CALIFORNIA
AIR RESOURCES BOARD

ASSEMBLY BILL 615 REPORT TO THE LEGISLATURE ON THE IMPACT OF THE CLEAN VEHICLE REBATE PROJECT ON CALIFORNIA'S ZERO-EMISSION VEHICLE MARKET

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Executive Summary

The Clean Vehicle Rebate Project (CVRP), established by the California Air Resources Board (CARB or Board) under the Air Quality Improvement Program (AQIP), is designed to support the long-term transformation of California's light-duty vehicle fleet and meets policy, statutory, and regulatory goals and requirements by increasing the number of zero-emission vehicles (ZEVs) in the State. CVRP provides consumer rebates on a first-come, first-served basis for light-duty ZEVs, plug-in hybrid electric vehicles, and zero-emission motorcycles, which directly supports the State's ZEV deployment goals of 1 million vehicles by 2023 as directed by Senate Bill (SB) 1275 (De León, Chapter 530, Statutes of 2014), over 1.5 million vehicles by 2025 as directed by Executive Order B-16-2012, and 5 million vehicles by 2030 as directed by Executive Order B-48-18.

SB 1275 directed CARB to make a number of changes to CVRP including limiting consumer eligibility based on income and considering incorporating pre-qualification and point-of-sale mechanisms. In early 2016, CARB adopted income caps consistent with Proposition 30, which was passed by California voters in 2012, but it must be noted that any consumer-based eligibility requirements preclude establishing a point-of-sale mechanism due to the necessity to verify eligibility prior to sale. Shortly thereafter, SB 859 (Committee on Budget and Fiscal Review, Chapter 368, Statutes of 2016) was passed in late 2016 to set the income caps lower.

Assembly Bill (AB) 615 (Cooper, Chapter 631, Statutes of 2017) extended the sunset date for CVRP modifications required by SB 859 and required CARB to contract with either the University of California or California State University to produce a report on the impact of CVRP on California's ZEV market. AB 615 specifically asked CARB to explore the impact of income caps, increased rebates for lower income consumers, and increased outreach, as well as quantify emission reductions attributable to CVRP.

Per the requirements of AB 615, CARB contracted with the University of California, Davis (UC Davis) to produce three white papers covering the impact of income caps, increased rebates for lower income consumers, and increased outreach, all of which were introduced to CVRP in 2016. In addition, CARB tasked the Center for Sustainable Energy (CSE), the CVRP administrator, to use program-specific data to refine emission reduction calculations and provide estimates of emission reductions attributable to CVRP over the life of the program.

Each white paper produced by UC Davis provided findings limited to individual program changes implemented in 2016 and did not make comprehensive findings across the program as a whole. Various market factors, such as external outreach efforts, new vehicle introductions, and additional incentives offerings, were not taken into consideration in the analysis.

The work performed by UC Davis indicates that implementing income caps, increasing outreach, and providing increased rebates to lower-income consumers are likely to have had relatively positive effects on the program and may have had a positive effect on the ZEV market in California when compared to the outcomes of the program and state of the ZEV market prior to implementation of these policies. Research shows that implementing an income cap could be an effective way to target rebates towards consumers who consider them essential to electric vehicle (EV) purchases while not having a negative impact on the EV market as a whole. Incorporating increased rebates for lower income consumers in CVRP is an effective policy to increase rebate equity and may have encouraged EV purchases in this population subset. Outreach is also essential to increasing EV awareness and deployment. Additional outreach efforts are needed to keep the momentum in the ZEV market going. Hence, the State will need to continue investing in outreach and incentives for Californians to encourage EV adoption thus meeting our various ZEV deployment goals. Lastly, the work done by CSE demonstrates that using program-specific data allows California to better refine emission reductions attributable to CVRP and explores avenues to further refine the calculations.

CARB staff will continue gathering and analyzing data on the market impacts of program changes to CVRP. CARB staff plans on including the information provided in this report as part of the analysis of CVRP design going forward.

I. Background

CVRP, established by CARB under AQIP, is designed to support the long-term transformation of California's light-duty vehicle fleet and meets policy, statutory, and regulatory goals and requirements by increasing the number of ZEVs in the State. CVRP provides consumer rebates on a first-come, first-served basis for light-duty ZEVs, plug-in hybrid electric vehicles, and zero-emission motorcycles, which directly supports the State's ZEV deployment goals of 1 million vehicles by 2023 as directed by SB 1275, over 1.5 million vehicles by 2025 as directed by Executive Order B-16-2012, and 5 million vehicles by 2030 as directed by Executive Order B-48-18.

AB 615 directs CARB to contract with the University of California or the California State University to prepare a report on CVRP's impact on the ZEV market in California. The report must include measuring the impact(s) of legislatively mandated program changes including limiting eligibility by income for higher-income consumers, providing increased rebates for low-income consumers, providing increased outreach and education, and quantifying emission reductions attributed to CVRP. In addition, this report is complemented by a parallel report by the California Department of Finance that evaluates the fiscal impacts of CVRP. Since its inception, CVRP has received funding through multiple programs including AQIP, the California Energy Commission's (CEC) Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP), and the Low Carbon Transportation Program.

AQIP was established by the California Alternative and Renewable Fuel, Vehicle Technology, Clean Air, and Carbon Reduction Act of 2007 (AB 118, Chapter 750, Statutes of 2007) to fund clean vehicle and equipment projects, including CVRP. Since the program launched in 2010, demand for CVRP has exceeded AQIP's annual budget resulting in funding gaps between budget cycles. In Fiscal Years (FY) 2010-11, 2012-13, and 2013-14, CARB received funding from CEC's ARFVTP to keep the program running until additional funding became available. In recent years, CVRP has been funded from Cap-and-Trade Auction Proceeds through the Low Carbon Transportation Program. However, demand for the program has continued to grow beyond what has been awarded through line item legislative appropriations in the budget. To better align with the annual budget and per statutory direction, CARB has implemented programmatic changes per statutory direction.

SB 1275 directed CARB to make a number of changes to CVRP including limiting consumer eligibility based on income and considering incorporating pre-qualification and point-of-sale mechanisms. In addition, SB 1275 required CARB to include a long-term plan every three years for light-duty vehicle incentives in the Board's annual Funding Plan for Clean Transportation Incentives. The plan includes a three-year forecast of funding needs to support the goals of technology advancement, market readiness, and consumer acceptance of advanced vehicle technologies; a market and technology assessment; and mechanisms that could be used to ramp down incentives as the market matures as well as possible alternative incentive structures that could be considered in future years.

In March 2016, CARB set income cap limits consistent with Proposition 30, which was passed by California voters in 2012. SB 859 mandated an additional set of program changes to CVRP. Changes included reducing income cap levels to $150,000 for single filers, $204,000 for head-of-household filers and $300,000 for joint filers. Fuel cell electric vehicle purchases were excluded from the income cap restriction. Additional changes included increasing rebate payments for low-income applicants by $500, prioritizing rebate payments for low-income applicants, conducting outreach to low-income consumers, and limiting CVRP eligibility for plug-in hybrid electric vehicles to vehicles with an electric range of at least 20 miles. CARB incorporated all of these changes to CVRP as part of the annual FY 2016-17 Funding Plan, and AB 615 extended these provisions through December 31, 2018, in addition to requiring this report to the Legislature.

II. CARB approach to this report

AB 615 required CARB to contract with the University of California or the California State University to help compile this report. CARB entered into contract with the University of California, Davis Policy Institute for Energy, Environment, and the Economy (UC Davis) in November 2018. UC Davis was responsible for compiling three white papers: one on the impact of CVRP income caps, one on the impact of increased incentives for lower-income consumers, and the last on the impact of increased outreach. In addition to compiling white papers, UC Davis also held a public webinar to discuss some of their findings from this study including other research projects. The webinar and corresponding slide deck can be viewed at: https://its.ucdavis.edu/webinar/californias-electric-vehicle-incentives-what-do-we-know/.

AB 615 also requires CARB to report on the emission reductions attributable to CVRP. CARB worked with CSE to use program-specific data to calculate the emission reductions attributable to CVRP.

Due to the length of the State contracting process and the time needed for CARB to identify internal resources because no additional resources were provided to CARB for a contract, the report was not finalized until mid-2019.

Report Timeline

- July 2018
  - Funds available for research contract
- November 2018
  - CARB entered into contract with UC Davis for three white papers

- December 2018 through April 2019
    - UC Davis white papers produced, reviewed, and finalized
    - CSE analysis of emission reductions attributable to CVRP
    - UC Davis held a public webinar in April 2019 to discuss preliminary findings related to this and other research contracts with CARB

- May 2019 through June 2019
    - AB 615 report compiled, reviewed, and finalized

III. Impact of CVRP on California's ZEV market

There are millions of cars on California's roads and those numbers are expected to grow as the population increases. In order to address the increase in vehicle miles traveled (VMT) and improve air quality, CARB adopted regulations that require manufacturers to reduce GHG and criteria pollutant emissions and produce the cleanest cars possible. Per legislative appropriations and direction, CARB, through a public process, also created incentive programs, such as CVRP, to encourage consumers to drive the cleanest vehicles. Regulations and incentives work hand in hand to spur technology development, increase consumer adoption and acceptance, and help California meet air quality and ZEV deployment goals.

As mentioned, various ZEV deployment targets have been set—1 million ZEVs by 2023, over 1.5 million ZEVs by 2025, and 5 million by 2030—and CVRP is instrumental in meeting these goals by incentivizing ZEV adoption. Vehicle technology is still developing and newer passenger models come to the market every year; however, ZEVs currently have purchase prices higher than those of comparable conventional vehicles. CVRP and a federal tax credit help consumers bridge this pricing gap and provides an incentive that is meaningful enough to encourage adoption of zero-emission technology.

The CVRP administrator, CSE, runs a continuous survey of program participants to explore program impact and better understand consumer characteristics, barriers, and needs in order to inform program design and outreach. Through these surveys, CSE has found that about half of the participants considered the rebate extremely important in making their EV purchase a possibility and they would not have purchased or leased their EV without the rebate. As changes are made to CVRP to further target the rebate towards consumers who consider it essential, the program will continue to make it possible for a larger number of Californians to drive an EV who otherwise would not have considered it.

Researchers from UC Davis and staff from CSE have gone into further detail on the impact of elements of CVRP in the attached white papers and emission reduction calculations, which are also summarized below. Each white paper provides background on the specific aspect of CVRP covered, summarizes key findings related to specific program changes, analyzes policy implications, and highlights research gaps and possible ways to fill them. Appendix B quantifies the emission reduction attributable to CVRP and covers the inputs included in the calculations as well as the results.

It is important to note, prior to reading the following summaries that each white paper studies a single variable in a multi-variable problem in isolation, which limits the utility of their findings.

a. *Summary of white paper #1: Income Caps*

This paper explores the impact of the introduction and implementation of income caps in CVRP. The Legislature passed two bills in 2016, which called for the introduction of income caps to increase the equitable distribution of rebates (SB 1275) and a reduction in the income caps set in March 2016 (SB 859). In the absence of peer-reviewed research on the specific impact of income caps on CVRP, UC Davis researchers examined literature regarding programs with similar policies as well as research that first identified inequitable distribution of rebates in CVRP and other incentive programs.

There were a number of key findings from the literature review. Buyers of new EVs tend to have higher incomes than those of average new car buyers but this is shifting over time likely due to changes in program policy such as the implementation of income caps. Literature has yet to validate the causality between the implementation of income caps and an equitable distribution of rebates but the correlation between the introduction in CVRP and a shift in rebates issued to lower income consumers is evident using CVRP data. The literature also suggested that introducing a cap on participant income can improve equity and increase the number of EVs on the road.

UC Davis evaluated various policy implications of income caps in CVRP. Researchers stated that income caps are a program element that can improve equity of ZEV incentives. Data also suggested that the introduction of an income cap in CVRP did not have a negative impact on ZEV sales in California. UC Davis researchers suggested that further research and an economic analysis of income caps is required to determine the absolute effect of this policy.

b. *Summary of white paper #2: Increased Rebates for Low-Income Consumers*

This paper explored the impact of CVRP's increased rebate amounts for lower income consumers, a program element implemented in March 2016 based on legislative direction in SB 1275, and further refined in November 2016 based on direction from SB 859. As for the white paper on income caps, no peer-reviewed research has been published discussing the impacts of increased rebates on CVRP. UC Davis researchers took a similar approach as with the first white paper and reviewed program data combined with research on programs with similar policies.

A number of the researchers' findings pointed to the importance of a rebate in the purchase decision for low- and middle-income consumers. Findings also show that providing increased rebate amounts based on income may encourage a larger uptake of EVs by low- and middle-income consumers. Lastly, program data indicated that the introduction of increased rebates in CVRP led to a higher share of rebate recipients with lower incomes. UC Davis suggests that further research needs to be done to analyze the direct impact of increased rebate amounts in CVRP. However, this is a fairly recent policy change and the impact may become more evident as additional program data are collected and analyzed.

UC Davis highlighted a handful of policy implications of increased rebate amounts for lower income consumers. Researchers indicated that increased rebate amounts are an important factor when comparing the cost of a ZEV with a conventional vehicle and this cost-competitiveness appears to be of greater importance to lower-income consumers. Additionally, targeting incentives toward lower-income populations could help achieve equity goals and increase access to EVs among a variety of Californians. Researchers indicated that since the number of EV buyers who consider the rebate essential to making a purchase is increasing, the rebate will likely need to remain in place for some time. Lastly, research indicated that California will need to make a continued investment in EV subsidies in order to meet its ZEV deployment goals.

c. *Summary of white paper #3: Increased Outreach*

This paper examined the impact of increased outreach through CVRP on the ZEV market. As directed by SB 1275, CVRP began a larger outreach effort in 2016 to increase outreach across the State, especially in low-income and disadvantaged communities. As with the first two white papers, no peer-reviewed research exists on this topic as it is a newer program feature. UC Davis reviewed literature pertaining to similar programs and the success or failure of their outreach efforts as well as research regarding the importance of outreach for incentive programs.

UC Davis indicated a number of key findings from its literature review. Research suggests that even though outreach efforts have increased, awareness and knowledge of EVs is still low in California. This indicates that outreach efforts may need to increase substantially in order to increase consumer awareness. Research also showed that automobile dealers have a low level of interest in selling EVs and their knowledge of EVs is relatively low. On a positive note, exposure to EVs, whether through advertising or ride and drive events, lead to an increase in knowledge of EVs and is an effective way to influence purchase decisions. Lastly, researchers indicated that providing information on the full cost of ownership of EVs relative to conventional vehicles in addition to educating consumers on EV range abilities helps decrease consumer uncertainty about the technology and eases range anxiety – both identified barriers to EV adoption.

A number of policy implications about EV outreach are highlighted in this white paper. Outreach is important in increasing awareness and ZEV deployment across the State. Research also indicated that focusing on the cost savings of EV ownership in outreach efforts may increase EV purchases. Lastly, UC Davis suggested that quantitative evaluation should be a component of program outreach efforts in order to better measure the effects on the market.

d. *Emissions Reductions Attributable to CVRP*

Staff with CSE, the CVRP administrator, used program data to refine the estimation of emission reductions attributable to CVRP as previous estimates performed by CARB were based on average conservative vehicle characterizations, which include using assumptions of an average new light-duty advanced technology vehicle as described in annual funding plans. CSE used application data from 270,637 rebates, totaling $609,094,993, issued and approved starting in March 2010 through August 31, 2018.

CSE staff produced emission reduction estimates using the Alternative Fuel Life-Cycle Environmental and Economic Transportation Tool and the following inputs: fuel economy, VMT, electric miles traveled, gasoline consumption, and Low Carbon Fuel Standard carbon intensity values for associated fuel types. Fuel economy values for over 270,000 specific vehicles rebated and metrics regarding rebate essentiality based on nearly 40,000 survey respondents were used. CSE estimated GHG emission reductions associated with all rebates and those associated with participants that consider the rebate essential to their EV purchase. For calculations of criteria pollutant reductions, CSE used an estimated ownership life to account for the possibility of vehicles leaving the state after a period of time equal to the average length of vehicle ownership. In all calculations, CSE also provided emission reduction estimates based on the project life of the vehicle—1, 2.5, or 3 years depending on the CVRP terms in place at the time of application.

CSE found that, when accounting for project life, GHG emission reductions attributable to all rebates issued (standard rebate, low- and moderate-income increased rebate, and fleet rebate) totaled 2.2 million metric tons of CO_2-equivalent emissions (tCO_2e), or an average of 8.2 tCO_2e per individual vehicle and 4.8 tons per fleet vehicle. To determine the cost-effectiveness of CVRP, CSE used the project-life benefit of 2.2 million tCO_2e avoided and the corresponding $609 million in rebates. This resulted in approximately $279 per metric ton avoided over the first 1 – 3 years.

CSE calculated criteria pollutant emission reductions using data from CARB's 2014 Emission Factors (EMFAC 2014) in addition to the same vehicle assumptions used to estimate GHG reductions. Criteria pollutant reductions attributable to all rebate types totaled 241 metric tons of oxides of nitrogen (NOx), 81 metric tons of PM 2.5, and 49 metric tons of reactive organic gases (ROG), when accounting for project life. Additional information is available in Appendix B.

CSE analyzed survey data to determine that over 50 percent of reductions are associated with participants who deem the rebate essential to their EV purchase. When compared to work previously done by CARB to produce results for the annual funding plan, CSE's results produce reductions that are over 20 percent greater, which indicates the significance of using project data when calculating emission reductions.

CSE identified areas for further refinement using program data such as VMT and fuel economy assumptions. CSE suggested that using project life as opposed to the vehicle life results in a conservative estimation of emission reductions but additional research and literature review could be conducted to determine a refined usage life for vehicles rebated by CVRP.

IV. Conclusion

The work performed by UC Davis indicates that implementing income caps may be an effective way to target rebates towards consumers who consider them essential to purchase an EV while not having a negative impact on the EV market as a whole. Incorporating increased rebates for lower-income consumers in CVRP may also be an effective policy change that could encourage EV purchases in this population subset while increasing rebate equity. Outreach is essential to increasing EV awareness and deployment and additional outreach efforts are needed to keep the momentum going. Additionally, the State should consider continuing investments in outreach and incentives to encourage EV adoption and meet our various ZEV deployment goals.

The work done by CSE demonstrates that using program-specific data allows us to better refine emission reductions attributable to CVRP and explores avenues to further refine these calculations. Their calculations indicate that when accounting for project life, GHG emission reductions attributable to over 270,000 rebated vehicles totaled 2.2 million tCO_2e, an average of 8.2 metric tons per individual vehicle and 4.8 tons per fleet vehicle. Criteria pollutant reductions attributable to all rebate types totaled 241 tons of NOx, 81 tons of PM 2.5, and 49 tons of ROG when accounting for project life. To determine the cost-effectiveness of CVRP, CSE used the project-life benefit of 2.2 million tCO2e avoided and the corresponding $609 million in rebates. This resulted in approximately $279 per ton avoided over the first 1 – 3 years.

Additional research is necessary to definitively determine the impact of various CVRP policies on California's ZEV market as they are relatively new introductions to the program. CARB staff will work with CSE to further explore areas of refinement for emission reduction calculations and plans on including the information provided in this report as part of the analysis of CVRP design going forward.

APPENDIX A:

UC DAVIS WHITE PAPERS ON THE IMPACT OF CVRP

UCDAVIS
POLICY INSTITUTE FOR ENERGY, ENVIRONMENT, AND THE ECONOMY

Impact of the Clean Vehicle Rebate Project's income cap on California's ZEV Market

ISSUE PAPER
May 2019

A research summary whitepaper for the California Air Resources Board

ABSTRACT

This paper reviews and summarizes the research regarding California's Clean Vehicle Rebate Project's (CVRP) implementation of income caps in March 2016 and increase of income caps in November 2016. Due to the recent nature of the program, no peer-reviewed research has been published about the specific effects of CVRP. Consequently, we review the literature regarding past and present programs with similar policies as well as studies that first identified the inequitable[1] and inefficient distribution of incentives in the CVRP and other programs.

Research indicates that the inequitable distribution of incentives is a problem for the sustainability and efficiency[2] of incentive programs. While we are limited in determining the specific effects of CVRP's income cap, but find evidence to suggest that income caps may be an efficient tool for increasing equitability while maintaining similar levels of rebated vehicles, since rebates matter less to high-income purchasers. Finally, we suggest a path forward for future research to identify the specific impacts of CVRP's income caps.

[1] Inequitable in the context of CVRP incentives primarily refers to income inequality. If 50% of incentives are realized by those in the top 20% of the income distribution, then the incentives are inequitable.

[2] Efficiency in the context of CVRP incentives refers to dollars spent per zero-emission vehicle (ZEV) purchase induced by the rebate.

1 Purpose

Assembly Bill (AB) 615 requires the California Air Resources Board (CARB) to "prepare and submit to the Legislature a report on the impact of the Clean Vehicle Rebate Project on the state's zero-emission vehicle market...The report shall include, but is not limited to, the impact of income caps, increased rebates for low-income consumers, and increased outreach on the electric vehicle market." This whitepaper supports CARB in fulfilling AB 615's mandate by assessing the impact of California's Clean Vehicle Rebate Project (CVRP) implementation of income caps in March 2016 and increase of income caps in November 2016. The assessment is based on a review of literature related to zero-emission vehicle (ZEV) incentive programs, including general findings, research gaps, and policy implications of both.

2 Policy description

California is a leader on combating climate change. The state has set bold goals of reducing statewide greenhouse gas (GHG) emissions to 80% below 1990 levels by 2050, as well of achieving 5 million ZEVs on the road by 2030. Reaching these goals will require effective policies and programs, as well as periodic assessment of both. A key state effort to incentivize ZEV adoption, and thus reduce emissions from the light-duty transportation sector, is the Clean Vehicle Rebate Program (CVRP).

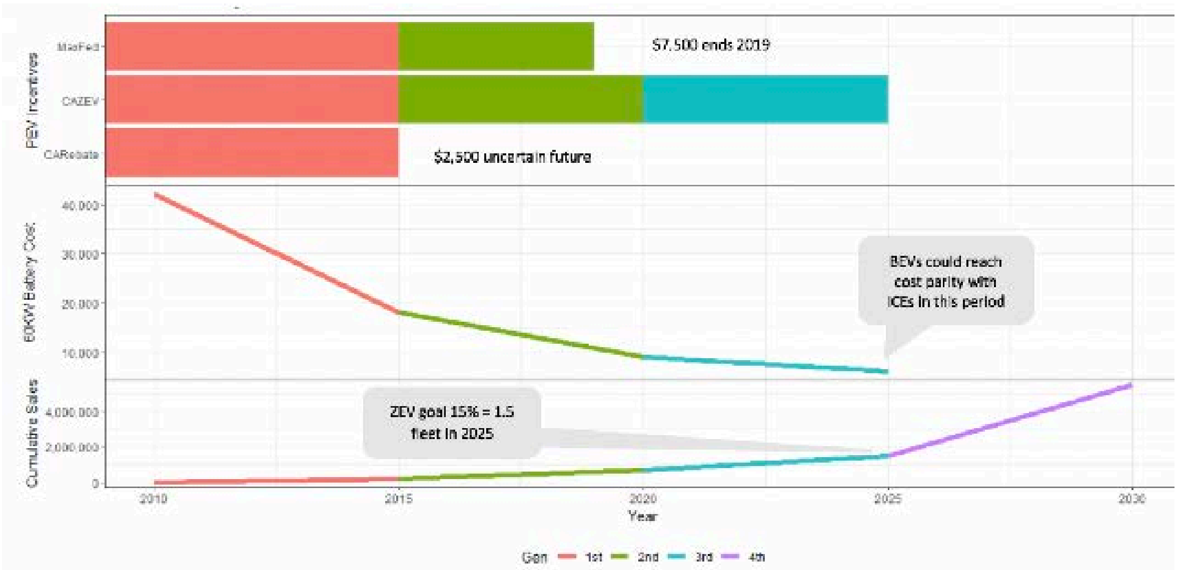
The CVRP was created by AB 118 in 2007 to incentivize ZEV purchasing and leasing. The CVRP's primary purpose is to support widespread commercialization of the cleanest vehicles by helping to motivate consumer purchase decisions. The program was originally designed to be "first-come, first-served" and only expected to be funded through 2015. Consequently, the program had no means-testing requirement at its inception, leading to a significant portion of incentives concentrated among high-income individuals.[3]

Senate Bill (SB) 1275, passed in 2014, was designed to address these issues. SB 1275 required CARB to develop a plan for realizing California's then-goal of achieving 1 million ZEVs on the road by 2023 without excluding low-income individuals. This bill required CARB "to adopt, no later than June 30, 2015, specified revisions to the criteria and other requirements for the Clean Vehicle Rebate Project; and to establish programs that further increase access to and direct benefits for disadvantaged, low-income, and moderate-income communities and consumers from electric transportation."[4] In March 2016, acting on CARB's recommendations, the state set income caps for CVRP participants so that financial incentives for ZEV purchases would not be wasted on those who did not need them. The caps were set at $250,000 for single individuals, $340,000 for a head of household, and $500,000 for a joint filing. In November 2016, SB 859 reduced the income caps to $150,000 for single individuals, $204,000 for a head of household, and $300,000 for joint filings.

3 Designing incentive programs

As seen in Figure 1, incentives are critical for spurring increased adoption in the first three generations of plug-in electric vehicles (PEVs).[5] Well-designed incentives should be efficient and equitable. Increasing ZEV incentive efficiency requires increasing the percentage of recipients who are induced to purchase a ZEV because of the incentive while decreasing the percentage of recipients who would have purchased a ZEV anyways. Increasing ZEV incentive equity means ensuring that incentives are evenly distributed across a range of demographics, especially income. These two objectives often go hand-in-hand, as low- and moderate-income individuals are the most likely to be influenced by incentives that reduce the financial impact of buying a ZEV. Failing to reach low- and moderate-income individuals will likely result in California missing its 5 million ZEVs by 2030 goal.

[3] Means testing is any requirement for a program that uses an individual's financial status to determine eligibility (normally income subset by tax filing status).
[4] It should be noted that while CVRP was an integral part of the state's efforts to increase ZEV adoption, the program was not the sole focus of SB 1275. For example, the mandate helped lead to the creation of EFMP Plus-Up, BlueLA, and Our Community Car Share.
[5] PEVs are a subset of ZEVs that excludes fuel-cell vehicles.



	1st Gen Innovators	2nd Gen Innovators & Followers	3rd Gen Innovators & Followers Next Purchase
PHEV Miles Traveled	10 – 40	15 – 50	50+
BEV Miles Traveled	80 – 250	150 – 300	200+
# of Models	20 – 30	30 – 100	200+
Designs	Compact, Subcompacts	Crossover, Midsize Sedans	Full-sized Vehicles

Figure 1. Charting the California plug-in electric vehicle (PEV) market from 2010–2030: past, present, and future.[6] *This figure highlights the importance of maintaining rebates (top panel) until battery-electric vehicles (BEVs) and ZEVs reach cost parity with internal combustion engine vehicles (ICEVs, middle panel). Moreover, these rebates will be necessary to spur enough adoption to reach California's ZEV goals (bottom panel). The figure also highlights the different stages of ZEV adoption (tables). Different groups of individuals are assumed to adopt ZEVs at different times. Innovators lead, then followers, then the second purchase of a ZEV by innovators and followers. Mass adoption occurs in the fourth generation.*

Multiple options exist for tackling both of these significant issues. Some have already been implemented in other states, such as manufacturer's suggested retail price (MSRP) caps on EV rebates in New York, Massachusetts, and Connecticut.[7] Two different approaches were implemented in California in 2016: (1) income caps and (2) increased incentives for low- and moderate-income individuals. Income caps are designed to prevent subsidizing ZEV purchases for high-income individuals, since these individuals have the means to purchase a ZEV without assistance and will hence ascribe less value to financial purchase incentives. By preventing resources from being "wasted" on the wealthy, income caps increase incentive availability for low- and moderate-income individuals. This increases incentive efficiency and equity alike.

Another critical determinant of incentive efficiency and equity is outreach. For incentives to reach target populations, individuals in those populations must be aware of both the qualifying product and the existence of the incentive. Hence outreach around ZEVs in general as well as ZEV purchase incentives is an essential aspect of efforts to increase ZEV deployment.

This whitepaper focuses on literature and analysis relevant to adding an income cap to the CVRP. For more information on the related policy of increased incentives for low- and moderate-income recipients, see a separate whitepaper in this series, "Impact of the Clean Vehicle Rebate Project's Increased Rebates for Low- and Moderate-Income Individuals on California's ZEV Market."

[6] Figure adapted from Turrentine et al. (2018). Note that CAZEV is comprised of all CA ZEV programs, including CVRP.
[7] MSRP caps essentially prevent expensive ZEVs like the Tesla Model X from qualifying for rebates, such that cheaper vehicles like the Chevy Bolt are the only subsidized ZEVs. These caps are designed to encourage manufacturers to produce vehicles that are more accessible to low- and moderate-income individuals. MSRP caps do not preclude high-income individuals from purchasing (and realizing subsidies on) eligible vehicles.

4 Key findings

These are the top findings based on our review of relevant literature.

- New buyers of ZEVs tend to be higher income than average buyers of new cars. This is shifting over time—likely because of changes in policy, such as income caps and increased rebates (Borenstein & Davis 2016; Helveston et al. 2015; Lee, Hardman, & Tal 2019).
- Past hybrid electric vehicle (HEV)[8] and ZEV subsidies predominantly went to higher-income buyers and many who are likely to have purchased EVs anyway (Chandra et al. 2010[9]; Diamond 2009; Helveston et al. 2015; Hardman & Tal 2016; Rubin & St. Louis 2016).
- The purchase decisions of higher-income car buyers appear to be far less sensitive to ZEV rebates than the purchase decisions of low- to moderate-income car buyers (Diamond 2009[10]; Hardman & Tal 2016; Helveston et al. 2015).
- Rebate recipients are becoming increasingly demographically similar to new car buyers overall, according to rebate program data (Williams 2018).
  - Literature has not yet demonstrated a conclusive causality between income caps and a more equitable rebate distribution, but the correlation between the implementation and the shift in rebates toward lower-income individuals is dramatic (Williams 2018).
  - Since introduction of income caps, the share of rebate recipients earning more than $300,000 annually (household income) has dropped from ~16% in March 2016 (when the income cap and increased rebates were implemented) to ~2% in June 2017. The share of rebate recipients with an annual household income lower than $50,000 increased from ~5% to ~10% over the same period (Williams 2018; Figure 2).[11]
- Rebate importance, captured in stated-preference surveys, has increased since the enactment of income caps and increased rebates. This is because more price-sensitive buyers have entered the market (Williams 2018).

In sum, the research indicates that without income caps or mean-testing in general, financial incentives for HEV and ZEV purchases are inequitably distributed based on income and demographics (Borenstein & Davis 2016; DeShazo 2010; Diamond 2009; Rubin & St. Louis 2016). The literature also suggests that targeting larger incentives to low-income consumers (and other salient demographic groups) and capping purchaser income or vehicle MSRP for rebate eligibility can improve ZEV purchase equity, make incentive programs more cost-effective, and increase total ZEV purchases (DeShazo 2016; Skerlos & Winebrake 2010). Multiple findings indicate that high-income consumers mostly disregard incentives when purchasing luxury battery electric vehicles (BEVs), and that high-income consumers are the most likely to purchase ZEVs without a subsidy (Diamond 2009; Hardman & Tal 2016; Helveston et al. 2015). Income and MSRP caps are likely to have little or no impact on the purchase decisions of high-income consumers (Diamond 2009; Hardman & Tal 2016; Helveston et al. 2015). More research needs to be done on the implementation of income caps and progressive rebates to assess their costs and downsides, as well as to see if they actually increase ZEV adoption and ZEV purchase equitability. Sophisticated models that can predict the impact of different levels of income caps would be useful for future policymaking.

Early CVRP rebate/demographic data shows that the CVRP income cap had a major impact in reducing the percentage of rebates received by households with an annual income of $300,000 or more (Williams 2018; Figure 2). The cap, along with increased rebates for lower-income individuals, also seems to have increased the percentage of rebates

[8] While HEVs are not ZEVs (they still require gasoline to run), research on HEV incentives is still relevant as the incentive programs for these vehicles were similar to that of ZEVs and the purchase demographics of early HEV adopters is similar to that of ZEVs.
[9] This paper uses a hypothetical situation, not past data, and analyzes HEVs.
[10] This paper assesses HEVs.
[11] It should technically be impossible for this percentage to be above 0% after the implementation of the cap. The 2% figure results from individuals sometimes misreporting their income.

received by households with an annual income of $50,000 or less, and likely had an impact on increasing the relative percentage of rebates received by households with annual incomes between $100,000 and $150,000. The percentage of rebates received by household with annual incomes between $150,000 and $300,000 stayed approximately constant.[12]

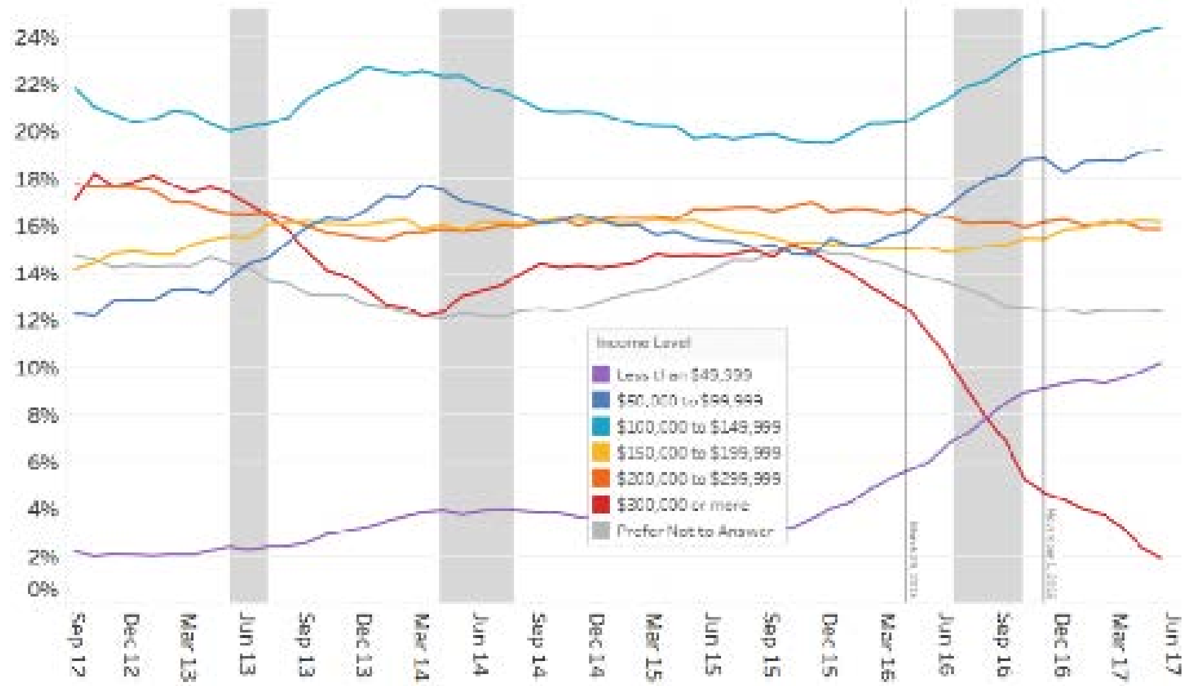


Figure 2. CVRP rebates by household income over time.[12] This figure shows the percentage trend of CVRP rebates dispersed by household income bracket. The income cap and increased rebates implementation/adjustment are indicated by the two gray lines (March and November 2016). There is a marked decrease after March 2016 in rebates received by households earning $300,000 or more annually, and a significant increase among those earning less than $50,000 annually. This comparison gives us an indication of the effectiveness of means-testing policies on increasing equitability of rebates.

Enacting income caps and increasing rebates for lower-income individuals does not seem to have had a significant impact on total number vehicles rebated (Figure 3). It is possible that the income cap marginally decreased ZEV sales, but that this decrease was offset by the positive effect of increased rebates for low-income individuals. It is also possible that neither policy had any effect and that changes in incentive distribution is due to other factors such as media coverage or the release of new vehicles that have better range and/or price. Conclusively determining whether the policies had significant effects—and separating the individual effects of each policy—requires substantial econometric analysis that is beyond the scope of this whitepaper.

5 Policy implications

Income caps are likely effective in improving efficiency and equity of ZEV purchase incentives

The research on high-income individuals' purchase intentions indicates that income caps likely have little effect on total ZEVs sold/leased. Furthermore, the initial CVRP data seems to show a strong correlation between the implementation of the income cap and increased rebates and an increase in low-income and decrease in high-income individuals receiving rebates. This indicates that the income cap had a significant effect on decreasing rebates for high-income "already-purchasers" while not reducing induced purchases by a significant amount.

[12] Figure taken from Williams (2018).

CVRP Rebates	
2010	135
2011	4,521
2012	11,219
2013	29,152
2014	43,702
2015	46,543
2016	44,455
2017	47,762
2018 (thru Aug.)	42,970
Total	270,459

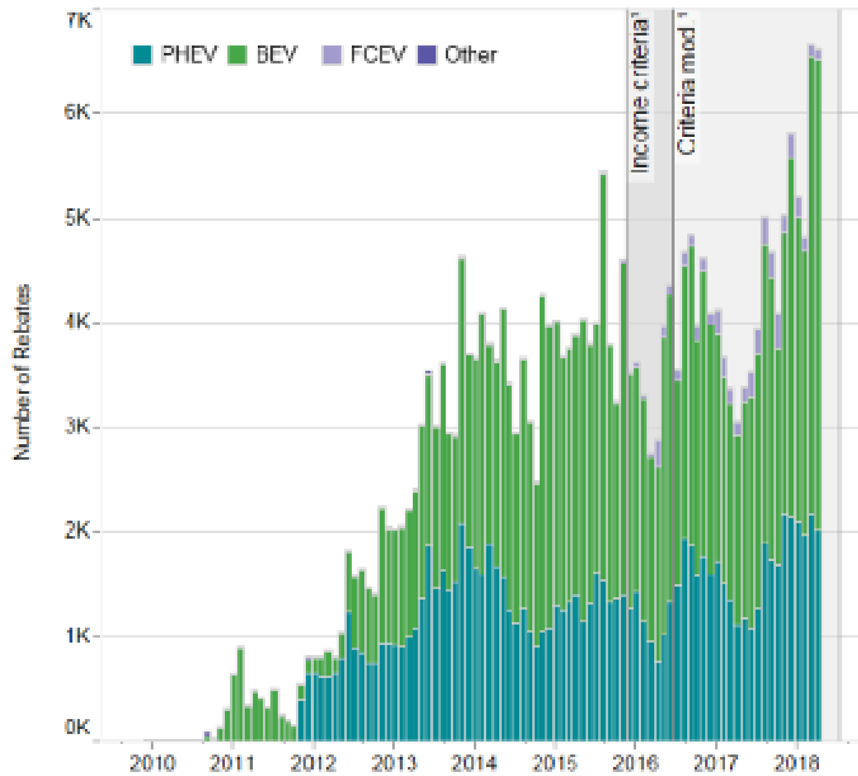


Figure 3. CVRP rebate volume over time.[13] *The data shows that an increasing trend in number of ZEVs rebated began before the implementation of income caps and increased rebates for lower-income individuals, suggesting that these policies have not had a substantial impact on total number of vehicles rebated.*

Sales of ZEVs in California have continued to grow despite income caps going into effect

Introducing income caps to the CVRP did not reverse an ongoing trend of increased ZEV purchases statewide. It is possible that income caps led to a marginal decrease in ZEV sales that was offset by increased rebates for lower-income individuals. The relative magnitude of the demand effects of each of these policies is difficult to assess without rigorous econometric analysis, and/or comparison with a reasonable control. However, for a given year, any change that reduces rebate availability overall would be expected to decrease sales, holding all other factors constant. According to the research, high-income individuals are the least likely to consider rebates "essential" for their purchase, and thus the removal of the rebate through an income-cap is unlikely to decrease a significant amount of ZEV purchases.

6 Highlighted works

This section summarizes some top findings and key methodological choices for the reviewed papers.

General (non-California-focused) studies

Borenstein & Davis (2016)
Study type: Observed data analysis
Geography: United States

The authors use U.S. tax-return data to examine the socioeconomic characteristics of "clean energy" tax credits. The authors compare effects across income groups, with other credits, and with other policies. They find that

[13] Figure taken from Williams (2018).
[14] Figure taken from Williams & Anderson (2018).

these credits are predominantly used by higher-income Americans. The most extreme is the PEV credit, where the top income quintile has received about 90% of all tax returns. Note that consumer eligibility to claim and benefit from CVRP rebates does not depend on tax liability.

Chandra et al. (2010)
Study type: Observed data analysis
Geography: Canada

The authors considered the cost and benefits of a potential tax rebate program for HEVs in Canada. The authors determined that those who would have benefited from the tax rebate due to sufficient tax liability were primarily consumers who would have purchased an HEV with or without a rebate. If early adopters of clean vehicles are likely to be higher-income consumers (which is backed up by the data), then the benefits of a tax incentive are not shared equally across income levels.

Diamond (2009)
Study type: Observed data analysis
Geography: United States

The author attempts to determine the factors driving HEV adoption in the United States using simple regressions on a panel dataset of market shares of different vehicle types in different states. The author finds no significant relationship between financial incentives and HEV adoption since incentive payments tend to be concentrated among high-income consumers who have sufficient tax liability to benefit, effectively subsidizing the wealthy without significantly affecting their purchase decisions. Note that consumer eligibility to claim and benefit from CVRP cash rebates does not depend on tax liability.

Helveston et al. (2015)
Study type: Survey, stated preference
Geography: United States and China

The authors aim to assess how vehicle preferences and the effects of subsidies differ across the world's two largest economies, the United States and China. The authors perform a stated preference survey comprising 312 and 667 respondents from the United States and China respectively. They find that older, wealthier and more educated consumers, especially those who own multiple vehicles and have children in households, are less sensitive to upfront and operating costs of PEVs. Furthermore, wealthy consumers are more likely to purchase PEVs without subsidy support. It should be noted that although the 384 respondents were weighted to better represent new car buyers in the United States, this analysis probably does not include enough respondents to reliably represent all U.S. consumers. The limited number of respondents included in this study stands in contrast to the tens of thousands of respondents included surveys conducted by the CVRP (e.g., to characterize rebate influence) and the University of California (e.g., to characterize rebate importance) that have reported similar findings.

California-focused studies

Hardman & Tal (2016)
Study type: Survey, stated preference
Geography: California

The authors conducted 553 surveys and 33 interviews to assess the motivation behind luxury BEV purchases. They found that purchasers of luxury BEVs (high-income earners) do not factor in incentives in their purchasing decisions, and thus an income cap could be implemented without reducing purchases from higher incomes.

Lee, Hardman, & Tal (2019)
Study type: Survey
Geography: California

The authors use a multi-year survey (2012–17) of the socio-demographic characteristics of 11,037 PEV adopters in California to analyze the different characteristics that drive early PEV adopters. This analysis identifies four groups of PEV buyers: high-income families (accounting for 49% of adopters), mid- to high-income older families (26%), mid- to high-income young families (20%), and mid-income renters (5%). The authors find that while high-income families are currently the largest group of PEV adopters, the relative size of this group may be decreasing. The authors stress the importance of meeting needs of the other groups in order to continue PEV market growth.

Rubin & St. Louis (2016)
Study type: Observed data analysis
Geography: California

The authors examine the distribution of CVRP rebates by census tracts in California. The authors find that the distribution of CVRP rebates is concentrated in higher-income census tracts. The authors also find that areas more affected by environmental issues receive more when income is controlled for, likely due to increased salience of emissions and their impacts. It should be noted that although the authors control for the number of vehicles in different census tracts, they do not control specifically for new-car buying volumes or consumer demographics. Thus, it is difficult to parse how large of a component of the findings is due to factors specific to EVs and EV rebates as opposed to the new-car market in general.

Williams (2018)
Study type: Initial data analysis
Geography: California

The author finds that since the introduction of CVRP income caps and increased rebates, the share of rebates received by households with annual incomes of more than $300,000 dropped from ~16% to ~2% (in June 2017). The share of rebate recipients with annual household incomes below $50,000 increased from ~5% to ~10% over the same time period, and the share of rebate recipients with annual household incomes between $50,000 and $150,000 increased as well (from ~21% to ~24%). The author also finds that rebate recipients are increasingly demographically similar to new car buyers overall, and that rebate importance for purchase has increased over time.

Williams & Santulli (2018)
Study type: Initial data analysis
Geography: California

The authors use CVRP data on reported household incomes to estimate the percentage of buyers that would have been excluded at different theoretical income caps. The authors suggest that lowering the cap further would likely have nonlinear effects as greater and greater fractions of buyers would be excluded. Further, the authors provide evidence that rebate influence decreases with income, and, as such, lowering caps is not only increasingly exclusionary, but increasingly excludes consumers who are more highly influenced by rebates. The authors do not quantify the components of the impacts of income caps that would contribute to a definitive characterization.

Arguments for means testing

DeShazo (2010)
Study type: Literature review
Geography: United States and California

The author provides a first-principles review of the economics behind and the characteristics of EV subsidies, as well as a history of EV subsidies in California. The author notes that EV subsidies are effective but inefficient, and recommends: (1) applying subsidies at point of sale; (2) increasing subsidies for BEVs relative to PHEVs; (3) linking vehicle purchase and retirement incentives; and (4) means-testing subsidies.

Skerlos & Winebrake (2010)
Study type: Observed data analysis
Geography: United States

The authors discuss the regional variability of PHEV social benefits and conclude that a uniform national policy for subsidizing PHEVs is at best sub-optimal, meaning that greater PHEV benefits could be achieved for the same government investment if subsidies were targeted to where the social benefits are largest. They argue that the federal PHEV tax credit would have higher social benefits if it were varied across income and location.

7 Ongoing research

UC Davis has several ongoing and planned projects that will continue to build knowledge on the impact of income caps. The majority of ongoing relevant research focuses on the characteristics of ZEV buyers and how those characteristics are changing over time, which will assist in evaluating the number of potential EV buyers who do not buy EVs due to the existence of caps. Forthcoming research will also consider how these characteristics interact with consumer purchase intentions and preferences regarding ZEVs. Other research projects at UC Davis are focusing on new buying populations, including repeat buyers, and buyers who already own various types of vehicles. Projects will assess the size of each potential ZEV market and the effect of changes in total cost of ZEV ownership on these markets, taking income caps into account.

8 Research gaps

Gaps in the research that could be filled by more targeted research efforts resulting from collaboration between academic researchers and regulatory agencies include:

- Modeling for the expected total market effects of different income caps.
- Benefit-cost analysis of the income cap approach, and how benefits and costs are expected to change over time as new ZEV models are introduced.
- Econometric assessments of the effects of the CVRP's income cap, i.e., that go beyond simple before-and-after comparisons.
- Exploration of whether high-income households became less likely to purchase ZEVs after income caps were implemented.

The research in its current state only allows for basic before-and-after comparisons of rebate recipient demographics, tangential inferences from other programs, and research on the drivers of ZEV purchases among high-income individuals. To fully understand the impact of income caps in general, and for CVRP specifically, more methodologically rigorous analyses need to be conducted.

The short time frame from when means-testing was implemented for CVRP (March/November 2016) does not lend itself to comprehensive analysis of the program's long-term impacts. However, the short-run impacts of these policies can be a bellwether for policymakers on how effective the program may be in the long run, and thus analyses can and should be done.

A notable gap in the literature is an analysis of the costs of an income cap, either a hypothetical or implemented one. Costs are driven by the possibility of lowering the total amount of ZEVs purchased (not rebated) due to the possible deterrence of purchases by high-income households. This concern is somewhat ameliorated by research, mentioned above, that finds rebates to be of little importance to high-income individuals. Because that research is based on information surveyed from ZEV purchasers, it likely does not give a full picture of the market. For example, there could be a large portion of high-income consumers who would only purchase a ZEV with a rebate but have not yet been informed of ZEVs or their benefits. Future research needs to estimate the number of high-income consumers who would have, once informed, been induced to purchase with an incentive.

Exploring these questions is essential given preliminary estimates that lowering the income cap to exclude households earning more than $150,000 annually would make it more difficult to realize California's ZEV deployment goals. Whether lowering the income gap is good policy hence depends in part on whether the money saved from reducing rebate availability could be used more effectively to support ZEV deployment in other ways.

Several of the research questions posed above could be examined through difference-in-differences studies focused on the time period before and after means testing for the CVRP was implemented. Carrying out such a study would require an appropriate control/counterfactual. This would likely be difficult at the state level. It may be easier to conduct such studies on different areas of California that have larger or smaller low-income populations, but are similar on other characteristics. One shortcoming of this approach is that it would have limited ability to parse the relative effects of adding an income cap for ZEV rebates and of increasing rebates for low-income individuals, since these two methods of means testing were implemented for the CVRP simultaneously.

Another approach would be a regression discontinuity study design that looks at similar individuals who just barely fall on either side of the income cap cutoff. Such a design has high data requirements and has so far proven challenging. Researchers should looking to other branches of economics for alternative study designs that may be valuable when it comes to informing future changes to the CVRP.

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Impact of the Clean Vehicle Rebate Project's increased outreach on California's ZEV Market

ISSUE PAPER
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A research summary whitepaper for the California Air Resources Board

ABSTRACT

This paper reviews and summarizes the research regarding California's Clean Vehicle Rebate Project's (CVRP) increased outreach efforts that began in 2016. Due to the recent nature of the program, no peer-reviewed research has been published about the specific effects of CVRP. Consequently, we review the literature regarding similar past and present programs and the success or failure of their outreach efforts. We also consider studies that identify the marked importance of outreach on the efficiency of an incentive program. While we are limited in determining the specific effects of CVRP's increased outreach, the literature suggests that outreach can have either a positive or negative effect on individuals' purchase intentions. This paper also recommends future research to identify the specific impacts of CVRP's outreach efforts.

1 Purpose

Assembly Bill (AB) 615 requires the California Air Resources Board (CARB) to "prepare and submit to the Legislature a report on the impact of the Clean Vehicle Rebate Project [CVRP] on the state's zero-emission vehicle market...The report shall include, but is not limited to, the impact of income caps, increased rebates for low-income consumers, and increased outreach on the electric vehicle market." This whitepaper supports CARB in fulfilling AB 615's mandate by assessing the impact of CVRP implementation and increase of income caps in 2016. The assessment is based on a review of literature related to zero-emission vehicle (ZEV) incentive programs, including general findings, research gaps, and policy implications of both.

2 Policy description

California is a leader on combating climate change. The state has set bold goals of reducing statewide greenhouse gas (GHG) emissions to 80% below 1990 levels by 2050, as well as achieving 5 million ZEVs on the road by 2030. Reaching these goals will require effective policies and programs and periodic assessment of both. A key state effort to incentivize ZEV adoption, and thus reduce emissions from the light-duty transportation sector, is the CVRP.

The CVRP was created by AB 118 in 2007 to incentivize ZEV purchasing and leasing. The CVRP's primary purpose is to support widespread commercialization of the cleanest vehicles by helping to motivate consumer purchase decisions. The program was originally designed to be "first-come, first-served" and only expected to be funded through 2015. Consequently, the program had no means-testing requirement at its inception, leading to a significant portion of incentives concentrated among high-income individuals.[1]

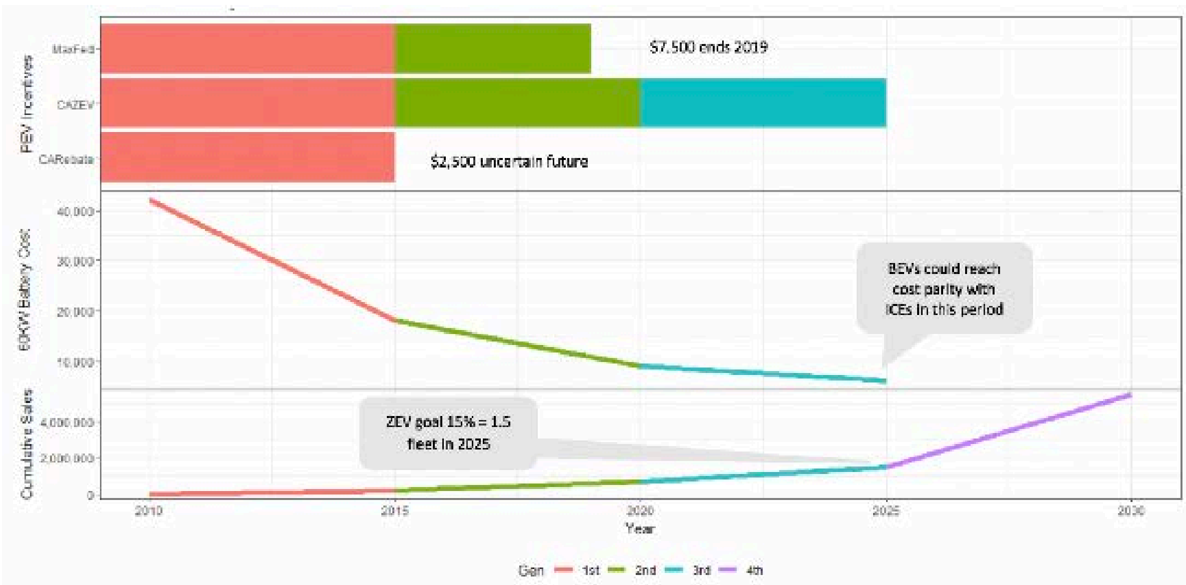
Senate Bill (SB) 1275, passed in 2014, was designed to address these issues. SB 1275 required CARB to develop a plan for realizing California's then-goal of achieving 1 million ZEVs on the road by 2023 without excluding low-income individuals. This bill required CARB "to adopt, no later than June 30, 2015, specified revisions to the criteria and other requirements for the Clean Vehicle Rebate Project; and to establish programs that further increase access to and direct benefits for disadvantaged, low-income, and moderate-income communities and consumers from electric transportation."[2] In March 2016, acting on CARB's recommendations, the CVRP expanded its general outreach efforts. Specifically, as stated in the CVRP 2014–2015 report, the Center for Sustainable Energy (CSE) "hired additional staff with experience in outreach to disadvantaged populations and developed a set of outreach and education activities to meet the needs of this population, while continuing general consumer outreach and education to car-buying consumers." As a result of this effort, CVRP outreach increased from 3,600 direct interactions with stakeholders in 2013 to 13,000 in 2014.

CVRP outreach included working with community-based organizations to host more ZEV "ride-and-drive" events in low-income areas and to increase participation in such events. CVRP also expanded outreach to car dealerships in low-income areas and created a new webpage designed to provide low-income consumers with information about purchasing EVs. In 2018, CARB, in collaboration with California's Department of Motor Vehicles (DMV), included information about ZEV purchase incentives in 700,000 DMV title notices distributed to vehicle owners who had either purchased their vehicles outright or had finishing paying off their car loans.

3 Designing incentive programs

As seen in Figure 1, incentives are critical for spurring increased adoption in the first three generations of plug-in electric vehicles (PEVs).[3] Well-designed incentives should be efficient and equitable. Increasing ZEV incentive efficiency requires increasing the percentage of recipients who are induced to purchase a ZEV because of the incentive while decreasing the percentage of recipients who would have purchased a ZEV anyways. Increasing ZEV

[1] Means testing is any requirement for a program that uses an individual's financial status to determine eligibility (normally income subset by tax filing status).
[2] It should be noted that while CVRP was an integral part of the state's efforts to increase ZEV adoption, the program was not the sole focus of SB 1275. For example, the mandate helped lead to the creation of EFMP Plus-Up, BlueLA, and Our Community Car Share.
[3] PEVs are a subset of ZEVs that excludes fuel-cell vehicles.



	1st Gen Innovators	2nd Gen Innovators & Followers	3rd Gen Innovators & Followers Next Purchase
PHEV Miles Traveled	10 – 40	15 – 50	50+
BEV Miles Traveled	80 – 250	150 – 300	200+
# of Models	20 – 30	30 – 100	200+
Designs	Compact, Subcompacts	Crossover, Midsize Sedans	Full-sized Vehicles

Figure 1. Charting the California plug-in electric vehicle (PEV) market from 2010–2030: past, present, and future.[4] *This figure highlights the importance of maintaining rebates (top panel) until battery-electric vehicles (BEVs) and ZEVs reach cost parity with internal combustion engine vehicles (ICEVs, middle panel). Moreover, these rebates will be necessary to spur enough adoption to reach California's ZEV goals (bottom panel). The figure also highlights the different stages of ZEV adoption (tables). Different groups of individuals are assumed to adopt ZEVs at different times. Innovators lead, then followers, then the second purchase of a ZEV by innovators and followers. Mass adoption occurs in the fourth generation.*

incentive equity means ensuring that incentives are evenly distributed across a range of demographics, especially income. These two objectives often go hand-in-hand, as low- and moderate-income individuals are the most likely to be influenced by incentives that reduce the financial impact of buying a ZEV. Failing to reach low- and moderate-income individuals will likely result in California missing its 5 million ZEVs by 2030 goal.

Multiple options exist for tackling both of these significant issues. Some have already been implemented in other states, such as manufacturer's suggested retail price (MSRP) caps on EV rebates in New York, Massachusetts, and Connecticut.[5] Two different approaches were implemented in California in 2016: (1) income caps and (2) increased incentives for low- and moderate-income individuals. Income caps are designed to prevent subsidizing ZEV purchases for high-income individuals, since these individuals have the means to purchase a ZEV without assistance and will hence ascribe less value to financial purchase incentives. By preventing resources from being "wasted" on the wealthy, income caps increase incentive availability for low- and moderate-income individuals. This increases incentive efficiency and equity alike.

Another critical determinant of incentive efficiency and equity is outreach. For incentives to reach target populations, individuals in those populations must be aware of both the qualifying product and the existence of the incentive. Hence outreach around ZEVs in general as well as ZEV purchase incentives is an essential aspect of efforts to increase ZEV deployment.

[4] Figure adapted from Turrentine et al. (2018). Note that CAZEV is comprised of all CA ZEV programs, including CVRP.

[5] MSRP caps essentially prevent expensive ZEVs like the Tesla Model X from qualifying for rebates, such that cheaper vehicles like the Chevy Bolt are the only subsidized ZEVs. These caps are designed to encourage manufacturers to produce vehicles that are more accessible to low- and moderate-income individuals. MSRP caps do not preclude high-income individuals from purchasing (and realizing subsidies on) eligible vehicles.

This whitepaper focuses on literature and analysis relevant to the potential impacts of increased CVRP outreach. For more information on CVRP's means-testing policies, see the other this series: "Impact of the Clean Vehicle Rebate Project's Income Cap on California's ZEV Market" and "Impact of the Clean Vehicle Rebate Project's Increased Rebates for Low- and Moderate-Income Individuals on California's ZEV Market."

4 Key findings

These are the top findings based on our review of relevant literature.

- Awareness of electric vehicles (as measured by individuals' knowledge of at least one EV) is low, even in California.
  - Awareness of EVs (as defined by the ability to correctly name a single available model) in California has not increased between 2014 and 2017.[6]
- Investment in outreach likely needs to be significantly higher than current levels to match general vehicle advertising expenditures.
- Dealers have very low levels of knowledge about and interest in selling ZEVs.
  - Selling ZEVs has potential to deliver financial benefits for car dealerships, but this potential is largely unrealized due to a lack of knowledge at most dealerships and a lack of ZEV sales incentives (Cahill 2015; Lunetta & Coplon-Neufield 2018; Matthews et al. 2017).
- Using EVs (e.g., through test drives) can increase the strength of positive consumer impressions (Buhler et al. 2014; Rezvani et al; Skippon et al. 2016). Test drive can also increase purchase intentions (Schmalfuss et al. 2017).
  - One study found a decrease in purchase intentions, but an increase in positive impressions after significant EV usage (Skippon et al. 2016).
- Range anxiety is a significant barrier to ZEV adoption for most individuals (Egbue & Long 2012; Franke & Krems 2013; Rauh et al. 2015).
  - Individuals tend to overestimate their actual range needs. Testing an EV can help alleviate range anxiety (Franke & Krems 2013; Rauh et al. 2015).
- "Green" characteristics of EVs only address a small segment of consumers. General uncertainty about EVs deters potential buyers (Egbue & Long 2012; Ottman et al. 2006; Rezvani et al. 2015).
  - Providing information on the full costs of ownership for EVs relative to ownership of conventional vehicles is more effective in increasing EV adoption than providing information on relative fuel costs alone (Dumortier et al. 2015; Sanguinetti et al. 2017).

In sum, the research indicates major awareness and engagement issues when it comes to consumer perception of EVs. Even in California, most people have very low levels of engagement with EVs. This problem is compounded by the fact that most car dealerships exhibit a low level of education and enthusiasm around EVs. The literature is less conclusive when it comes to the effectiveness of specific outreach efforts. Some studies have shown that using an EV increases an individual's willingness to buy, but at least one study found that the opposite is true. Many people exhibit "range anxiety" when it comes to EVs, though people tend to overestimate their range needs. Giving people the opportunity to test EVs in person can help people learn their true range needs and hence alleviate range anxiety. Some studies have found that stressing the environmental benefits of EVs increases the likelihood of consumer adoption, while other studies have found the opposite (Rezvani et al. 2015; Ottman et al.

[6] For more on this topic, see the UC Davis Institute of Transportation Studies blog post "Automakers and Policymakers May Be on a Path to Electric Vehicles; Consumers Aren't."

2006). Adoption tends to increase when individuals have high self-congruity[7] and when environmental issues are salient (Rezvani et al. 2015). Adoption tends to decrease when environmental issues are overemphasized. This may be due to a "crowding out" of information about the significant cost-savings that EVs can offer (Ottman et al. 2006).

One common thread in the outreach literature is that information is important. Providing comparisons of total costs of ownership between EVs and conventional vehicles (Dumortier et al. 2015) and having informed car salesmen selling EVs (Cahill 2015; Matthews et al. 2017; Lunetta & Coplon-Neufield 2018) have been demonstrated to increase ZEV adoption. Information about the total cost of ownership is particularly important for potential buyers, and has more influence over purchase decisions than information about only fuel costs (Dumortier et al. 2015). One study suggests that providing potential buyers with information about total cost of ownership may help overcome initial "sticker shock" at high ZEV purchase and lease prices (Rezvani et al. 2015). The amount of knowledge that car dealerships and salespeople have on EVs is a second key determinant of EV adoption. The likelihood that a consumer purchases an EV drops significantly if the consumer interacts with an uninformed dealership (Cahill 2015; Matthews et al. 2017; Lunetta & Coplon-Neufield 2018). Data from future outreach efforts will be very helpful in determining best practices for increasing ZEV engagement and awareness.

5 Policy implications

Low awareness is a key barrier to EV deployment, increasing the importance of outreach

Awareness of and engagement with ZEVs are precursors to ZEV purchases. Unfortunately, ZEV awareness and engagement remains low, even in California. Awareness and engagement levels have remained stagnant over the past several years, even as EV deployment has increased severalfold. If outreach does not expand soon, adoption rates will decrease as the pool of informed potential buyers who have not yet purchased a ZEV diminishes. Several studies have observed that people often learn about clean energy technology, including EVs, from others in their social group (such as neighbors and friends). Leveraging social effects could be useful in ZEV outreach efforts.

Focusing on cost savings may help spur EV purchases for those who are already aware of EVs

For the minority who are already aware of EVs, outreach can increase propensity to purchase. Some studies have shown that the most effective outreach methods for these consumers focus on the financial benefits of EV ownership relative to conventional vehicles, though the literature in this area is inconclusive. Findings are convincing enough to indicate that financial benefits of EVs should be included in outreach efforts along with environmental benefits.

Evaluation should be included in outreach efforts

Very little quantitative information is available about the effects of various EV outreach efforts. No published study estimates the direct effects of increased ZEV outreach by CARB. Coupling outreach efforts with high-quality evaluation strategies is critical for accurate assessments.

[7] Self-congruity is defined as the match between a brand image and an individual's self-concept (Sirgy and Su, 2000).

6 Highlighted works

This section summarizes some top findings and key methodological choices for studies reviewed in this whitepaper.

General (non-California-focused) studies

Bühler et al. (2014)
Study type: Observed data analysis
Geography: Germany

The authors found that using EVs positively affects consumer perceptions of EVs and the likelihood that a consumer recommends an EV. This indicates that giving consumers an opportunity to test EVs in person is a good outreach and marketing strategy. The authors further found that using EVs does not significantly affect individual purchase intentions. Simply giving consumers EV testing opportunities does not appear sufficient to increase EV adoption.

Dumortier et al. (2015)
Study type: Survey (experimental)
Geography: United States

The authors found that providing information on the full cost of ownership for EVs relative to conventional vehicles led those who used small to mid-sized cars to have a higher probability of selecting an EV relative to providing information only on relative fuel costs. This result is not observed for those who use small sport utility vehicles. The authors conclude that providing full-cost-of-ownership information at point of sale could be very effective in selling more expensive EVs.

Egbue & Long (2012)
Study type: Survey, stated preference
Geography: United States

Using a survey, the authors attempted to identify “socio-technical” barriers to adoption of new EV technologies, with a focus on a likely first-adopter demographic: tech enthusiasts. The authors concluded that uncertainty around EV attributes (e.g., ranges, costs of ownership, reliability) impedes EV adoption. The authors further found that sustainability concerns are much less important for most potential EV buyers than cost and range concerns.

Franke & Krems (2013)
Study type: Experimental
Geography: Germany

The authors attempted to determine what factors influence range preferences for vehicles, including EVs. The authors found that people who have little to no experience with EVs tend to have preferences that far exceed their actual needs. The more exposure individuals have to using EVs, the closer their preferences become to reflecting their actual needs. This study suggests that consumer preferences for EV-relevant characteristics are malleable.

Matthews et al. (2017)
Study type: Qualitative data analysis
Geography: United States

The authors found that EV availability is limited at many dealerships and that EV salespeople frequently provide inaccurate information. This underscores the importance of dealerships and salespeople in driving or deterring EV adoption.

Ottman et al. (2006)
Study type: Qualitative data analysis
Geography: United States

The authors discuss how marketing for certain products with distinct environmental benefits can overemphasize those benefits such that cost savings of using the product are neglected. This finding is highly relevant to outreach concerning EVs.

Rauh et al. (2015)
Study type: Experimental
Geography: Germany

The authors compared 12 motorists who had high levels of experience with battery-electric vehicles (BEVs) to 12 motorists with no experience. The comparison centered on a test drive where the trip length exceeded the remaining range—i.e., a drive designed to lead to a "critical range situation." The authors compared range appraisal and range stress (range anxiety) on cognitive, emotional, and behavioral levels between the two driver groups. They found that drivers with BEV experience exhibited far lower negative appraisals of range and range anxiety than those without experience. This indicates that experience with BEVs leads to a better understanding of and ability to adapt to range issues. This study also indicates that learned experience can decrease range anxiety.

Rezvani et al. (2015)
Study type: Literature review
Geography: United States

The authors found that drivers of EV adoption include pro-environmental attitudes, symbolic meanings, identity, innovativeness, and emotions. The low cost of using EVs is a driver of positive feelings, but the high cost of purchase is a significant barrier. The authors found that using an EV positively affects consumer feelings towards EVs, but not enough to affect purchase intentions.

Schmalfuss et al. (2017)
Study type: Survey, stated preference
Geography: United States

Using a survey and field test, the authors found that direct usage of EVs positively impacts preferences of EVs, including purchase intentions. This finding stands in direct contrast to Bühler et al. (2014) and Rezvani et al. (2015). Schmalfuss et al. also found that extending "trial periods" to individuals considering EV purchases could be a good marketing/outrach strategy.

Skippon et al. (2016)
Study type: Experimental
Geography: United States

The authors used a randomized control trial of mass-market car consumers—where the treatment group was given a modern BEV and the control group given an equivalent combustion-engine vehicle—to determine the effect of exposure to BEVs on attitudes and purchase intentions. Although individuals' self-reported feeling ratings of the BEV were higher than the ratings of the conventional vehicle, people's willingness to adopt a BEV decreased overall after use. The exception was an increase in purchase proclivity among a subset of subjects who expressed high self-congruity, attributed to these individuals using the BEV to express their identity (i.e. using this vehicle outwardly tells others that the user is environmentally conscious).[8]

[8] Again, self-congruity is defined as the match between a brand image and an individual's self-concept (Sirgy and Su, 2000).

California-focused studies

Sanguinetti et al. (2017)
Study type: Experimental
Geography: California

The authors evaluated an online tool called "EV Explorer" that enables personalized cost comparisons of different vehicles. The evaluation involved an online experiment that measured users' perceptions of the tool. The authors found that tools like "EV Explorer" have significant positive effects on individual perceptions of EVs relative to conventional vehicles.

Dealership studies

Cahill (2015)
Study type: Observed and qualitative data analysis
Geography: United States

The authors found that due to a high learning curve on how to sell EVs and uncertainty in profiting from selling EVs, many dealers may choose to forego opportunities to sell PEVs or to make PEV-specific investments. Pervasive state franchise laws further ban manufacturers from selling PEVs directly to customers and restrict options by which manufacturers might bolster the PEV retail experience through existing dealer channels. This paper suggests (1) aligning government-funded incentive programs with industry practices through more "retail-friendly" policies, and (2) empowering manufacturers to pursue alternative market introduction approaches for distributing PEVs.

Lunetta & Coplon-Neufield (2018)
Study type: Qualitative data analysis
Geography: United States

The authors examined consumer EV-shopping experiences in multiple states. The study was based on surveys conducted by volunteers who called or visited 308 different auto dealerships and stores across ten states to inquire about EVs. The report found that there is "tremendous room for improvement among the dealerships and the automakers" in providing information about EVs. The study did identify some dealers that provided excellent information. These dealers could serve as models for dealer outreach programs.

7 Ongoing research

Ongoing research at UC Davis related to outreach and awareness is focused on collecting data for California to continue tracking consumer awareness of PEVs, knowledge of incentives, and how changes in awareness and knowledge affect intent to purchase and actual purchase of PEVs. Early results show very limited changes in awareness levels between 2014–2017 and 2019. Early results also show static spatial differences in awareness levels between California and the United States. Because this may begin to change as EV deployment continues and further investments are made in awareness and outreach, more research in this area is key.

8 Research gaps

Gaps in the research that could be filled by more targeted research efforts resulting from collaboration between academic researchers and regulatory agencies include:

- Scientific evaluation of past and ongoing outreach investments (like nonprofit ZEV promoters Forth and Veloz).
- Research on best practices to inform dealers about EVs and incentivize selling.

- Further study of how to best ameliorate EV anxieties (e.g., range & high purchase costs).
- Direct evaluation of California investments in outreach.

Very little quantitative information is available about the effects of various EV outreach efforts. No published study estimates the direct effects of increased ZEV outreach by CARB. Coupling outreach efforts with high-quality evaluation strategies is hence critical. In most cases, the ability to conduct a high-quality evaluation will depend on the quality of data collected before, during, and after outreach. Specifically, tracking whether individuals who were contacted through outreach efforts ended up purchasing a ZEV is a very useful metric for determining outreach effectiveness. Surveying ZEV purchasers about what factors drove their purchase (e.g., rebate, overall cost of ownership, environmental impact) is also useful. Surveying dealerships that have high ZEV sales to find out what information they provide and how they provide it could help less-informed dealerships improve sales. Finally, surveying individuals who considered purchasing a ZEV but ultimately decided against it could help identify barriers to adoption that could be addressed through future outreach efforts.

Researchers should work with outreach providers to evaluate the effectiveness of a wide variety of outreaech methods. One possible approach is giving some car buyers certain information about ZEVs information (e.g., total cost of ownership relative to conventional vehicles) while withholding such information from others. This would be an even more useful experiment if done at point of vehicle sale. Another approach is sending out mailers or hosting informational events in one area but not another similar area, to see if the general rate of EV purchases increases over a set time (i.e., a differences-in-differences approach).

Finally, there has yet to be any academic, peer-reviewed research on the effect of CARB's mailers on individuals' purchase intentions. This is a notable gap as specific research on outreach specific to California and/or the CVRP could and should inform any future state efforts.

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Impact of the Clean Vehicle Rebate Project's increased rebates for low- and moderate-income individuals on California's ZEV Market

ISSUE PAPER
May 2019

A research summary whitepaper for the California Air Resources Board

ABSTRACT

This paper reviews and summarizes the research regarding California's Clean Vehicle Rebate Project's (CVRP) implementation of increased rebates for low- and moderate-income recipients in March 2016 and increase of these rebates in November 2016. Due to the recent nature of the program, no peer-reviewed research has been published about the specific effects of CVRP. Yet some research explores the effects of rebates for low- and moderate-income individuals as part of other programs, such as the Enhanced Fleet Modernization Program (EFMP). Consequently, we review the literature evaluating past and present programs with similar policy features as well as survey-based research that takes a stated-preference approach.

Research indicates that incentives have largely accrued to higher-income households and individuals, raising concerns about inequitable[1] incentive distribution. There may be related cost-effectiveness concerns if wealthy households would have purchased zero-emission vehicles (ZEV) in the absence of a subsidy. While we are limited in determining the specific effects of CVRP's increased rebates, the literature suggests that rebates are a significant factor in the purchase decisions of low- and moderate-income individuals, as the purchase price of a ZEV is typically much higher than the purchase price of a traditional vehicle.

This whitepaper includes recommendations for future research to identify the specific impacts of CVRP's increased rebates.

[1] Inequitable in the context of CVRP incentives primarily refers to income inequality. If 50% of incentives are realized by those in the top 20% of the income distribution, then the incentives are inequitable.

1 Purpose

Assembly Bill (AB) 615 requires the California Air Resources Board (CARB) to "prepare and submit to the Legislature a report on the impact of the Clean Vehicle Rebate Project on the state's zero-emission vehicle market...The report shall include, but is not limited to, the impact of income caps, increased rebates for low-income consumers, and increased outreach on the electric vehicle market." This whitepaper supports CARB in fulfilling AB 615's mandate by assessing the impact of California's Clean Vehicle Rebate Project (CVRP) implementation of increased rebates for low- and moderate-income recipients in March 2016 and increase of these rebates in November 2016. The assessment is based on a review of literature related to zero-emission vehicle (ZEV) incentive programs, including general findings, research gaps, and policy implications of both.

2 Policy description

California is a leader on combating climate change. The state has set bold goals of reducing statewide greenhouse gas (GHG) emissions to 80% below 1990 levels by 2050, as well of achieving 5 million ZEVs on the road by 2030. Reaching these goals will require effective policies and programs, as well as periodic assessment of both. A key state effort to incentivize ZEV adoption, and thus reduce emissions from the light-duty transportation sector, is the Clean Vehicle Rebate Program (CVRP).

The CVRP was created by AB 118 in 2007 to incentivize ZEV purchasing and leasing. The CVRP's primary purpose is to support widespread commercialization of the cleanest vehicles by helping to motivate consumer purchase decisions. The program was originally designed to be "first-come, first-served" and only expected to be funded through 2015. Consequently, the program had no means-testing requirement at its inception, leading to a significant portion of incentives concentrated among high-income individuals.[2]

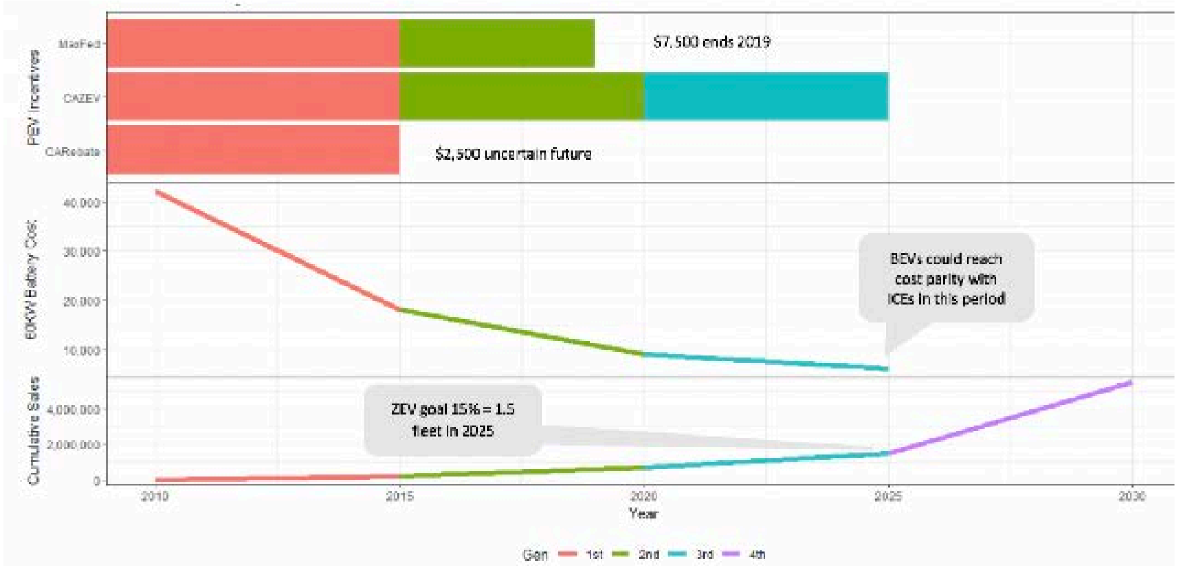
Senate Bill (SB) 1275, passed in 2014, was designed to address these issues. SB 1275 required CARB to develop a plan for realizing California's then-goal of achieving 1 million ZEVs on the road by 2023 without excluding low-income individuals. This bill required CARB "to adopt, no later than June 30, 2015, specified revisions to the criteria and other requirements for the Clean Vehicle Rebate Project; and to establish programs that further increase access to and direct benefits for disadvantaged, low-income, and moderate-income communities and consumers from electric transportation."[3] In March 2016, acting on CARB's recommendations, the state set an increased rebate of $1,500 for CVRP participants with incomes below 300% of the federal poverty level. In November 2016, SB 859 added an additional $500 rebate, bringing the total rebate to $2,000 for participants with incomes below 300% of the federal poverty level.[4]

3 Designing incentive programs

As seen in Figure 1, incentives are critical for spurring increased adoption in the first three generations of plug-in electric vehicles (PEVs).[5] Well-designed incentives should be efficient and equitable. Increasing ZEV incentive efficiency requires increasing the percentage of recipients who are induced to purchase a ZEV because of the incentive while decreasing the percentage of recipients who would have purchased a ZEV anyways. Increasing ZEV incentive equity means ensuring that incentives are evenly distributed across a range of demographics, especially income. These two objectives often go hand-in-hand, as low- and moderate-income individuals are the most likely to be influenced by incentives that reduce the financial impact of buying a ZEV. Failing to reach low- and moderate-income individuals will likely result in California missing its 5 million ZEVs by 2030 goal.

Multiple options exist for tackling both of these significant issues. Some have already been implemented in other

[2] Means testing is any requirement for a program that uses an individual's financial status to determine eligibility (normally income subset by tax filing status).
[3] It should be noted that while CVRP was an integral part of the state's efforts to increase ZEV adoption, the program was not the sole focus of SB 1275. For example, the mandate helped lead to the creation of EFMP Plus-Up, BlueLA, and Our Community Car Share.
[4] This income requirement changes depending on household size, increasing with each additional member.
[5] PEVs are a subset of ZEVs that excludes fuel-cell vehicles.



	1st Gen Innovators	2nd Gen Innovators & Followers	3rd Gen Innovators & Followers Next Purchase
PHEV Miles Traveled	10 – 40	15 – 50	50+
BEV Miles Traveled	80 – 250	150 – 300	200+
# of Models	20 – 30	30 – 100	200+
Designs	Compact, Subcompacts	Crossover, Midsize Sedans	Full-sized Vehicles

***Figure 1. Charting the California plug-in electric vehicle (PEV) market from 2010–2030: past, present, and future.**[6] This figure highlights the importance of maintaining rebates (top panel) until battery-electric vehicles (BEVs) and ZEVs reach cost parity with internal combustion engine vehicles (ICEVs, middle panel). Moreover, these rebates will be necessary to spur enough adoption to reach California's ZEV goals (bottom panel). The figure also highlights the different stages of ZEV adoption (tables). Different groups of individuals are assumed to adopt ZEVs at different times. Innovators lead, then followers, then the second purchase of a ZEV by innovators and followers. Mass adoption occurs in the fourth generation.*

states, such as manufacturer's suggested retail price (MSRP) caps on EV rebates in New York, Massachusetts, and Connecticut.[7] Two different approaches were implemented in California in 2016: (1) income caps and (2) increased incentives for low- and moderate-income individuals. Income caps are designed to prevent subsidizing ZEV purchases for high-income individuals, since these individuals have the means to purchase a ZEV without assistance and will hence ascribe less value to financial purchase incentives. By preventing resources from being "wasted" on the wealthy, income caps increase incentive availability for low- and moderate-income individuals. This increases incentive efficiency and equity alike.

Another critical determinant of incentive efficiency and equity is outreach. For incentives to reach target populations, individuals in those populations must be aware of both the qualifying product and the existence of the incentive. Hence outreach around ZEVs in general as well as ZEV purchase incentives is an essential aspect of efforts to increase ZEV deployment.

This whitepaper focuses on literature and analysis relevant to providing increased CVRP rebates to low- and moderate-income ZEV buyers. For more information on the related policy of income caps, see a separate whitepaper in this series, "Impact of the Clean Vehicle Rebate Project's Income Cap on California's ZEV Market."

[6] Figure adapted from Turrentine et al. (2018). Note that CAZEV is comprised of all CA ZEV programs, including CVRP.

[7] MSRP caps essentially prevent expensive ZEVs like the Tesla Model X from qualifying for rebates, such that cheaper vehicles like the Chevy Bolt are the only subsidized ZEVs. These caps are designed to encourage manufacturers to produce vehicles that are more accessible to low- and moderate-income individuals. MSRP caps do not preclude high-income individuals from purchasing (and realizing subsidies on) eligible vehicles.

4 Key findings

These are the top findings based on our review of relevant literature.

- Low- and moderate-income consumers are more responsive to price than high-income consumers, meaning that low- and moderate-income consumers exhibit greater elasticity of demand for ZEVs—i.e., that demand decreases more given a set price increase (Muehlegger and Rapson 2018).
- Lower-income individuals and individuals who purchase vehicles with a lower MSRP generally state that rebates are more important to their purchase decisions (Williams 2018).
- Steep progressive rebates based on income may induce larger increases in demand than the status quo—a single increase for low-income and an income cap—in California (DeShazo et al. 2017).
- After CVRP rebates were increased for low- and moderate-income individuals and an income cap was introduced, the share of rebate recipients with household incomes below $50,000 annually increased from ~5% (in March 2016) to ~10% (in June 2017). The share of rebate recipients with annual household incomes between $50,000 and $150,000 increased as well (from ~21% to ~24%) over the same time period (Williams 2018).[8]

The literature generally suggests that without means-testing, ZEV purchase incentives tend to be concentrated among high-income individuals. Furthermore, these individuals are the least likely to consider a subsidy important in deciding whether or not to purchase a ZEV. While there is not much literature on the benefits of an increased rebate for lower-income individuals, Skerlos & Winebrake (2010) provide a roadmap for how rebates that vary based on income could help maximize ZEV adoption. DeShazo et al. (2017) similarly conclude that the most efficient policy for incentivizing increased EV adoption is a steeply progressive rebate based on income. These limited studies indicate that increasing rebates for low-income individuals has a positive effect.

Further research also needs to be done to assess the impact of increased rebates for low-income individuals with regard to the CVRP specifically. These impacts may become clearer with time; after all, it has only been three years since increased rebates were implemented for the CVRP. Early data is promising. Since the increased rebates were implemented, the percentage of CVRP recipients earning less than $50,000 annually increased from ~5% to ~10% (Figure 2).

5 Policy implications

Incentives that target specific purchaser types can be useful in achieving policy objectives

Multiple researchers (e.g., DeShazo 2010; Lee, Hardman, & Tal 2019; Pierce et al. 2019;, Skerlos and Winebrake 2010) have argued that targeting incentives towards specific purchasers can be useful in achieving policy objectives. The value that incentive targeting provides often justifies the added layer of policy complexity that targeting adds. Increasing ZEV purchase rebates for low-income individuals is a relatively straightforward example of incentive targeting.

Targeting ZEV purchase incentives to lower-income individuals can improve the efficiency of ZEV incentive programs

The objective of many incentive programs is to deliver social benefits by subsidizing technologies that deliver positive externalities. The CVRP subsidizes EVs in recognition of the social benefits they provide, such as reduced emissions and reduced demand for fossil fuels that can be costly to import and environmentally harmful to extract. Targeting ZEV purchase incentives to those (i.e., lower-income individuals) who are most likely to be influenced

[8] This could be attributed to both the income cap and the increased rebates, but the total volume of rebates was increasing at the same time, so the percentage change cannot be completely attributed to the exclusion of high income. Further research should try to disentangle these effects.

by such incentives can improve the efficiency of ZEV incentive programs, thereby increasing the social benefits realized for a set program cost. Lower-income groups are also less likely to own reliable vehicles, which leads to employment and community challenges. Targeting ZEV purchase incentives to lower-income individuals can help address this issue as well.

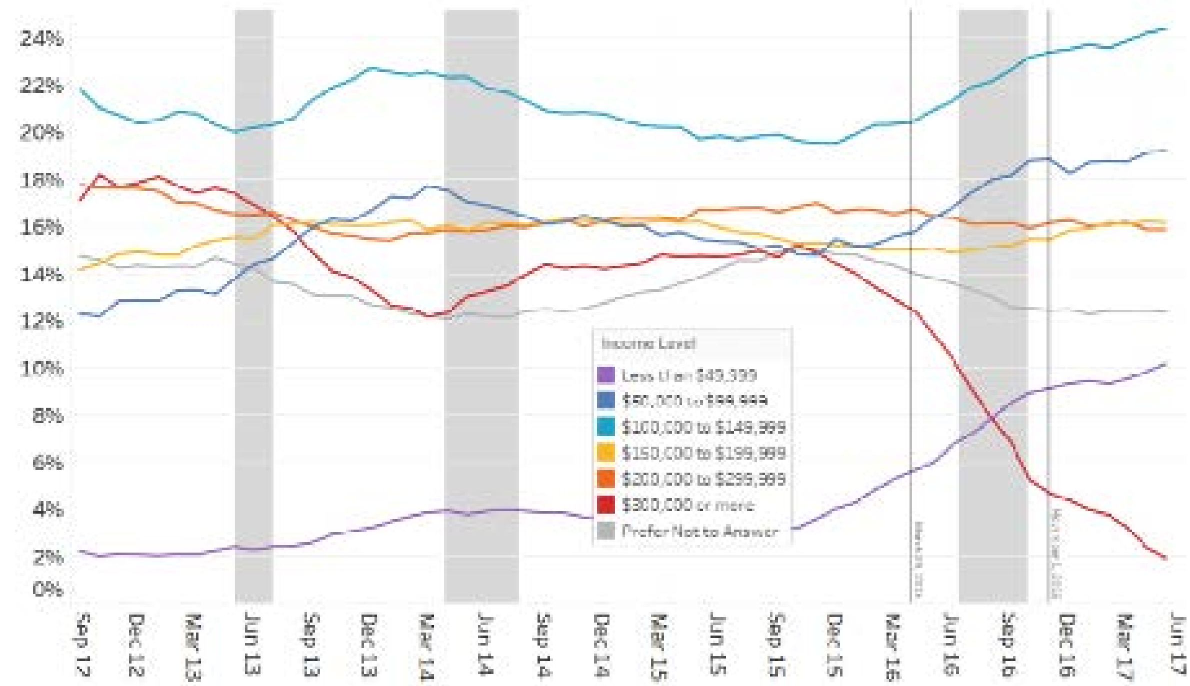


***Figure 2. CVRP rebates by household income over time.*[9]** *This figure shows the percentage trend of CVRP rebates dispersed by household income bracket. The income cap and increased rebates implementation/adjustment are indicated by the two gray lines (March and November 2016). There is a marked decrease after March 2016 in rebates received by households earning $300,000 or more annually, and a significant increase among those earning less than $50,000 annually. This comparison gives us an indication of the effectiveness of means-testing policies on increasing equitability of rebates.*

Implementing targeted incentives for more populations could accelerate ZEV adoption

In the coming years, EVs will be purchased by a widening variety of customers. Targeting incentives to different population groups could ensure that appropriate incentives are delivered to those most likely to benefit from and/or be influenced by them. For instance, financial incentives could be targeted across more income brackets in order to better match rebate amounts with ability to pay (DeShazo 2010; DeShazo et al. 2017; Lee, Hardman, & Tal 2019; Pierce et al. 2019; Skerlos & Winebrake 2010). Other incentives, such as priority access to high-occupancy vehicle (HOV) lanes for ZEV purchasers, could be targeted to those for whom cost is less of an object (Jenn et al. 2019). Further targeting is likely to further increase efficiency and equity of ZEV incentive programs.

Availability of rebates will likely be an important determinant of future ZEV adoption rates

While rebate policy should be designed with its long-term existence in mind, incentives will be needed to sustain ZEV adoption for the foreseeable future. In seeming contradiction to the “common paradigm” shown in Figure 3, research shows that the importance of rebates in California has actually increased over time (Williams & Anderson 2018). This research is also supported by two major surveys that stress the growing importance of incentives for ZEV adoption (Jenn et al. 2019; Lee, Hardman, & Tal 2019). As the market has expanded for ZEVs, the importance of the rebate has consistently increased, indicating that if the government wants to spur more growth, the rebate will likely need to remain in place. This is likely due to an influx of more price-sensitive customers entering the

[9] Figure taken from Williams (2018).

ZEV market—due to increased outreach and implementation of increased rebates for low- and moderate-income individuals—and points to the importance of a long-term perspective.

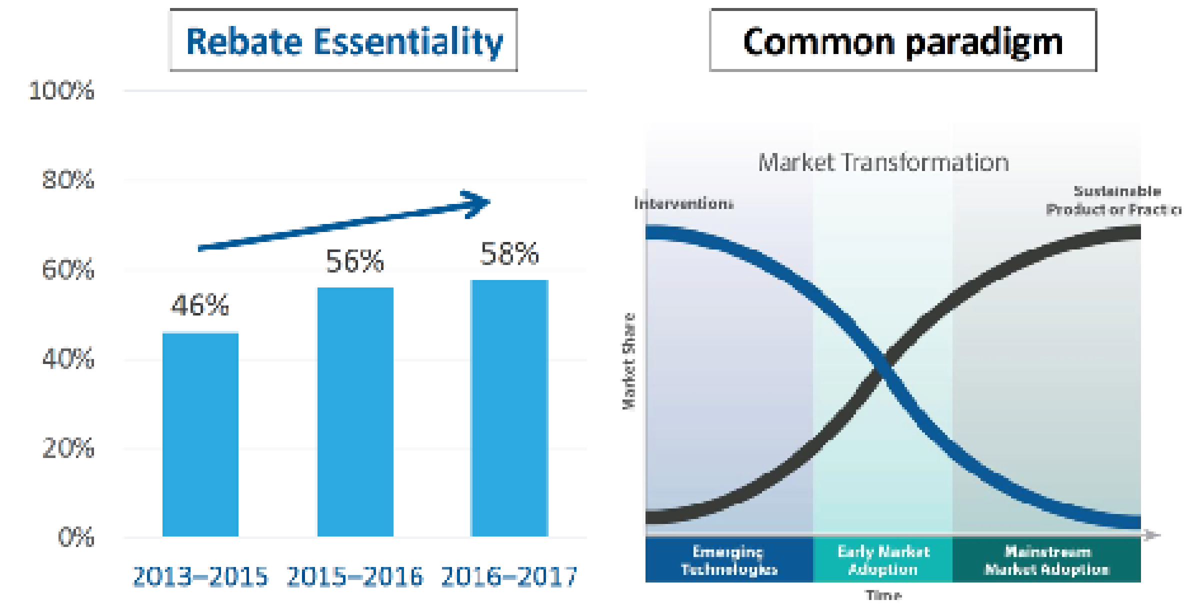


Figure 3. ***CVRP rebate essentiality over time, in contrast to the common paradigm.***[10] *Rebate essentiality is determined by asking rebate recipients if they would have purchased a ZEV without a rebate, which demonstrates how "essential" the rebate was to the purchase.*

6 Highlighted works

This section summarizes some top findings and key methodological choices for the reviewed papers.

General (non-California-focused) studies

General incentive studies (overall effectiveness & effectiveness among low-income)

Beresteanu & Li (2011)
Study type: Observed data analysis
Geography: United States

The authors study the effect of gasoline prices and federal tax incentives on hybrid electric vehicle (HEV) sales. Using both household-level data and aggregate market-level sales data, the authors estimate a market equilibrium model. The authors attempt to estimate the net effect of tax deductions and credits by simulating the benefits to three income groups: those earning less than $50,000 annually, those earning between $50,000 and $100,000, and those earning more than $100,000. The authors found that the lowest-income group was about twice as sensitive to prices as the middle group, while the highest-income group was one-third as sensitive to prices as the middle group.

Diamond (2009)
Study type: Observed data analysis
Geography: United States

The author attempts to determine the factors driving HEV adoption in the United States using simple regressions on a panel dataset of market shares of different vehicle types in different states. The author finds no significant

[10] Figure taken from Williams & Anderson (2018).

relationship between financial incentives and HEV adoption since incentive payments tend to be concentrated among high-income consumers who have sufficient tax liability to benefit, effectively subsidizing the wealthy without significantly affecting their purchase decisions. Note that consumer eligibility to claim and benefit from CVRP cash rebates does not depend on tax liability.

Gallagher & Muehlegger (2011)
Study type: Observed data analysis
Geography: United States

The authors report that HEV sales increase more in response to sales tax exemptions than to income tax credits/ exceptions. This paper is loosely related to distributional concerns as it implies that consumers at all income levels are more responsive to subsidies with immediate effect.

California-focused studies

General incentive studies (overall effectiveness & effectiveness among low-income)

Muehlegger & Rapson (2018)
Study type: Observed data analysis
Geography: California

The authors attempt to determine the effectiveness of incentives for EVs in the mass-market, specifically those aimed at low- and moderate-income consumers in California. Through transaction-level data, the authors determine that low- and moderate-income consumers are very sensitive to rebates and that at current subsidy levels the entirety of the rebate is needed to induce purchase. Overall, this paper indicates that low- and moderate-income users significantly benefit from EV rebates and that rebates induce purchases without significant free-riding within those income groups.

Jenn et al. (2019)
Study type: Survey
Geography: California

Using a comprehensive survey of over 14,000 ZEV purchasers in California, the authors analyze individuals' stated reasons for ZEV adoption. The most important factors for PEV adoption are the federal tax credit, the CVRP, and High Occupancy Vehicle (HOV) lane access. The authors further find that the importance of incentives and incentive effect on purchase intentions are changing over time as ZEV technology and trends move towards the mass market and away from early adopters. They conclude that if rebates are removed, respondents would be more likely to change their decision and not purchase a ZEV at all.

Lee, Hardman, & Tal (2019)
Study type: Survey
Geography: California

The authors use a multi-year survey (2012–17) of the socio-demographic characteristics of 11,037 PEV adopters in California to analyze the different characteristics that drive early PEV adopters. This analysis identifies four groups of PEV buyers: high-income families (accounting for 49% of adopters), mid- to high-income older families (26%), mid- to high-income young families (20%), and mid-income renters (5%). The authors find that while high-income families are currently the largest group of PEV adopters, the relative size of this group may be decreasing. The authors stress the importance of meeting needs of the other groups in order to continue PEV market growth.

Explicitly low-income incentive studies

DeShazo et al. (2017)
Study type: Observed data analysis
Geography: California

The authors assess the performance of rebate designs for plug-in electric vehicles (PEVs) based on cost-effectiveness and equity. They perform a state-wide representative survey of prospective car buyers in California, which informs a structural model of vehicle choice. The empirical model estimates price elasticities of demand and willingness to pay for different vehicles, which in turn permits a simulation of alternative rebate designs. The rebate designs are compared over three main criteria: (1) additional PEVs purchased; (2) total program cost; and (3) the distribution of rebate funding across consumer income classes. Finally, the paper finds that progressive rebates (a specific, steep set) are likely to be more effective across all observed measures than the status quo.

Pierce et al. (Forthcoming)
Study type: Survey
Geography: California

Using a statewide survey of 1,604 low- and moderate-income households, the authors conduct choice experiments to determine if PEV purchase incentives are cost-effective. They find that rebates of $2,500, $5,000, or $9,500 increase PEV purchases by around 20%, 40%, and 60–80%, respectively. Incentives had a significantly larger influence on purchase decisions than did guaranteed financing options. However, offering both together another did not significantly increase purchase intentions relative to offering only the rebate. This research indicates that incentives may be a cost-effective way to increase PEV adoption among low- and moderate-income households.

Williams (2018)
Study type: Initial data analysis
Geography: California

The author finds that since the introduction of CVRP income caps and increased rebates, the share of rebates received by households with annual incomes of more than $300,000 dropped from ~16% to ~2% (in June 2017). The share of rebate recipients with annual household incomes below $50,000 increased from ~5% to ~10% over the same time period, and the share of rebate recipients with annual household incomes between $50,000 and $150,000 increased as well (from ~21% to ~24%). The author also finds that rebate recipients are increasingly demographically similar to new car buyers overall, and that rebate importance for purchase has increased over time.

Williams & Anderson (2018)
Study type: Observed data analysis
Geography: California

The authors use logistic regression to examine the relationship between rebate influence and consumer factors (demographic, household, and transaction characteristics; motivations; and experience). They find that if household income has become a poorer indicator of proclivity to purchase a ZEV, this is likely due to the means-testing implemented for CVRP in 2016. This also finds that traditionally higher-income complements—such as housing type, solar panels, workplace charging availability, and size of household—were all insignificant predictors of proclivity to purchase a ZEV. This may suggest that ZEVs are suitable for a diverse set of consumers.

Arguments for means-testing

DeShazo (2010)
Study type: Literature review
Geography: United States and California

The author provides a first-principles review of the economics behind and the characteristics of EV subsidies, as well as a history of EV subsidies in California. The author notes that EV subsidies are effective but inefficient, and recommends: (1) applying subsidies at point of sale; (2) increasing subsidies for BEVs relative to PHEVs; (3) linking vehicle purchase and retirement incentives; and (4) means-testing subsidies.

Skerlos & Winebrake (2010)
Study type: Observed data analysis
Geography: United States

The authors discuss the regional variability of PHEV social benefits and conclude that a uniform national policy for subsidizing PHEVs is at best sub-optimal, meaning that greater PHEV benefits could be achieved for the same government investment if subsidies were targeted to where the social benefits are largest. They argue that the federal PHEV tax credit would have higher social benefits if it were varied across income and location.

7 Ongoing research

The majority of ongoing research focuses on the characteristics of ZEV buyers and how those characteristics are changing over time. Ongoing research also considers how these characteristics affect purchase intentions and preferences regarding ZEVs. Preliminary results support—albeit based on much more data, especially for California—previous findings regarding the characteristics of ZEV buyers and the need for increased incentives and attention to low- and middle-income individuals.

8 Research gaps

Gaps in the research that could be filled by more targeted research efforts resulting from collaboration between academic researchers and regulatory agencies include:

- Econometric assessments of the effects of the CVRP's increased rebates, i.e., that go beyond simple before-and-after comparisons.
- Analysis of decreasing average ZEV MSRP on rebate effect.
- Analysis of the extent to which varying rebate amounts based on income would alter rebate effectiveness.

The research in its current state only allows for basic before-and-after comparisons of rebate recipient demographics, tangential inferences from other programs, and research on the drivers of ZEV purchases among high-income individuals. To fully understand the impact of increased rebates for low-income individuals in general, and for CVRP specifically, more methodologically rigorous analyses need to be conducted.

The short time frame from when means-testing was implemented for CVRP (March/November 2016) does not lend itself to comprehensive analysis of the program's long-term impacts. However, the short-run impacts of these policies can be a bellwether for policymakers on how effective the program may be in the long run, and thus analyses can and should be done. It is particularly important to determine how many new ZEV purchases were induced by the increased rebates for low-income individuals—i.e., how many of these purchases would not have occurred had the rebates not been increased.

Several of the research questions posed above could be examined through difference-in-differences studies focused on the time period before and after means testing for the CVRP was implemented. Carrying out such a study would require an appropriate control/counterfactual. This would likely be difficult at the state level. It may be easier to conduct such studies on different areas of California that have larger or smaller low-income populations, but are similar on other characteristics. One shortcoming of this approach is that it would have limited ability to parse the relative effects of adding an income cap for ZEV rebates and of increasing rebates for low-income individuals, since these two methods of means testing were implemented for the CVRP simultaneously.

Another approach would be a regression discontinuity study design that looks at similar individuals who just barely fall on either side of the income rebate cutoff. Such a design has high data requirements and has so far proven challenging. Researchers should looking to other branches of economics for alternative study designs that may be valuable when it comes to informing future changes to the CVRP.

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APPENDIX B:

EMISSION REDUCTIONS ATTRIBUTABLE TO CVRP

Preliminary Estimation of Emission Reductions Associated with California's Clean Vehicle Rebate Project (CVRP)

Version: May 6, 2019

Nicholas Pallonetti
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Center for Sustainable Energy

on behalf of California Air Resources Board Staff, Innovative Light-Duty Strategies Section

The California Air Resources Board's Clean Vehicle Rebate Project provides cash rebates to consumers for the purchase/lease of eligible light-duty electric vehicles and motorcycles. Prior estimates of emission reductions associated with the program were based upon average vehicle characterizations and intentionally conservative as a starting point for future refinement. Here we inform that process by utilizing project-specific data to create a preliminary but more detailed picture of emission impacts through August 2018 (N=270,637 participants).

Greenhouse-gas (GHG) emission reduction estimates were produced using factors characterizing vehicle-specific fuel economy, vehicle miles traveled (VMT), and electric VMT, as well as Low Carbon Fuel Standard carbon intensity values for gasoline, electricity, and hydrogen. GHG emission reductions are calculated for the first year of vehicle operation and then multiplied up to "*vehicle life*," which is conservatively assumed to be the average vehicle age in the U.S., or 11.6 years. For criteria pollutants, reductions are conservatively reported in terms of "*ownership life*," to allow for the possibility the vehicle might leave the state after the average length of vehicle ownership (6.6 years). In both cases, these best-guess estimates are bounded by "*project life*" (1–3 years, based upon CVRP requirements in place at the time of each vehicle's purchase/lease) and "*project-comparison life*" (15 years, as used by other projects, to facilitate comparisons).

GHG reductions attributable to rebated plug-in hybrid electric vehicles (PHEVs), battery electric vehicles (BEVs), range-extended battery electric vehicles (BEVxs), and fuel cell electric vehicles (FCEVs) over an 11.6-year vehicle life were estimated to be approximately 9.5 million metric tons of CO_2-equivalent. For individuals and fleets respectively, savings averaged 34.7 and 20.3 tons per PHEV, 36.4 and 22.1 tons per BEV, 35.4 and 21.9 tons per BEVx, and 28.4 and 16.8 tons per FCEV. The differences between individual and fleets is primarily due to lower assumed VMT for fleet vehicles. For individuals, fifty-three percent of the reductions were associated with "rebate-essential" participants who were most highly influenced by the rebate to purchase/lease. Paring total vehicle-life results down to a project lifespan (2.5 or 3 years per vehicle for individuals and 1, 2.5 or 3 years per vehicle for fleets, based upon the program's vehicle ownership requirement in place at the time of each vehicle acquisition and fleet ownership provision) decreases the reductions to 2.2 million tons or 8.2 tons per individual vehicle and 4.8 tons per fleet vehicle. Scaling these results up to a 15-year project-comparison lifespan increases the reductions to 12.3 million tons or 46.0 tons per individual vehicle and 27.7 tons per fleet vehicle.

Another noteworthy but preliminary observation relates to cost-effectiveness: comparing the vehicle-life benefit of 9.5 million metric tons of avoided GHG emissions to the $609 million in corresponding rebates results in an estimate of roughly $64 per ton avoided ($63 for individuals and $124 for fleets) over the first 11.6 years, or about 15.6 kg of CO_2e avoided over that period per incentive dollar invested. Counting reductions over the 1–3-year project life would increase that cost to $279 per ton avoided. This does not include other factors, such as the additional benefits that could be realized as the grid decarbonizes.

Sensitivity analysis determined the sum of effects from deviations in input assumptions to be bounded between -59% and +47% for individuals and -56% and +120% for fleets, relative to baseline emission-reduction estimates. The estimates were most sensitive to baseline fuel economy and—particularly for fleets—VMT assumptions, indicating opportunities for further refinement using participant-specific inputs. Nevertheless, the approach explored here increased estimated program GHG reductions by >20% for individual model year 2017 BEVs and PHEVs. These findings indicate that use of project-derived data can significantly enhance characterizations of the impact of incentive programs.

Criteria pollutant reduction estimates were produced using emission factors for gasoline- and electric-fueled vehicles from the California Air Resources Board's 2014 Emission Factors (EMFAC2014) model, as well as the same fuel economy, VMT, and electric VMT used to estimate GHGs. Criteria pollutant reductions attributable to rebated PHEVs, BEVs, BEVxs, and FCEVs over a 6.6-year ownership-life were estimated to be approximately 595 metric tons of NOx, 203 metric tons of PM 2.5, and 121 metric tons of ROG. Paring total vehicle-life results down to a project lifespan decreases the reductions to 241 metric tons of NOx, 81 metric tons of PM 2.5, and 49 metric tons of ROG. Scaling these results up to a 15-year project-comparison lifespan increases the reductions to 1,350 tons of NOx, 460 metric tons of PM 2.5, and 274 metric tons of ROG. Emission reductions at various lifespans by vehicle and rebate type can be found in Tables 1 and 2 below.

Table 1 Emission Reductions by Vehicle Type

Vehicle Type	**Rebate Funding**	**Number of Rebates**	**GHG Reductions (*thousand* metric tons of CO_2e) Vehicle-Life/ Project-Life/Project-Comparison-Life***	**Criteria Pollutant Reductions (metric tons) Ownership-Life/Project-Life/Project-Comparison-Life***		
				NOx	**PM 2.5**	**ROG**
PHEV	$166,955,961	104,918	VL= 3,600 PL= 836 PCL= 4,655	OL= 183 PL= 75 PCL= 417	OL= 89 PL= 36 PCL= 202	OL= 37 PL= 15 PCL= 85
BEV	$401,811,110	154,566	VL= 5,541 PL= 1,268 PCL= 7,166	OL= 385 PL= 156 PCL= 874	OL= 106 PL= 42 PCL= 240	OL= 78 PL= 32 PCL= 178
BEVx	$16,830,921	6,559	VL= 229 PL= 50 PCL= 296	OL= 16 PL= 6 PCL= 36	OL= 5 PL= 2 PCL= 10	OL= 3 PL= 1 PCL= 7
FCEV	$23,497,001	4,594	VL= 128 PL= 28 PCL= 166	OL= 10 PL= 4 PCL= 24	OL= 3 PL= 1 PCL= 7	OL= 2 PL= 1 PCL= 5
All	$609,094,993	270,637	VL= 9,499 PL= 2,182 PCL= 12,283	OL= 595 PL= 241 PCL= 1,350	OL= 203 PL= 81 PCL= 460	OL= 121 PL= 49 PCL= 274

* *Vehicle life* (VL) = 11.6 years = average age of vehicles in the U.S.; *Project life* (PL) = 1–3 years = rebate-program requirement; *Project-comparison life* (PCL) = 15 years used by other programs; *Ownership life* (OL) = 6.6 years = average ownership length in U.S.

Table 2 Emission Reductions by Rebate Type

Rebate Type	Rebate Funding	Number of Rebates	GHG Reductions (*thousand* metric tons of CO_2e) Vehicle-Life/ Project-Life/Project-Comparison-Life*	Criteria Pollutant Reductions (metric tons) Ownership-Life/Project-Life/Project-Comparison-Life*		
				NOx	**PM 2.5**	**ROG**
Standard Rebate for Individuals	$546,114,651	251,960	VL= 8,950 PL= 2,063 PCL= 11,574	OL= 562 PL= 229 PCL= 1,277	OL= 191 PL= 77 PCL= 433	OL= 114 PL= 46 PCL= 259
LMI Increased Rebate for Individuals	$39,514,685	9,859	VL= 360 PL= 77 PCL= 465	OL= 19 PL= 7 PCL= 44	OL= 8 PL= 3 PCL= 18	OL= 4 PL= 1 PCL= 9
Fleet Rebate	$23,465,657	8,818	VL= 189 PL= 42 PCL= 245	OL= 13 PL= 5 PCL= 29	OL= 4 PL= 2 PCL= 9	OL= 3 PL= 1 PCL= 6
All	$609,094,993	270,637	VL= 9,499 PL= 2,182 PCL= 12,283	OL= 595 PL= 241 PCL= 1,350	OL= 203 PL= 81 PCL= 460	OL= 121 PL= 49 PCL= 274

* *Vehicle life* (VL) = 11.6 years = average age of vehicles in the U.S.; *Project life* (PL) = 1–3 years = rebate-program requirement; *Project-comparison life* (PCL) = 15 years used by other programs; *Ownership life* (OL) = 6.6. years = average ownership length in U.S.

Preliminary Estimation of Emission Reductions from California's Clean Vehicle Rebate Project

Nicholas Pallonetti – Analyst

Brett Williams, M.Phil. (cantab), Ph.D. – Senior Principal Advisor, Clean Transportation

Thanks also to Keir Havel, Laura Parsons, Jaclyn Vogel, Ryan Bodanyi, and others at CSE

Cap and Trade Dollars at Work

California Climate Investments

California Air Resources Board

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EV Rebate Design (as of Jan. 2019)

	California Clean Vehicle Rebate Project	MOR-EV Massachusetts Offers Rebates for Electric Vehicles	CHEAPR Connecticut Hydrogen and Electric Automobile Purchase Rebate	New York State
Fuel-Cell EVs 	$5,000	$1,500	$5,000	e-miles ≥ 120 $2,000 ≥ 40 $1,700 ≥ 20 $1,100 < 20 $500
All-Battery EVs 	$2,500	$1,500	e-miles ≥ 200 $2,000 ≥ 120 $1,500 < 120 $500	
Plug-in Hybrid EVs 	$2,500 (i3 REx) $1,500	BEVx only: $1,500	≥ 45 $1,000 < 45 $500	
Zero-Emission Motorcycles 	$900	$450		
	e-miles ≥ 20 only; Consumer income cap and increased rebates for lower-income households	MSRP ≤ $50k, no fleet rebates	MSRP ≤ $60k FCEVs, ≤ $50k BEVs, PHEVs; dealer assignment; $150 dealer incentive	MSRP > $60k = $500 max.; point-of-sale via dealer

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Paper Outline

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Disclaimer and Thanks

This study was conducted to inform
the Clean Vehicle Rebate Project (CVRP)

– It does not necessarily represent the views of the Clean Vehicle Rebate Project or the California Air Resources Board

– Nor does it represent a final determination for project-reporting purposes

We thank CARB staff for the opportunity
to contribute to, and foster, the conversation

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Summary: GHG Results (part 1)

- Over Vehicle Lifespan (11.6* years per vehicle):
  - 9.5 million tons or 36 tons per individual and 21** tons per fleet vehicle
  - Individuals (tons): 34.7 per PHEV, 36.4 per BEV, 35.4 per BEVx, 28.4 per FCEV
  - Fleets** (tons): 20.3 per PHEV, 22.1 per BEV, 21.9 per BEVx, 16.8 per FCEV
  - 53% of individual reductions from “Rebate-Essential” participants
  - $64 per ton avoided (15.6 kg of CO2e per rebate $)
- Over Project Lifespan (either 1, 2.5 or 3 years per vehicle):
  - 2.2 million tons or 8.2 tons per individual and 4.8** tons per fleet vehicle
  - Individuals (tons): 8.0 per PHEV, 8.3 per BEV, 7.7 per BEVx, 6.1 per FCEV
  - Fleets** (tons): 4.7 per PHEV, 4.8 per BEV, 4.8 per BEVx, 3.6 per FCEV
  - $279 per ton avoided (3.6 kg of CO2e per rebate $)

* (6) [references provided at end of presentation]

** Fewer annual VMT assumed for fleet vehicles based on a passenger vehicle average from (FY 2017 Federal Fleet Report)

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Summary: GHG Results (part 2)

- Over Project-Comparison Lifespan (15 years per vehicle):
  - 12.3 million tons or 46 tons per individual and 28** tons per fleet vehicle
  - Individuals (tons): 45 per PHEV, 47 per BEV, 46 per BEVx, 37 per FCEV
  - Fleets** (tons): 26 per PHEV, 29 per BEV, 28 per BEVx, 22 per FCEV
  - $50 per ton avoided (20 kg of CO2e per rebate $)
- Do not include grid decarbonization over time, other factors
- Partial use of project-derived data increased savings by >20% (so far) for individual MY 2017 BEVs and PHEVs

* (6) [references provided at end of presentation]

** Fewer annual VMT assumed for fleet vehicles based on a passenger vehicle average from (FY 2017 Federal Fleet Report)

Summary: Criteria Pollutant Results

- Over Ownership Lifespan (6.6 years per vehicle):
  - NOx: 595 metric tons
  - PM 2.5: 203 metric tons
  - ROG: 121 metric tons
- Over Project Lifespan (either 1, 2.5 or 3 years per vehicle):
  - NOx: 241 metric tons
  - PM 2.5: 81 metric tons
  - ROG: 49 metric tons
- Over Project-Comparison Lifespan (15 years per vehicle):
  - NOx: 1,350 metric tons
  - PM 2.5: 460 metric tons
  - ROG: 274 metric tons
- Does not include performance decrease over time, other factors

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Summary: Emission Reductions by Vehicle Type

Vehicle Type	Rebate Funding	Number of Rebates	GHG Reductions (*thousand* metric tons of CO_2e) VL/PL/PCL*	Criteria Pollutant Reductions (metric tons) OL/PL/PCL*		
				NOx	PM 2.5	ROG
PHEV	$166,955,961	104,918	VL= 3,600 PL= 836 PCL= 4,655	OL= 183 PL= 75 PCL= 417	OL= 89 PL= 36 PCL= 202	OL= 37 PL= 15 PCL= 85
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BEVx	$16,830,921	6,559	VL= 229 PL= 50 PCL= 296	OL= 16 PL= 6 PCL= 36	OL= 5 PL= 2 PCL= 10	OL= 3 PL= 1 PCL= 7
FCEV	$23,497,001	4,594	VL= 128 PL= 28 PCL= 166	OL= 10 PL= 4 PCL= 24	OL= 3 PL= 1 PCL= 7	OL= 2 PL= 1 PCL= 5
All	$609,094,993	270,637	VL= 9,499 PL= 2,182 PCL= 12,283	OL= 595 PL= 241 PCL= 1,350	OL= 203 PL= 81 PCL= 460	OL= 121 PL= 49 PCL= 274

* *Vehicle life* (VL) = 11.6 years = average age of vehicles in the U.S.; *Project life* (PL) = 1–3 years = rebate-program requirement; *Project-comparison life* (PCL) = 15 years used by other programs; *Ownership life* (OL) = 6.6 years = average ownership length in U.S.

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Summary: Emission Reductions by Rebate Type

Rebate Type	Rebate Funding	Number of Rebates	GHG Reductions (*thousand* metric tons of CO_2e) VL/PL/PCL*	Criteria Pollutant Reductions (metric tons) OL/PL/PCL*		
				NOx	PM 2.5	ROG
Standard Rebate for Individuals	$546,114,651	251,960	VL= 8,950 PL= 2,063 PCL= 11,574	OL= 562 PL= 229 PCL= 1,277	OL= 191 PL= 77 PCL= 433	OL= 114 PL= 46 PCL= 259
LMI Increased Rebate for Individuals	$39,514,685	9,859	VL= 360 PL= 77 PCL= 465	OL= 19 PL= 7 PCL= 44	OL= 8 PL= 3 PCL= 18	OL= 4 PL= 1 PCL= 9
Fleet Rebate**	$23,465,657	8,818	VL= 189 PL= 42 PCL= 245	OL= 13 PL= 5 PCL= 29	OL= 4 PL= 2 PCL= 9	OL= 3 PL= 1 PCL= 6
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* *Vehicle life* (VL) = 11.6 years = average age of vehicles in the U.S.; *Project life* (PL) = 1–3 years = rebate-program requirement; *Project-comparison life* (PCL) = 15 years used by other programs; *Ownership life* (OL) = 6.6 years = average ownership length in U.S.
** Fewer annual VMT assumed for fleet vehicles based on a passenger vehicle average from (FY 2017 Federal Fleet Report)

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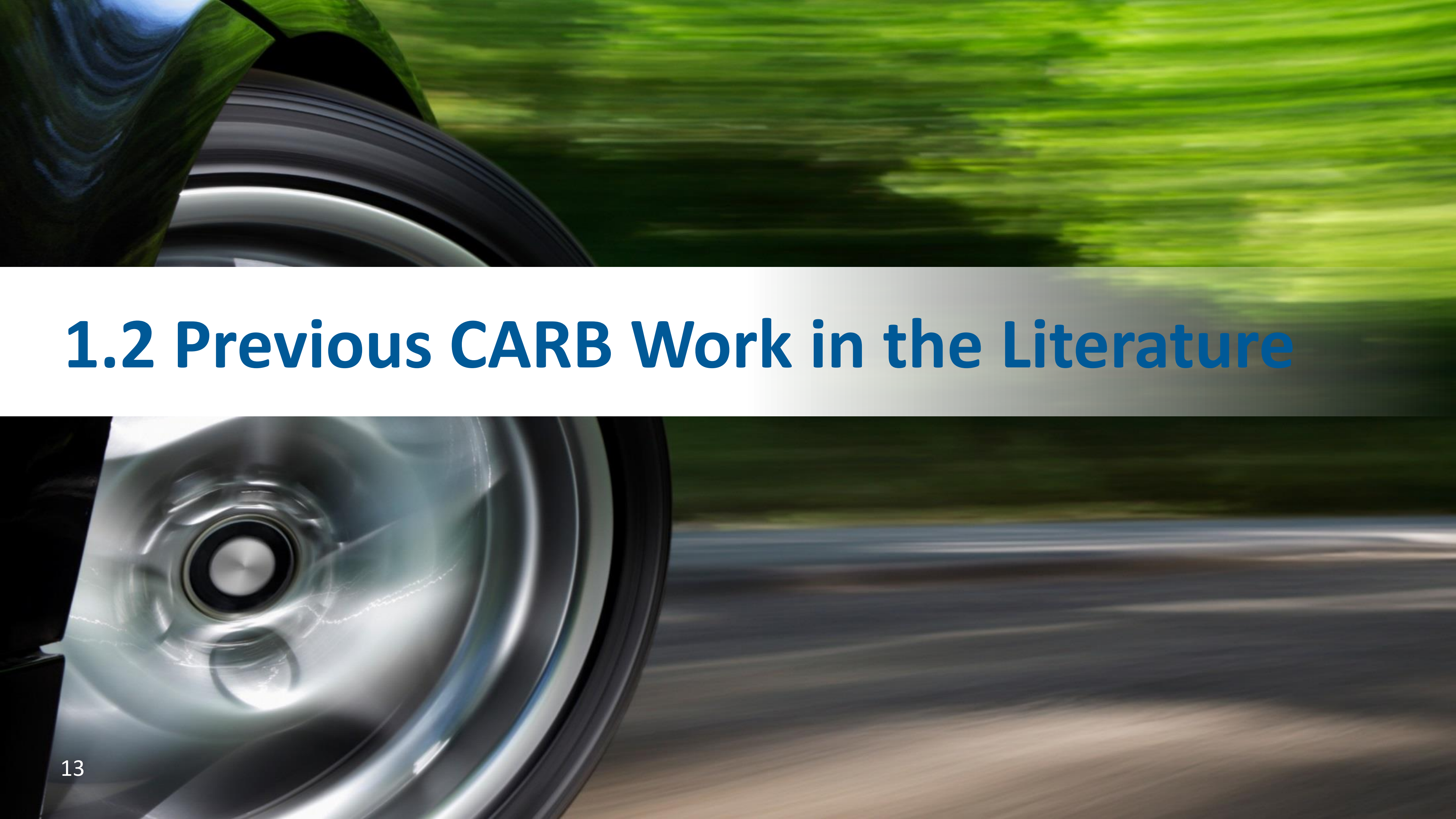
1. INTRODUCTION

Motivation, Previous Work, Contributions, Overview



1.2 Previous CARB Work in the Literature

Average Emission Factor (EF) Per Mile

Baseline gasoline vehicle

$$EF_{gasoline} = f(carbon\ intensity\ of\ gasoline, fleet\ ave.\ gasoline\ consumption)$$

Low Carbon Fuel Standard (LCFS) CA Emissions Factors data (EMFAC)

BEV

$$EF_{BEV} = f(fleet\ ave.\ fuel\ consumption, energy\ economy\ ratio, carbon\ intensity\ of\ electricity)$$

LCFS LCFS

PHEV

40% of VMT on electricity…

The 2017-2018 AQIP Funding Plan provides a description of their quantification methodology for emissions reduction calculations at: https://www.arb.ca.gov/msprog/aqip/fundplan/proposed_1718_funding_plan_final.pdf

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Emissions Reductions

per BEV =

$$(EF_{gasoline} - EF_{BEV}) * Annual\ VMT_{BEV} * \#\ of\ BEVs * 2.5\ years$$

per PHEV =

$$(EF_{gasoline} - EF_{PHEV}) * Annual\ VMT_{PHEV} * \#\ of\ PHEVs * 2.5\ years$$

The 2017-2018 AQIP Funding Plan provides a description of their quantification methodology for emissions reduction calculations at: https://www.arb.ca.gov/msprog/aqip/fundplan/proposed_1718_funding_plan_final.pdf

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1.3 Contributions

1.3 Contribution highlights

- Using disaggregated and project-derived data
  - Fuel economy values corresponding to over 270,000 specific vehicle models rebated
  - Electric VMT values corresponding to over 100,000 specific PHEV models rebated
  - Metrics of rebate influence from nearly 40,000 corresponding survey respondents

- Additional context-specific information incorporated in the form of MY-specific CA sales-weighted baseline fuel economy calculations

3. DATA SUMMARY

Application, Survey, and Vehicle Registration Data

3.1–2 Data Summary (Rebates to Individuals Only*)

CVRP Consumer Survey Data

	2013 2015 Edition	2015 2016 Edition			Total
			PHEVs and BEVs	FCEVs	
Responses				n = 410	n = 40,305
Weighted to represent**				N = 1,749	N = 185,362
Vehicle Purchase/ Leases				Dec. 2010 – May 2017	**PHEVs and BEVs:** Sep. 2012 – May 2017 **FCEVs:** Dec. 2010 – May 2017

CVRP Application Data

	2013 2015 Edition	2015 2016 Edition	PHEVs and BEVs	FCEVs	Total
Total participants assigned	N = 102,997	N = 47,746	N = 106,658	N = 4,418	N = 261,819
Vehicle Purchase/ Leases	Mar. 2009 – May 2015	April 2015 – May 2016	May 2016 – Aug. 2018	June 2010 – Aug. 2018	Mar. 2009 – Aug. 2018

* See Table “Summary: Emission Reductions by Incentive Type” for fleet-data details
**Along the dimensions of vehicle model, county, and buy vs. lease (raking method)

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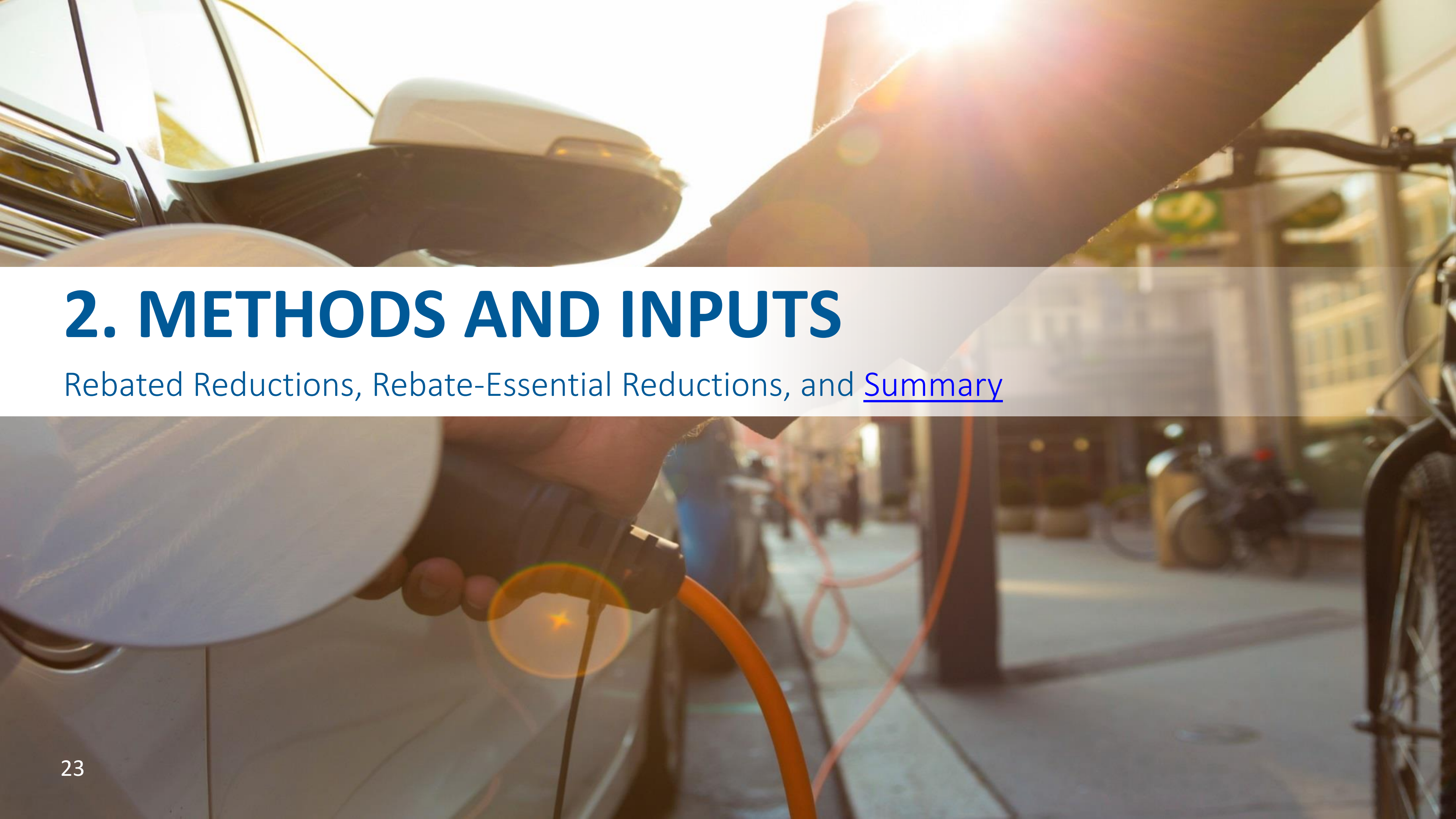
3.3 Vehicle Registration Data

- Monthly new light-duty gasoline vehicle registrations in California from March 2010 through July 2018
- Used for baseline-vehicle sales-weighted fuel economy calculations (MY 2011–2018)



2. METHODS AND INPUTS

Rebated Reductions, Rebate-Essential Reductions, and Summary

2.1 Approach

Background and Approach

Background

- Prior estimates were based upon fleet-average vehicle characterizations as conservative starting point
- We inform that process by utilizing project-specific data through August 2018 (N=270,637 participants) and other forms of disaggregated, context-specific inputs and calculations

Approach

- Low Carbon Fuel Standard carbon intensity values for gasoline, electricity, and hydrogen
- EMFAC2014 criteria pollutant emission factors
- Other factors include: fuel economy, vehicle miles traveled (VMT), electric VMT

Greenhouse-Gas Emissions

$$Emissions_{i,baseline\ or\ rebated} = \sum_{f} (Carbon\ Intensity_{f,y} \times Fuel\ Consumption_{f,m,MY,y} \times Vehicle\ Miles\ Traveled_{d,f,y,bc})$$

Where:

f = fuel = {gasoline, electricity, hydrogen}

y = year of operation

m = vehicle model (utilized here for rebated vehicles only)

MY = model year

d = drivetrain category (technology type) = {gasoline, PHEV, BEV, BEVx, FCEV}

bc = behavior change (not explored here), e.g., household vehicle substitution

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Criteria Pollutant Emissions

$$Emissions_{i,baseline\ or\ rebated} = \sum_{f} (Emission\ Factor_{d,f,MY,y} \times Vehicle\ Miles\ Traveled_{d,f,y,bc})$$

Where:

f = fuel = {gasoline, electricity, hydrogen}

d = drivetrain category (technology type) = {gasoline, PHEV, BEV, BEVx, FCEV}

MY = model year

y = year of operation

bc = behavior change (not explored here), e.g., household vehicle substitution

Emission Reductions

$$Rebated\ reductions = \sum_{i,y} (Emissions_{baseline} - Emissions_{rebated})$$

Where:

i = individual rebated vehicle (N=270,637)

y = year of operation

Total (Lifetime) Emission Reductions

$$Rebated\ Reductions_{\,i,life} =$$
$$Rebated\ Reductions_{\,i,1st-year} \times Life\ (years)_i$$

Where:

- *Vehicle life* (VL) = 11.6 years = average age of vehicles in the U.S. (used for GHGs)
- *Ownership life* (OL) = 6.6 years average ownership length in U.S. (used for criteria pollutants)
- *Project life* (PL)* = 1–3 years = rebate-program requirement (lower bound)
- *Project-comparison life* (PCL) = 15 years used by other programs, for comparison

* 2.5 or 3 years per vehicle for individuals and 1, 2.5 or 3 years per vehicle for fleets, based upon the program's vehicle ownership requirement in place at the time of each vehicle acquisition and fleet ownership provision

2.3 Summary of Inputs, Sources, and Sensitivity

Vehicle Characteristics

Factor	Rebated vehicle	Baseline vehicle
Drivetrain category	**Values*** {PHEV, BEV, BEVx, FCEV}	**Values** {Gasoline}, consistent with (1)
Model year	**Values*** Individual = {MY2009 … MY2019} Fleet = {MY2009 … MY2018}	**Values** Same as rebated vehicle, consistent with (1)

* Rebate application

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Well-to-Wheels Carbon Intensity

Rebated vehicle	Baseline vehicle
Values*	**Values***
Gasoline = 11,406 gCO2e/gal	11,406 gCO2e/gal
Electricity = 379 gCO2e/kWh	
Hydrogen = 11,986 gCO2e/kg	
Sensitivity test (GHG)	
Upper bound: 100% carbon-free electricity and hydrogen	
Sensitivity of reductions (GHG)	
Individuals = +37.7%	
Fleets = +42.6%	

* Low Carbon Fuel Standard

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Fuel Economy

Rebated vehicle	Baseline vehicle
Values* Combined city/hwy EPA-adjusted (when available) rating for each specific vehicle's model/MY	**Values**** • CA-sales-weighted average of combined city/hwy EPA-adjusted ratings for top 30 gasoline models in MYs 2011 – 2018 (MY 2018 value used for partial MY 2019); • EPA-adjusted *production* average for cars for MY 2009, 2010 **Sensitivity test (GHG)***** Change to EPA *production* average incl. light-duty *trucks* or ~ [-10 to -15%] / +15% **Sensitivity of reductions (GHG)** Individuals = -21.6% / +24.3% Fleets = -21.5% / +24.4%

* rebate application for model/MY, (14) for fuel economy values
** calculation using data from (14), (15), (16)
*** (16)

Baseline Vehicle Fuel Economy Value by Model Year

Model Year	Baseline Vehicle Fuel Economy Value (miles per gallon)	Source
2009	25.4	EPA production-weighted
2010	25.8	EPA production-weighted
2011	25.1	EPA/IHS Markit/CSE sales-weighted
2012	27.9	EPA/IHS Markit/CSE sales-weighted
2013	27.9	EPA/IHS Markit/CSE sales-weighted
2014	28.2	EPA/IHS Markit/CSE sales-weighted
2015	28.4	EPA/IHS Markit/CSE sales-weighted
2016	28.7	EPA/IHS Markit/CSE sales-weighted
2017	28.0	EPA/IHS Markit/CSE sales-weighted
2018	28.8	EPA/IHS Markit/CSE sales-weighted
2019	28.8*	EPA/IHS Markit/CSE sales-weighted

*Model year 2018 value used due to limited 2019 data availability
EPA Fuel Economy Trends Report (2009–2010 values): https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100TGDW.pdf
EPA fuel economy data: https://www.fueleconomy.gov/feg/download.shtml
Registration data licensed from IHS Markit

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Annual Vehicle Miles Traveled (VMT)

<table>
<tr><th>Rebated vehicle</th><th>Baseline vehicle</th></tr>
<tr><td>Values*
Individuals = {PHEVs = 14,855; BEVs, BEVxs, FCEVs = 11,059}
Fleets = {PHEVs = 9,207; BEVs, BEVxs, FCEVs = 6,854}
Sensitivity test (GHG)**
Individuals = {PHEVs = 11,122 – 15,283;
BEVs, BEVxs = 7,916 – 13,494; FCEVs = 7,916 – 15,283}
Fleets = {PHEVs = 6,893 – 15,283;
BEVs, BEVxs = 4,906 –13,494; FCEVs = 4,906 – 15,283}
Sensitivity of reductions (GHG)
Individuals = -27.2% / +14.9%
Fleets = -27.5% / +89.0%</td><td>Values
Same as rebated vehicle</td></tr>
</table>

* (8), (9) in (1) for individuals; calculation using data from (FY 2017 Federal Fleet Report) for fleets

** (10), (11), (12) in (13) for individuals; (10), (11), (12) in (13), calculation using data from (FY 2017 Federal Fleet Report) for fleets

PHEV Electric Operation

Rebated vehicle	Baseline vehicle
Values* Model/MY-specific percentage from literature (when available) or regression of electric operation on electric range **Sensitivity test (GHG)*** 12 – 74.5% **Sensitivity of reductions (GHG)** Individuals = -10.6% / +7.5% Fleets = -7.2% / +6.4%	n.a.

* (13), (UCD eVMT Report)

BEVx (BMW i3 REx) Electric Operation

Rebated vehicle	Baseline vehicle
Values* 92% electric fuel **Sensitivity test (GHG)*** +/- 8 percentage points **Sensitivity of reductions (GHG)** Individuals = +/-0.1% Fleets = +/-0.1%	n.a.

* (13)

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Rebate Essentiality

Rebated vehicle	Baseline vehicle
Values* {1,0} for those with survey responses; for others, used the average by tech. type for the corresponding program era**, ranging 41.3% – 66.9%	[applies to case as a whole: emission reductions counted are proportional to rebate-essentiality value (e.g., case excluded if not rebate essential)]

* Survey data (unweighted direct responses and weighted averages)
**Average by tech. type for the corresponding *survey edition* for FCEVs

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Weighted Rebate Essentiality by Survey Edition and Vehicle Category*

Rebate Essential: Would not have purchased/leased their EV without rebate

Vehicle Category	2013–15 Edition	2015–16 Edition	2016–17 Edition
All	46%	56%	57%
BEV (incl. BEVx)	50%	61%	64%
PHEV	41%	47%	47%
FCEV	N/A	N/A	67%

* Specific to this analysis; see details of trimmed dataset

Criteria Pollutants: Emission Factor Assumptions

Model year-specific light-duty gasoline and electric emission factors from EMFAC2014 where:

Factor	Value
Year of operation*	Model year + 1
PHEV tailpipe factors*	Gasoline factors x 0.48
BEVx tailpipe factors	PHEV factors x 0.08
FCEV tailpipe factors	Treated as electric
Rebated brake wear factors*	Gasoline brake wear factor x 0.5

*Consistent with (1)

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Criteria Pollutants: Tank-to-Wheels Emission Factors

Model Year	Gasoline			PHEV			BEV and FCEV			BEVx		
	NOx	PM 2.5	ROG	NOx	PM 2.5	ROG	NOx	PM 2.5	ROG	NOx	PM 2.5	ROG
2009	0.0370	0.0180	0.0078	0.0178	0.0100	0.0037	0.0000	0.0099	0.0000	0.0014	0.0099	0.0003
2010	0.0384	0.0181	0.0079	0.0184	0.0100	0.0038	0.0000	0.0099	0.0000	0.0014	0.0099	0.0003
2011	0.0384	0.0182	0.0079	0.0184	0.0101	0.0038	0.0000	0.0099	0.0000	0.0014	0.0099	0.0003
2012	0.0384	0.0184	0.0079	0.0184	0.0102	0.0038	0.0000	0.0099	0.0000	0.0014	0.0099	0.0003
2013	0.0384	0.0187	0.0079	0.0184	0.0103	0.0038	0.0000	0.0099	0.0000	0.0014	0.0099	0.0003
2014	0.0384	0.0191	0.0079	0.0184	0.0105	0.0038	0.0000	0.0099	0.0000	0.0014	0.0099	0.0003
2015	0.0366	0.0194	0.0075	0.0176	0.0107	0.0036	0.0000	0.0099	0.0000	0.0014	0.0099	0.0003
2016	0.0338	0.0196	0.0068	0.0162	0.0108	0.0033	0.0000	0.0099	0.0000	0.0013	0.0099	0.0003
2017	0.0313	0.0198	0.0063	0.0150	0.0109	0.0030	0.0000	0.0099	0.0000	0.0012	0.0100	0.0002
2018	0.0281	0.0199	0.0056	0.0135	0.0109	0.0027	0.0000	0.0099	0.0000	0.0011	0.0100	0.0002
2019	0.0259	0.0198	0.0051	0.0124	0.0109	0.0025	0.0000	0.0099	0.0000	0.0010	0.0100	0.0002

6. SUMMARY

Summary: GHG Results (part 1)

- Over Vehicle Lifespan (11.6* years per vehicle):
  - 9.5 million tons or 36 tons per individual and 21** tons per fleet vehicle
  - Individuals (tons): 34.7 per PHEV, 36.4 per BEV, 35.4 per BEVx, 28.4 per FCEV
  - Fleets** (tons): 20.3 per PHEV, 22.1 per BEV, 21.9 per BEVx, 16.8 per FCEV
  - 53% of individual reductions from "Rebate-Essential" participants
  - $64 per ton avoided (15.6 kg of CO2e per rebate $)
- Over Project Lifespan (either 1, 2.5 or 3 years per vehicle):
  - 2.2 million tons or 8.2 tons per individual and 4.8** tons per fleet vehicle
  - Individuals (tons): 8.0 per PHEV, 8.3 per BEV, 7.7 per BEVx, 6.1 per FCEV
  - Fleets** (tons): 4.7 per PHEV, 4.8 per BEV, 4.8 per BEVx, 3.6 per FCEV
  - $279 per ton avoided (3.6 kg of CO2e per rebate $)

* (6) [references provided at end of presentation]

** Fewer annual VMT assumed for fleet vehicles based on a passenger vehicle average from (FY 2017 Federal Fleet Report)

Summary: GHG Results (part 2)

- Over Project-Comparison Lifespan (15 years per vehicle):
  - 12.3 million tons or 46 tons per individual and 28** tons per fleet vehicle
  - Individuals (tons): 45 per PHEV, 47 per BEV, 46 per BEVx, 37 per FCEV
  - Fleets** (tons): 26 per PHEV, 29 per BEV, 28 per BEVx, 22 per FCEV
  - $50 per ton avoided (20 kg of CO2e per rebate $)
- Do not include grid decarbonization over time, other factors
- Partial use of project-derived data increased savings by >20% (so far) for individual MY 2017 BEVs and PHEVs

* (6) [references provided at end of presentation]

** Fewer annual VMT assumed for fleet vehicles based on a passenger vehicle average from (FY 2017 Federal Fleet Report)

Summary: GHG Sensitivity Analysis

- Substantial uncertainty remains
  - Summing the impacts of using extreme low values or extreme high values indicates results bounded between:
    - -59% and +47% for individuals
    - -56% and +120% for fleets
- Most sensitive to:
  - Baseline fuel economy
    - -22% to +24% for both individuals and fleets
  - VMT
    - -27% to +15% for individuals
    - -28% to +89% for fleets
- Upside potential of 100% carbon-free electricity and hydrogen for individuals and fleets is +38% and +43%, respectively

Summary: Criteria Pollutant Results

- Over Ownership Lifespan (6.6 years per vehicle):
  - NOx: 595 metric tons
  - PM 2.5: 203 metric tons
  - ROG: 121 metric tons
- Over Project Lifespan (either 1, 2.5 or 3 years per vehicle):
  - NOx: 241 metric tons
  - PM 2.5: 81 metric tons
  - ROG: 49 metric tons
- Over Project-Comparison Lifespan (15 years per vehicle):
  - NOx: 1,350 metric tons
  - PM 2.5: 460 metric tons
  - ROG: 274 metric tons
- Does not include performance decrease over time, other factors

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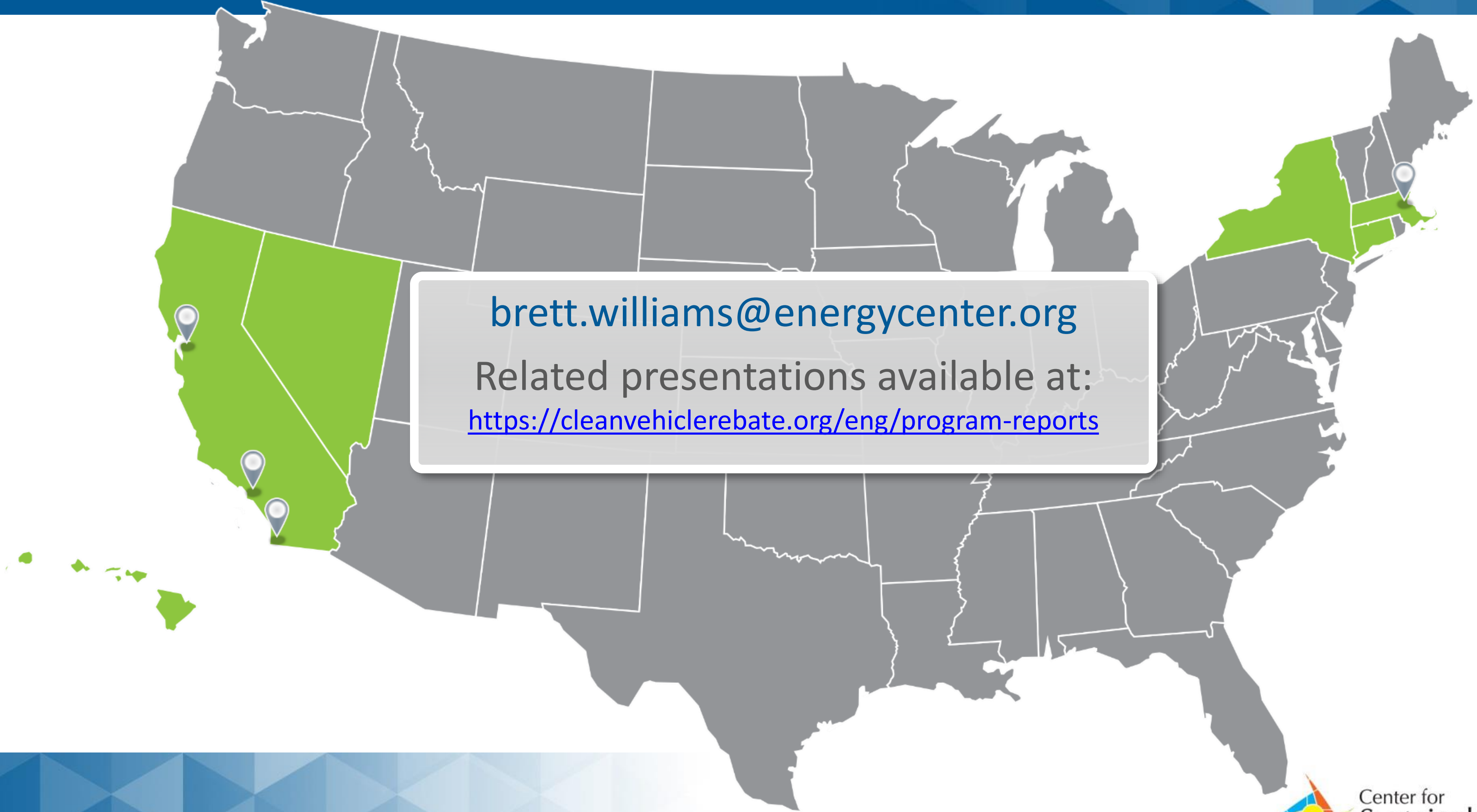
Thank you for your attention.



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Related presentations available at:

https://cleanvehiclerebate.org/eng/program-reports

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UCD eVMT Report	UC Davis. "Advanced Plug-in Electric Vehicle Travel and Charging Behavior Final Report .” [Online].; 2019.

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APPENDIX

TRB Presentation Content (that has not been updated)

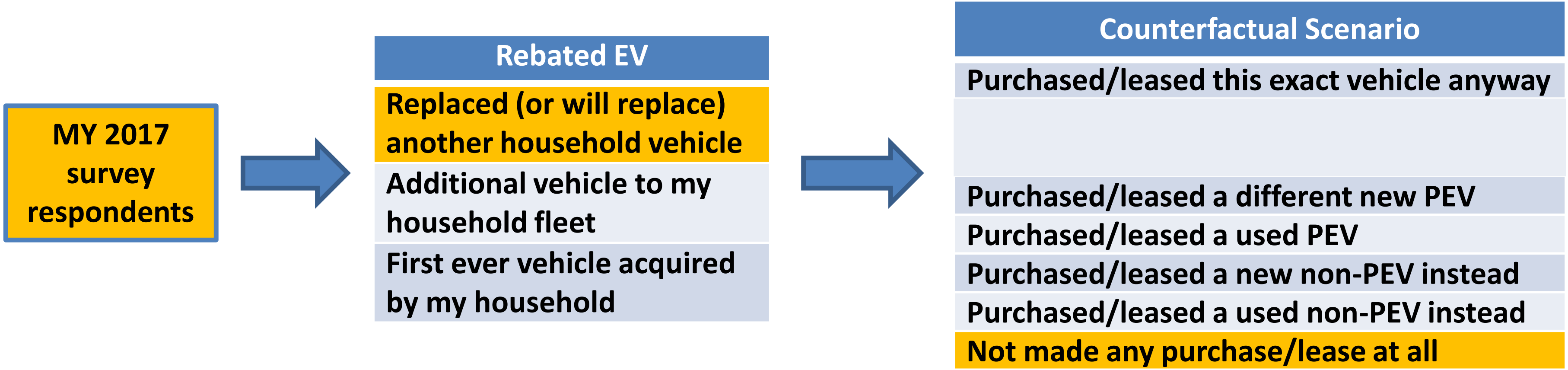
Rebate Essentiality

Rebated vehicle	Baseline vehicle
Values* {1,0} for those with survey responses; for others, used the average by tech. type for the corresponding program era, ranging 41.3%–63.6% **Sensitivity test** +/- margin of error (ranging from 1.2 to 2.2 percentage points) **Sensitivity of reductions** +/- 2.6%	[applies to case as a whole: emission reductions counted are proportional to rebate-essentiality value (e.g., case excluded if not rebate essential)]

* Survey data (unweighted direct responses and weighted averages)

Preliminary Counterfactual Vehicle Analysis

- **Re-assigned counterfactual fuel economy averages based on specific vehicles replaced** (next slide)
- Other response combinations were unchanged (2017 gasoline fuel economy)
- Non-respondents were assigned the average per-vehicle emissions of the new counterfactual fleet (by rebated vehicle category/survey edition)



Replaced Vehicle Fuel Economy Assignment

	Gasoline	Diesel	HEV	PHEV	BEV	Flex-fuel/E85	CNG	FCEV
MY 1994 or earlier–2010	MY-specific production-weighted ave. for cars ("1994 or earlier" assigned MY 1994 value)	2011 CA-sales-weighted ave. fuel economy				Treated as non-respondents		
MY 2011–2017	MY-specific CA-sales-weighted ave. of top 30 gasoline models	MY-specific CA-sales-weighted ave. of all models						

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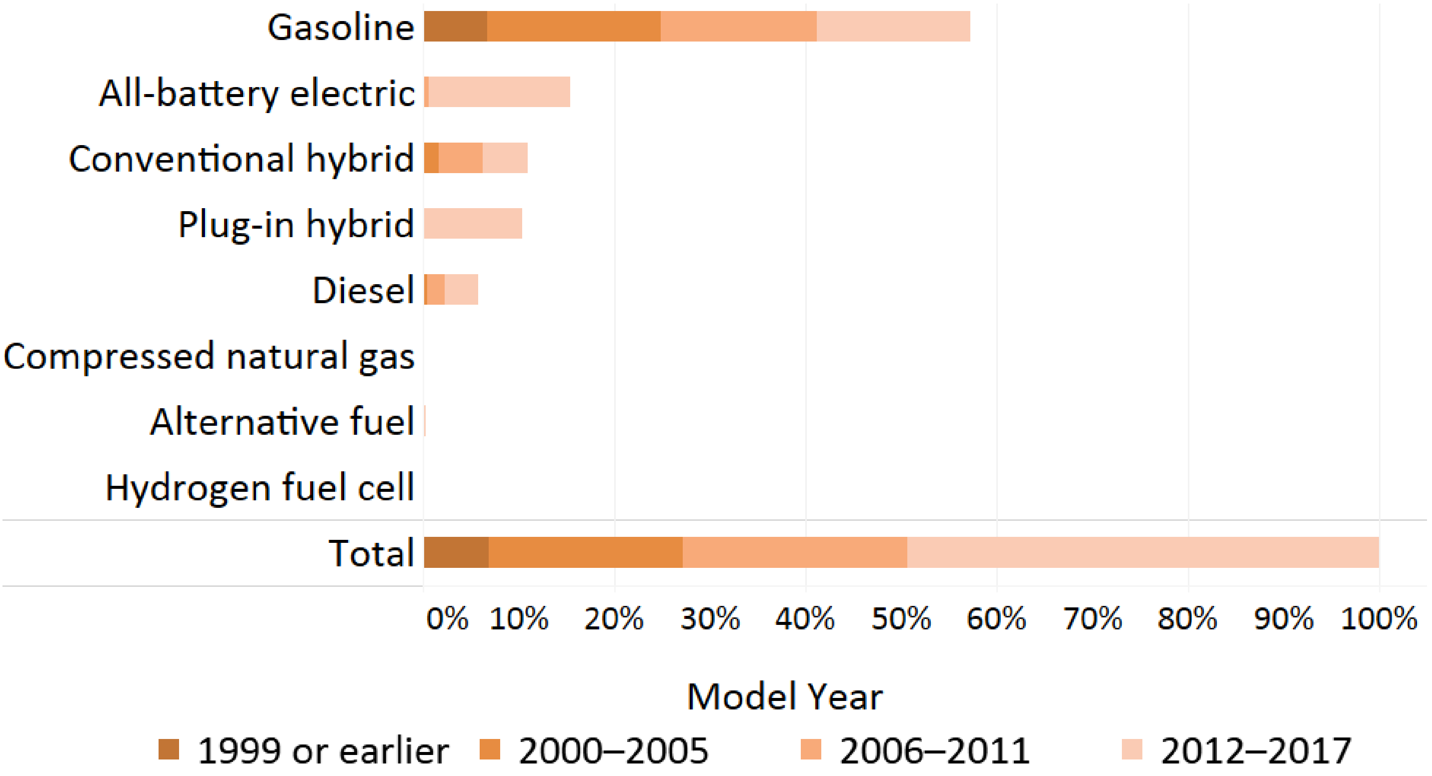
Additional Project Data: Counterfactual Purchase Behavior

- Result: per-vehicle 1st-year reduction +19% vs. Funding Plan
  - Down from +21%: recently replaced vehicles may be less-emitting than average new gasoline vehicles

What vehicle types have rebates helped replace?
Current Program



CVRP Consumer Survey. ***2016–2017*** edition, **trimmed to start *November 2016***,
PEV respondents only, weighted, n=4,695

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