, March 2010-November 2019

Source: CVRP, 2019h

Table 8 and Figure 8 are two different formats presenting the same data: the numbers of the CVRP rebates issued to consumers residing in low-income communities, sorted by ZEV type and the percentage of the CVRP rebates issued to consumers in low-income communities by ZEV type (CVRP, 2019h). From March 2010 to November 2019, a total of 66,869 rebates have been issued to consumers in low-income communities. BEVs are the ZEV type that rebates were issued for most to consumers in low-income communities with 38,690, which accounts for 57.9% of total rebates issued consumers in low-income communities, followed by PHEVs with 39.7%, and then by FCEVs with 1.9% (CVRP, 2019h).

Figure 9: CVRP Rebates Issued to Consumers in Low-Income Communities by Vehicle Manufacturer, March 2010-November 2019

Source: CVRP, 2019h

Figure 9 illustrates the number of CVRP rebates issued to consumers residing in low-income communities, sorted by vehicle manufacturer, from March 2010 to November 2019 (CVRP, 2019h). The vehicle manufacturer with the greatest number of rebates issued to consumers residing in low-income communities is Tesla, which accounts for 22.6% of total rebates issued to consumers residing in low-income communities, followed by Chevrolet with 20.1%, Toyota with 13.3%, Nissan with 9.4%, and Ford with 8.9% (CVRP, 2019h).

Figure 10: CVRP Rebates Issued to Consumers in Low-Income Communities by Amount, March 2010-November 2019

Source: CVRP, 2019h

Figure 10 portrays the CVRP rebates issued to consumers residing in low-income communities, sorted by amount, from March 2010 to November 2019 (CVRP, 2019h). The rebate amount issued most is \$2,500, which accounts for 51.5% of total rebates issued to consumers residing in low-income communities. Table 1 shows that this is the “standard” rebate amount issued to moderate-income consumers who adopt BEVs. Following that, the second most rebate amount issued is \$1,500 with 34.7% of total rebates issued to consumers residing in low-income communities. This is the “standard” rebate amount issued to moderate-income consumers who adopt PHEVs. Following that, the third most rebate amount issued is \$3,500 with 4.5%. This is the rebate amount issued to low-income consumers who adopt BEVs. Following that, the fourth most rebate amount issued is \$4,500 with 4.3%. This is the rebate amount issued to low-income consumers who adopt PHEVs. Following that, the fifth most rebate amount issued is \$5,000 with 0.6%. This is the rebate amount issued to higher- and moderate-income consumers who adopt FCEVs (CVRP, 2019h).

Findings on CVRP Rebates Issued to Low-Income Consumers

Table 9: CVRP Rebates Issued to Low-Income Consumers, March 2016-November 2019

Year	Total CVRP Rebates Issued	CVRP Rebates Issued to Low-Income Consumers	Percentage of Total CVRP Rebates Issued
2016	44,455	2,358	5.30%
2017	47,758	4,435	9.29%
2018	73,380	5,011	6.83%
2019	65,099	5,987	9.20%
Total 2016-2019	230,692	17,791	Average 2016-2019: 7.71%

Source: CVRP, 2019h

Figure 11: SPSS Output of CVRP Rebates Issued to Low-Income Consumers, March 2016-November 2019

	N	Sum	Mean
Total CVRP Rebates Issued to Low-Income Consumers March 2016-November 2019	17,791	\$72,658,786	\$4,084.02

Source: CVRP, 2019h

In March 2016, the CVRP introduced increased rebate amounts for low-income consumers. Table 9 displays the number of overall CVRP rebates from March 2016 through November 2019, compared to the number of CVRP rebates issued to low-income consumers, and the percentage of the CVRP rebates issued to low-income consumers out of the overall CVRP rebates issued (CVRP, 2019h). During this period of time, a total of 17,791 CVRP rebates were issued to low-income consumers, accounting for 7.71% of total rebates issued. Figure 11 is an output from SPSS, detailing that the total amount of CVRP rebates issued to low-income consumers is \$72,658,786, and the average rebate amount issued is \$4,084.02.

Table 10: CVRP Rebates Issued to Low-Income Consumers by ZEV Type, March 2016-November 2019

ZEV Type	CVRP Rebates Issued to Low-Income Consumers	Percentage of CVRP Rebates Issued to Low-Income Consumers by ZEV Type
FCEV	7,657	2.8%
PHEV	9,631	43.0%
BEV	17,791	54.1%
Total of all ZEV Types	7,657	100.0%

Source: CVRP, 2019h

Figure 12: CVRP Rebates Issued to Low-Income Consumers by ZEV Type, March 2016-November 2019

Source: CVRP, 2019h

Table 10 and Figure 12 are two different formats depicting the same data: the numbers of the CVRP rebates issued to low-income consumers by ZEV type and the percentage of the CVRP rebates issued to low-income consumers by ZEV type (CVRP, 2019h). From March 2016 to November 2019, a total of 7,657 rebates were issued to low-income consumers. BEVs are the ZEV type that rebates were issued for most to low-income consumers with 17,791, which accounts for 54.1% of total rebates issued recipients in low-income communities, followed by PHEVs with 43.0%, and then by FCEVs with 2.8% (CVRP, 2019h).

Figure 13: CVRP Rebates Issued to Low-Income Consumers by Vehicle Manufacturer, March 2016-November 2019

Source: CVRP, 2019h

Figure 13 illustrates the CVRP rebates issued to low-income consumers, sorted by vehicle manufacturer, from March 2016 to November 2019 (CVRP, 2019h). The vehicle manufacturer with the greatest number of rebates issued to low-income consumers is Tesla, which accounts for 20.0% of total rebates issued to consumers residing in low-income communities, followed by Chevrolet with 18.8%, Toyota with 15.4%, FIAT with 9.3%, and Honda with 7.8% (CVRP, 2019h).

Figure 14: CVRP Rebates Issued to Low-Income Consumers by Vehicle by Amount, March 2016-November 2019

Source: CVRP, 2019h

Figure 14 displays the CVRP rebates issued to low-income consumers, sorted by amount from March 2016 to November 2019 (CVRP, 2019h). The rebate amount issued most often is \$4,500, which accounts for 47.6% of total rebates issued to low-income consumers. Table 1 indicates that this is the rebate amount issued to low-income consumers who adopt BEVs. Following that, the second rebate amount issued most often is \$3,500 with 38.9% of total rebates issued. This is the rebate amount issued to low-income consumers who adopt PHEVs. Following that, the third rebate amount issued most often is \$4,000 with 6.5% of total rebates issued. This rebate amount does not correspond to any of the CVRP rebate amounts offered to low, moderate, or higher-income consumers, as shown in Table 1.

Figure 15: SPSS Output of Correlation Between CVRP Rebate Recipients Residing in Low-Income Communities and CVRP Low-Income Rebate Recipients

Low-Income Community and Low-Income Increased Rebate Crosstabulation			Low-income Increased Rebate		Total
			0	1	
Low-Income Community	0	Count	173,726	11,378	185,104
		% within Low-Income Community	93.9%	6.1%	100.0%
		% within Low-income Increased Rebate	81.6%	64.0%	80.2%
		% of Total	75.3%	4.9%	80.2%
	1	Count	39,175	6,413	45,588
		% within Low-Income Community	85.9%	14.1%	100.0%
		% within Low-income Increased Rebate	18.4%	36.0%	19.8%
		% of Total	17.0%	2.8%	19.8%
Total		Count	212,901	17,791	230,692
		% within Low-Income Community	92.3%	7.7%	100.0%
		% within Low-income Increased Rebate	100.0%	100.0%	100.0%
		% of Total	92.3%	7.7%	100.0%

Source: CVRP, 2019h

Figure 15 is an output from SPSS portraying the correlation between the two income indicators used by this research: CVRP rebate recipients residing in low-income communities and the CVRP rebate recipients who are low-income (CVRP, 2019h). As highlighted in yellow, 6,413 or 36% of low-income rebate recipients also reside in low-income communities. This means that 64% of low-income rebate recipients do *not* reside in low-income communities.

Findings on CVRP Consumer Survey 2013-2017

The CVRP Consumer Survey 2013-17 asked 40,028 voluntary respondents to rate the importance and the essentiality of the CVRP rebate on their capability to adopt a PEV (which includes both BEVs and PHEVs). It also inquired what their interest level in PEVs was during the initial vehicle search (CVRP, 2019k). The questions did not address FCEVs.

Table 11: Rebate Importance: CVRP Consumer Survey 2013-17

Question: How important was the state rebate (CVRP) in making it possible to acquire a PEV?			
Value	Description of Value	Number of Respondents Who Selected this Value	Percentage of Total Respondents
1	Not at all important	1,203	3.0%
2	Slightly important	2,887	7.2%
3	Moderately important	6,324	15.8%
4	Very important	10,890	27.2%
5	Extremely important	17,993	45.0%
N/A	Did not make a selection	731	1.8%
Total		39,297	100.0%

Source: CVRP, 2019k

Figure 16: Rebate Importance: CVRP Consumer Survey 2013-17

Source: CVRP, 2019k

Table 11 and Figure 16 are two different formats conveying how important the CVRP rebate was in making it possible for respondents to adopt a ZEV. A vast majority (95.2%) answered that that the CVRP rebate was important to some extent (CVRP, 2019k).

Table 12: Rebate Essentiality: CVRP Consumer Survey 2013-17

Question: Would you have purchased or leased or PEV without the CVRP rebate?			
Value	Description of Value	Number of Respondents Who Selected this Value	Percentage of Total Respondents
0	No	19,360	48.4%
1	Yes	20,164	50.4%
N/A	Did not make a selection	504	1.3%
Total		40,028	100.0%

Source: CVRP, 2019k

Figure 17: Rebate Essentiality: CVRP Consumer Survey 2013-17

Source: CVRP, 2019k

Table 12 and Figure 17 are two different formats representing data on whether respondents would have adopted a PEV without the CVRP rebate. The responses were closely split, with 48.4% answering that they *would not* have adopted a PEV without the CVRP rebate and 50.4% answering that they *would* have (CVRP, 2019k).

Table 13: PEV Interest: CVRP Consumer Survey 2013-17

Question: Which of the following statements best describes your interest in acquiring a PEV when you started your search for a new vehicle?			
Value	Description of Value	Number of Respondents Who Selected this Value	Percentage of Total Respondents
1	I did not know PEVs existed	670	1.7%
2	I had no interest in a PEV	1,592	4.0%
3	I had some interest in a PEV	7,409	18.5%
4	I was very interested in a PEV	12,637	31.6%
5	I was only interested in a PEV	17,592	43.9%
N/A	Did not make a selection	128	0.3%
Total		39,990	100.0%

Source: CVRP, 2019k

Figure 18: PEV Interest: CVRP Consumer Survey 2013-17

Source: CVRP, 2019k

Table 13 and Figure 18 are two different formats illustrating respondents' level of interest in PEVs when they began searching for a new vehicle. Nearly all (98%) expressed some level of interest in PEVs prior to adopting one (CVRP, 2019k).

Findings on GHG Emissions in California

Table 14: Total GHG Emissions of Light-Duty Vehicles in California 2010-2017

Year	Total GHG Emissions from Light-Duty Vehicles in Million Tonnes	Percentage Change of GHG Emissions from Previous Year
2010	112.90	N/A
2011	110.10	-2.48%
2012	110.49	0.36%
2013	110.27	-0.21%
2014	110.88	0.56%
2015	114.82	3.55%
2016	117.45	2.29%
2017	118.20	0.64%

Source: CARB, 2020b

CARB's Greenhouse Gas Emissions Inventory lists the total amount of GHG emissions produced by light-duty vehicles, which includes passenger cars, trucks, SUVs (and excludes motorcycles) in California from 2010 to 2017, as reflected in Table 14 (CARB, 2020b). The unit of measurement used is million tonnes. A tonne is a metric unit of mass equal to 1,000 kilograms or approximately 2,204.6 pounds. From 2010 to 2017, the average total GHG emissions from light-duty vehicles was 113.14 million tonnes. The year 2017 had the highest total of GHG emissions at 118.20 million tonnes, while the year 2011 had the lowest total of GHG emissions at 110.10 million tonnes.

Comparison of ZEV and ICEV Operating Costs and Emissions

Figure 19: Calculation of Annual Operating Cost and Emissions of ZEV Compared to ICEV

Vehicle	Annual Fuel Use	Annual Electricity Use	Annual Fuel/Elec Cost	Annual Operating Cost	Cost Per Mile	Annual Emissions (lbs CO ₂)
2019 Toyota Camry Gasoline	344 gal	0 kWh	\$1,123	\$3,380	\$0.28	8,265
2019 Tesla Model 3 Standard Range EV	0 gal	3,100 kWh	\$596	\$2,701	\$0.23	1,575

Source: DOE, 2019b

Figure 19 is from the DOE website's Vehicle Cost Calculator, a tool used to compare the annual operating cost of a ZEV to a similar gasoline-fueled ICEV (DOE, 2019b). This comparison is between two vehicles similar in class (four-door sedans with room for five passengers) and popularity: 1) the most purchased ZEV in California, the 2019 Tesla Model 3 base model (with a Manufacturer Suggested Retail Price or MSRP of \$35,000), and 2) the most purchased ICEV in California, the 2019 Toyota Camry LE/SE model (MSRP \$24,095). The Vehicle Cost Calculator was inputted with the most up-to-date March 2020 average gasoline price of \$3.26/gallon in California (EIA, 2020a), and the most up-to-date January 2020 average electricity price of 19.94 cents/kilowatt hour in California (EIA, 2020b). According to this tool, the annual operating cost of the ZEV is \$2,701, while the annual operating cost of the ICEV is \$3,380. It costs \$0.23 per mile to drive the ZEV and it costs \$0.26 per mile to drive the ICEV. Annually, the ICEV uses 344 gallons of gasoline and emits 8,265 pounds of carbon dioxide (CO₂), which is a GHG. Annually, the ZEV uses 0 gallons of gasoline since it is powered by electricity and it emits 1,575 pounds of carbon dioxide.

ANALYSIS

The main objective of this research is to evaluate the impact of CVRP rebates on the adoption of ZEVs by low-income consumers. By using the measures M₁-M₄ specified in the Logic Model (Table 2), the research will determine if the program is meeting the anticipated outcomes AO₁-AO₅.

Analysis of Measures and Outcomes

M₁ (Track total number of ZEV registrations in California)

M₂ (Track percentage of registration changes of ZEVs compared to ICEVs in California)

The number of ZEV registrations is increasing in California (Table 3) so *AO₁ (Total number of ZEV registration should increase in California)* is being met. Between 2018 and 2019, the number of ZEVs registered went from 345,239 to 479,542, which represents a 38.9% increase. In comparison, during that period of time, the number of ICEVs registered only increased 4.36%. In 2018, ZEVs accounted for 1.13% of total vehicle registrations in 2018. In 2019, ZEV accounted for 1.50% of total vehicle registrations (Table 3). That is a 33% increase so *AO₂ (Percentage of ZEV registrations compared to ICEV registrations in California should increase)* is being met.

The increasing number of ZEV registrations can be attributed to the growing number of new ZEVs purchased or leased. Although there is a decrease in the total number of new vehicles registered from 2018 through 2016, the numbers of new ZEVs registered during those years increased, indicating rising levels of ZEV adoption (Table 4). In 2016, new ZEV registrations accounted for 3.73% of all new vehicle registrations (Table 4). By 2018, that number rose to 8.55%, confirming that more consumers are adopting ZEVs (Table 4). From 2016 to 2017, the number of new ZEV registrations ascended 31.15%, meaning that many more ZEVs were adopted. From 2017 to 2018, that number soared 60.12% (Table 4).

A factor that may affect why more consumers are adopting ZEVs is that these vehicles have lower annual operating costs than ICEVs. The assessment in Figure 19 found that the annual operating cost of the ICEV model is 25.1% more than the ZEV. Furthermore, some consumers are interested in reducing GHG emissions levels and may be drawn to ZEVs because their emissions are considerably less than ICEVs. Figure 19 also showed that the ICEV model emits 524.76% more carbon dioxide than the ZEV model.

M₃ (Track total number of CVRP rebates issued annually)

M₄ (Track percentage change in rebates issued to consumers residing in low-income communities and to low-income consumers)

The total number of CVRP rebates issued steadily increased every year from 2010 to 2018, except for in 2016 (Table 5) so *AO₃ (Total number of rebates issued should increase)* is being met. The number for 2019 is not complete as it is only updated up to November 2019. However, in the CVRP Rebate Statistics data, it can be pinpointed that from January 2018 to November 2018, the number of CVRP rebates issued was 64,825 (CVRP, 2019h). From January 2019 to November 2019, that number was 65,099. This implies that the number of CVRP rebates issued in 2019 is on trend to be close to the number of CVRP rebates issued in 2018 (CVRP, 2019h).

The number of CVRP rebates issued to consumers residing in low-income communities climbed each year from 2010 to 2019 (Table 7). The number of CVRP rebates issued to low-income consumers is also rising each year from when the supplementary rebates were implemented in 2016 through November 2019 (Table 9) so *AO₄ (Total number of rebates issued to consumers residing in low-income communities and to low-income consumers should increase year after year)* is being met.

Based on the data from the CVRP Consumer Survey 2013-2017, most consumers find the CVRP rebates fairly important in their capability to adopt a ZEV. Eighty-eight percent of respondents stated that the CVRP rebate is moderately, very, or extremely important in making it possible to acquire a PEV (Table 11). Ninety-four percent of respondents answered that during the early stages of their search for a new vehicle, they had some interest in a PEV, they were very interested in a PEV, or they were only interested in a PEV (Table 13). This data was evaluated using logistical regression to examine the relationship between rebate essentiality, rebate importance, and PEV interest. Logistic regression is used when there is a binary dependent variable, such as rebate essentiality (0 = No, 1 = Yes). The other factors, rebate importance and PEV interest, were controlled using SPSS. A logistic regression test was run with the question, “Would you have purchased or leased your PEV without the CVRP rebate?” as the dependent variable to get the change outcome of 1 or “Yes” with every unit change in the other two questions, “How important was the state rebate (CVRP) in making it possible to acquire a PEV?” and “Which of the following statements best describes your interest in acquiring a PEV when you started your search for a new vehicle?”

The SPSS result in Figure 20 affirms that both of these questions are statistically important. This is because with every unit of change in the question, “How important was the state rebate (CVRP) in making it possible to acquire a PEV?”, it decreases the odds of adopting a PEV by 0.211 or 21.1%. This means the more important the CVRP rebate is to a consumer, the less likely they are to adopt a PEV without the rebate. With every unit of change in question, “Which of the following statements best describes your interest in acquiring a PEV when you started your search for a new vehicle?”, it increases the odds of adopting a PEV by 0.038 or

3.8%. This means the more interested a consumer is in a PEV, the more likely they are to adopt a PEV without the CVRP rebate.

Figure 20: SPSS Output of Relationship Between Rebate Essentiality, Rebate Importance, and PEV Interest

Coefficients ^a								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	1.189	.013		89.385	.000	1.163	1.216
	How important was the state rebate (CVRP) in making it possible to acquire a PEV?	-.211	.002	-.461	-102.784	.000	-.215	-.207
	Which of the following statements best describes your interest in acquiring a PEV when you started your search for a new vehicle?	.038	.002	.072	16.165	.000	.033	.042

a. Dependent Variable: Would you have purchased or leased your PEV without the CVRP rebate?

Source: CVRP, 2019k

The assessments of measures M1-M4 indicate that anticipated outcomes AO1-AO4 are being met, but how well are they being met? The percentage of CVRP rebates issued to consumers residing in low-income communities (out of the total CVRP rebates issued) initially decreased in 2012 and 2013, but since then, it has gradually increased (Table 7). Pursuant to AB 1550, at least 35% of the proceeds from the Greenhouse Gas Reduction Funds should assist “priority populations,” including disadvantaged communities, low-income communities, and low-income households (CARB, 2018). However, only three air districts, South Coast SQMD, Bay Area AQMD, and San Diego County APCD, account for 86.6% of where CVRP rebate recipients reside (Figure 5). This illuminates that CVRP rebates are not equitably dispersed—Figure 1 illustrates that AB 1550 low-income communities exist throughout many parts of California and mostly outside of the regions of the three air districts stated.

Since 35% of CVRP funding is apportioned to vulnerable populations, it is reasonable to expect that 35% of CVRP rebates should be issued to consumers residing in low-income communities and/or to low-income consumers. However, CVRP rebates issued to consumers residing in low-income communities only account for 18.3% of total CVRP rebates issued between 2010 and 2019 (Table 7). In addition, CVRP rebates issued to low-income consumers only account for 7.71% of total CVRP rebates issued between 2016 and 2019 (Table 9). It can be inferred that *AO4 (Total number of rebates issued to consumers residing in low-income communities and to low-income consumers should increase year after year)* is not being met very well.

Table 15: Comparing Percentage Change of CVRP Rebates Issued, Percentage Change of CVRP Rebates Issued to Consumers in Low-Income Communities, and Percentage Change of CVRP Rebates Issued to Low-Income Consumers

Year	CVRP Rebates Issued	Percentage Change of CVRP Rebates from Previous Year	CVRP Rebates Issued to Consumers in Low-Income Communities	Percentage Change of CVRP Rebates Issued to Consumers in Low-Income Communities from Previous Year	CVRP Rebates Issued to Low-Income Consumers	Percentage Change of CVRP Rebates Issued to Low-Income Consumers from Previous Year
2010	135	N/A	23	N/A	N/A	N/A
2011	4,521	3248.89%	856	3621.74%	N/A	N/A
2012	11,219	148.15%	1,645	92.17%	N/A	N/A
2013	29,152	159.84%	4,175	153.80%	N/A	N/A
2014	43,702	49.91%	7,121	70.56%	N/A	N/A
2015	46,543	6.50%	7,461	4.77%	N/A	N/A
2016	44,455	-4.49%	7,785	4.34%	2,358	N/A
2017	47,758	7.43%	9,488	21.88%	4,435	88.08%
2018	73,380	53.65%	14,426	52.04%	5,011	12.99%
2019	65,099	-11.29%	13,889	-3.72%	5,987	19.48%
Average 2010-2019		51.21%		49.48%		40.18%

Source: CVRP, 2019h

Table 15 presents the number of overall CVRP rebates issued, the number of CVRP rebates issued to consumers residing in low-income communities, and the number of CVRP rebates issued to low-income consumers (CVRP, 2019h). It also details the percentage changes from the previous year for each of the three rebate categories mentioned. On average, the percentage change from the previous year is the highest for overall CVRP rebates issued at 51.21%. The percentage change for CVRP rebates issued to consumers residing in low-income communities averaged 49.48%. The percentage change for CVRP rebates issued to low-income consumers averaged 40.18%. This verifies that *AO5 (The percentage of rebates issued to consumers residing in low-income communities and the percentage of rebates issued to low-income consumers should increase at greater rates than overall rebates issued)* is not being met.

How can CVRP improve and meet all of its anticipated outcomes? In other words, how can CVRP rebates be issued to more “priority populations”? These populations face greater threats of GHG emissions-related health issues so they stand to benefit more if CVRP is successful in meeting its legislative intent of reducing GHGs by putting more ZEVs on the road. Since 35% of the funding for CVRP is directed to these populations, it is imperative to address the barriers that prevent them from adopting ZEVs in higher numbers and receiving 35% of the rebates.

One impediment is the concern of finding a charging location. As discussed in the literature review, charging PEVs can be done in the garage of a single-family home, but many low-income households live in apartment complexes and condominiums that do not offer access to PEV charging. California is evidently taking action to improve charging infrastructure—EO B-48-18 will fund 250,000 PEV charging stations and 200 FCEV hydrogen stations by 2025 (California Office of the Governor, 2018). It is also auspicious that the CALeVIP program offers financial assistance for the installation of public PEV charging stations (CEC, 2018, p. 9-10). However, it needs to be ensured that these stations will be accessible to low-income drivers. The locations of the stations should be deliberately planned so that they are equitably distributed throughout California, with at least 35% in SB 535 designated disadvantaged communities and AB 1550 designated low-income communities (Figure 1). To assure that low-income drivers can afford to access public charging stations, California should set limits on the pricing.

This research along with the two reports from UC Davis have concluded that CVRP rebates have largely gone to moderate-and higher-income consumers instead of to low-income consumers, demonstrating an inequitable distribution among income groups (UC Davis, 2019a), (UC Davis, 2019b). To be a more efficient program, the percentage of rebate recipients

persuaded to adopt a ZEV because of an incentive should increase while the percentage of rebate recipients who would have adopted a ZEV anyway should decrease. To be a more equitable program, incentives should be evenly disbursed to all income groups. If not enough consumers from all income groups, including low-income consumers, are convinced to adopt ZEVs, California will not meet its goal of five million ZEVs on the roads by 2030 nor will the state achieve its GHG emission targets.

There are several approaches to tackle the objectives to an efficient and equitable program. One option is to enact another income cap. Currently, higher-income consumers only receive rebates for rebates for FCEVs, and not for BEVs and PHEVs. An income cap could be instituted so that higher-income consumers are not eligible for any rebate, not even the one for FCEVs since that particular one is a relatively high amount of \$5,000. While FCEVs are the least adopted out of the three ZEV types, overall, \$26,303,168 million in rebates have still been issued for them from 2010 to 2019 (CVRP, 2019h). Although it is not enumerated how much of this was issued to higher-income consumers, the discontinuance of rebates for this income group would free up resources that could instead be used to increase rebate amounts for low-income consumers. Research also uncovers that since higher-income consumers have the financial means to adopt a ZEV without assistance, rebates offered do not carry much significance to them (UC Davis, 2019a). Studies show that income caps would reduce rebates issued to higher-income consumers while not decreasing the amount of ZEVs adopted overall (UC Davis, 2019b, p. 5). Rebate programs are mainly utilized by higher-income consumers who would have adopted a ZEV anyway, not because of the incentive (Chandra et al, 2010, p. 92). This is supported by evidence that higher-income consumers of luxury BEVs are typically not motivated by financial

incentives (Hardman & Tal, 2016, p. 5). Consequently, an income cap would likely not reduce the number of ZEVs adopted by higher-income consumers.

Another hurdle to broad ZEV adoption is the higher cost to purchase or lease a ZEV. The vehicles compared in Figure 19, the ZEV, 2019 Tesla Model 3 base model has an MSRP of \$35,000, while the ICEV 2019 Toyota Camry LE/SE model has an MSRP of \$24,095. Over time, a ZEV will have lower operating costs than an ICEV (Figure 19), however, the upfront price premium to purchase or lease negates the savings and deters low-income consumers. One way for the program to be more efficient and equitable, and also reduce upfront costs is to increase CVRP rebate amounts for low-income consumers. The CVRP Consumer Survey and numerous studies have identified that low-income consumers are the most likely to be swayed to adopt ZEVs by financial incentives (CVRP, 2019k), (DeShazo et al, 2017), (UC Davis, 2019b). Incentives offered are off enormous importance in their decisions to adopt ZEVs (DeShazo et al, 2017), (UC Davis, 2019b). The UC Davis report suggests that the rebate amounts should be increased in order to appeal to more low-income consumers and will lead to greater adoption of ZEVs by them (UC Davis, 2019b, p. 10). This is referred to as incentive targeting and ensures that “appropriate incentives are delivered to those most likely to benefit from and/or be influenced by them” (UC Davis, 2019b, p. 5).

Similarly, DeShazo et al. determined the most effective strategy to maximize ZEV adoption is to issue progressive rebates based on income. One of the suggestions is to increase rebate amounts and to also put a cap at a specific income of \$100,000 so those who earn more than this are not eligible. All consumers with incomes of “less than \$100,000 would receive a rebate of \$5,000 for BEVs and \$3000 for PHEVs (DeShazo et al, 2017, p. 41). The research deduced that this policy would substantially raise the numbers of BEVs and PHEVs sold by 39%

compared to the status quo policy, but it would also require a 23% increase in the program budget (DeShazo et al, 2017, p. 41). Another proposed policy is to offer “consumers purchasing BEVs who make incomes of 1) less than \$25,000, a rebate of \$7,500, 2) \$25,000–\$50,000, a rebate of \$5,000, 3) \$50,000–\$75,000, a rebate of \$2,000, and 4) over \$75,000, no rebate. Consumers purchasing a PHEV in these same income categories would receive \$4,500, \$3,000, and \$1,000, respectively” (DeShazo et al, 2017, p. 41). The research discovered that this policy would sell approximately as many BEVs and PHEVs as the status quo policy while leading to considerably more equity of rebates across income groups (DeShazo et al, 2017, p. 41). It would also be 26% more cost-effective than the status quo policy. Both of the recommended policies of sharply progressive rebates are likely to have a positive effect on the adoption of ZEVs by low-income consumers.

AB 1046 (Air Quality Improvement Program: Clean Vehicle Rebate Project) was a bill introduced in 2019 by Assemblyman Phil Ting (Shwe, 2019). He contended that if California is to meet Governor Brown’s goal of five million ZEVs on the roads by 2030, there needs to be a more attractive financial incentive for consumers to adopt them since they are situated at a higher price point. AB 1046 proposed tripling the CVRP rebate amount to make the cost of ZEVs competitive with ICEV. In addition, CVRP has been underfunded, exhausting its budget before the end of every fiscal year. This has resulted in consumers being placed on a waitlist for a rebate until legislators approve additional funding. These delays have undermined the success of CVRP. AB 1046 would require CARB to find a stable and uninterrupted pot of funding for the CVRP. However, the bill would need \$10-\$16 billion to fund CVRP rebates to get to five million ZEVs on the road by 2030 (Shwe, 2019), (Gardiner, 2019). This lofty price tag was among the reasons why the bill was killed by legislators in August 2019 (Gardiner, 2019).

California is not likely to meet its GHG emissions reduction goals. Enacted in 2006, AB 32 aimed to reduce the state's GHG emissions to 1990 levels by 2020. Expanding on this, SB 32 (California Global Warming Solutions Act of 2006: emissions limit) was signed into law by Governor Brown in 2016, setting a target of decreasing GHG emissions to 40% below 1990 levels by 2030 (Next 10, 2019, p. 1). At the existing rate of progression, California will not meet its 2030 emissions target until 2061 (Next 10, 2019, p. 1). The total amount of GHG emissions produced by light-duty vehicles in California from 2010 to 2017 has increased by 4.7% overall (Table 14). The numbers of ZEVs being adopted are rising, but not enough to make an environmentally positive effect because there is the counterbalancing issue of consumers' ICEV preferences. According to a study by the nonpartisan organization Next 10, in late 2018, Californians purchased or leased more pick-up trucks, mini-vans, and SUVs than they did five years before. While those vehicles made up 39.3% of new vehicle registrations in 2013, they comprised 57.3% of new vehicle registrations in 2018 (Next 10, 2019, p. 2). Consumers may favor these less fuel-efficient vehicles because they want the capacity to carry more passengers and items, they prefer the experience of being higher up from the ground, and they like the more rugged appearances of the vehicles (Gibson, 2016). There are not many pick-up truck, mini-van, and SUV ZEV models that qualify for the CVRP rebate. Currently, there are only three: the Tesla Model Y (which has been announced, but not yet released), which is a BEV SUV, the Chrysler Pacifica, which is a PHEV mini-van, and the Kia Niro Plug-in Hybrid, which is a PHEV SUV (CVRP, 2020). The Next 10 study suggests that ZEVs cannot truly replace ICEVs until there are more ZEV options for consumers and the infrastructure to support them (Next 10, 2019, p. 2). Vehicle manufacturers would need to produce more ZEV models of pick-up trucks, mini-vans, and SUVs with design features that appeal to a broad range of consumers.

The computations from the DOE's Vehicle Cost Calculator are in line with research from the literature review stating that the annual operating cost of ZEVs are less than ICEVs (Figure 19). However, based on the purchasing and leasing tendencies of low-income consumers, this information may not be commonly known so CVRP should ascertain how to steer targeted marketing to them. In order for CVRP rebates to reach this specific demographic, the program should undertake an extensive campaign to educate them on the lower than expected operating costs of ZEVs. Low-income consumers should also be informed of the supplementary CVRP rebate available to them, which would result in reduced upfront adoption costs. It would be useful for the CVRP website to introduce its own vehicle cost calculator tool with the option for users to compare the purchasing/leasing costs and the annual operating costs of ZEV models and ICEV models. The tool should also allow users to enter their income so that the output factors in the user's estimated CVRP rebate amount as well as the federal PEDVC of \$2,500 to \$7,500 for the purchase or lease of PHEVs (IRS, 2019). The tool should provide final outputs of purchasing or leasing costs of each vehicle model in addition to its annual operating cost and amount of GHG emissions. This tool's calculations would be a straightforward way for potential consumers to grasp that the costs of adopting and owning ZEVs are within their reach. Outreach in the form of community events, consumer education workshops, and media placements should be directed to low-income consumers to advise them that the widespread adoption of ZEVs will result in the reduction of GHG emissions. It is crucial to highlight that this effect will advance health outcomes so that low-income consumers recognize the benefits on their own well-beings. This should lead to increased numbers of low-income consumers who value ZEVs positively and deem that they are worth investing in.

Limitations

The findings of this research should be considered with some limitations in mind. One limitation is that ZEVs are usually discussed as one monolith, however there is a big distinction between PEVs and FCEVs. Most information on ZEVs (such as their electricity costs, maintenance costs, emission levels, and CVRP Consumer Survey responses) only concern PEVs. Information on the hydrogen fueling costs, maintenance costs, emission levels, and consumer opinions of FCEVs is rarely addressed, presumably because this ZEV type has not been around as long, there are not many models on the market, and they are adopted in substantially smaller numbers than PEVs.

Another limitation is that the DMV's total vehicle registration data for ZEVs and ICEVs are only available for 2018 and 2019. It would be valuable to see the effects of CVRP rebates on ZEV adoption from the time the CVRP program was implemented in 2010. CNCDA's Green Vehicle Reports also only cover new registrations of ZEVs and ICEVs from 2016 through 2018—it would be beneficial if the data was provided since 2010 to gauge what kind of effect CVRP has had on ZEV adoption since the program's induction.

The CVRP Rebate Statistics do not capture all new ZEVs purchased or leased in California. Not every eligible ZEV consumer applies for a rebate and not every ZEV is eligible for a rebate. Over the first five years of the program from 2010 to 2015, approximately three-quarters (>74%) of eligible consumers received CVRP rebates (CVRP, 2019h). This leaves one-quarter of eligible consumers who did not receive CVRP rebates so their information is missing from the CVRP Rebate Statistics. As a result, the findings based on this data may be imprecise.

It is meaningful to note that 6,413 or only 36% of CVRP low-income rebate recipients also reside in low-income communities (Figure 15). Hence, the majority (64%) of CVRP low-

income rebate recipients do *not* reside in low-income communities. This reveals that most CVRP rebate recipients who reside in low-income communities are *not* also low-income recipients.

Another limitation is the additional CVRP rebates for low-income consumers began in 2016 so the data for these rebates is only available from 2016 to 2019 (CVRP, 2019h). It may take more than four years for the percentage of rebates issued to low-income consumers to increase at a greater rate.

The CVRP Consumer Survey data was collected from 40,028 rebate recipients from who voluntarily responded and not all rebate recipients (CVRP, 2019k). Therefore, the survey results offer a snapshot of the motivations of respondents who purchased or leased PEVs, meaning that the sample obtained may not be representative of the entire population of CVRP rebate recipients.

Future Areas of Research

The CVRP program is funded annually. While its budget may seem high, \$238 million in FY 2019-20, (CARB, 2019c, p. iv), it is usually exhausted before the end of the fiscal year, resulting in consumers waiting for additional funding to become available (CVRP, 2019j). This research establishes that increased CVRP rebates for low-income consumers will accelerate their adoption of ZEVs. California legislators should authorize significantly more funding to CVRP. AB 1046 had proposed \$10-\$16 billion to supplement CVRP's current budget, but legislators rejected this bill, believing the amount was too high. Nevertheless, future research is needed to accurately forecast how much is required to properly fund CVRP in order to provide for increased rebate amounts and concentrated outreach to low-income consumers. The dollar amount that CVRP rebates should increase to in order to appeal to low-income consumers should also be examined.

Moreover, it should be studied how much funding would be saved if an income cap is enacted so that higher-income consumers are no longer eligible for CVRP rebates.

If California follows through on its plan to build additional hydrogen stations for FCEVs, more FCEV models are manufactured, and more FCEVs are adopted, there will be extensive data for future research to explore about this type of vehicle since it is routinely omitted from studies about ZEVs in the U.S. It would be worthwhile to compare the fueling costs, maintenance costs, emission levels, and consumer opinions of FCEVs, PEVs, and ICEVs.

Conclusion

The intriguing outcome of the efforts of CVRP is that the number of overall rebates issued is increasing as more consumers are utilizing the program. However, the percentage of rebates issued to low-income consumers is not increasing at the same rate. While California is seeing a rise in the adoption of ZEVs, more bold action is needed to hasten this trend. It is crucial to assuage consumer reservations about ZEVs, such as upfront adoption costs, operating costs, charging availability, and performance characteristics. Well-aimed outreach to low-income consumers should also emphasize that the mass adoption of ZEVs will lead to a radical decline of GHG emissions in California, which will reduce health disparities experienced most acutely by this demographic. It will also lessen healthcare costs for the state. To make practical ZEV adoption a reality for low-income consumers, the CVRP rebate amounts issued for them should be markedly increased. By taking these recommended actions, CVRP will achieve greater rebate allocative equity among income groups (conceivably with 35% of CVRP rebates issued to priority populations), accelerate ZEV adoption by low-income consumers, and be closer to California's target of five million ZEVs on the roads by 2030, making it plausible for the state to attain its GHG emission goals.

REFERENCES

- American Lung Association (ALA). (2020). 20th Annual State of The Air Grades Reveal Wildfire and Extreme Heat Impacts on Clean Air Progress. Retrieved from <https://www.lung.org/media/press-releases/20th-sota-ca>
- Borenstein, S., & Davis, L. W. (2015). The distributional effects of U.S. clean energy tax credits. *National Bureau of Economic Research, Inc.* Retrieved from <http://dx.doi.org.libaccess.sjlibrary.org/10.3386/w21437>
- Brinklow, A. (2017, August 11). California: Worst home markets for low-income people in the U.S. *Curbed*. Retrieved from <https://sf.curbed.com/2017/8/11/16135688/home-owner-gap-california-homes>
- California Air Resources Board (CARB). (2014). Assembly Bill 32 Overview. Retrieved from <https://ww3.arb.ca.gov/cc/ab32/ab32.htm>
- California Air Resources Board (CARB). (2016). California Clean Vehicle Rebate Project increases incentives for low- and moderate-income drivers. Retrieved from <https://ww2.arb.ca.gov/news/california-clean-vehicle-rebate-project-increases-incentives-low-and-moderate-income-drivers>
- California Air Resources Board (CARB). (2018). Priority Population Investments. Retrieved from <https://ww3.arb.ca.gov/cc/capandtrade/auctionproceeds/communityinvestments.htm>
- California Air Resources Board (CARB). (2019a). About. Retrieved from <https://ww2.arb.ca.gov/about>
- California Air Resources Board (CARB). (2019b). Clean Vehicle Rebate Program (CVRP). Retrieved from <https://ww3.arb.ca.gov/msprog/lct/cvrp.htm>
- California Air Resources Board (CARB). (2019c). Proposed Fiscal Year 2019-20 Funding Plan

for Clean Transportation Incentives for Low Carbon Transportation Investments and the Air Quality Improvement Program. Retrieved from <https://ww2.arb.ca.gov/sites/default/files/2019-09/fy1920fundingplan.pdf>

California Air Resources Board (CARB). (2020a). California Air Districts. Retrieved from <https://ww2.arb.ca.gov/california-air-districts>

California Air Resources Board (CARB). (2020b). Greenhouse Gas Emission Inventory - Query Tool for years 2000 to 2017 (12th Edition). Retrieved from https://www.arb.ca.gov/app/ghg/2000_2017/ghg_sector.php?

California Energy Commission (CEC). (2015). Zero-Emission Vehicles in California. Retrieved from https://www.energy.ca.gov/sites/default/files/2019-06/TRAN-Zero_Emission_Vehicles.pdf

California Energy Commission (CEC). (2018). Tracking Progress: Zero-Emission Vehicles and Infrastructure. Retrieved from https://www.energy.ca.gov/sites/default/files/2019-12/Zero-Emission_Vehicles_and_Infrastructure_ada.pdf

California Environmental Protection Agency (CalEPA). (2017). Designation of Disadvantaged Communities Pursuant to Senate Bill 535 (De León). Retrieved from <https://calepa.ca.gov/wp-content/uploads/sites/6/2017/04/SB-535-Designation-Final.pdf>

California Environmental Protection Agency (CalEPA). (2019). California Climate Investments to Benefit Disadvantaged Communities. Retrieved from <https://calepa.ca.gov/envjustice/ghginvest/>

California Department of Motor Vehicles (DMV). (2018). Fuel Type by County as of 1/1/2018.

Retrieved from https://www.dmv.ca.gov/portal/wcm/connect/2156a052-c137-4fad-9d4f-db658c11c5c9/MotorVehicleFuelTypes_County.pdf?MOD=AJPERES&CVID=

California Department of Motor Vehicles (DMV). (2019). Fuel Type by County as of 1/1/2019.

Retrieved from https://www.dmv.ca.gov/portal/wcm/connect/e52e6d02-6fa6-483a-bbcd-d888f1b4035b/MotorVehicleFuelTypes_County_190913.pdf?MOD=AJPERES&CVID=

California New Car Dealers Association (CNCDA). (2019). Green Vehicle Report. Retrieved from <https://www.cncda.org/news/?category=green-vehicle-report>

California Office of the Governor. (2018). Governor Brown Takes Action to Increase Zero-Emission Vehicles, Fund New Climate Investments. Retrieved from <https://www.ca.gov/archive/gov39/2018/01/26/governor-brown-takes-action-to-increase-zero-emission-vehicles-fund-new-climate-investments/index.html>

California Public Utilities Commission (CPUC). (2019). Zero-Emission Vehicles. Retrieved from <https://www.cpuc.ca.gov/zev/>

Clean Vehicle Rebate Project (CVRP). (2015). Clean Vehicle Rebate Project Participation Rates: The First Five Years (March 2010 – March 2015). Retrieved from <https://cleanvehiclerebate.org/sites/default/files/attachments/2015-10%20CVRP%20Participation.pdf>

Clean Vehicle Rebate Project (CVRP). (2019a). About CVRP. Retrieved from <https://cleanvehiclerebate.org/eng/about-cvrp>

Clean Vehicle Rebate Project (CVRP). (2019b). Apply for a Rebate: CVRP Eligible Vehicles. Retrieved from <https://cleanvehiclerebate.org/eng/eligible-vehicles>

Clean Vehicle Rebate Project (CVRP). (2019c). Electric Vehicle Charging Overview. Retrieved from <https://cleanvehiclerebate.org/eng/ev/technology/fueling/electric>

- Clean Vehicle Rebate Project (CVRP). (2019d). Eligibility Guidelines. Retrieved from <https://cleanvehiclerebate.org/eng/eligibility-guidelines>
- Clean Vehicle Rebate Project (CVRP). (2019e). FAQs. Retrieved from <https://cleanvehiclerebate.org/eng/faqs>
- Clean Vehicle Rebate Project (CVRP). (2019f). Implementation Manual. Retrieved from <https://cleanvehiclerebate.org/sites/default/files/docs/nav/transportation/cvrp/documents/CVRP-Implementation-Manual.pdf>
- Clean Vehicle Rebate Project (CVRP). (2019g). Rebate Map. Retrieved from <https://cleanvehiclerebate.org/eng/cvrp-rebate-map>
- Clean Vehicle Rebate Project (CVRP). (2019h). Rebate Statistics. Retrieved from <https://cleanvehiclerebate.org/eng/rebate-statistics>
- Clean Vehicle Rebate Project (CVRP). (2019i). State and Federal Electric Vehicle Incentives. Retrieved from <https://cleanvehiclerebate.org/eng/ev/incentives/state-and-federal>
- Clean Vehicle Rebate Project (CVRP). (2019j). Summary of CVRP Rebate Eligibility and Funding Availability Over Time. Retrieved from https://cleanvehiclerebate.org/sites/default/files/attachments/CVRP_Disruptions_Fact_Sheet.pdf
- Clean Vehicle Rebate Project (CVRP). (2019k). Survey Dashboard. Retrieved from <https://cleanvehiclerebate.org/eng/survey-dashboard/ev>
- Clean Vehicle Rebate Project (CVRP). (2020). CVRP Eligible Vehicles. Retrieved from <https://cleanvehiclerebate.org/eng/eligible-vehicles>
- Chandra, A., Gulati, S., & Kandlikar, M. (2010). Green drivers or free riders? An analysis of tax

- rebates for hybrid vehicles. *Journal of Environmental Economics and Management*, 60(2), 78-93. Retrieved from <https://doi.org/10.1016/j.jeem.2010.04.003>
- DeShazo, J., Sheldon, T., & Carson, R. (2017). Designing policy incentives for cleaner technologies: Lessons from California's plug-in electric vehicle rebate program. *Journal of Environmental Economics and Management*, 84(C), 18-43. Retrieved from <https://doi.org/10.1016/j.jeem.2017.01.002>
- Egbue, O., & Long, S. (2012). Barriers to widespread adoption of electric vehicles: An analysis of consumer attitudes and perceptions. *Energy Policy*, 48, 717-729. Retrieved from <https://doi.org/10.1016/j.enpol.2012.06.009>
- EV Adoption. (2019a). Available PHEVs in the US. Retrieved from <https://evadoption.com/ev-models/available-phevs/>
- EV Adoption. (2019b). BEV Models Currently Available in the US. Retrieved from <https://evadoption.com/ev-models/bev-models-currently-available-in-the-us/>
- Gallagher, K. S., & Muehlegger, E. (2011). Giving green to get green? Incentives and consumer adoption of hybrid vehicle technology. *Journal of Environmental Economics and Management*, 61(1), 1-15. Retrieved from <https://doi.org/10.1016/j.jeem.2010.05.004>
- Gardiner, D. (2019, September 11). California lawmakers kill plan to triple electric-vehicle rebates. *San Francisco Chronicle*. Retrieved from <https://www.sfchronicle.com/politics/article/California-lawmakers-kill-plan-to-triple-14432606.php>
- Gayer, T., & Parker, E. (2013). Cash for Clunkers: An Evaluation of the Car Allowance Rebate System. *Economic Studies at Brookings*. Retrieved from https://www.brookings.edu/wp-content/uploads/2016/06/cash_for_clunkers_evaluation_paper_gayer.pdf

- Gibson, K. (2016, February 18). Americans revert to buying gas-guzzlers. *CBS News*. Retrieved from <https://www.cbsnews.com/news/americans-revert-to-buying-gas-guzzlers/>
- Hardman, S., & Tal, G. (2016). Exploring the Decision to Adopt a High-End Battery Electric Vehicle: Role of Financial and Nonfinancial Motivations. *Transportation Research Record*, 2572(1), 20-27. Retrieved from <https://doi-org.libaccess.sjlibrary.org/10.3141/2572-03>
- Internal Revenue Service (IRS). (2005). Highlights of the Energy Policy Act of 2005 for Individuals. Retrieved from <https://www.irs.gov/pub/irs-news/fs-06-14.pdf>
- Internal Revenue Service (IRS). (2009). Internal Revenue Bulletin: 2009-48. Retrieved from https://www.irs.gov/irb/2009-48_IRB
- Internal Revenue Service (IRS). (2019). Plug-In Electric Drive Vehicle Credit (IRC 30D). Retrieved from <https://www.irs.gov/businesses/plug-in-electric-vehicle-credit-irc-30-and-irc-30d>
- Jenn, A., Azevedo, I. L., & Ferreira, P. (2013). The impact of federal incentives on the adoption of hybrid electric vehicles in the United States. *Energy Economics*, 40, 936. Retrieved from <https://doi.org/10.1016/j.eneco.2013.07.025>
- Jenn, A., Springel, K., & Gopal, A. (2018). Effectiveness of electric vehicle incentives in the United States. *Energy Policy*, 119, 349. Retrieved from <https://doi.org/10.1016/j.enpol.2018.04.065>
- Johnson, C., & Williams, B. (2017). Characterizing Plug-In Hybrid Electric Vehicle Consumers Most Influenced by California's Electric Vehicle Rebate. *Transportation Research Record*, 2628(1), 23-31. Retrieved from <https://doi-org.libaccess.sjlibrary.org/10.3141/2628-03>

Kaslikowski, A. (2019, November 15). All the hydrogen vehicles available for purchase today.

Digital Trends. Retrieved from <https://www.digitaltrends.com/cars/hydrogen-cars-for-sale>

Krause, R., Carley, S., Lane, B., & Graham, J. (2013). Perception and reality: Public knowledge of plug-in electric vehicles in 21 U.S. cities. *Energy Policy*, 63(C), 433-440. Retrieved from <https://doi.org/10.1016/j.enpol.2013.09.018>

Legislative Analyst's Office (LAO). (2018). Assessing California's Climate Policies—Transportation. Retrieved from <https://lao.ca.gov/reports/2018/3912/climate-policies-transportation-122118.pdf>

National Conference of State Legislatures (NCSL). (2017). State Efforts to Promote Hybrid and Electric Vehicles. Retrieved from <http://www.ncsl.org/research/energy/state-electric-vehicle-incentives-state-chart.aspx>

New York State Department of Environmental Conservation (DEC). (2019). Controlling Air Pollution from Motor Vehicles. Retrieved from <https://www.dec.ny.gov/chemical/8394.html>

Next 10. (2018). The Road Ahead for Zero-Emission Vehicles in California Market Trends & Policy Analysis. Retrieved from <https://www.next10.org/sites/default/files/2019-06/ca-zev-brief.pdf>

Next 10. (2019). California will hit climate targets more than 100 years too late if current pace of emissions reductions holds. Retrieved from https://www.next10.org/sites/default/files/2019-10/2019-california-green-innovation-index-press-release_3.pdf

Plugin Cars. (2019). Compare Electric Cars and Plug-in Hybrids By Features, Price, Range.

- Retrieved from
https://www.plugin cars.com/cars?sort_by=field_msrp_value&sort_order=ASC
- Rubin, D., & St-Louis, E. (2016). Evaluating the Economic and Social Implications of Participation in Clean Vehicle Rebate Programs: Who's In, Who's Out? *Transportation Research Record*, 2598(1), 67-74. Retrieved from <https://doi-org.libaccess.sjlibrary.org/10.3141/2598-08>
- Shwe, E. (2019, July 10). How much would it take to get you to buy an electric car? California could increase rebates. *Sacramento Bee*. Retrieved from
<https://www.sacbee.com/news/politics-government/capitol-alert/article232424717.html>
- Sylvia, R. D., & Sylvia, K. M. (2012). *Program planning and evaluation for the public manager* (4th ed). Long Grove, Illinois: Waveland Press.
- Tal, G., & Nicholas, M. (2016). Exploring the Impact of the Federal Tax Credit on the Plug-In Vehicle Market. *Transportation Research Record*, 2572(1), 95-102. Retrieved from
<https://doi-org.libaccess.sjlibrary.org/10.3141/2572-11>
- UC Davis. (2019a). Impact of the Clean Vehicle Rebate Project's income cap on California's ZEV Market. Retrieved from https://policyinstitute.ucdavis.edu/wp-content/uploads/CVRP_Income_Caps_0519.pdf
- UC Davis. (2019b). Impact of the Clean Vehicle Rebate Project's increased rebates for low- and moderate-income individuals on California's ZEV Market. Retrieved from
https://policyinstitute.ucdavis.edu/wp-content/uploads/CVRP_Rebates_0519.pdf
- U.S. Department of Energy (DOE). (2013). Internal Combustion Engine Basics. Retrieved from
<https://www.energy.gov/eere/vehicles/articles/internal-combustion-engine-basics>
- U.S. Department of Energy (DOE). (2019a). Fuel Cell Electric Vehicles. Retrieved from

https://afdc.energy.gov/vehicles/fuel_cell.html

U.S. Department of Energy (DOE). (2019b). Vehicle Cost Calculator. Retrieved from

<https://afdc.energy.gov/calc/>

U.S. Department of Energy (DOE). (2019c). Vehicle Cost Calculator Assumptions and Methodology. Retrieved from

https://afdc.energy.gov/calc/cost_calculator_methodology.html

U.S. Energy Information Administration (EIA). (2020a). California All Grades All Formulations Retail Gasoline Prices. Retrieved from

https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=emm_epm0_pte_sca_dpg&f=m

U.S. Energy Information Administration (EIA). (2020b). Table 5.6.A. Average Price of Electricity to Ultimate Customers by End-Use Sector. Retrieved from

https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a

Wardlaw, C. (2019, August 9). California's 40 Hydrogen Stations Push Toward Fuel-Cell Viability. *Wards Auto*. Retrieved from <https://www.wardsauto.com/10-best-engines/california-s-40-hydrogen-stations-push-toward-fuel-cell-viability>

ZEV Task Force. (2019). About the ZEV Task Force. Retrieved from

<https://www.zevstates.us/about-us/>