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CALIFORNIA'S POLICY APPROACH TO REDUCING MOBILE SOURCE EMISSIONS

A Qualitative Evaluation

JUNE 2023

Policy Report

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ABOUT THIS REPORT

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CONTENTS

FIGURES & TABLES

I. EXECUTIVE SUMMARY

In order to reduce air pollution and achieve California's greenhouse gas emissions reduction goals, the California Air Resources Board (CARB) has developed a policy mix of regulations and incentive programs to target emissions from on-road vehicles. Policy experts consider this mix to be crucial for the state to achieve its long-term goals to cut greenhouse gas emissions by 85% below 1990 levels and achieve carbon neutrality by 2045.

In February 2021, the California State Auditor (CSA or "Auditor") published a report titled "Improved Program Measurement Would Help California Work More Strategically to Meet Its Climate Change Goals" that contained a review of CARB's policy mix approach related to transportation and assessed its effectiveness in encouraging changes in consumer behavior, advancing social equity, and achieving further greenhouse gas emissions reductions. The report concluded that CARB's accounting mechanisms have overstated the impact of its programs and that its failure to collect relevant program data greatly limits its ability to inform the legislature and other stakeholders about whether the programs are effective. The Auditor's report ultimately recommended that CARB officials make efforts to better estimate the precise greenhouse gas emissions reductions (as well as other potential co-benefits, like jobs and socioeconomic impacts) from each individual transportation program.

Following the Auditor's report, CARB contracted with the Center for Law, Energy and the Environment (CLEE) at the University of California (UC) Berkeley School of Law, along with the Plug-In Hybrid & Electric Vehicle Research Center at UC Davis and Transportation Sustainability Research Center at UC Berkeley. Together, these research groups are developing a methodology to analyze and calculate emissions reductions and other impacts retrospectively

from specific CARB programs, as well as recommending methodologies and data collection for assessment in the future. The final report from the UC research team will be available in late 2023. In the interim, this white paper summarizes California's policy mix approach to decarbonizing transportation and the known impacts to date and responds to several findings and recommendations by the Auditor.

CARB has developed a mix of incentive and regulatory programs to achieve greenhouse gas emissions reduction, market acceleration of zero emission vehicle (ZEV) deployment, and improved access to ZEVs in priority populations.[1] These programs are designed to work in concert, as no single approach is likely sufficient to achieve such a significant transformation of the transportation sector. The regulatory programs help ensure that manufacturers produce and supply ZEVs to the market and establish new greenhouse gas (GHG) emissions standards for a variety of vehicles. The incentive programs then help spur demand for these products by encouraging consumers and fleet operators to purchase or lease ZEVs and promote access by reducing costs for consumers who cannot afford costly new technologies.

For purposes of this report, "ZEV" includes both battery-electric and hydrogen fuel cell vehicles (as well as plug-in hybrid electric vehicles [PHEVs], to the extent that the California policies discussed in this report included these models within their scope). However, given the dominance of battery-electric vehicles in the light duty market to date, this report predominantly refers to battery-electric vehicles when using the term ZEV.

CARB's regulatory programs in this study's scope of work include:

- **Zero-emission Vehicle Regulation ("ZEV Regulation")**: requires vehicle manufacturers to produce and sell an annually increasing number of light-duty ZEVs
- **California Phase 1 & 2 Greenhouse Gas Standards**: promote production of cleaner, more fuel-efficient trucks by encouraging the development and deployment of new and advanced cost-effective technologies

CARB's incentive programs in this study's scope of work include:

- **Clean Vehicle Rebate Project (CVRP)**: provides incentives for the purchase or lease of eligible new vehicles with an increased rebate for lower-income consumers and public fleets located in disadvantaged communities
- **Clean Cars 4 All (CC4A)**: provides incentives for scrapping older, higher polluting vehicles and replacing them with eligible used or new vehicles; the program is available in select air districts for low-income consumers and disadvantaged communities

1. Priority populations include disadvantaged communities (DACs), low-income communities, and low-income households. DACs are defined as the top 25% of communities experiencing disproportionate amounts of pollution, environmental degradation, and socioeconomic and public health conditions according to the CalEnviroScreen tool (https://oehha.ca.gov/calenviroscreen). Low-income communities and households are those with incomes either at or below 80% of the Statewide median or below a threshold designated as low-income by the Department of Housing and Community Development.

- **Clean Vehicle Assistance Program (CVA Program)**: helps lower-income Californians overcome barriers to financing for eligible new and used vehicles by providing low-interest loans and price buy-downs
- **Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP)**: incentivizes eligible commercially available zero-emission, hybrid, or cleanest combustion technologies through point-of-purchase price reductions

These ZEV programs have contributed to a significant and increasing market transformation. For example, according to an analysis by CARB, over its 32-year life, the state's light-duty ZEV regulation has helped spur the sale of approximately 916,000 vehicles (as of 2021), including 588,200 battery-electric vehicles (BEVs) and range-extended vehicles, 12,700 fuel cell electric vehicles, and 314,700 plug-in hybrid electric vehicles. Although the UC research team cannot attribute all of these sales solely to CARB programs, relevant studies have found an association between the presence of a ZEV regulation and the strength of the ZEV market.

Based on this qualitative analysis, it is evident that CARB's light-duty ZEV regulation and incentive programs have likely helped increase access to ZEVs in priority populations. By accelerating manufacturer production of ZEVs and providing consumer rebates and incentives for purchase, these programs have stimulated the availability of first-generation ZEVs and fostered the growth of the used ZEV market, making ZEVs more affordable and attainable for all buyers. On the heavy-duty side, the agency's clean truck regulations and incentives are likely to improve public health statewide, particularly in disadvantaged communities given that truck emissions disproportionately occur in low-income neighborhoods and communities of color.

The ongoing ZEV market transformation in California has had far-reaching implications, extending beyond the state's borders, impacting various related industries and markets. Notably, the resale of these vehicles outside California shapes their acceptance and adoption in wider markets, showcasing the broader significance and interconnectedness of California's ZEV initiatives. It has also led to significant "second-order" effects beyond greenhouse gas emissions reduction. For example, the light-duty ZEV regulation and CVRP have helped create and expand a used ZEV and plug-in hybrid-electric vehicle (PHEV) market. Further, increases in vehicle sales have effects that go beyond reducing manufacturing costs, such as increasing dealer and consumer familiarity and building robust supply chains necessary for innovation. CARB's regulatory and incentive programs also indirectly result in increased funding for the deployment of ZEV charging infrastructure. Since charging a growing number of ZEVs requires a robust network of charging infrastructure, the market acceleration of ZEVs through CARB's incentive and regulatory programs has substantially increased the demand for ZEV charging infrastructure across the state and the country. California has also supported consumer education and outreach efforts that increase ZEV awareness and interest in ZEV uptake.

The impacts of the aforementioned actions are likely to extend beyond California as other states or jurisdictions adopt or develop similar regulations and incentives, following California's state regulatory authority granted under

the Federal Clean Air Act. These second order impacts likely further reduce the state's greenhouse gas emissions beyond even the direct effects, though policy makers will need additional analysis to verify and quantify. It is important to note that the State Auditor's Report, which claims that CARB "...overstated greenhouse gas emissions reductions its incentive programs achieve" did not take into account these second-order effects, which are crucial but inherently difficult to quantify. The subsequent quantitative analysis by the research team will further explore this question.

While these CARB programs all contribute to greenhouse gas emissions reductions, analysts face difficulty quantifying their impacts because of the programs' interrelated nature, their second-order impacts, and market behaviors that are influenced by but may not directly result from the programs. As described below, the UC research team recommends that state leaders could potentially improve their impact evaluations through further analysis of existing sales data, such as by geography, customer class, and time, and by comparing California's results with experiences in different jurisdictions that use varying policy approaches to improve ZEV deployment.

To better estimate and quantify impacts from specific ZEV programs, CARB has two options: (1) further analyze existing sales and vehicle registration data, comparing ZEV purchases in California to other states with ZEV programs and those without such programs; (2) collect and analyze more data on consumer decision-making involving ZEVs. In other words, causal analysis of programs like Clean Cars for All would require combining the existing vehicle registration data with sociodemographic information. In support of this claim, the forthcoming quantitative research for this project will demonstrate this and provide suggestions for the possible causal analysis methods. In some cases, however, when the analysis is dependent on survey data, the data may not be available, can be confidential, incomplete, or unrepresentative. These data issues, combined with the fact that consumers can be simultaneously eligible for multiple incentive programs (such as the federal tax credit and the CVRP along with other local rebates and incentives), make it impossible to fully disentangle the precise impacts of specific programs with the current survey data. Going forward, the research team recommends enhanced data collection that could better inform these estimates, while acknowledging the inherent challenge and limitations of results.

The challenges in determining the impacts of individual programs are twofold:

- The programs rely on each other for success, as an incentive without vehicle supply is worthless and vehicle supply may not be enough without incentives to help consumers offset any higher upfront costs.
- Given the complexity of consumer decision making and the lack of comprehensive survey data, the UC research team cannot precisely determine how much of a ZEV sale or lease is due to any particular CARB program.

II. INTRODUCTION

The California Air Resources Board (CARB) is responsible for setting and achieving California's ZEV deployment goals. On August 25, 2022, CARB approved the Advanced Clean Cars (ACC) II rule, establishing a year-by-year roadmap so that by 2035, 100% of new cars and light trucks sold in California will be ZEVs, defined as zero tailpipe emissions vehicles and plug-in hybrid-electric vehicles.[2] Governor Gavin Newsom laid the foundation for the rule with Executive Order N-79-20, which directed CARB to initiate a rulemaking to achieve the 2035 target for light-duty vehicles, alongside new targets for heavy-duty vehicles and state fleets.[3]

CARB leaders approach the internal combustion engine (ICE) phaseout goal with a long history of regulatory innovation designed to accelerate the market for ZEVs. Pursuant to the agency's authority to regulate tailpipe emissions under the federal Clean Air Act, CARB has launched various initiatives to boost ZEV technology development and sales, most prominently the ZEV Regulation for automakers, along with multiple incentive programs. Given that transportation accounts for almost half of California's greenhouse gas emissions (when including industrial emissions from petroleum production),[4] CARB's regulatory programs are crucial to the state achieving its long-term

2. CARB, "California moves to accelerate to 100% new zero-emission vehicle sales by 2035', available at https://ww2.arb.ca.gov/news/california-moves-accelerate-100-new-zero-emission-vehicle-sales-2035.

3. "Executive Department State of California, Executive Order N-79-20", available at https://www.gov.ca.gov/wp-content/uploads/2020/09/9.23.20-EO-N-79-20-Climate.pdf.

4. CARB, "Current California GHG Emission Inventory Data" (2021), available at https://ww2.arb.ca.gov/ghg-inventory-data.

greenhouse gas emissions reduction goals to cut emissions by 85% below 1990 levels and achieve carbon neutrality by 2045.

In February 2021, the California State Auditor identified flaws regarding how CARB accounts for emissions reductions from its transportation-related programs, including ZEV regulatory and incentive programs that the agency has promulgated. In the report *California Air Resources Board: Improved Program Measurement Would Help California Work More Strategically to Meet Its Climate Change Goals*, the Auditor assessed eight of CARB's regulatory programs and nine incentive programs. The authors determined that CARB's methodologies for estimating emissions reductions were "generally reasonable on a program-by-program basis."[5] However, the report noted that the agency failed to account for the "potential overlap" in measuring each program's individual greenhouse gas emissions reduction impact. It further stated that because CARB assumes that all vehicle purchases supported by its incentives would not otherwise have occurred, the agency "overstates the incentive programs' greenhouse gas emissions reductions" to an unknown extent.[6]

The Auditor's report ultimately recommended that CARB officials better estimate the exact greenhouse gas emissions reductions (as well as other potential co-benefits, like jobs and socioeconomic impacts) from each individual transportation program. In addition, going forward, the Auditor recommended that CARB staff improve their data collection to verify these benefits and emissions reductions under a more comprehensive and tailored tracking methodology.

CARB contracted with the Center for Law, Energy and the Environment (CLEE) at UC Berkeley School of Law, along with the Plug-In Hybrid & Electric Vehicle Research Center at UC Davis and Transportation Sustainability Research Center, to develop a methodology to analyze and calculate emissions reductions and other impacts retrospectively from specific CARB programs and to recommend methodologies and data collection for assessment in the future. The final report is due toward the end of 2023.

The research team is currently assessing the available data on ZEV purchases, including consumer behavior, automaker sales, and infrastructure deployment, among others, to help make these retrospective determinations. Some of the data, however, is confidential, unavailable, or incomplete. Other data, as well as examples from other jurisdictions, does exist, is accessible, and is informative for this analysis. In addition, the team is developing methodologies to help CARB more accurately quantify impacts and emissions reductions prospectively.

Making a precise quantitative determination of the effect of an individual or multiple incentive programs on purchases of ZEVs requires knowledge of consumer decision-making and behavior which can be difficult or impossible to measure. Furthermore, because the various ZEV programs work in concert,

5. California State Auditor (CSA), *Improved Program Measurement Would Help California Work More Strategically to Meet Its Climate Change Goals* (2021), available at: http://auditor.ca.gov/pdfs/reports/2020-114.pdf.

6. *Id.*

the role of any one policy is impossible to disentangle with precision from among various consumer and business decisions to purchase or lease ZEVs.

The research question of how CARB's ZEV programs influence consumer decisions is valuable not just to meet the Auditor's request, but also could help improve the effectiveness of CARB's program design going forward. In addition, future recommendations for new data collection can inform better, more targeted policymaking by CARB and other jurisdictions seeking to boost ZEV sales. While some of that data may be impossible to collect, either because it is confidential or unobtainable from a representative sample of consumers, some of it may be feasible to gather and analyze. As a result, California could use the data to improve its policy approach, and in the process provide other jurisdictions with a potential model for improved policy analysis and assessment.

BACKGROUND ON CALIFORNIA'S GREENHOUSE GAS EMISSIONS QUANTIFICATION

California has enacted several laws to decrease the state's greenhouse gas emissions, such as Assembly Bill 32 (Nuñez, 2006), Senate Bill 32 (Pavley, 2016), and Assembly Bill 1279 (Muratsuchi, 2022), as well as various programs to help achieve them. For example, state leaders designed the Cap-and-Trade program to reduce greenhouse gas emissions from major industrial sources by requiring them to bid for allowances to pollute while using the proceeds to fund off-site measures that are in addition to the regulatory requirements of the Cap-and-Trade program. This program complements other initiatives to ensure that California cost-effectively meets its goals for greenhouse gas emissions reductions.[7]

In order to estimate the greenhouse gas emissions reductions and co-benefits of programs, CARB develops model tools and quantification methodologies. For example, the EMission FACtor (EMFAC) emissions inventory model estimates emission factors of on-road vehicles, which are rates of emissions per mile driven, and vehicle miles driven. CARB uses EMFAC to calculate statewide or regional emissions inventories, using California vehicle emissions and activity data to create a model tailored to California's vehicle use patterns.[8] CARB regularly updates the model to account for increasingly complex technological solutions, with the last update in 2021. The EMFAC model can be used to create custom emissions projections by vehicle type, vehicle year, and engine technology. For incentive projects funded by the California Climate Investments, CARB develops quantification methodologies to estimate the outcomes of the proposed projects and track the results of the funded projects. Specifically, CARB staff uses EMFAC, along with well-to-wheel carbon intensities developed for the Low Carbon Fuel Standard, to calculate potential greenhouse gas and air quality benefits from individual projects.

7. CARB, "Cap-and-Trade Program" (webpage), available at https://ww2.arb.ca.gov/our-work/programs/Cap-and-Trade-program.

8. CARB, *EMFAC2021 Volume III Technical Document* (2021), p.14, available at https://ww2.arb.ca.gov/sites/default/files/2021-08/emfac2021_technical_documentation_april2021.pdf.

For the ACC II regulations, CARB estimated emissions benefits by comparing emissions against a business-as-usual (BAU) baseline. The BAU baseline is based on California's current emissions inventory, accounting for any existing state and federal regulations. Staff estimate the per-vehicle emissions difference between the average regulated and non-regulated vehicle. CARB calculates the tank-to-wheel emissions using the EMFAC2021 model and the well-to-tank emissions using the California VISION model. These total emissions are summed over the expected vehicle sales, and the nitrogen oxides, particulate matter, and greenhouse gas emissions calculated in CO_2 equivalent units. Since the EMFAC model is unable to calculate CO_2 equivalent emissions directly, staff estimated CO_2 equivalent emissions based on the historical relationship between the EMFAC model and the emission of CO_2.[9]

For the California Phase 2 GHG emissions standards, CARB estimated emissions benefits by comparing vehicle emissions against a scenario with no GHG regulation model and Phase 1 standards. The "no GHG regulation" model is based on California's current emissions inventory without Phase 1 benefits, while the Phase 1 model is part of EMFAC 2014, the inventory used for the rulemaking analysis. In 2018, CARB calculated the projected emissions reduction for California Phase 1 GHG emissions standards using the EMFAC2014 model.[10]

To measure California's overall progress in reducing greenhouse gas emissions and to establish historical trends, the state compiles an annual statewide greenhouse gas emissions inventory. Per California Health and Safety Code Section 39607.4, CARB is responsible for maintaining and updating California's greenhouse gas inventory.[11] The inventory, along with the data collected through various California Global Warming Solutions Act (AB 32) programs, demonstrates the state's progress in achieving the statewide greenhouse gas reduction targets. As per the inventory, California reduced statewide emissions below the 2020 target of 431 million metric tons of CO_2 equivalent ($MMTCO_2e$) in 2014 and consistently maintained emissions levels below that threshold, reaching a low of 369.2 $MMTCO_2e$ in 2019.[12] It also provides estimates of anthropogenic greenhouse gas emissions within California, as well as emissions associated with imported electricity (natural sources are not included in the inventory).

This white paper, like CARB's emissions inventory, follows Health and Safety Code Section 38505, which identifies seven greenhouse gases that CARB is responsible to monitor and regulate in order to reduce emissions: carbon dioxide, methane, nitrogen oxide, hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride, and nitrogen trifluoride.

9. CARB, *"Advanced Clean Cars II Final Statement of Reasons, Appendix F"* (2022), p. 8, available at https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/fsorappf.pdf.

10. CARB, *"California Phase 2 Initial Statement of Reasons, Appendix F"* (2018), available at https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2018/phase2/appf.pdf.

11. 17 Cal. Code Regs. § 95161.

12. CARB, "California Greenhouse Gas Emissions for 2000 to 2020: Trends of Emissions and Other Indicators", available at https://ww2.arb.ca.gov/sites/default/files/classic/cc/inventory/2000-2020_ghg_inventory_trends.pdf

The process of estimating benefits requires significant assumptions that CARB acknowledges. First, the agency quantifies emissions reductions based on projections, as actual vehicle models may not be known. Additionally, the agency assumes that every recipient of incentives receives the maximum incentive possible under that program. For example, CARB assumes that if a participant lives in a disadvantaged community and participates in the CVA Program to purchase a ZEV, then the participant would also receive a ZEV charge card through the program. All CARB incentive programs also have a time-based ownership requirement, and the agency quantifies total emissions reductions over the course of that ownership period, which likely serves to underestimate the benefits, as ZEVs continue to generate emissions benefits beyond the CARB-defined ownership period; for example CVRP bases its emissions reductions on a 30 month ownership period, which is the minimum lease term required by the program.[13] Most significantly, however, the methodology sums the emissions difference between a ZEV bought using the incentive program and a conventional ICE vehicle of the latest model year.

13. Clean Vehicle Rebate Project, "CVRP Terms and Conditions" (webpage), available at https://cleanvehiclerebate.org/en/terms-and-conditions.

III. CARB'S COMPLEMENTARY POLICY APPROACH

Over the last decade, governments in key ZEV markets around the world have adopted a variety of supportive policies and incentives for electric vehicles (BEV and PHEV). Collectively they have played a major role in the expansion of BEV and PHEV models.[14] This policy mix has been critical to increasing the availability and accessibility of more light-, medium- and heavy-duty vehicle models (this report defines a "policy mix" as the presence of multiple policies in the same region, during the same time period, to achieve the same goal[15]). By contrast, a single-policy approach is likely insufficient to achieve these goals in a timely and efficient manner. A comprehensive study by Rogge *et al.* in 2017 analyzed 15 papers on policy mixes with different analytical perspectives drawn from a range of social science disciplines, describing how policy makers increasingly recognize that an integrative mix of policies is more effective than a single policy approach in fostering a successful market transition.[16]

California's ZEV policy mix is driven largely by manufacturer regulations combined with financial and non-financial incentives. Regulatory

Regulatory programs ensure that manufacturers produce and supply electric vehicles to the market. Incentive programs spur demand for these vehicles by offsetting their upfront costs.

14. International Energy Agency (IEA), *Global EV Outlook 2020* (2020), available at https://www.iea.org/reports/global-ev-outlook-2020.

15. Jonn Axsen et al., "Crafting Strong, Integrated Policy Mixes for Deep CO2 Mitigation in Road Transport", Nature Climate Change (2020), available at https://www.nature.com/articles/s41558-020-0877-y.

16. Karoline Rogge et al., "Conceptual and Empirical Advances in Analyzing Policy Mixes for Energy Transitions," Energy Research & Social Science (2017), available at https://www.sciencedirect.com/science/article/pii/S2214629617303092#bib0100.

programs ensure that manufacturers produce and supply vehicles to the market (e.g., the ZEV regulation). Incentive programs spur demand by further enhancing the benefits of a ZEV purchase or lease and offsetting some of their less desirable characteristics (such as upfront costs, range, or charging times). CARB's incentive program mix seeks to strike a balance of investment across technologies, stages of market development, and vehicle applications that provide cost-effective, near-term emissions benefits and long-term, transformative zero-emission technologies to ensure cost-effective applications in new segments of the transportation sector. Both near-term and long-term emissions reduction incentive programs are needed to foster continued ZEV market growth to meet national ambient air quality standards and California's climate goals.

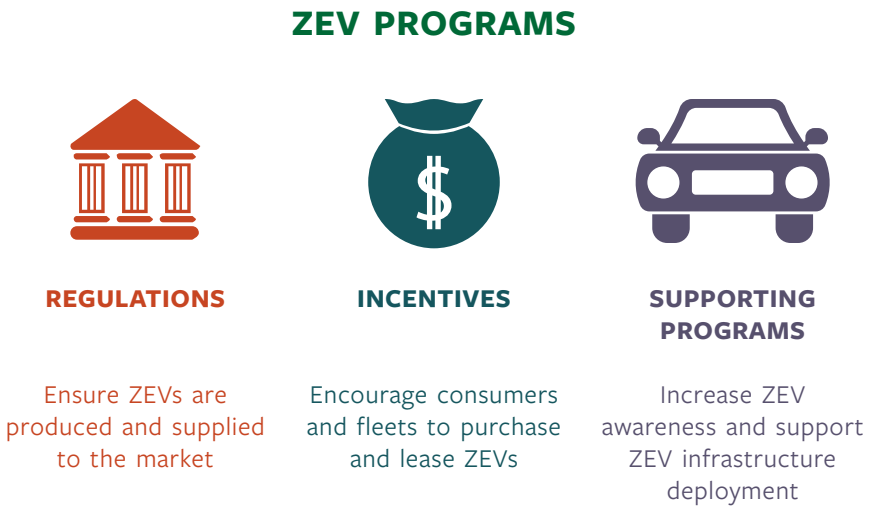

Figure 1: Synergy between CARB's ZEV Programs. Source: Adapted from CARB[17]

CARB ensures the production of ZEVs and a backbone for a light-duty ZEV market through the ZEV regulation, which sets annually increasing ZEV sales targets for manufacturers. Manufacturers that sell light-duty vehicles in California must produce a minimum number of ZEVs or purchase ZEV credits.[18] CARB awards credits based on the type and range of the vehicle sold. Manufacturers generate credits (and demonstrate compliance) by producing a ZEV and delivering that vehicle to a dealer. If a manufacturer produces and delivers fewer ZEVs than required to meet its ZEV credit obligation in a given model year, it must make up the deficit by the next model year. If they fail to do so, they can avoid penalties for noncompliance by purchasing credits from other automakers.

CARB's light-duty vehicle incentive programs (summarized in Tables 1 and 2 below) work together to bolster ZEV demand and improve access, especially in disadvantaged communities (as defined by CalEnviroScreen, disadvantaged communities refer to the areas throughout California which suffer most from a combination of economic, health, and environmental burdens). CVRP focuses on providing incentives for the purchase or lease of eligible new vehicles with

17. CARB, Draft: Assessment of Carb's Zero-Emission Vehicle Programs per Senate Bill 498, available at https://ww2.arb.ca.gov/resources/documents/draft-assessment-carbs-zero-emission-vehicle-programs-sb-498

18. 13 Cal. Code Regs. §§ 1962.1, 1962.2.

an increased rebate for lower-income consumers and public fleets located in disadvantaged communities. CC4A and the CVA Program are focused on low-income and disadvantaged communities' access to ZEVs and include support for ZEV charging. In select air districts, the CC4A program incentivizes the retirement of a functioning, high-polluting vehicle with the replacement of a new or used conventional hybrid vehicle, or a ZEV. This program complements the CVA Program that helps lower-income consumers overcome barriers to financing for new and used vehicles by providing low-interest loans and vehicle price buy-downs. Researchers have identified specific circumstances where the presence of two or more complementary policies can yield a greater social benefit than the sum of each individual policy alone.[19]

California Phase 1 and Phase 2 Greenhouse Gas Standards for medium- and heavy-duty engines and vehicles seek to promote a new generation of cleaner, more fuel-efficient trucks by encouraging the development and deployment of new and advanced cost-effective technologies. The California Phase 2 GHG standard regulations and amendments are generally aligned with the Federal Phase 2 GHG emissions standards. However, some distinctions exist between the two that would allow CARB to verify and enforce the Phase 2 regulatory standards, thereby potentially leading to higher levels of compliance. The California distinctions, along with the Federal Phase 2 emissions standards in California, are expected to result in a reduction of 207.6 $MMTCO_2e$ emissions in California from 2019 to 2050. This is equivalent to saving 20.5 billion gallons of diesel fuel over the same time period.[20] However, the regulations alone will not result in a sufficient increase in ZEV sales if not combined with incentives, making a multi-pronged policy approach necessary. The regulations, incentives, and supporting programs work in conjunction to expand the ZEV market beyond early adopters and to ensure equitable access to zero-emission mobility. Table 1 describes and summarizes the goals of the incentive and regulatory programs in this study's scope of work.

The regulations alone will not result in a sufficient increase in ZEV sales if not combined with incentives, making a multi-pronged policy approach necessary.

19. Jonn Axsen et al., "Crafting Strong, Integrated Policy Mixes for Deep CO2 Mitigation in Road Transport", supra.

20. CARB, *Staff Report: Initial Statement of Reasons for Proposed Rulemaking- Proposed California Greenhouse Gas Emissions Standards for Medium-and Heavy-duty Engines and Vehicles and Proposed Amendments to the Tractor-trailer GHG Regulation*, p. III.2 (2018) available at https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2018/phase2/isor.pdf.

COMPARING ZEV LEADERS: CALIFORNIA AND NORWAY

Norway and California are both leaders in electric vehicle uptake as a percentage of all vehicle sales, though Norway has a significant advantage in market share.[21] Generous incentives have in turn positioned Norway as the leading battery-electric vehicle market in the world. Specifically, Norway lowered taxes on ZEVs and exempted drivers from road tolls to reduce the upfront costs of owning the vehicles. In addition, the country calculates purchase taxes for all new vehicles by a combination of weight, carbon dioxide emissions, and nitrogen oxide emissions, which results in cars with high emissions being more expensive than ZEVs. Along with this emphasis on emissions, the country also imposes an increased value-added tax[22] and a car-scrapping fee on gas-powered cars, which contributed to a rapid expansion of its ZEV market. Partly as a result of these stringent tax policies, the country went from 1% ZEV market share to 64% in a decade, becoming one of the world's leaders on ZEV deployment.[23]

Whereas Norway's ZEV strategy involves a combination of incentives and tax exemptions complemented by a high carbon tax, California's approach includes manufacturer regulations in addition to financial incentives.[24] California's ZEV policies have pushed incumbent automakers to manufacture ZEVs and created market space for entrants like Tesla, which contributed to the supply development in Norway. As a result, the two governments have created a global policy mix with California supply mandates and Norwegian incentives combining to boost ZEV market share. Additionally, Norway's adoption of strategies to support the transition to ZEVs through a combination of incentive programs, tax exemptions for ZEVs, and a high tax on conventional vehicles, demonstrates that a combination of fiscal and incentive policies can achieve significant uptake of ZEVs.

21. Erik Figenbaum, "Perspectives on Norway's supercharged electric vehicle policy" (2017), Environ. Innov. Societal Transitions, available at https://www.sciencedirect.com/science/article/pii/S2210422416301162; Gustavo Collantes and Daniel Sperling, "The origin of California's zero emission vehicle mandate" (2008), Transportation Research- A, available at https://www.sciencedirect.com/science/article/abs/pii/S0965856408001195.

22. Value-added tax is a consumption tax on goods and services that is levied at each stage of the supply chain where value is added, from initial production to the point of sale.

23. Norsk elbilforening, "Norwegian EV policy" (webpage), available at https://elbil.no/english/norwegian-ev-policy/.

24. John Axen, Patrick Plötz, Michael Wolinetz, "Crafting Strong, Integrated Policy Mixes for Deep CO2 Mitigation in Road Transport", supra.

PROGRAM	DESCRIPTION	TARGETED OR ELIGIBLE VEHICLES	TARGETED PARTY
Clean Vehicle Rebate Project (CVRP)	Provides incentives for the purchase or lease of eligible new vehicles with an increased rebate for lower-income consumers and public fleets located in disadvantaged communities. The primary goals are air quality improvement, greenhouse gas emissions reduction, market acceleration and benefits for priority populations with increased rebates.	New BEVs, PHEVs, FCEVs, and zero-emission motorcycles	Consumers, including priority populations and fleets
Clean Cars 4 All (CC4A)	Provides incentives for scrapping older, higher polluting vehicles and replacing them with eligible used or new vehicles; programs available in select air districts for low-income consumers and disadvantaged communities. The primary goals are air quality improvement and benefiting priority populations.	New and used BEVs, PHEVs, FCEV, and conventional hybrid vehicles	Consumers-priority populations
Clean Vehicle Assistance (CVA) Program	Helps lower-income Californians overcome barriers to financing for new and used vehicles by providing low-interest loans and vehicle price buy-downs to consumers for eligible vehicles. The primary goal is benefiting priority populations.	New and used BEVs, PHEVs, FCEVs, and conventional hybrid vehicles	Consumers-priority populations
Hybrid and Zero-emission Truck and Bus Voucher Incentive Project (HVIP)	Incentivizes eligible commercially available zero-emission, hybrid or cleanest combustion technologies. The primary goals are air quality improvement, greenhouse gas emissions reduction, and accelerating market growth.	Commercial zero-emission medium- and heavy-duty trucks and buses	Fleets / independent operators
Zero-Emission Vehicle (ZEV) Regulation	Sets a zero emissions standard for vehicle manufacturers to meet by producing and selling light-duty ZEVs. The primary goals are air quality improvement, greenhouse gas emissions reduction and accelerating market growth for light-duty vehicles.	New passenger vehicles and light-duty trucks	Vehicle Manufacturers
California Phase 1 Greenhouse Gas Standards California Phase 2 Greenhouse Gas Standards	Promotes a new generation of cleaner, more fuel-efficient trucks by encouraging the development and deployment of new and advanced cost-effective technologies. The primary goals are air quality improvement, greenhouse gas emissions reduction and market acceleration.	New medium- and heavy-duty vehicles	Vehicle Manufacturers

Table 1: Summary of the incentive and regulatory programs in the scope of work

INCENTIVE PROGRAM	ELIGIBLE VEHICLES	MAXIMUM FUNDING	INCOME CRITERIA	STATUS
Clean Vehicle Rebate Project (CVRP)	New BEVs, PHEVs, FCEV, and zero-emission motorcycles	Rebates up to $7,000	Individuals with income up to $135,000, and increased rebate by $2,000 for consumers with household incomes less than or equal to 400% of the federal poverty level (FPL)	Launched in 2010; major changes in 2016 to place additional focus on lower-income consumers
Clean Cars 4 All (CC4A)	New and used BEVs, PHEVs, FCEVs, and conventional hybrid vehicles	Grants up to $9,500 to replace old high-polluting cars with a new or used hybrid or electric vehicle	Accepts applications from residents with incomes at or below 400% of the FPL.	Launched starting in 2015, currently operating in four air districts and is expanding into more
Clean Vehicle Assistance Program (CVA)	New and used BEVs, PHEVs, FCEVs, and conventional hybrid vehicles	Grants and financing assistance up to $5,000	Accepts applications from residents with incomes at or below 400% of the FPL.	Regional pilot launched in 2016 and statewide pilot launched in 2018

Table 2: Description of the incentive programs in this study's scope of work.

CALIFORNIA'S INFLUENCE ON OTHER STATES' PROGRAMS

California's ZEV regulation is a first-in-the-nation policy approach requiring the industry to manufacture light-duty ZEVs. California has the authority to set these standards based on a carve-out in the federal Clean Air Act, subject to U.S. Environmental Protection Agency approval when certain baseline requirements are satisfied. In turn, under Section 177 of the act, a number of other states in the U.S. have joined California's standards for their state markets, with 17 states adopting California's Low-Emission Vehicle (LEV) regulations (covering 40.1% of US total new light-duty vehicle sales), out of which 15 states also adopted the state's ZEV regulation (covering 35.9% of US total new light-duty vehicle sales) as of May 2022.[25]

Table 3 summarizes the share of ZEVs out of all vehicles registered in the states that adopted California's standards, as well as the provisions available to consumers in these states in the form of incentives programs and other rebates. The sales figures in these states could help researchers quantify the impacts of ZEV incentive policies, as these varied in-state incentives could potentially explain the differences in sales across the states, along with infrastructure availability and support. However, because manufacturers are allowed to reach their sales targets in Section 177 states through sales in California through 2018

25. CARB, "States that have Adopted California's Vehicle Standards under Section 177 of the Federal Clean Air Act" (2022), available at https://ww2.arb.ca.gov/sites/default/files/2022-05/%C2%A7177_states_05132022_NADA_sales_r2_ac.pdf.

(known as the "travel provision"), the differing sales figures in these states may not be entirely the result of disparate in-state incentive policies but rather attributable to automaker decisions to meet their Section 177 obligations entirely in California up through 2018. The state also allows automakers to "pool" their excess credits from one state to meet targets in other states, making it a challenge to estimate the impact of incentive programs by comparing the market share of California versus other states. At the same time, automakers may be more willing to meet their sales requirements in California due to that state's incentive programs, which increase consumer demand. The results also point to the importance of California's ZEV regulation in general, by increasing the demand on automakers to produce ZEVs. Ultimately, Section 177 data can help inform quantification efforts but are likely too limited to be definitive. However, as the pooling and travel provisions phase out, the data could prove effective in helping to quantify impacts of various state incentive programs.

STATE	ZEV REGULATION FIRST IMPLEMENTATION	ZEV REGISTRATIONS (% OF US TOTAL, 2021)[26]	EV REGISTRATIONS (% OF ALL STATE LIGHT-DUTY VEHICLES, 2021)[27]	CHARGING REBATES, TAX CREDITS OR EXEMPTIONS	VEHICLE INCENTIVE PROGRAMS	INCENTIVE IMPLEMENTATION YEAR
California	1990	38.71%	12.96%	Yes	Yes	2010- present
New York	1993	3.57%	3.93%	Yes	Yes	2016- present
Massachusetts	1995	2.09%	5.45%	Yes	Yes	2014- present
Vermont	2000	0.23%	5.48%	Yes	Yes	2019-2020, 2022-present
Maine	2001	0.21%	3.74%	Yes	Yes	2022- present
Connecticut	2008	0.92%	5.15%	Yes	Yes	2015- present
Rhode Island	2008	0.18%	3.69%	Yes	Yes	2022- present
Oregon	2009	2.08%	7.58%	Yes	Yes	2018- 2024
New Jersey	2009	3.29%	5.19%	Yes	Yes	2020- present
Maryland	2011	1.76%	5.06%	Yes	Fleet operators only	2021-present
Colorado	2023	2.54%	6.24%	Yes	Low income only	2021-present
Washington	2025	4.59%	7.76%	Yes	Select Districts	2021-present
Minnesota	2025	1.03%	2.93%	Yes	No	
Nevada	2025	1.19%	5.70%	Yes	Low income only	2022-present

26. Alternative Fuels Data Center, "Electric Vehicle Registrations by State," (webpage) available at https://afdc.energy.gov/data/10962.

27. Alliance for Automotive Innovation, *Electric Vehicle Quarterly Report*, available at https://www.autosinnovate.org/posts/papers-reports/Get%20Connected%20EV%20Quarterly%20Report%20Q4.pdf.

STATE	ZEV REGULATION FIRST IMPLEMENTATION	ZEV REGISTRATIONS (% OF US TOTAL, 2021)[26]	EV REGISTRATIONS (% OF ALL STATE LIGHT-DUTY VEHICLES, 2021)[27]	CHARGING REBATES, TAX CREDITS OR EXEMPTIONS	VEHICLE INCENTIVE PROGRAMS	INCENTIVE IMPLEMENTATION YEAR
Virginia	2025	2.11%	4.16%	Yes	Yes	2022- present
New Mexico	2026	0.29%	2.22%	Yes	No	

Table 3: Summary of the ZEV sales in States under Section 177 that joined California's ZEV regulation as of May 2022.

California's incentive programs have also helped to inform other states' approaches. The state established CVRP in 2010 to support the ZEV market by providing rebates to consumers for purchasing or leasing light-duty ZEVs and PHEVs. Many other states in the country then followed this model to incentivize the purchase of ZEVs. In 2014, Massachusetts launched the Massachusetts Offers Rebates for Electric Vehicles (MOR-EV) program and has offered more than 26,000 rebates as of September 2022.[28] Connecticut started its Connecticut Hydrogen and Electric Automobile Purchase Rebate (CHEAPR) program in 2015 and has since provided more than 8,000 in-state rebates as of August 2022.[29] Similarly, New York launched a program in 2019 to offset some of the upfront cost of purchasing ZEVs through the Drive Clean Rebate for Electric Cars program, which applies a financial incentive to vehicle purchases directly at the dealership. This program has provided more than 77,000 rebates in New York as of October 2022.[30] CARB could potentially review and assess sales figures in these states as a means of quantifying the impact of various incentive programs that are similar to California's. Additionally, comparing the ZEV sales figures of California with other states that have no incentive programs in place could help in quantitatively measuring the benefits of the state's incentive programs.

On the heavy-duty vehicle incentive side, the California Air Resources Board launched HVIP in 2009; it has supported the purchase of more than 11,000 clean vehicles since its inception.[31] HVIP was replicated in New York in the form of the New York Truck Voucher Incentive Program, which makes it easier for fleets to adopt ZEV technologies while removing the oldest, dirtiest diesel engines from New York roads.[32] Massachusetts and New Jersey are also planning medium- and heavy-duty incentive programs, inspired by the success

28. Massachusetts Offers Rebates for Electric Vehicles, "Program Statistics" (webpage), available at https://mor-ev.org/program-statistics.

29. Connecticut Hydrogen and Electric Automobile Purchase Rebate, "CHEAPR Statistics" (webpage), available at https://portal.ct.gov/DEEP/Air/Mobile-Sources/CHEAPR/CHEAPR---Program-Statistics.

30. New York State, "Drive Clean Rebate for Electric Cars Primary Statistics" (webpage), available at https://www.nyserda.ny.gov/All-Programs/Drive-Clean-Rebate-For-Electric-Cars-Program/Rebate-Data/Rebate-Stats.

31. California HVIP, "Voucher Map and Data" (webpage), available at https://californiahvip.org/impact/#deployed-vehicle-mapping-tool.

32. New York State, "Truck Voucher Incentive Program" (webpage), available at https://www.nyserda.ny.gov/All-Programs/Truck-Voucher-Program.

of HVIP.[33] Going forward, the deployment results in these states could help California better estimate the impacts on sales from HVIP, by comparing sales before and after the introduction of the incentives, both within these states and compared to others without the incentive.

33. IEA, *Policies to promote electric vehicle deployment*, supra.

IV. INCENTIVE & REGULATORY PROGRAM IMPACTS

MARKET IMPACTS

In 2022, annual sales of ZEVs in California rose to around 345,000, an increase of 270% over 2017, although some of the ZEVs sold do not continue to operate on California roadways.[35] CARB-administered incentives and regulatory mandates have likely propelled much if not most of this market development, although the extent is unclear. Chief among CARB's ZEV policies is the light-duty ZEV regulation, which requires automakers to sell a growing percentage of ZEVs, increasing to 22% of vehicles produced by 2025, given by their average production volume in the prior second, third, and fourth model year.[36] CARB designed this approach to create market stability and predictability, ensuring that manufacturers can prepare to provide a predictable minimum (and increasing over time) share of clean vehicles or purchase credits equal to that amount from other automakers with surplus sales over the minimum. The sales requirement of light-duty ZEV regulation has correlated with more innovation from manufacturers, as measured by patent activity and falling battery costs over the last

California dominates the U.S. ZEV market, accounting for approximately 40% of the nation's ZEVs despite having just 10% of the cars.[34]

34. California Governor's Office, "California Leads the Nation's ZEV Market, Surpassing 1 Million Electric Vehicles Sold" (February 25, 2022) (press release), available at https://www.gov.ca.gov/2022/02/25/california-leads-the-nations-zev-market-surpassing-1-million-electric-vehicles-sold/. For national EV sales data, see https://www.veloz.org/ev-market-report/.

35. California Energy Commission (CEC), "New ZEV sales in California" (webpage), available at https://www.energy.ca.gov/data-reports/energy-insights/zero-emission-vehicle-and-infrastructure-statistics/new-zev-sales.

36. 13 Cal. Code Regs. §§ 1962.2.

decade.[37] This progress on battery costs in turn has helped to lower ZEV prices and increase their range, helping to stimulate more demand.

Peer-reviewed literature by UC Davis, "Driving the Market for Plug-in Vehicles: Understanding ZEV Mandates," supports the claim that California's light-duty ZEV regulation has had a positive impact on innovation activity based on vehicle manufacturers increasing research and development, forming partnerships, and filing patents.[38] This research documents a correlation between the presence of a ZEV regulation and ZEV sales, although the studies did not determine causality. The study also concluded that the California ZEV regulation appears to have met its goals of accelerating industry investment in ZEV technology, discouraging industry procrastination, establishing initial supply chains, and signaling to the many related companies and governments that they should engage sooner and more deeply with the transition to ZEVs.

As mentioned above, California's light-duty ZEV regulation now covers 15 other states that have adopted the CARB standards under Section 177 of the Clean Air Act, including the recent additions of Colorado, Washington, New Mexico, Virginia, Minnesota, and Nevada.[39] This development suggests a significant market impact not just in California but in many parts of the United States.

CARB's consumer incentive programs, including CVRP, CC4A, and the CVA Program, work in tandem with the ZEV regulation by financially supporting individual ZEV purchases. While the ZEV regulation promotes a growing supply of ZEVs, policy makers designed these incentives to boost consumer demand by offsetting some of the upfront cost of buying or leasing eligible vehicles. In total, consumers have purchased more than 500,000 vehicles using CVRP assistance,[40] more than 13,000 with CC4A,[41] and more than 4,000 with the CVA Program.[42] For the light-duty incentive programs, CVRP aims to accelerate the market transformation in the general population and fleets, while CVRP, CC4A and CVA Program aim to do so in priority populations faster than the market would otherwise. Figure 2 illustrates the upward trend in ZEV sales in California, accompanied by CARB's progressive updates on their light-duty ZEV programs.

37. Virginia McConnell and Benjamin Leard, "Pushing New Technology into the Market: California's Zero Emissions Vehicle Mandate," Review of Environmental Economics and Policy(2021), available at https://www.journals.uchicago.edu/doi/epdf/10.1086/713055.

38. Scott Hardman et al.,"Driving the Market for Plug-in Vehicles: Understanding ZEV Mandates." UC Davis International EV Policy Council (2018), available at https://phev.ucdavis.edu/wp-content/uploads/zev-mandates-policy-guide.pdf.

39. CARB, "States that have Adopted California's Vehicle Standards under Section 177 of the Federal Clean Air Act", supra.

40. As of December 2022. Data from Clean Vehicle Rebate Project (CVRP), "Clean Vehicle Rebate Project Rebate Statistics" (webpage), available at https://cleanvehiclerebate.org/en/rebate-statistics.

41. As of March 2022. Data from CARB, *EFMP Scrap and Replace and CC4A Summary Report* (2022), available at https://ww2.arb.ca.gov/sites/default/files/2022-07/EFMP%20Website%20Statistics%20Tables%20Cumulative%202022_Q1.pdf.

42. As of April 2022. Data from Clean Vehicle Assistance Program, "Program Data" (webpage), available at https://cleanvehiclegrants.org/program-data/.

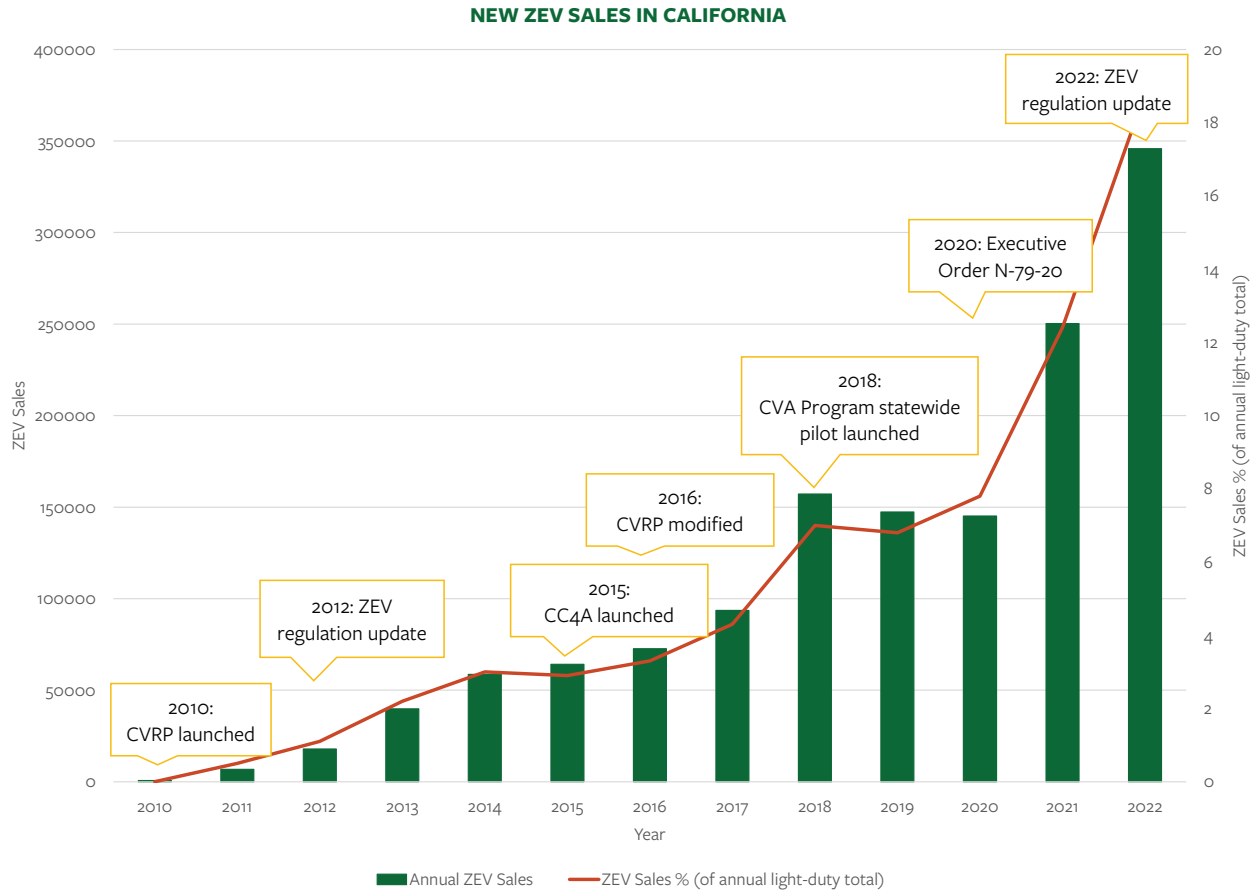

Figure 2: Graph illustrating the increase in ZEV sales in California, with insights on the status of CARB's light-duty programs. Data source: California Energy Commission.

On the medium- and heavy-duty side, CARB expects California Phase 1 and Phase 2 Greenhouse Gas Standards for medium- and heavy-duty trucks to result in a reduction of 207.6 million metric tons of CO_2 equivalent emissions in California from 2019 to 2050. Manufacturers can meet the Phase 2 GHG standards through a variety of technologies, including improved aerodynamics, low rolling resistance tires, engine and accessory optimization, weight reduction, idle reduction systems, hybridization, powertrain electrification, and more. Arguably, California's commitment to developing a Phase 2 rule that maximizes greenhouse gas reductions and spurs development of critical advanced technologies helped point the way for federal leaders to promulgate aspects of their Phase 2 standards.

California's Phase 2 GHG regulation also complements and supports the state's Advanced Clean Trucks regulation, which requires manufacturers to sell zero-emission medium- and heavy-duty vehicles as an increasing percentage of their annual sales from 2024 to 2035. Both regulations impact the medium- and heavy-duty market by requiring an increasing production of cleaner, lower CO2 emitting vehicles and manufacturers can comply with both regulations simultaneously by building ZEVs. A detailed summary of the regulatory programs in this study's scope is available in Appendix I.

Finally, HVIP extends an incentives-based approach to trucks and buses, alongside California Phase 1 and Phase 2 Greenhouse Gas Standards. As of October 2022, fleets have deployed more than 11,000 trucks and buses funded with HVIP vouchers, 52% of which were for ZEVs. HVIP purchasers rated the importance of the HVIP voucher in deciding to purchase a vehicle as 4.7 out of 5 for zero-emission trucks (where 5 meant very important to the purchase decision), which implies that the vouchers directly benefited most of the purchasers and in turn helped spur the sale of these advanced technology vehicles. HVIP is also likely to promote the purchase of electric last-mile delivery trucks, especially among smaller businesses.[43]

As noted above, HVIP complements the state's Phase 2 GHG standards for medium- and heavy-duty vehicles and will continue to be important for implementing the underlying ICT, ACF, and ACT programs as well. These regulations are designed to have an incremental effect of transitioning fleets, which creates complexities in terms of determining how much overall market development for ZEV technologies is related to the regulations themselves versus the impact of the HVIP, given that they are complementary in nature. As noted above, ZEV truck purchasers have reported a high degree of necessity for the HVIP vouchers to enable their purchases in recent years. Improved surveys and interviews with fleet managers could yield more insight into this question in the future. The issue of disentangling the impact of the HVIP on the overall market is also complicated by the ability of fleets to stack federal (e.g. DOT and DOE), state (HVIP), and local AQMD incentives in some cases. Also worth noting is that historically, CARB has not allowed the use of incentive funds to go toward direct compliance with regulations (only early or over-compliance), but as these latest regulations become more stringent and fully binding, the agency may revisit how the HVIP can be best structured to promote and potentially accelerate ZEV adoption in support of the state's climate and air pollution goals.

The number and variety of commercially available vehicles in HVIP have continued to grow in recent years with offerings from dozens of manufacturers across most medium- and heavy-duty vehicle types including delivery vans, school buses, refuse trucks, cutaway shuttles, terminal tractors, and passenger vans. HVIP has seen particularly strong demand for class 8 zero-emission trucks, especially those for use in drayage. Commercial BEV and FCEV tractors are offered by almost every major truck OEM and hundreds of these vehicles are on order in the state.[44]

Though CARB programs may have a meaningful impact on consumer decision-making, researchers and policy makers cannot ascertain how many additional vehicles automakers have offered for sale in California as a result of the incentives, beyond the minimum required to comply with the ZEV regulation. Furthermore, current survey data is insufficient and inadequate for analysis.

43. Miguel Jaller et al., "Empirical Analysis of the Role of incentives in Zero-Emission Last-Mile Deliveries in California," Journal of Cleaner Production (2021), available at https://doi.org/10.1016/j.jclepro.2021.128353.

44. California HVIP, 'Voucher Map and Data' (accessed on May 5, 2023), available at https://californiahvip.org/impact/#deployed-vehicle-mapping-tool

Improved user data collection could provide policy makers enhanced insight into the effectiveness of programs by better illuminating which incentives are the most effective at influencing purchasing decisions.

EMISSIONS IMPACTS

The estimated cumulative emissions reductions from vehicles purchased through CARB's consumer incentive programs by May 2022 are summarized in table 4. Though researchers cannot assume all of these emissions reductions have occurred due to the incentive funding,[45] the outcomes nonetheless represent a substantial reduction in on-road emissions. Overall, analysts expect the federal Phase 2 program in California, plus the state's additional requirements, to result in a reduction of 207.6 MMTCO2e emissions in California from 2019 to 2050,[46] while the HVIP incentive program could contribute to 1 MMTCO2e of emissions reductions; however, these are likely overestimates,[47] and the complementary nature of Phase 2 regulation and HVIP makes it difficult to disentangle the emissions benefits.

CARB INCENTIVE PROGRAM	GREENHOUSE GAS REDUCTION (1,000 $MTCO_2E$)
Clean Cars 4 All	85
Clean Vehicle Rebate Project	6,777
Financing Assistance for Lower-Income Consumers	24
Clean Truck & Bus Voucher (HVIP)	975

Table 4: Greenhouse gas emission reductions as of May 2022 through CARB incentive programs in this study's scope of work.[48]

In 2022, CARB projected that the ACC II regulations could result in a cumulative reduction over the period of 2026 to 2040 of 69,569 tons NOX, 4,469 tons PM2.5 and 383.5 MMT of CO2 emissions (wells-to-wheels emissions accounting for fuel production). PM2.5 and NOx emissions have a causal relationship with premature mortality and cardiovascular disease and are likely to have

45. Auditor of the State of California, "California Air Resources Board: Improved Program Measurement Would Help California Work More Strategically to Meet Its Climate Change Goals," (February 2022), available at https://auditor.ca.gov/pdfs/reports/2020-114.pdf.

46. CARB, "Staff Report: Initial Statement Of Reasons For Proposed Rulemaking- Proposed California Greenhouse Gas Emissions Standards For Medium-And Heavy-Duty Engines And Vehicles And Proposed Amendments To The Tractor-Trailer GHG Regulation", supra.

47. CARB, *Advanced Clean Cars Staff Report: Initial Statement of Reasons* (2022), p.134, available at https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/isor.pdf; California Climate Investments, "2022 Annual Report to the Legislature on California Climate Investments Using Cap-and-Trade Auction Proceeds" (2022), available at https://ww2.arb.ca.gov/sites/default/files/auction-proceeds/cci_annual_report_2022.pdf.

48. California Climate Investments, "2022 Mid-Year Data Update" (2022), available at https://ww2.arb.ca.gov/sites/default/files/auction-proceeds/cci_2022_mydu_cumulativeoutcomes.pdf.

a causal relationship with developmental and reproductive effects.[49] Sulfur oxides, also present in exhaust gases, cause short-term respiratory effects and long-term cardiovascular effects. Diesel exhaust is particularly dangerous, diesel particulate matter is a toxic air contaminant, along with the mix of toxic compounds it is composed of, many of which are carcinogens.[50] Since diesel is most commonly used in trucks, and trucks emit disproportionately more in low-income communities, California Phase 1 and 2 Greenhouse Gas Standards are likely to be effective in alleviating this co-pollution in the most affected communities.[51] Besides increased mobility and more reliable transportation, CARB's incentive and regulatory programs improve public health and reduce exposure to environmental contaminants by reducing emissions from vehicles operating in or near disadvantaged and low-income communities and provide an economic benefit to those priority populations that participate.

A recent study that compared the data on total ZEV registration, air pollution levels and asthma-related emergency room visits across California between 2013 to 2019, found that as ZEV adoption increased within a given zip code, local air pollution levels and emergency room visits dropped.[52] The results of this study indicate the possible extent of the co-benefits of the early-phase transition to ZEVs, though due to the adoption gap among populations with lower socioeconomic status this distribution of possible co-benefits is not yet equitable. In an effort to address this challenge, CARB's ZEV programs aim to increase adoption and provide incentives to low-income communities, with the goal to promote fairness in the distribution of the co-benefits of ZEV adoption.

The research team is currently reviewing the available data on ZEV purchases to better estimate the number of ZEVs that are purchased or leased as a direct result of CARB's regulatory and incentive programs. Depending on the results, the resulting calculations could potentially help inform how CARB determines the corresponding public health benefits from the avoided air pollutants.

EQUITY IMPACTS

CARB's incentive programs aim to stimulate ZEV adoption in disadvantaged communities. Given that the weighted average sales price for a ZEV sold in California in 2021 was approximately $13,000 more than the average ICE counterpart, affordability is one of the greatest barriers to ZEV adoption in

49. California Air Resources Board, Advanced Clean Cars Staff Report: Initial Statement of Reasons, supra, p.134. ; U.S. Environmental Protection Agency & U.S. Department of Transportation, *Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles- Phase 2: Regulatory Impact Analysis* (2016), p. 6.1 - 6.7.

50. Id., p. 6.4-6.12.

51. American Geophysical Union, "Pollution from Fright Traffic Disproportionately Impacts Communities of Color Across 52 US Cities" (2021), available at https://www.sciencedaily.com/releases/2021/10/211007122234.htm.

52. Erica Garcia et al., "California's early transition to electric vehicles: Observed health and air quality co-benefits", Science of The Total Environment (2023), available at https://doi.org/10.1016/j.scitotenv.2023.161761

low-income communities.[53] The light-duty ZEV regulation has likely contributed to a substantial decline in ZEV prices by spurring automaker investment in lithium-ion battery manufacturing, which in turn has helped spur the decreases in overall vehicle prices over the past decade. The decreased prices for longer-range vehicles, coupled with the availability of first-generation ZEVs on the secondary market, have put ZEVs within the reach of more buyers who cannot otherwise afford them. The decreased prices and increased availability will likely extend beyond California to the national ZEV market.

The impacts of climate change and air pollution affect all Californians, but residents in disadvantaged and low-income communities are disproportionately burdened and face the most severe impacts. Low-income communities stand to gain the most in monetized health benefits per capita from ZEV adoption over the baseline.[54] By increasing the number of ZEVs on the road and continuing to clean up conventional ICE vehicles, the ACC II regulatory proposals will reduce exposure to vehicle pollution in communities throughout California, including in frontline communities that are disproportionately exposed to vehicular pollution.

The current equitability of CARB's consumer incentives (CVRP, CC4A, and the CVA program) is less clear. Since 2016, CVRP has both an income cap limiting eligibility along with an increased rebate for lower-income households.[55] The income cap serves not to provide additional incentives to lower-income car buyers but to exclude higher-income consumers from participation. Although designed to make ZEV purchases more affordable, the CVRP is still less likely to be accessed by lower-income buyers, who represent a smaller portion of ZEV purchasers and are more sensitive to high ZEV prices, producing a highly regressive benefit distribution.[56] While this impact has been lessened through the introduction of the income cap,[57] beneficiaries of the program in areas that are whiter, wealthier, more educated, and where vehicle air pollution is lower, received three times as many CVRP rebates per thousand households.[58] Recent studies have shown that an increased adoption of electric vehicles in communities facing the highest air pollution exposure, along with accelerated clean-energy generation, could ameliorate the associated environmental inequities.[59]

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53. ICF, *Environmental Justice Impacts of Zero Emission Vehicles* (2022), available at https://zevalliance.org/wp-content/uploads/2023/01/Environmental-Justice-Impacts-of-ZEVs_Final-Report.pdf.

54. Id.

55. Clean Vehicle Rebate Program. "Income Eligibility" (webpage), available at https://cleanvehiclerebate.org/eng/income-eligibility.

56. Arthur Ku and John Graham, "Is California's Electric Vehicle Rebate Regressive? A Distributional Analysis," Journal of Benefit Cost Analysis (March 2022), available at https://doi.org/10.1017/bca.2022.2.

57. Suocheng Guo and Eleftheria Kintou, "Disparities and Equity Issues in Electric Vehicles Rebate Allocation," Energy Policy (2021), available at https://www.sciencedirect.com/science/article/pii/S0301421521001609.

58. Yang Ju et al., "An Equity Analysis of Clean Vehicle Rebate Programs in California," Climatic Change (2020), available at https://link.springer.com/article/10.1007/s10584-020-02836-w.

59. Mejía-Duwan J, Hino M, Mach KJ, "Emissions redistribution and environmental justice implications of California's clean vehicle rebate project", PLOS (May 2023), available at https://doi.org/10.1371/journal.pclm.0000183.

While California is still accepting applications for CVRP, the state experienced significant processing delays in early 2022 due to high application volumes and shortage of vehicle supply. CVRP applicants must wait on average more than two months to be notified if they are selected, and they have an additional waiting period to receive the actual rebate.[60] This delay and uncertainty in receiving the rebates may reduce lower-income and less financially stable applicants' comfort with the incentive process, making them less likely to apply, hence limiting the socioeconomic and health benefits that could be achieved by replacing a higher-polluting car with a zero-emission one. However, as of November 2022, the average time for the application review has improved to a period of 3-15 days.[61]

While CVRP influences the purchasing decisions among many consumers, higher-income buyers tend to exhibit less price sensitivity to ZEV rebates than their middle- and lower-income counterparts.[62] In select air districts, consumers can pair the CVRP with the CC4A to replace higher polluting vehicles. CARB's funding plan for FY 2022-23 includes allotting $381 million for clean transportation equity investments to help increase access to clean transportation and mobility options benefiting individuals who live in disadvantaged communities.[63] These burdens include poverty, high unemployment, air and water pollution, and presence of hazardous wastes, as well as high incidence of asthma and heart disease.[64] CC4A is currently administered in the five largest air districts in California: South Coast Air Quality Management District (AQMD), San Joaquin Valley Air Pollution Control District (APCD), Bay Area AQMD, Sacramento Metropolitan AQMD, with an upcoming program in San Diego APCD. CARB's funding proposal also includes statewide expansion of CC4A, which will improve equitable access to clean transportation by expanding program eligibility to all areas of the state that are not able to participate in existing district programs. These areas include low-income communities, rural communities, tribal communities, and other priority populations that could benefit from more reliable transportation.[65] Like CVRP, CC4A is likely to result in some additional ZEV purchases by lower-income consumers who could not otherwise afford them. However, given that no comprehensive user survey data are available, analysts have yet to determine the magnitude of this impact and the cost effectiveness of this approach.

60. Nadia Lopez, "Can Californians Afford Electric Cars? Wait Lists for Rebates are Long and Some Programs have Shut Down," Cal Matters (2022), available at https://calmatters.org/environment/2022/08/california-electric-cars-rebates/.

61. CVRP, "How long will it take to process my application", (accessed on Nov 22, 2022), available at https://cleanvehiclerebate.org/en/faqs/how-long-will-it-take-process-my-application.

62. UC Davis Policy Institute for Energy, Environment, and the Economy, *Impact of the Clean Vehicle Rebate Project's income cap on California's ZEV Market* (2019), available at https://ww2.arb.ca.gov/sites/default/files/2020-05/CVRP_Income_Caps_0519.pdf.

63. CARB, "CARB Approves Historic $2.6 Billion Investment — Largest to Date — for Clean Cars, Trucks, Mobility Options" (webpage), available at https://ww2.arb.ca.gov/news/carb-approves-historic-26-billion-investment-largest-date-clean-cars-trucks-mobility-options.

64. California Office of Environmental Health Hazard Assessment, *CalEnviroScreen 4.0* (2021), available at https://oehha.ca.gov/media/downloads/calenviroscreen/report/calenviroscreen40reportf2021.pdf.

65. CARB, *Proposed Fiscal Year 2022-23 Funding Plan for Clean Transportation Incentives*, available at https://ww2.arb.ca.gov/sites/default/files/2022-10/proposed_fy2022_23_funding_plan_final.pdf.

CC4A offers incentives to low-income residents in or near disadvantaged communities, with the largest incentives available for the lowest-income participants. Because of this feature, 98% of the 2021 CC4A funding was accessed by priority populations.[66] Through the end of June 2018, 88% of program participants who have obtained a BEV or PHEV had annual incomes below 225% of the federal poverty level. According to CARB data, as of June 2022, CC4A has directly helped replace over 9,000 higher-polluting vehicles with a more reliable BEV, FCEV or PHEV.[67] However, like other incentive programs, the funding for CC4A is based on the funding the state receives each year from the Cap-and-Trade program that provides the revenue from auction proceeds. This fluctuation sometimes results in state leaders having to pause the program in certain regions due to depleted funds. Additionally, Californians who may need the funds the most are not accessing the program as quickly as other income groups, as they often need help to get through the application process, as well as more time to find a used vehicle of their choice.[68] These uncertainties present challenges to lower-income applicants that likely limit the program's socioeconomic benefits.[69] However, the state is taking measures to improve the program access. Senate Bill 1382 would require regulations for the Clean Cars 4 All Program to work with local air districts, non-profits, and community organizations to identify barriers to accessing the program and improve outreach efforts. The bill would also require a performance analysis to identify populations that are not participating in the program and to propose solutions to overcome these barriers.[70]

Lastly, the CVA program has income eligibility requirements, with two-thirds of its incentives going towards low-income households and 17% towards disadvantaged communities.[71] However, state leaders limit applications to the CVA program and have not accepted any new additions to the reservation list since April 2021.[72] The pandemic-induced price inflation, combined with fewer electric vehicles in supply, has created long wait lists for new models and increased the prices for new and used vehicles.[73]

On the heavy-duty side, California Phase 2 Greenhouse Gas Standards set requirements for heavy-duty glider vehicles, glider engines, and glider kits. Such glider vehicles have NOx and toxic diesel particulate matter emissions

66. California Climate Investments, "Clean Cars 4 All" (webpage), available at https://www.caclimateinvestments.ca.gov/clean-cars-4-all.

67. CARB, *EFMP Scrap and Replace and CC4A Summary Report*, available at https://ww2.arb.ca.gov/our-work/programs/clean-cars-4-all/efmp-scrap-and-replace-and-cc4a-summary-report.

68. Id.

69. Trisha Litong and Sita Syal, *Uncovering the Barriers and Inequities of a Clean Mobility Program Using Journey Mapping* (2022), available at https://dive.stanford.edu/sites/g/files/sbiybj18606/files/media/file/idetc_paper_for_dive_website_0.pdf.

70. Senate Bill 1382 (Gonzalez, Chapter 375), available at https://legiscan.com/CA/text/SB1382/2021.

71. California Climate Investments, "Financing Assistance for Lower-Income Consumers" (webpage), available at https://www.caclimateinvestments.ca.gov/financing-assistance-for-lowerincome-consumers.

72. Clean Vehicle Assistance Program, "Grant Application" (webpage), available at https://cleanvehiclegrants.org/apply/.

73. Id.

that are significantly higher than modern engines. These standards will limit the production of glider vehicles and that only 2010 and newer model year engines would be allowed to be used in glider vehicles, which will be of particular benefit in environmental justice communities, which tend to be located near areas frequented by heavy-duty trucks.

SECOND-ORDER IMPACTS

The total impact of CARB's regulatory and incentive programs goes beyond the direct impact on the initial consumer purchase decisions. The second-order impacts can include effects on resale value, consumer awareness, and support for charging infrastructure, among others, that are difficult to accurately quantify solely based on available data. These second order impacts likely further reduce the state's greenhouse gas emissions beyond even the direct effects, though policy makers will need additional analysis to verify and quantify. It is important to note that the State Auditor's Report which claims that CARB "…overstated greenhouse gas emissions reductions its incentive programs achieve" did not take into account these second-order effects, which are crucial but inherently difficult to quantify.

Resale Value

As the U.S. ZEV market expands over time, especially for used vehicles, ZEVs will likely become more affordable and attractive to lower-income households. There have been roughly 1.6 million cumulative electric vehicle sales in the United States as of September 2020, and many of these are now entering the used car market.[74] In disadvantaged communities in California, used ZEVs are purchased at higher rates than new EVs.[75] While ZEV resale values are now increasing with improved range and increased demand, historically they remained substantially lower than those of ICE vehicles. Before the dramatic fluctuations in new and used car markets beginning in 2020, in 2017 the average resale value of ICE vehicles 36 months after purchase was around 50-60% of their list price, compared to an average of 30-40% for Battery Electric Vehicles (BEVs).[76] While these data predate significant innovation in the market, the reasons for the relatively low resale values included battery degradation or fear thereof, as subsequent owners might have to invest significantly in replacement batteries or end up with a car with reduced battery capacity and range; the fact that the original list price did not reflect the federal and

74. International Council on Clean Transportation, *When might lower-income drivers benefit from electric vehicles? Quantifying the economic equity implications of electric vehicle adoption* (2021), available at https://theicct.org/sites/default/files/publications/EV-equity-feb2021.pdf.

75. Kathryn Canepa *et al*. "An early look at plug-in electric vehicle adoption in disadvantaged communities in California,". Transport Policy 78 (2019), p.19–30, available at https://www.researchgate.net/publication/345479351_An_early_look_at_plug-in_electric_vehicle_adoption_in_disadvantaged_communities_in_California.

76. Moody's Analytics, "Electric Vehicle Residual Value Outlook" (2017), available athttps://www.moodysanalytics.com/-/media/presentation/2017/electric-vehicle-residual-value-outlook.pdf.

state tax credits, rebates, and other incentives that made their actual paid price lower for consumers (and therefore the difference between the original paid and used prices much smaller); and the rapid pace of ZEV development rendering older models outdated sooner.[77]

As used vehicle prices increased due to limited supply of new vehicles induced by COVID-19 and the semiconductor and other supply chain shortages, the overall used ZEV market saw a much less significant increase, likely due to the same hesitancies causing the already low resale value.[78] Tesla is the only manufacturer that consistently bucked this trend within this market, with vehicles such as the Model 3 appreciating in value over the last two years.[79] High-end models introduced recently by firms which boast longer ranges have also seemed to maintain stronger resale values, though their introduction is too recent to analyze. These figures seem to suggest that range parity with new ZEVs is a significant factor in resale value.[80] In addition, plug-in hybrid electric vehicles (PHEVs) and hybrid electric vehicles (HEVs) have better resale values, with averages of 45-50% of their list price for PHEVs and 50% for HEVs. This dynamic is likely due to their smaller and therefore less expensive batteries, as well as their decreased reliance on battery power for driving range.[81]

Given that affordability is the most significant barrier to ZEV adoption for low-income households, the used ZEV market is a critical pathway for low-income houses towards ZEV adoption.[82] The CC4A and CVA programs offer incentives for used vehicles, representing around 30% of the programs' total incentive volume.[83] In addition, since CARB's incentive and regulatory programs have bolstered overall ZEV supply, they have in turn increased the supply of used ZEVs and given more lower-income households access to these vehicles.

Critically, CARB does not offer its largest incentive programs (CVRP and HVIP) for used vehicles. Additionally, the incentives offered by CC4A and

77. Zhaomiao Guo and Yan Zhou, "Residual Value Analysis of Plug-in Vehicles in the United States," Energy Policy 125 (2019), p.455, available at https://doi.org/10.1016/j.enpol.2018.10.023.

78. Ira Boudway, "Electric Cars Left Behind as Used Car Prices Soar," Bloomberg (July 30, 2021), available at https://www.bloomberg.com/news/newsletters/2021-07-30/hyperdrive-daily-electric-cars-left-behind-as-used-car-prices-soar.

79. Recurrent Auto, *Used Electric Car Prices & Market Report - Q2 2022* (2022), available at https://www.recurrentauto.com/research/used-electric-vehicle-buying-report.

80. Matt DeLorenzo, "EV Resale Values Climb Yet Still a Buyer's Market," Kelly Blue Book (26 June, 2020), available at https://www.kbb.com/car-news/ev-resale-short-circuiting-the-electric-dream/.

81. Zhaomiao Guo and Yan Zhou, "Residual Value Analysis of Plug-in Vehicles in the United States", supra.

82. International Council on Clean Transportation, *Understanding and Supporting the Used Zero-Emission Vehicle Market* (2021), available at https://zevalliance.org/wp-content/uploads/2021/12/ZEVA-used-EVs-white-paper-v2.pdf.

83. Clean Vehicle Assistance Program , "Program Data" (webpage), supra; Center for Sustainable Energy, *Clean Vehicle Assistance Program Final Report* (2021), p. 8, available at https://cleanvehiclegrants.org/wp-content/uploads/2022/03/2021-CVAP-Report.pdf.

CVA to used ZEV owners are lower in value relative to their purchase price and are mostly (85% for CC4A) applied to hybrid vehicles.[84] On a national level, the Inflation Reduction Act of 2022 updated the federal tax credit program to make federal credits available for used EV purchases for the first time. The used EV tax credit is for $4,000 or up to 30% of the vehicle price (whichever is lower.)

While beyond the scope of UC researchers' report, if CARB seeks to expand the used ZEV market to stimulate adoption in low-income communities, more incentives for these vehicles could be a significant motivator, given how much they factor into buyers' decisions to purchase a used EV.

Willingness of Automakers to Provide Vehicles

The light-duty ZEV regulation has been critical to ensuring automakers provide ZEVs. As a whole, the auto industry is over complying with its minimum ZEV production targets, and almost all firms have a significant credit balance. However, nine of the sixteen manufacturers under the ZEV Regulation had a reduction in their credit balance during the course of 2021.[85] Going forward, many large legacy automaker groups such as Stellantis, Volkswagen Group, and Daimler-Benz have declared that they will no longer make any significant investments in new ICE vehicles,[86] while others such as Ford, GM, and BMW have committed to substantially larger ZEV investments than their current ICE investments. These groups have also committed to increasing investments in ZEV production infrastructure, allowing for significantly higher production volumes.[87]

However, by doing the minimum required to comply with the ZEV production targets, and through recent political fights against the implementation of these regulations, many manufacturers have historically signaled that they are reluctant to provide ZEVs, presumably due to the economics of switching technologies and lack of faith in the long-term economic viability of ZEVs. Their intransigence indicates that CARB regulations have played a significant role in stimulating ZEV production that would otherwise not have occurred had automakers been left to their own plans. Going forward, the success of these programs will require more uniform industry compliance across all firms.

CARB's incentive policies (specifically the CVRP, CC4A, and the CVA programs) work in concert with the light-duty ZEV regulation to stimulate consumer demand for ZEVs; this increase in demand in turn can improve manufacturer

84. Id., p.8-9

85. CARB, *2020 ACC ZEV Credit Annual Disclosure Report* (2020), available at https://ww2.arb.ca.gov/sites/default/files/2021-12/2020_zev_credit_annual_disclosure_ac.pdf.

86. Jim Motavalli, "Phasing Out Internal Combustion Engines? It's Already Happening," Autoweek (April 30, 2021), available at https://www.autoweek.com/news/a36292118/phasing-out-internal-combustion-engines/.

87. Paul Lienert and Tina Bellon, "Global Carmakers Now Target $515 Billion for EVs, Batteries," Reuters (November 10, 2021), available at https://www.reuters.com/business/autos-transportation/exclusive-global-carmakers-now-target-515-billion-evs-batteries-2021-11-10/.

willingness to supply ZEVs, ideally beyond the minimum production targets. Additionally, CARB regulations have forced many manufacturers to produce ZEVs that are now price competitive on the market, which can in turn create a market transformation that may no longer require stringent regulations. For example, a recent analysis by Reuters found that even though policy makers may expect initial opposition to technology-forcing regulations like the light-duty ZEV regulation, as regulated entities innovate and foster stronger technological competition, these incumbent manufacturers may start to focus on shaping policy interventions rather than opposing them. This decreased opposition from the manufacturers in turn can create vital political support for policy makers to increase regulatory targets.[88] As more automakers pivot to producing ZEVs, CARB's strategic investments to increase consumer demand can help reinforce automaker compliance, though which incentives and at what levels are most cost effective will require new data to better estimate.

Increased Deployment of ZEV Charging Infrastructure

CARB's CC4A and CVA programs offer home charger incentives or prepaid charge cards where home charger installations are not an option to lower-income consumers living in priority population areas; and by July 2023, CVRP would include a prepaid charge card that would be issued to low-income beneficiaries.[89] Additionally, CARB's support for ZEVs could be a significant factor in third-party investment in ZEV charging infrastructure. As more vehicles are on the road, demand for charging increases, leading to more investment by utilities, automakers like Tesla that fund infrastructure, and independent charging companies. This infrastructure deployment could in turn stimulate new ZEV purchases to some degree, particularly in disadvantaged communities where residents often lack access to dedicated parking spots with chargers. For example, prior research indicated a causal relationship between charging infrastructure availability and new ZEV sales,[90] although recent studies by UC Davis Institute of Transportation Studies have called this claim into question. These studies show that charging location density has a statistically insignificant effect on ZEV purchasing decisions and that prior ZEV engagement is the most important factor.[91] That dynamic could be the

88. Joeri Wesseling et. al., "Exploring car manufacturers' responses to technology-forcing regulation: The case of California's ZEV mandate." Environ. Innov. and Societal Trans. 16 (2015), available at https://doi.org/10.1016/j.eist.2015.03.001.

89. CARB, *Proposed Fiscal Year 2022-23 Funding Plan for Clean Transport Incentives*, supra.

90. California Public Utilities Commission, "Transportation Electrification" (webpage), available at https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/infrastructure/transportation-electrification; California Energy Commission, "Tracking Progress: Zero Emission Vehicles and Infrastructure" (webpage), available at https://www.energy.ca.gov/sites/default/files/2019-12/Zero-Emission_Vehicles_and_Infrastructure_ada.pdf; Easwaran Narassimhan and Caley Johnson, "The Role of Demand-Side Incentives and Charging Infrastructure of Plug-in Electric Vehicle Adoption: Analysis of US States," Environmental Research Letters 13 (2018), available at https://iopscience.iop.org/article/10.1088/1748-9326/aad0f8.

91. University of California Institute of Transportation Studies, *Understanding the Impact of Charging Infrastructure on the Consideration to Purchase an Electric Vehicle in California* (2022), p.37-79, available at https://escholarship.org/uc/item/6jx7m6pd.

result of a high proportion of current ZEV drivers who live in single-family homes and are therefore able to charge in their dedicated parking spots with access to electricity, while those who live in multifamily housing or lack a dedicated parking spot (40% of California's residents) are unable to do so. The public charger access disparities are more pronounced in areas with a higher proportion of multi-unit housing, where they are critical for ZEV operation due to a lower likelihood of residential charger access.[92] As such, 50 to 80% of California residents who live in multifamily homes will rely on public chargers.[93] Disadvantaged populations, who are more likely to purchase used ZEVs and inhabit multifamily housing, are therefore disproportionately affected by a lack of charging infrastructure.[94]

The increase in demand and supply of ZEVs through CARB's incentive and regulatory programs has substantially increased the need for ZEV charging infrastructure across the state and the country as charging the growing number of ZEVs requires a robust network of stations for both consumers and fleets. California currently has around 56,000 public EV chargers but will need 1.2 million by 2030 to supply electricity for their target number of EVs.[95] The California Energy Commission (CEC) has set a goal of 250,000 public ZEV chargers by 2025, but at the current rate, agency leaders expect that they will fall 57,000 chargers short. In addition to the 1.2 million chargers for passenger vehicles, the CEC expects 157,000 chargers will be required by 2030 to support the anticipated 180,000 medium- and heavy-duty electric trucks and buses. Volkswagen created Electrify America with $2 billion in funding as part of its settlement with the U.S. and California over its well-publicized diesel emissions-cheating device scandal. Electrify America is spending the money on infrastructure and consumer education, and their charging stations are being outfitted to allow any plug-based vehicle to connect, though Tesla owners will need an optional, proprietary adapter.[96] The CEC and other state agencies have increased their investment to speed up implementation. The California Public Utilities Commission (CPUC) has authorized utilities to spend around $1.8 billion on transportation electrification investments including for the medium- and heavy-duty sectors.[97] These efforts and investments to

92. Chih-Wei Hsu and Kevin Fingerman, "Public electric vehicle charger access disparities across race and income in California," Transport Policy 100 (2021), available at https://doi.org/10.1016/j.tranpol.2020.10.003.

93. Center for Law, Energy, and the Environment (CLEE), *Electric Vehicles and Global Urban Adoption* (2019), p.4, available at https://www.law.berkeley.edu/wp-content/uploads/2019/11/Electric-Vehicles-and-Global-Urban-Adoption.pdf.

94. CLEE and Emmett Institute on Climate Change and the Environment, *Driving Equity: Policy Solutions to Accelerate Electric Vehicle Adoption in Lower-Income Communities* (2022), p.25, available at https://www.law.berkeley.edu/wp-content/uploads/2022/04/Driving-Equity-May-2022.pdf.

95. California Energy Commission, *Assembly Bill 2127 Electric Vehicle Charging Infrastructure Assessment: Analyzing Charging Needs to Support Zero-Emission Vehicles in 2030* (July 2021), available at https://www.energy.ca.gov/programs-and-topics/programs/electric-vehicle-charging-infrastructure-assessment-ab-2127.

96. Paul Eisenstein, "VW's $2 billion penalty for diesel scam, Electrify America, builds electric charging network across US to boost EV market," CNBC (May 10, 2019), available at https://www.cnbc.com/2019/05/10/vws-2-billion-penalty-for-diesel-scam-builds-ev-charging-network-across-us.html.

97. California Public Utilities Commission, *Decision on Transportation Electrification Policy and Investment* (2022), available at https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M497/K622/497622010.PDF.

deploy charging infrastructure by government and private companies across California and the country could be directly linked to the increase in ZEV production and sales through CARB's ZEV programs. However, no existing literature exists to help CARB quantify these impacts, and no feasible data collection or analysis is possible to provide an educated guess, therefore researchers can only acknowledge these second-order impacts qualitatively as a benefit of CARB's policy approach.

Impact on Increased Consumer Awareness of ZEVs

Research shows that an effective way to increase the likelihood of a consumer purchasing or leasing a ZEV is to experience driving or using a ZEV.[98] California has supported consumer education and outreach efforts such as the DriveClean website,[99] the CVRP outreach,[100] ride-and-drives and Veloz's Statewide consumer awareness campaign. Lower-income communities have disproportionately lower levels of ZEV awareness, lack trusted sources of ZEV information and marketing, see lower levels of funding and resources for community-based outreach, and have lower concentrations of ZEVs in their community.[101] Although surveys of vehicle owners or potential purchasers conducted between 2019 and 2021 show that less than 5% of respondents were unaware of ZEVs,[102] more than 55% in the 2019 California Vehicle Survey said they had "little to no experience with BEVs," with no family, friends, or neighbors with BEVs.[103] More than two-thirds of U.S. consumers said in 2020 that they had never sat in a BEV.[104] Since experience with ZEVs is one of the most significant factors affecting purchasing decisions,[105] and 60% of consumers who have never been in a BEV have an extremely low likelihood of purchasing one,[106] CARB programs to increase consumer experience could be critical to increased ZEV adoption. Additionally, exposure to ZEVs through participation in ride-and-drives and car sharing programs has been shown to increase consumer interest in

98. Turrentine, et al., *Steering the Electric Vehicle Transition to Sustainability,* University of California, Davis, 2018, available at https://escholarship.org/content/qt1w3836d3/qt1w3836d3_noSplash_372a97de5dcbcce64a63b272be5a771e.pdf.

99. CARB. "DriveClean" (webpage), available at https://www.driveclean.ca.gov/.

100. Clean Vehicle Rebate Program, "Local events and workshops", available at https://cleanvehiclerebate.org/eng/local-events-and-workshops.

101. CLEE and Emmett Institute on Climate Change and the Environment, *Driving Equity: Policy Solutions to Accelerate Electric Vehicle Adoption in Lower-Income Communities,* supra, p.29-33

102. National Renewable Energy Laboratory, *California Vehicle Survey* (2019), available at https://www.nrel.gov/transportation/secure-transportation-data/tsdc-2019-california-vehicle-survey.html; Consumer Reports, *Consumer Attitudes Towards Electric Vehicles and Fuel Efficiency in California* (2020), p. 4, available at https://advocacy.consumerreports.org/wp-content/uploads/2021/03/California-EV-FE-Survey-Report-3.8.21.pdf.

103. NREL, *California Vehicle Survey* supra.

104. J.D. Power, *2020 Q3 Mobility Confidence Index Study* (2020), available at https://www.jdpower.com/business/press-releases/2020-q3-mobility-confidence-index-study.

105. J.D. Power, *2019 Q2 Mobility Confidence Index Study* (2019), available at https://www.jdpower.com/business/press-releases/2019-q2-mobility-confidence-index-study-fueled-surveymonkey-audience.

106. J.D. Power, *2020 Q3 Mobility Confidence Index Study,* supra.

ZEV adoption.[107] Though the direct impact of CARB's program portfolio on consumer awareness is likely to be limited, the agency may have a positive indirect impact through the many education and outreach programs. Most users of CARB's programs have some awareness of ZEVs before beginning their vehicle search, and just 2% of 2017-2020 CVRP survey respondents had no awareness of ZEVs when they decided to purchase a new vehicle.[108]

CARB runs outreach programs such as conferences, auto shows, and workshops, which not only advertise the incentive programs themselves but offer high-quality information on purchasing and using ZEVs. Since each CARB program runs its own outreach, leaders can target initiatives around a specific audience and subject. In order to increase community engagement to ensure that the programs are aligned with community needs, CARB engaged with environmental justice advocates and community-based organizations (CBO) and received feedback on ways in which automakers could best help increase access to ZEVs. This CBO outreach also occurs through CVRP, CC4A, CVA Program, and CARB plans to expand these partnerships in the coming years to reach priority populations. CARB also promotes cross-program collaborations to understand the interactions between their outreach programs and their audiences. For example, the Access Clean California Program is a centralized network for light-duty vehicle outreach programs, specializing in disadvantaged communities. In order to make the programs accessible to low-income and disadvantaged communities, CARB's approach to consumer education and outreach must resonate with those audiences and be customized to meet their needs.[109] Access Clean California provides a single application to maximize participation in CARB's Low Carbon Transportation Equity Projects to promote advanced technology vehicle adoption in disadvantaged communities, low-income communities, and low-income households.[110] Splitting outreach by audience instead of by program would reduce overlap and still allow for effective targeting. For lower-income communities, CARB is focusing on collaborating with community-based organizations, as they are viewed as trusted local information sources. Existing programs such as the San Joaquin Valley Clean Vehicle Empowerment Collaborative, under the CVRP Community Partner Network, demonstrate the effectiveness of local outreach and education events.[111] Lastly, CARB's incentive and regulatory programs may have indirect benefits to consumer awareness of ZEVs through increasing ZEV adoption. This in turn increases the density of ZEVs in a community, which is one of the most important factors in increasing ZEV

107. Consumer Federation of America, "New Data Shows Consumer Interest in Electric Vehicles Is Growing" (2016), available at https://consumerfed.org/press_release/new-data-shows-consumer-interest-electric-vehicles-growing/.

108. CVRP, *Electric Vehicle Consumer Survey, 2017-2020 edition* (2020), available at https://cleanvehiclerebate.org/en/rebate-survey-dashboard.

109. CARB, *Low-Income Barriers Study, Part B: Overcoming Barriers to Clean Transportation Access for Low-Income Residents* (2018), available at https://ww2.arb.ca.gov/sites/default/files/2018-08/sb350_final_guidance_document_022118.pdf.

110. CARB, "The Truckstop" (webpage), available at https://ww2.arb.ca.gov/sites/default/files/truckstop/truckstop.html.

111. CLEE and Emmett Institute on Climate Change and the Environment, *Driving Equity: Policy Solutions to Accelerate Electric Vehicle Adoption in Lower-Income Communities*, supra.

awareness quality. As 20% of CVRP funding reaches low-income communities[112] and the CC4A and CVA programs target ZEV adoption in these communities, increasing this share of funding could significantly affect consumer awareness for low-income residents.

CARB could improve the adoption of ZEVs by enhancing these outreach and education efforts, which heighten consumer interest in acquiring one.[113] Participating in ride-and-drives and car-sharing programs expose consumers to ZEVs and can therefore generate more interest in their adoption.[114] Carsharing allows individuals to gain the benefits of using a private car without the associated costs and responsibilities of owning a car.[115] To provide greater access to ZEVs, CARB offers incentive programs that help launch car sharing services that use clean transportation options, including PHEV or BEV, and serve disadvantaged, low-income, and tribal communities. Understanding how awareness levels vary across communities and their access to information will lead to more effective awareness programs, especially for lower-income populations. Though survey data exists on CVRP users' ZEV awareness, this data is not necessarily representative and is limited to one program. CARB could instead consider developing more comprehensive surveys going forward, as discussed in the recommendations section below. The agency could also potentially analyze existing sales data to estimate potential links between policies that boost ZEV awareness, sales, and leases.

112. Clean Vehicle Rebate Project, "Clean Vehicle Rebate Project Rebate Statistics," supra.

113. Consumer Federation of America, "New Data Shows Consumer Interest in Electric Vehicles Is Growing," supra.

114. Susan Shaheen, et al.,"Zero-emission vehicle exposure within U.S. carsharing fleets and impacts on sentiment toward electric-drive vehicles," Transport Policy 85 (2020), p.A23-32, available athttps://doi.org/10.1016/j.tranpol.2019.09.008.

115. CARB, 'Carsharing & Clean Mobility Options Incentive Programs in Disadvantaged Communities', available at https://ww2.arb.ca.gov/sites/default/files/movingca/carsharing.html.

V. RECOMMENDATIONS

UNTAPPED OPPORTUNITIES FOR CARB TO PURSUE WITHOUT FURTHER RESEARCH

In order to more comprehensively understand and evaluate market impacts, CARB can analyze the existing data on sales or vehicle registration to complement the survey response data. To date, CARB's reporting system has assumed that vehicles purchased under its incentive programs would not have been purchased otherwise—a practice that both the Legislative Analyst's Office (2018)[116] and the State Auditor (2021) have questioned.[117] CVRP, the sole program that collects the consumer's opportunity cost through voluntary consumer survey data, shows that roughly half of all respondents would still have purchased the vehicles without the incentive, though 89% of respondents believed that CVRP was 'moderately', 'very', or 'extremely important' in making it possible to purchase the vehicle.[118] With a potentially unrepresentative and relatively low response rate under 20%, as well as other factors, policy makers may face limits relying on this data. Despite the limitations of survey data, they may be the most effective way to collect data on the importance of CVRP in the purchase/lease decision. CARB could also potentially analyze the ZEV sales figures in other states as a means of quantifying the impact of various

116. Legislative Analyst's Office, *Assessing California's Climate Policies—Transportation* (December 2018), available at https://lao.ca.gov/reports/2018/3912/climate-policies-transportation-122118.pdf.

117. Auditor of the State of California, *California Air Resources Board: Improved Program Measurement Would Help California Work More Strategically to Meet Its Climate Change Goals,* supra.

118. CVRP, *Electric Vehicle Consumer Survey*, supra.

incentive programs that are similar to California's. Additionally, comparing the ZEV sales figures of California with other states that have no incentive programs in place could help in quantitatively measuring the benefits of the state's incentive programs.

Regarding heavy duty programs, the current focus of the HVIP is on zero-emission technologies that are based on batteries and fuel cell propulsion systems, with characteristics that are new to many types of fleets, including the required refueling/recharging infrastructure, maintenance requirements, and driver and other staff training needs. A deeper understanding of these additional aspects of ZEV adoption for these sectors can help to identify implementation barriers and how they may be resolved and improved moving forward. More generally, along with statewide totals, HVIP market penetration can be analyzed on a county-level basis with existing data to understand the geographic impacts of the program across the state in more detail. Analysis of voucher levels (in dollars) for various vehicle classes can help with understanding how effectively the program covers the difference in the first cost of the clean vehicles relative to their conventional counterparts.

FUTURE-FACING RESEARCH AND DATA COLLECTION OPTIONS

CARB can prospectively improve its survey program and make the instruments consistent across the light-duty incentive programs to better inform their quantification estimates. Vehicle sales or registration data can help estimate the causal impact of certain programs administered by CARB like the CC4A, primarily because the program design allows for a natural experiment setup. In other words, as the program is administered for certain socio-demographic groups and in particular air quality management districts, it allows UC researchers to leverage causal analysis methods to estimate the impact of the program on consumer behavior. In other cases, like the CVRP, survey data is a better resource to understand the impact of the program on consumer preference for ZEVs since it is distributed throughout the state.

While it is challenging to untangle the effects of CARB's incentives and regulatory programs accurately and comprehensively, UC researchers are analyzing existing data and developing long-term data collection and analysis tools—with the goal of supporting state policies to achieve environmental and social goals. To complement or supplement incomplete or unrepresentative responses, researchers can leverage vehicle sales data sourced from either the California Department of Motor Vehicles registration records or third-party data sources as in the literature cited earlier.[119] Furthermore, CARB can design surveys to improve program design, by capturing data regarding the challenges that CC4A applicants may have in accessing the program, such as numerous steps,

119. Tamara Sheldon and Rubal Dua, "Assessing the Effectiveness of California's 'Replace Your Ride,'" Energy Policy 132 (2019), available at https://doi.org/10.1016/j.enpol.2019.05.023; Erich Muehlegger and David Rapson, *Subsidizing Mass Adoption of Electric Vehicles: Quasi-Experimental Evidence from California* (2018), available at http://rapson.ucdavis.edu/uploads/8/4/7/1/84716372/mr_mass_ev_adoption.pdf.

difficult timelines, and limited avenues for help.[120] Surveys could help CARB leaders understand the impact these obstacles may have on the effectiveness of the programs.

Going forward, CARB could ask the survey questions in relation to other incentives an individual consumer may have had access to, such as the federal tax credit, High-Occupancy Vehicle Lane access, and other local rebates. Moreover, since the application process for CVRP can often involve a waiting period and higher uncertainty relative to the tax credit or the HOV lane access sticker, CARB could add questions to track the impact of the uncertainty on respondents. In the process, CARB could give respondents the opportunity to rank the incentives received by effectiveness and then answer how their decision may have been different without the incentives. Though these responses would constitute "stated intention" data, they could give CARB the opportunity to analyze the importance of CVRP relative to the other monetary and other incentives available to consumers.

For other incentive programs like CC4A, CARB could survey owners to understand the criticality of the program to their decisions, as well as the effects of combining incentives on purchasing decisions, and attempt to compare data on purchases either before and after the introduction of the incentives or with comparable areas that do not have these or similar incentives. A survey similar to the CVRP one for both the CC4A and CVA program could allow CARB to analyze the impact of these incentives on consumer decisions within priority populations, as well as provide a uniform instrument to compare the importance of these complementary programs on the purchase/lease decision of consumers.

More generally, CARB could improve survey data collection going forward. Currently, comprehensive post-purchase survey data is only collected for the CVRP and HVIP programs. For these programs, the response rate is around 15% and 20% respectively, which calls into question how representative the results may be. As CARB strengthens its outreach programs and its relationship with community organizations, both the agency and these organizations can aid in increasing survey participation, especially among program target communities. Additionally, due to differences in the questions and response format, cross-program comparisons are challenging. CARB could perform surveys for all incentive programs and standardize answering formats. Though the surveys will differ depending on program targets, some questions could be standardized to allow for cross-program comparison. Lastly, CARB could draft questions more effectively to measure targeted outcomes, such as separating consumers by what type of vehicle they would have purchased without a rebate.

For heavy-duty vehicles, researchers can assess HVIP program effectiveness in terms of the market penetration of zero and low-emission vehicles by vehicle class over time that the program supports, relative to the full population

120. Trisha Litong and Sita Syal, "*Uncovering the Barriers and Inequities of a Clean Mobility Program Using Journey Mapping*", supra.

of vehicles in each weight class. A classic cost-effectiveness analysis of the program requires a better understanding of HVIP vehicle activity, in terms of miles driven in each year, for each vehicle supported by the program, and then a subsequent emissions analysis including understanding (for electricity) the timing and location of vehicle charging. However, the full benefits of technology development-supporting programs such as HVIP go well beyond narrow cost-effectiveness in terms of their impacts on technology improvement, cost reduction, behavioral change, and overall market transformation. Understanding these broader impacts of HVIP would require survey and other data gathering efforts to:

- Assess how the HVIP program is altering manufacturer behavior to produce additional makes and models of medium and heavy-duty ZEVs;
- Understand how the HVIP program is changing the behavior of fleets in making vehicle purchase decisions, including potentially for vehicles that may (or may not) receive other types of (e.g., Federal) incentives and not necessarily also including HVIP vouchers

This analysis could then carry further the UC Berkeley HVIMPACT model that examines the market penetration of MDV/HDVs across several vehicle categories, for individual California counties as well as the statewide totals. The HVIMPACT analysis covers the period from 2015-2020, focusing on the availability of HVIP and overall EMFAC fleet data. HVIMPACT will measure the introduction of zero-emission trucks, buses, delivery vans, and other vocational vehicles relative to the overall vehicle stock in each county. The model currently assumes that vehicles placed in service from 2010 onward are still in service, although this assumption is likely not entirely accurate in practice and could be subject to further refinement. However, even with these steps to improve data collection and analysis, researchers will still struggle to make precise determinations, only better estimates, and they have no guarantees that survey responses will be representative.

QUANTIFYING THE UNQUANTIFIABLE: EXAMINING THE LIMITS OF PROGRAM IMPACT MEASUREMENT

Ultimately, given the data currently available, UC researchers will have difficulty disentangling the effect of programs like the CVRP on consumer behavior, primarily because consumers can be simultaneously eligible for multiple incentive programs like the federal tax credit and the CVRP along with other local rebates and incentives. However, UC researchers can aim to recommend the type of data collection that can allow CARB to better disentangle the impacts in the future. This could include questionnaire survey designs that would estimate the impact of bundles of incentives (e.g., CVRP, HOV lane access, and the federal tax credit) on PEV adoption and the individual impact of specific incentives in bundles. Current surveys (including the CSE CVRP Survey and UC Davis eVMT survey) typically ask respondents to consider only the impact of individual incentives and do not account for the impact of other incentives buyers receive.

While the CARB programs all contribute to greenhouse gas emissions reductions and second-order benefits, analysts face difficulty quantifying the impact of adopting and implementing any individual program because of the programs' interrelated nature. The challenges are twofold: first, the programs rely on each other for success, as an incentive without vehicle supply is worthless and vehicle supply may not be enough without consumer incentives to help consumers offset any higher upfront costs; second, given the complexity of consumer decision making and the lack of comprehensive survey data, the UC research team cannot precisely determine how much of a ZEV sale or lease is due to any particular CARB program. Going forward, the research team recommends enhanced data collection that could better inform these estimates, while acknowledging the inherent challenge and limitation of results.

VI. CONCLUSION

California's ZEV policies serve as a model for policy makers across the United States and the world, while stimulating innovations and investments in low-carbon technologies. California's complementary policy approach, driven by regulations and incentive programs, has likely stimulated investments in ZEV manufacturing, contributed to a substantial decline in ZEV prices, and increased the sales of these vehicles both domestically and globally. While the California State Auditor has criticized CARB's approach to measuring the extent of these impacts, the lack of existing data and difficulty in disentangling the role of these policies makes a more precise accounting difficult, given that the incentive and regulatory programs work together to achieve greenhouse gas emissions reduction, market acceleration of ZEVs, and air quality improvements. Improving consumer data collection would therefore help in giving the public a better understanding of the impacts of these programs.

The UC Davis and UC Berkeley research team is currently working on refining methodologies that quantify the greenhouse gas reductions from an incentive to purchase a vehicle or equipment, considering the role of regulations, other incentives, and any other factors deemed appropriate. The team is also performing quantitative analysis using available data to understand the impact of CARB programs on consumer choice. The next stage of this research will present methodologies, discuss the strengths and limitations of the proposed approaches and provide recommendations to address identified limitations.

Collectively, by directly requiring that automakers invest in clean technology and providing financial incentives to purchase ZEVs, CARB's ZEV programs are encouraging manufacturers to produce ZEVs. This production in turn helps to build a sustainable consumer market for ZEVs, which encourages members

of priority populations to access ZEVs and contributes to greenhouse gas emission reductions and improved air quality. Therefore, these programs are contributing to California's efforts to reduce emissions of greenhouse gases and other air pollutants and deliver other co-benefits in the process. However, the accurate extent of the impact is unclear and the magnitude and speed of change needed to achieve California's goals is unprecedented. Ideally, these data collection and analytical reforms could improve the policies that have made California a leader in both climate equity and ZEV deployment.

GLOSSARY OF TERMS, ABBREVIATIONS, AND SYMBOLS

AB	Assembly Bill
ACC	Advanced Clean Cars
ACF	Advanced Clean Fleets
ACT	Advanced Clean Trucks
APCD	Air Pollution Control District
AQMD	Air Quality Management District
BAU	Business as Usual
BEV	Battery-Electric Vehicle
CARB	California Air Resources Board
CBO	Community Based Organization
CC4A	Clean Cars 4 All
CEC	California Energy Commission
CHEAPR	Connecticut Hydrogen and Electric Automobile Purchase Rebate
CLEE	Center of Law, Energy, and the Environment
CO_2	Carbon Dioxide
CPUC	California Public Utilities Commission
CSA	California State Auditor
CVA	Clean Vehicle Assistance program
CVRP	Clean Vehicle Rebate Project
DOT	US Department of Transportation
EMFAC	Emission Factor
EPA	US Environmental Protection Agency
FCEV	Fuel Cell Electric Vehicles
GHG	Greenhouse Gas
HEV	Hybrid Electric Vehicle
HVIP	Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project
ICE	Internal Combustion Engine
ICT	Innovative Clean Transit
LCFS	Low Carbon Fuel Standard
LDV	Light Duty Vehicle

LEV	Low Emissions Vehicle
MOR-EV	Massachusetts Offers Rebates for Electric Vehicles
$MMTCO_2e$	Million Metric Tons of Carbon Dioxide Equivalents
MY	Model Year
NO_2	Nitrogen Dioxide
NO_x	Nitrogen Oxides
PHEV	Plug-in Hybrid Electric Vehicle
$PM_{2.5}$	Fine Particulate Matter with a diameter of 2.5µm or less
ZEV	Zero-Emission Vehicle

APPENDIX

Detailed summary of the regulatory programs in this study's scope of work.

DETAIL	ACC ZEV REGULATION	CALIFORNIA PHASE 2 REGULATION
Applicable Model Years	ACC I: MY 2018-2025[121] ACC II: MY 2026-[122]	MY 2020 - Effective for trailers[123] MY 2021 - Effective for class 2b-8 trucks[124]
Regulated Entities	High volume manufacturers, meaning manufacturers with five consecutive 3-year average California production volumes exceeding 20,000 new cars, light-duty trucks, and medium-duty vehicles[125] Medium volume manufacturers, and manufacturers with five consecutive 3-year average California production volumes exceeding 4,500 new cars, light-duty trucks, and medium-duty vehicles[126]	All medium- and heavy-duty engine and vehicle, and all trailer manufacturers who intend to sell engines and vehicles in California.
Scope of equipment	New light-duty ZEVs under 8,500 lbs. from MY2012[127] New light-duty PHEVs under 8,500 lbs. from MY2012[128]	New class 2b-8 medium- and heavy-duty trucks and engines from MY2021 onward[129] New trailers from MY2020 onward[130]
Percent of ZEVs required	Based on ACC I, a manufacture is required to generate ZEV credit equaling 4.5% of total average volume of all passenger cars and light-duty trucks under 8,500 lbs. delivered for sale in California in MY 2018, increasing linearly to 22% by MY 2025.[131] Note that each advanced technology vehicle can generate a credit of 0.4-4 based on ACC I. Based on ACC II, 35% of total average volume of all light-duty vehicles delivered for sale in California in MY 2026, increasing nonlinearly to 100% by MY 2035[132]	N/A (Covered by Advanced Clean Trucks regulation)

121. 13 Cal. Code Regs, §§ 1962.2.

122. 13 Cal. Code Regs §§ 1962.4.

123. CARB, *Staff Report: Initial Statement of Reasons for Proposed Rulemaking- Proposed California Greenhouse Gas Emissions Standards for Medium-and Heavy-duty Engines and Vehicles and Proposed Amendments to the Tractor-trailer GHG Regulation*, supra.

124. Id.

125. 13 Cal. Code Regs, §§ 1900.

126. Id

127. 13 Cal. Code Regs, §§ 1962.1, 1962.2.

128. Id.

129. CARB, *Staff Report: Initial Statement of Reasons for Proposed Rulemaking- Proposed California Greenhouse Gas Emissions Standards for Medium-and Heavy-duty Engines and Vehicles and Proposed Amendments to the Tractor-trailer GHG Regulation*, supra, p.II.3.

130. Id.

131. CARB, *2020 ACC ZEV Credit Annual Disclosure Report* (2020), p.1, available at https://ww2.arb.ca.gov/sites/default/files/2021-12/2020_zev_credit_annual_disclosure_ac.pdf.

132. 13 Cal. Code Regs §§ 1962.4.

DETAIL	ACC ZEV REGULATION	CALIFORNIA PHASE 2 REGULATION
How requirements are structured	Based on ACC I, each medium- and high-volume manufacturer is given a credit requirement, which is an increasing percentage of their average production volume. Credits are carried over from previous years, and the overall credit requirement increases annually.[133] A formula is used to give each model a credit value of 0.4-1.3 for a PHEV and 1-4 for a BEV, which depends on the range of the vehicle.[134]	Vehicle standards establish maximum gCO_2/ton-mile requirements dependent on vehicle class. Each class has increasing standards for MY2021, 2024, and 2027 vehicles. Standards are also split amongst diesel and gasoline engines, and amongst vehicle use cases.[135] Trailer standards establish maximum gCO_2/ton-mile requirements for box vans and trailers, dependent on vehicle type. Each type has increasing standards for MY2020, 2021, 2024, and 2027 vehicles. Standards also exist for standalone trailers, which have maximum rolling resistance requirements and technological requirements.[136] Engine standards establish maximum gCO_2/ton-mile requirements for heavy-duty tractor engines, and gCO2/bhp-hr. requirements for vocational diesel engines. Increasing standards exist for MY2021, 2024, and 2027 vehicles.[137]

133. Id., p.5-7.

134. Id., p.3-4.

135. CARB, *Staff Report: Initial Statement of Reasons for Proposed Rulemaking- Proposed California Greenhouse Gas Emissions Standards for Medium-and Heavy-duty Engines and Vehicles and Proposed Amendments to the Tractor-trailer GHG Regulation*', supra, p. III.4-III.8.

136. Id., p. III.9-III.10.

137. Id., p. III.11-III.12.

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