WHITE PAPER

BUILDING A BEACHHEAD: CALIFORNIA'S PATH TO ACCELERATING ZERO-EMISSION COMMERCIAL VEHICLES

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CALSTART is the nation's leading clean transportation nonprofit organization, working nationally and internationally with businesses and governments to develop clean, efficient, and equitable transportation and mobility solutions. CALSTART is a solutions network that connects companies and government agencies and helps them do their jobs better. From technology firms to transit operators and from vehicle manufacturers to research institutions, we connect every element of the clean energy sector, offering customized services, information, and programming. CALSTART's 270+ member firms and agencies include vehicle fleets, manufacturers, suppliers, technology firms, alternative fuel providers, electric utilities, government agencies, academic institutions, non-governmental organizations (NGOs), financial institutions, and other businesses interested in the future of sustainable transportation.

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LIST OF ACRONYMS

AB	Assembly Bill
ACT	Advanced Clean Trucks regulation
AQIP	Air Quality Improvement Program
AQMD	Air Quality Management District
BAAQMD	Bay Area Air Quality Management District
BAU	Business-as-Usual
CalEPA	California Environmental Protection Agency
Caltrans	California Department of Transportation
CARB	California Air Resources Board
CEC	California Energy Commission
CI	Carbon Intensity
CNRA	California Natural Resources Agency
CO	Carbon Monoxide
CORE	Clean Off-Road Equipment Voucher Incentive Project
CPUC	California Public Utilities Commission
DC	Direct Current
EER	Energy Economy Ratio
EPA	US Environmental Protection Agency
EU	European Union
EV	Electric Vehicle
FY	Fiscal Year
GGRF	Greenhouse Gas Reduction Fund
GHG	Greenhouse Gas
GO-Biz	Governor's Office of Business and Economic Development
GVWR	Gross Vehicle Weight Rating
HDT	Heavy-Duty Truck
HVIP	Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project

LIST OF ACRONYMS

ICT	Innovative Clean Transit regulation
IOU	Investor-Owned Utility
LCFS	Low Carbon Fuel Standard
MHDV	Medium- and Heavy-Duty Vehicle
NOx	Nitrogen Oxides
NYTVIP	New York's Truck Voucher Incentive Program
NZEV	Near- Zero-Emission Vehicle
PAVE	Port Advanced Vehicle Electrification
PG&E	Pacific Gas & Electric
PM	Particulate Matter
SB	Senate Bill
SCAQMD	South Coast Air Quality Management District
SCE	Southern California Edison
SDG&E	San Diego Gas & Electric
SJVAPCD	San Joaquin Valley Air Pollution Control District
START	Sustainable Terminals Accelerating Regional Transformation Project
TEU	Twenty-foot Equivalent Unit
TOU	Time-of-Use
TRU	Transport Refrigeration Unit
U.S.	United States
VIP	Voucher Incentive Program
WAIRE	Warehouse Actions and Investments to Reduce Emissions
ZANZEFF	Zero- and Near-Zero Emission Freight Facility
ZEB	Zero-Emission Bus
ZECV	Zero-Emission Commercial Vehicle
ZE-MHDV	Zero-Emission Medium- and Heavy-Duty Vehicle
ZEV	Zero-Emission Vehicle

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CHAPTER 1

EXECUTIVE SUMMARY

On September 23, 2020, Governor Gavin Newsom committed the State of California's transportation sector to a 100% zero-emission future, issuing an executive order with requirements and measures to achieve this goal by 2045. The Governor's Executive Order came three months after the California Air Resources Board (CARB) adopted the Advanced Clean Trucks (ACT) regulation, a first-of-its-kind rulemaking requiring the sale of zero-emission heavy-duty trucks (HDTs) beginning with Model Year 2024.

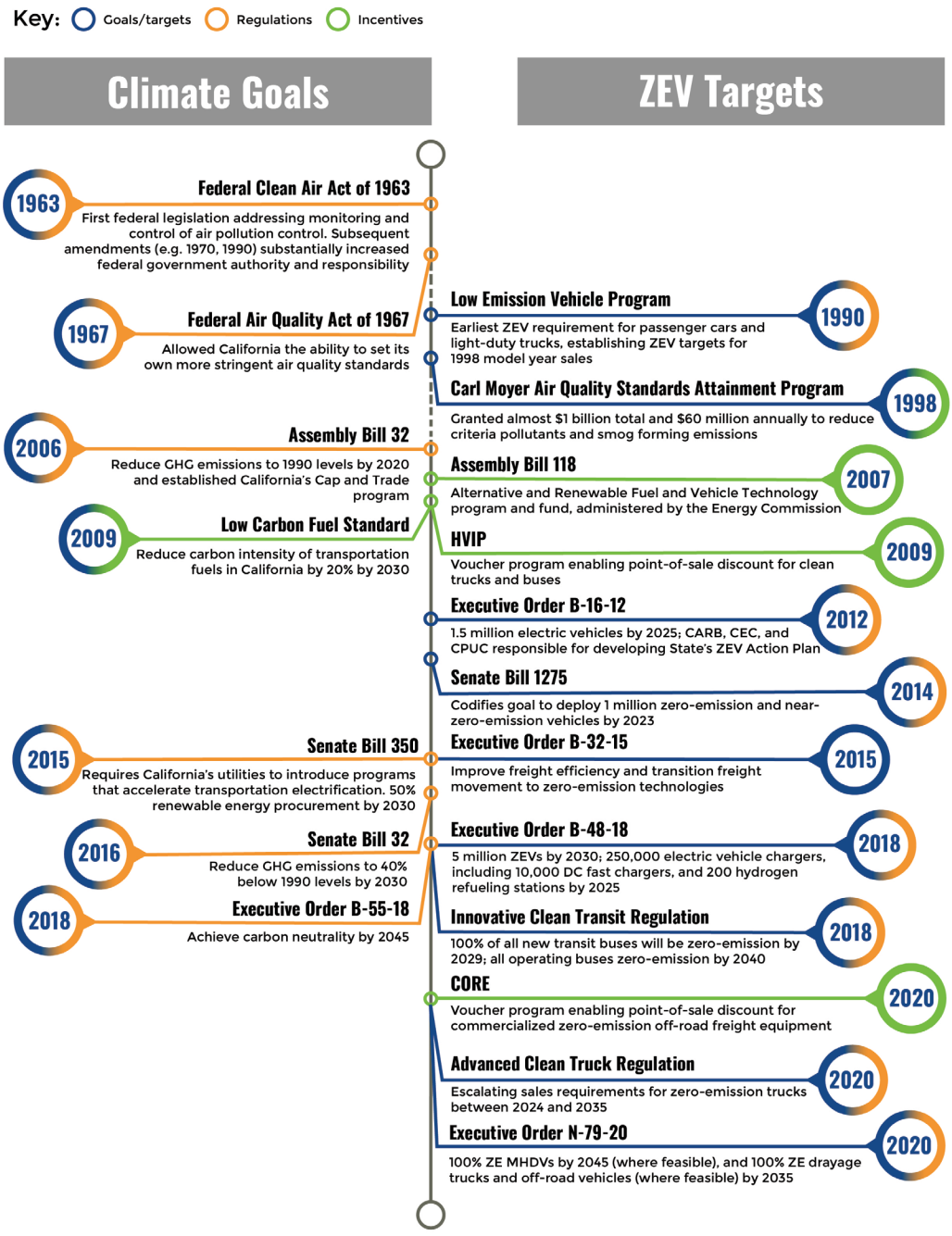
While momentous, these announcements represented a culmination of California's longstanding efforts to improve air quality, fight climate change, and spur transportation sector innovation. Building on more than a decade of global leadership, California has created a supportive ecosystem for zero-emission commercial vehicle (ZECV)[1] deployment through multiple aligned policies, regulations, incentives, infrastructure investments, and pilot projects. This approach has enabled California to steadily increase both its policy ambitions and market readiness for ZECV deployment.

A. CALIFORNIA SETS AMBITIOUS GOALS

California's efforts to accelerate ZECVs are underpinned by the state's climate goals, which were first established in 2006 through the adoption of Assembly Bill 32 (AB 32), the Global Warming Solutions Act of 2006. The state has since expanded these goals through subsequent policy, ultimately aiming to achieve carbon neutrality by 2045 under Executive Order B-55-18, signed by former Governor Jerry Brown in 2018. In addition to these overarching climate goals, the state has adopted several related and supporting policies, regulations, and investment programs to expedite the deployment of zero-emission vehicles (ZEVs) (Figure 1.1). These targets have scaled over time and in tandem with zero-emission technology readiness, reflecting increasing levels of commercial viability and market progress.

1 The terms "zero-emission commercial vehicle" or "ZECV" and "zero-emission medium- and heavy-duty vehicle" or "ZE-MH-DV" are used interchangeably to refer to trucks and buses with a gross vehicle weight rating (GVWR) of over 8,500 pounds. The definition of "zero-emission" includes vehicles with drivetrains that cannot produce tailpipe greenhouse gases (GHGs) or air pollutants, indicating vehicles powered solely by electricity or hydrogen.

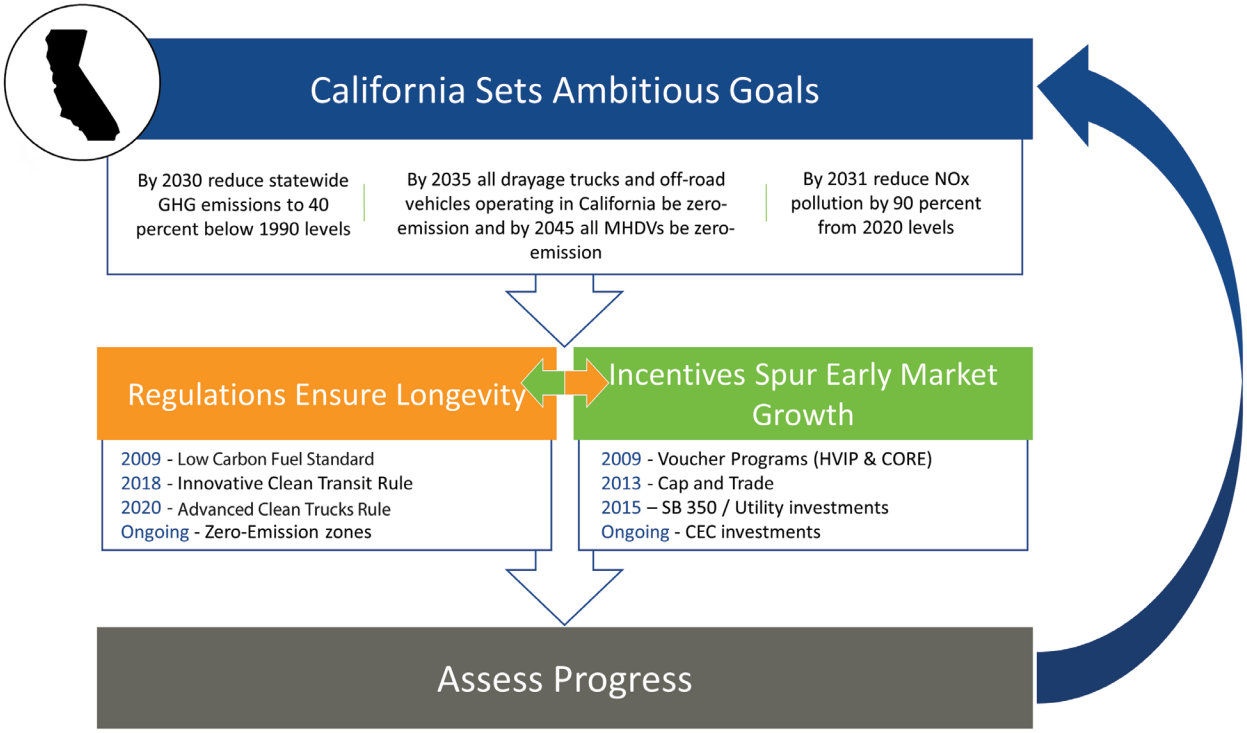
Figure 1.1. California Climate Goals & ZEV Targets



Together, these interrelated goals, regulations, and incentives have enabled California to cultivate a supportive ecosystem for ZECV deployment. Though rooted in the state's unique statutory authority to regulate vehicle tailpipe emissions, and informed by 15 years of progressive policy development, California's experience can be translated into a framework approach to market transformation, with key elements and constituent policies summarized in Figure 1.2. Guided by clear and progressively more ambitious targets, California has used a mix of incentives and regulations to catalyze and sustain

ZECV market transformation, supported by dedicated public investment and a continual assessment of technology readiness and progress.

Figure 1.2. California's Approach to Market Transformation



California's strategy for ZECV technology commercialization has focused on vehicle applications that are most likely to succeed—referred to as first-success or "beachhead" applications. Initial regulations and incentives have targeted beachhead segments like transit buses, with fixed routes, predictable duty cycles, and return-to-base depot charging. As early ZECV beachhead segments grow, regulations and incentives can shift focus to subsequent ZECV segments in tandem with technology transfers from first-success applications to follow-on applications, thereby accelerating the overall ZECV market. This strategy, known as the Beachhead Strategy, is fundamental to the design of regulations and incentives for ZECVs in California.

B. REGULATIONS ENSURE ZEV MARKET LONGEVITY

California has developed several key regulations in support of the state's climate goals and ZEV targets, many of which have been the first of their kind. These technology forcing regulations provide strong market signals and a clear, long-range path towards market transformation, targeting overall transportation emissions and specific beachhead segments.

The **Low Carbon Fuel Standard (LCFS)**, enacted through AB 32 and implemented in 2011, is a market-based mechanism that reduces the greenhouse gas (GHG) content of transportation fuels and provides an increasing range of low-carbon and renewable alternatives through a cap on the carbon intensity of all transportation fuels that produce GHGs. Importantly for ZECVs, the program creates incentives and a potential funding stream for hydrogen fueling and electric charging infrastructure via a market-based system of tradable credits for clean fuel production. The LCFS enables low-carbon fuel producers to sell credits and requires fossil fuel producers to buy credits.

The 2018 **Innovative Clean Transit (ICT)** rule was one of California's first ZECV-focused regulations, targeting the transit bus beachhead segment and reflecting the early-stage commercial readiness of zero-emission transit buses (ZEBs). The ICT requires public transit agencies in California to transition 100% of bus purchases to zero-emission by 2029, and all their bus fleet operations to 100% zero emission by 2040, with a phased implementation timetable for required ZEB purchases beginning in 2023 for large transit agencies.

The **Advanced Clean Trucks (ACT)** regulation, adopted in 2020, takes a similar approach to ICT in mandating a 100% transition to zero-emission trucks. But whereas the ICT focuses on transit fleet procurement, the ACT requires truck manufacturers to meet minimum ZEV sales as a percentage of total truck sales between 2024 and 2035 depending on gross vehicle weight rating (GVWR). By 2035, the zero-emission truck sales share would need to be 55% for Class 2b – 3 trucks, 75% for Class 4 – 8 straight trucks, and 40% for truck tractors.

C. INCENTIVES SPUR EARLY MARKET GROWTH

In addition to these regulations, California has implemented a variety of complimentary incentive and investment programs to spur demand and early market growth for ZECVs. Like the LCFS, California's **Cap-and-Trade** program was established via AB 32. The Cap-and-Trade program is a market-based mechanism that sets a statewide limit on GHG emissions from major sources. Through a system of decreasing emission allowances, the program motivates major polluters to curb emissions while rewarding those who have already begun to adopt cleaner practices in their operations. Importantly, the Cap-and-Trade program utilizes an allowance auction system for the purchase of offset credits needed by major polluters to meet compliance. Proceeds from allowance auctions are deposited into a Greenhouse Gas Reduction Fund (GGRF), which in turn funds the California Climate Investments program. From 2012 through November 2021, the GGRF has generated $18.2 billion in revenue, which has been used to fund many of California's ZECV incentive and investment programs (CARB, 2021c).

Among the most important incentive programs spurring ZECV adoption, California has implemented two voucher incentive programs to reduce the high upfront purchase costs of ZEVs compared to diesel-engine equivalents and to overcome one of biggest barriers to ZECV adoption. California's **Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP)** was initiated in February 2010, initially with funding from license fees, and since 2012 with funding from Cap-and-Trade auction proceeds via California Climate Investments. Through voucher requests totaling $400 million through 2020, HVIP

has deployed over 4,000 all-electric and hybrid vehicles, and low-NOx (nitrogen oxides) engines. An additional $165 million in available voucher funding was opened in June 2021, with internal combustion engine technologies removed from eligibility. The **Clean Off-Road Equipment (CORE)** program, borrowing from the HVIP design, was launched in 2020 to encourage California fleets to purchase zero-emission off-road equipment. In its first year of operation, CORE distributed $44 million for clean off-road vehicles, technologies, and charging equipment, w ith more than 70% of vouchers supporting vehicle deployments in communities disproportionately impacted by air pollution.

Through the **Clean Transportation Program**, previously known as the Alternative and Renewable Fuel and Vehicle Technology Program, the California Energy Commission (CEC) invests in a broad portfolio of transportation and fuel projects to advance state-wide goals on climate change, petroleum reduction, electric vehicle adoption, air quality improvements, and long-term economic development. The program was established in 2007 via Assembly Bill 118, and is funded through vehicle registration fees, which generally collect approximately $100 million a year. Since the initial funding allocation in 2009, the program has invested more than $1 billion to support alternative fuels and advanced vehicle technologies. The CEC-led **School Bus Replacement** program was funded by California's "Proposition 39," which closed a tax loophole, and is helping schools throughout California to replace older, polluting diesel school buses with newer zero- or low-emission vehicles. As of March 2021, the School Bus Replacement program has funded the replacement of 235 school buses, covering almost 100% of the costs.

Finally, recognizing the need for energy system upgrades required to achieve climate and ZECV goals, California has also invested heavily in electrical utility infrastructure. California's **Senate Bill 350 (SB 350)**, passed in 2015, requires the California Public Utilities Commission (CPUC) to direct the state's six investor-owned electric utilities (IOUs) to file applications for programs that "accelerate widespread transportation electrification" and also to ensure that electric rates make electric vehicle charging cheaper than fueling with gasoline or diesel. To date, the CPUC has approved nearly $700 million in make-ready investments to support commercial fleet electrification, which are expected to support over 2,000 new make-ready installations that could serve nearly 20,000 ZE-MHDVs. California's IOUs have also developed programs that support customer-side infrastructure, and new commercial EV rates to ensure that fleets will save money on fuel by adopting EVs. Finally, the CPUC has also addressed the IOUs to develop pilot programs for vehicle-grid-integration for MHDV fleets.

In addition to these programs, California's regional Air Quality Management Districts, Port Authorities, and other regional and local partners have implemented many complementary policies and programs to accelerate ZECV deployment, often in partnership. For example, Proposition 1B, approved by California voters in 2006, established the Goods Movement Emission Reduction Program and appropriated $1 billion in bond funding for CARB to quickly reduce air pollution emissions and health risks from freight movement along California's priority trade corridors in partnership with local agencies, air districts, and seaports. Through ambitious goals, targeted policy regulations, and innovative financial mechanisms, California has become a leader in the global effort to reduce the impact of ZECVs on the environment and public health. By understanding the progress that has been made in California, other regions can begin to explore the impact that various policies and actions might have in their regions.

CHAPTER 2

INTRODUCTION

With over 15.5 million registered trucks and buses, California is the largest medium- and heavy-duty vehicle (MHDV) market in the United States (U.S.) (USDOT Federal Highway Administration, 2020). Though just 5% of the global on-road fleet, MHDVs are responsible for a disproportionate share of fuel consumption, air pollution, and greenhouse gas (GHG) emissions—estimated at over 35% of on-road fuel and 70% of on-road particulates that negatively affect air quality and human health (Welch et al., 2020). At the same time, MHDVs fulfill many of the critical transportation and industrial services that underpin dynamic, 21st century economies, ranging from long-haul and regional freight distribution to construction, sanitation, public transit, and urban delivery. Modernizing and replacing these vehicles with zero-emission technologies present a strategic opportunity to mitigate climate change and simultaneously improve urban air quality, spur industrial advancements, and create new clean technology jobs.

Through ambitious yet achievable targets, California has taken a leadership position in accelerating the deployment of zero-emission commercial vehicles (ZECVs). In June 2020, the California Air Resources Board (CARB) adopted the Advanced Clean Trucks (ACT) regulation, a first-of-its-kind rulemaking that will require the sale of zero-emission MHDVs (ZE-MHDVs) beginning with Model Year 2024. Governor Gavin Newsom went a step further in September 2020 by signing Executive Order N-79-20, establishing the goal that 100% of sales of new passenger vehicles be zero-emission by 2035, and that 100% of MHDVs be zero-emission by 2045 for all application where feasible, and by 2035 for drayage trucks (Office of the Governor, 2020). As major policy achievements, these announcements are part of a systematic approach to market transformation and technological innovation.

A. AN ECOSYSTEM APPROACH TO MARKET TRANSFORMATION

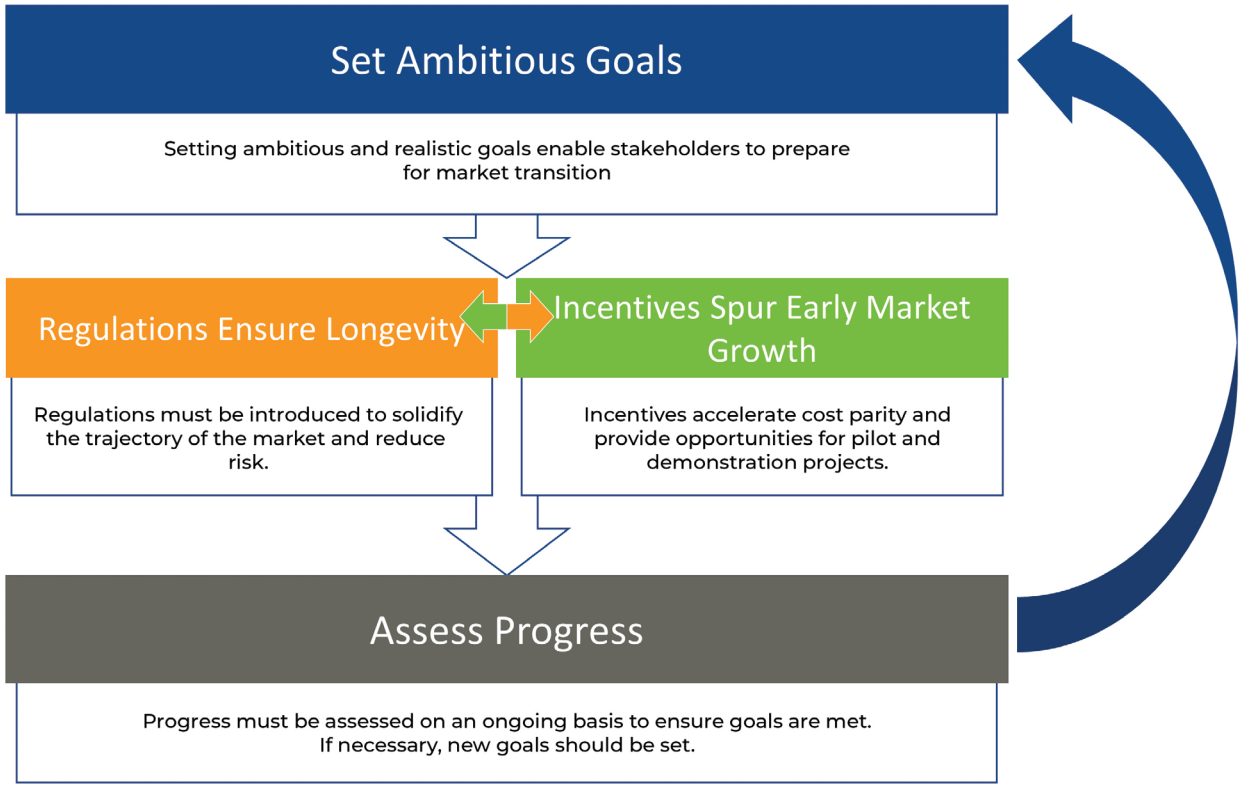
Despite their technological progress and increasing commercial readiness, ZECVs have faced several barriers to commercial competitiveness and widespread deployment, including higher upfront costs, the need for new charging and fueling infrastructure, and limited (though growing) model availability for the diverse and often specialized duty cycles. Likewise, no single stakeholder—whether government, fleet owners, or vehicle manufacturers—can address these challenges alone. Rapid ZECV

deployment will happen only if these barriers are tackled through a multi-pronged strategy to market transformation that is:

1. Guided by clear goals and targets;
2. Initiated and accelerated by incentives;
3. Institutionalized through regulations; and
4. Supported continuously through pilot projects, infrastructure investments, and multi-stakeholder implementation.

Modelling this ecosystem methodology, the state of California has been an innovator and driver of impactful policies and has established itself as a leading global region in the deployment of zero-emission vehicle (ZEV) technology. Through a sustained and varied approach of incorporating successive and increasingly ambitious policy formulation, short- and long-term planning, public- and private-sector coordination, and a mix of financial incentive "carrots" and regulatory "sticks," California has developed and demonstrated the necessary components for a supportive framework for ZECV market transformation, as conceptually represented in Figure 2.1.

Figure 2.1. Framework for ZECV Market Transformation

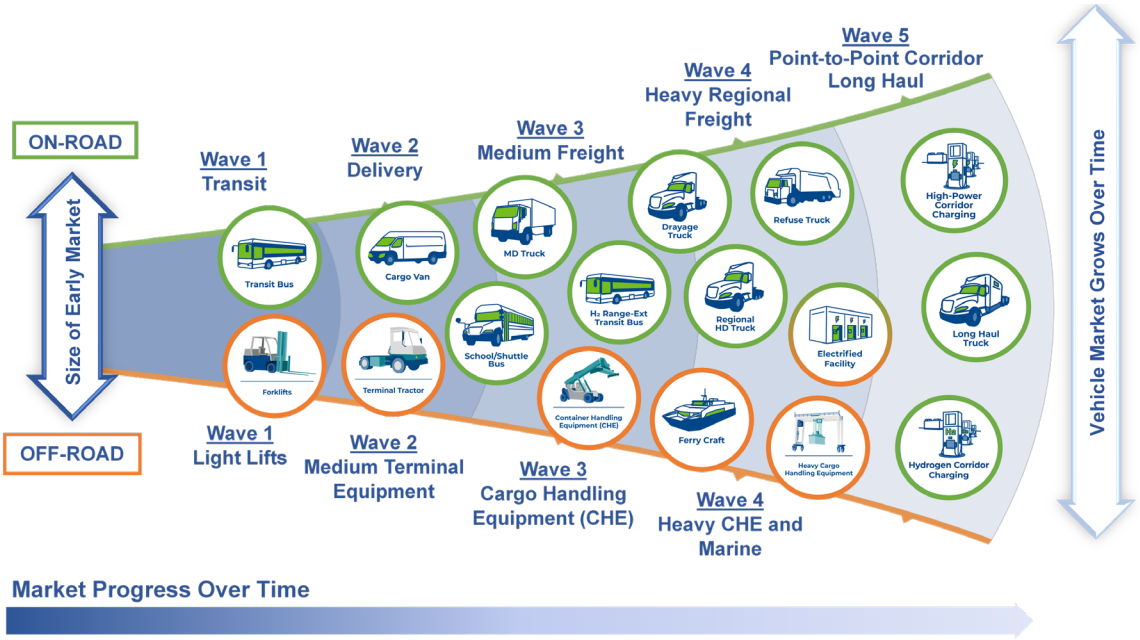


B. ZERO-EMISSION TECHNOLOGY COMMERCIALIZATION THEORY OF CHANGE

California has devised its investment plan in ZECV technologies based on a technology commercialization strategy developed jointly with CALSTART (CARB, 2021g). By focusing on ZECV applications that are most likely to succeed—referred to as first-success or "beachhead" applications—and implementing the necessary regulations and incentives to support them, the ZECV market can accelerate as technology transfers from first-success applications to the rest of the market. This strategy, known as the Beachhead Strategy, was fundamental to the regulations and incentives for ZECVs in California.

Despite California's sizeable MHDV market, economies of scale will advance only at the pace and to the point required to meet the state's climate and air pollution goals if zero-emission technology for commercial vehicles is deployed in other regions worldwide. To enable this global alignment and expedite the growth of global ZECVs, CALSTART launched its Global Commercial Vehicle Drive to Zero program and campaign (Drive to Zero™) for zero-emission technology to achieve commercial viability by 2025 in specific vehicle segments and regions, and dominate new vehicle sales globally by 2040. Drive to Zero seeks to align ZECV deployments and policies globally in order to accelerate economies of scale and expand the ZECV market from first-wave beachhead applications to successive segments (Figure 2.2).

Figure 2.2. "Beachhead Pathways" for Zero-Emission Vehicle Commercialization



ZECV deployment follows a well-established strategy in which zero-emission technologies arrive in waves, taking hold first in transit buses due to predictable routes and the ability to charge at depots overnight (i.e., Wave 1). Because multiple vehicle applications use similar components such as powertrains, batteries, and power electronics, progress in first-success applications will lead to further

technological development and transfer to other on-road, off-road, and marine sectors as components mature, volumes grow, and costs decrease (Welch, 2020).

C. CLEAN TRANSPORTATION HISTORY & CONTEXT

As the largest vehicle market in the U.S. and a major national and international hub for goods movement, transportation is critical to California's economy and a longstanding focus area for technological innovation. The transportation sector also imposes significant health and environmental costs, as the number one source of smog and GHG pollution across the state. In addition to GHGs, exhaust from diesel-powered MHDVs generates a suite of pollutants, including particulate matter (PM); oxides of nitrogen (NOx), which contribute to ground-level ozone (smog) and acid rain; hydrocarbons; carbon monoxide (CO); and other hazardous air pollutants. While heavy-duty trucks make up only a fraction of the state's vehicle fleet, they produce about 25% of diesel engine PM pollution, a cancer-causing pollutant that also contributes to respiratory illness and heart disease, including an estimated 1,400 premature deaths every year from cardiovascular disease (Becker, 2020). Pollution from diesel trucks hits Latino, Black, Asian American, and lower-income Californians the hardest (Reichmuth, 2019), and is a major source of smog, soot, and other cancer-causing pollution in the neighborhoods around the ports of Los Angeles and Long Beach—two of the busiest container ports in the world (Becker, 2020).

As former CARB Chair Mary Nichols remarked, California has long been "willing to be the experimental proving ground for new technologies and new policies" (CALSTART 2020 Annual Meeting), including requirements for clean cars, fuels, and other innovative solutions to reduce GHG emissions (CARB, n.d.). California has a lengthy history of regulating motor vehicle pollution due to its particularly severe motor vehicle-related air quality challenges and related public health impacts. This history has helped the state develop strong, ambitious, and forward-looking regulatory capabilities, and has given California a unique leadership position within the U.S.

In the U.S., criteria air pollutant emissions from motor vehicles—which include ground-level ozone, PM, CO, and NOx—are regulated under the 1970 Clean Air Act. However, California's air pollution regulations precede the Clean Air Act, dating back to 1967 when Governor Ronald Reagan approved the Mulford-Carrell Air Resources Act, creating the State Air

"The Waiver" & Section 177

Under the federal Clean Air Act, California must request a waiver from the US Environmental Protection Agency (EPA) to implement any proposed new motor vehicle emissions regulations that exceed federal standards. Under this provision, CARB has to date requested and received over 50 waivers ("US: Section 177 States | Transport Policy" n.d.). While California is the only state with the authority to set its own vehicle emission standards, Section 177 of the Clean Air Act enables other states to voluntarily adopt California's standards in lieu of federal standards without the need for EPA approval. This rule has been an important tool in enabling California's clean transportation efforts to influence market transformation at a larger scale.

Resources Board and committing California to an aggressive, unified, statewide approach to tackling air pollution. The Los Angeles region began experiencing the effects of smog pollution—including episodes of low visibility, nausea, and burning eyes and lungs—beginning in the 1940s. It was not until the 1950s that this pollution was correctly attributed to internal combustion engine exhaust from automobiles, caused by a chemical reaction of sunlight, NOx, and volatile organic compounds. A California Institute of Technology biochemistry professor, Dr. Arie Haagen-Smit, first made this discovery, and went on to lead California's air quality standards regulation, becoming the first Chair of CARB in 1968 after serving for eight years as an original board member on CARB's predecessor agency, the Motor Vehicle Pollution Control Board. In developing its own vehicle regulations prior to the Clean Air Act, California has retained the authority to set its own more stringent, state-specific air quality rules, as recognized by the Federal Air Quality Act of 1967, to align with the state's "unique geography, weather and expanding number of people and vehicles" (CARB, n.d.).

Despite California's long-standing efforts to address motor-vehicle emissions, the transportation sector continues to be a major source of pollution. MHDVs are the largest single source of NOx pollution, responsible for 35% of statewide emissions and for 50% of statewide GHGs (CARB, 2019b). Though California's overall GHG emissions have decreased from 1990 levels—primarily due to electric utility sector progress to improve efficiency, set Renewable Portfolio Standards, and advance rooftop solar—emissions from the transportation sector have continued to increase since the state adopted Assembly Bill 32 (AB 32), the Global Warming Solutions Act of 2006, and are the largest source of carbon pollution in the state, accounting for roughly 50% of in-state emissions when including upstream emissions from oil extraction and refining (Brecht, 2020).

D. KEY ACTORS

California's ZECV transition requires active coordination and collaboration between the public and private sectors, including several state and local government entities, public and private fleet owners and operators, infrastructure providers, and ZEV manufacturers and equipment suppliers. As demonstrated by the California Governor's Office of Business and Economic Development's (GO-Biz) Zero-Emission Market Development Strategy, the state's ZEV transition necessitates a "whole of government" effort, with collaboration and coordination across 29 state government agencies to achieve large scale equitable market development, improve air quality, reduce GHG emissions, increase access, create jobs, and support broader economic development (GO-Biz, 2021).

For MHDV segments specifically, five key state and regional actors have significant influence and authority to advance California's climate, energy, and clean air goals, and play an instrumental role in fostering a supportive ecosystem for ZECVs:

- California Air Resources Board (CARB), under the California Environmental Protection Agency (CalEPA)
- Air Quality Management Districts (AQMDs)

- California Energy Commission (CEC), under the California Natural Resources Agency (CNRA)
- California Public Utilities Commission (CPUC)
- Major Port facilities, including the municipally-governed Ports of Los Angeles, Long Beach and Oakland, and their privately operated terminal facilities

California Air Resources Board (CARB)

CARB is one of six boards, departments, and offices under the CalEPA, a Cabinet-level agency with unified environmental authority over air, water, and soil quality; pesticide use; and waste recycling and reduction. CalEPA's mission is to restore, protect, and enhance the environment, to ensure public health, environmental quality, and economic vitality.

Charged with protecting the public from the harmful effects of air pollution and developing programs and actions to fight climate change, CARB is the lead agency for climate change programs and oversees all air pollution control efforts in California to attain and maintain health-based air quality standards.

AB 32 expanded CARB's role to include developing and overseeing California's GHG reduction programs, including Cap-and-Trade, the Low Carbon Fuel Standard (LCFS), and the ZEV programs described in Chapter 3 (CARB, n.d.). Furthermore, under Executive Order N-79-20 signed by Governor Gavin Newsom, CARB is mandated to develop and propose strategies that achieve 100% zero emissions from MHDVs statewide by 2045 (Newsom, 2020). In its capacity as a lead agency coordinating California's ZECV transition, CARB oversees a number of incentives and regulations to advance the wide-scale deployment of ZE-MHDVs.

Through its Low Carbon Transportation Investments and Air Quality Improvement Program (AQIP), CARB provides incentives to reduce GHG and criteria air pollutant emissions through the deployment of advanced technology and clean transportation in the light- and heavy-duty vehicle sectors. As of Fiscal Year (FY) 2020-21, CARB has funded over $350 million towards heavy-duty demonstration and pilot projects, and $552 million towards voucher incentive funding for the purchase of hybrid and zero-emission trucks and buses. From FY2013-14 through FY2019-20, CARB has invested over $2.1 billion in Low Carbon Transportation project funding across light- and heavy-duty duty vehicle sectors (CARB, 2021g). In July 2021, California appropriated over $1.5 billion in new incentive funding for ZEVs, with nearly $800 million directed towards ZE-MHDV programs (Skinner, 2021).

Air Quality Management Districts (AQMDs)

Complementing CARB, California's 35 regional AQMDs are responsible under the Federal Clean Air Act for regional air quality planning, monitoring, and stationary source and facility permitting (Figure 2.3). The districts can regulate all stationary sources of air pollution within their jurisdiction and administer air quality improvement grant programs, clean vehicle programs for light and heavy-duty vehicles, and are CARB's primary partners in efforts to ensure that all Californians breathe clean air. Amongst the most active and influential AQMDs supporting ZECV deployment, the South Coast Air Quality Management District (SCAQMD) is responsible for improving air quality and public health across a region of over 17 million people, encompassing Los Angeles, Orange County, Riverside, and San Bernardino counties.

Figure 2.3. California Air Districts

California Energy Commission (CEC)

The CEC is the state's primary energy policy and planning agency, working to transition California to a 100% clean energy future. The CEC is an Executive Branch agency under the CNRA.

As a key stakeholder in California's ZEV transition, the CEC plays a lead role in infrastructure development and a supporting role with vehicle deployment, workforce development, and end user support. CEC responsibilities include ZEV infrastructure investment and analysis, fuel consumption tracking, energy system resilience and forecasting, ZEV technology research and demonstration, ZEV-related manufacturing, and workforce training and development (GO-Biz, 2021). Through its Clean Transportation Program, formerly known as Alternative and Renewable Fuel and Vehicle Technology Program, the CEC invests up to $100 million annually in a broad portfolio of transportation and fuel

transportation projects to advance state-wide goals on climate change, petroleum reduction, electric vehicle adoption, air quality improvements, and long-term workforce and economic development. Established via AB 118 in 2007, the program has been extended through 2024 and uses funds collected from vehicle and vessel registration, vehicle identification plates, and smog abatement fees.

Since the initial allocation of funds in 2009, the CEC has invested more than $1 billion in projects that support alternative fuels and advanced vehicle technologies, including:

- $182.81 million for light-duty electric vehicle charging infrastructure, including 9,124 charging connectors and direct current (DC) fast chargers;
- $160 million for to install or upgrade 83 publicly available hydrogen stations capable of light-duty vehicle fueling;
- $125.67 million for advanced technology freight and fleet vehicles, including 54 demonstrations; and
- $32.02 million for hybrid and ZEV deployment, including 10,700 cars and 150 trucks (includes Clean Vehicle Rebate Project, Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP), and Low-Income Mobility Incentives) (Brecht, 2020).

California Public Utilities Commission (CPUC)

The CPUC regulates and oversees the state's investor-owned utilities and is responsible for protecting consumers, safeguarding the environment, approving rates, and ensuring access to safe and reliable utility infrastructure and services. With respect to the energy industry, the CPUC regulates the state's six investor-owned utilities (IOUs)—Pacific Gas & Electric (PGE), Southern California Edison (SCE), San Diego Gas & Electric (SDGE), PacifiCorp, Liberty Utilities, and Bear Valley Electric Service—overseeing rate-setting and electric generation and distribution infrastructure investment planning. The CPUC plays a key role in advancing California's clean energy and climate goals, and has increasingly approved utility investment in infrastructure for a zero-emission transportation system. The CPUC also required the IOUs to propose, and has since approved, rates for ZECVs that make charging with electricity cheaper than fueling vehicles with gasoline or diesel—a critical policy for ensuring that the benefits of ZECVs can be fully realized by California's fleets.

Under Senate Bill (SB) 350, the Clean Energy and Pollution Act of 2015, the CPUC focuses energy procurement decisions on reducing GHG emissions by 40% by 2030, including efforts to achieve at least 50% renewable energy procurement, double energy efficiency, and promote transportation electrification. As of March 2021, the CPUC has authorized approximately $1.45 billion in ratepayer spending for transportation electrification programs, including $700 million for necessary utility upgrades to electrify ZECVs (CPUC, 2021).

The Governor's Office Inter-Agency Working Group Summary

In addition to CARB, CEC, and CPUC, several other State agencies have played an active role in California's ZEV transition. Executive Order B-16-12, signed by former Governor Jerry Brown in March 2012, established a goal of deploying 1.5 million ZEVs. CARB, CEC, and CPUC were tasked with establishing benchmarks and an implementation roadmap to achieve this goal. The first of the implementation roadmaps, the ZEV Action Plan, was finalized in 2013, followed by updates in 2016 and 2018. Along with CARB, CEC, and CPUC, several other state agencies formed an interagency working group led by the Governor's Office:

- California Air Resources Board (CARB)
- California Department of Food and Agriculture, including the Division of Measurement Standards (CDFA)
- California Department of Transportation (Caltrans)
- California Energy Commission (CEC)
- California Housing and Community Development Department (HCD)
- California Independent System Operator (CAISO)
- California Labor and Workforce Development Agency, including the Employment Training Panel (ETP)
- California Public Utilities Commission (CPUC)
- Department of General Services (DGS), including the Division of the State Architect (DSA) and Building Standards Commission (BSC)
- Governor's Office of Business and Economic Development (GO-Biz)
- Governor's Office of Planning and Research (OPR)

Under Executive Order N-79-20, signed by Governor Gavin Newsom in September 2020, GO-Biz was tasked with leading the administration's ZEV Market Development Strategy, outlining pathways to California's 100% ZEV vision and transition (GO-Biz ZEV Market Development Strategy, Feb. 2021).

Major Port Facilities

California is home to three of the 10 busiest container ports in the U.S., handling over 20 million twenty-foot equivalent units (TEU) combined in 2018 (U.S. Department of Transportation, Bureau of Transportation Statistics, 2020):

- Port of Long Beach: 8,091,000 TEUs
- Port of Los Angeles: 9,459,000 TEUs

- Port of Oakland: 2,547,000 TEUs

Given the intensity of heavy freight activity concentrated within and around these port facilities—as many as 16,000 trucks serve the neighboring ports of Los Angeles and Long Beach, along with an assortment of ships, tugboats, cranes, top lifters, forklifts, yard tractor, and other freight-handling equipment—they are amongst the largest sources of air pollution in California. Port-related truck activity is responsible for a large share of traffic along the Interstate 710 corridor in Los Angeles—as many as 36,000 average daily trucks (two-way) in 2013, and a projected 55,000 in 2035—which is home to many disadvantaged communities exposed to diesel pollution (Wick, 2018).

Along with CARB, CEC, CPUC, and AQMDs, California's major ports are key stakeholders in the state's effort to accelerate ZECVs. While port terminal facilities are typically operated by private sector tenants, California's three major ports are municipally governed by publicly appointed boards and commissions, including the Port of Long Beach's Harbor Commission, the Los Angeles Board of Harbor Commissioners, and the Port of Oakland's Board of Port Commissioners. In partnership with private terminal operators, each port has adopted ambitious clean air and climate targets, prioritized the phase-out of polluting diesel engines, and piloted the deployment of zero-emission trucks and cargo-handling equipment (Vock, 2019). The San Pedro Bay Ports Clean Air Action Plan of 2006—a collaborative effort of the Port of Los Angeles and Long Beach—has achieved decreases in diesel PM, NOx, and sulfur oxides of 87%, 58%, and 97% respectively through efforts to phase out the oldest and dirtiest vehicles serving the ports. In 2017, the ports of Los Angeles and Long Beach adopted goals to reduce GHG emissions to 40% below 1990 levels by 2030 and 80% below 1990 levels by 2050, and to transition all cargo-handling equipment within the ports to ZEVs by 2030 and all trucks servicing the ports to zero-emission by 2035 (Vock, 2019). In addition, the adoption of the Statewide Drayage Truck Regulation in 2007—requiring emission reductions from drayage trucks transporting cargo to and from California's ports and intermodal rail yards—laid the foundation for accelerated fleet renewal and the introduction of zero-emission drayage trucks (CARB, 2013). More recently CARB's Project 800 was launched to support the deployment of zero-emission trucks serving California ports by setting a goal of 800 zero-emission drayage truck orders in 2021 (CARB, 2021e). A more detailed discussion of port-led regulations and investments is included in Chapter 3.

Additional Stakeholders

Though not comprehensive, the five key actors discussed above are amongst the most influential in accelerating the deployment of ZECVs in California. In addition, many other state and regional agencies play a role in California's ZECV transition. At the State level, the California State Transportation Agency and the Department of Transportation (Caltrans) are supporting California's ZECV transition through overall transportation sector planning and policy, including zero-emission technology funding and technical assistance for the state's transit agencies. At the regional level, metropolitan planning organizations such as the Southern California Association of Governments and the San Francisco Bay Area Metropolitan Transportation Commission, as well as other regional authorities such as the Mobile Source Air Pollution Reduction Review Committee in Southern California, contribute additional funding and policy support for ZEV technology and the replacement of diesel trucks and equipment.

The remainder of this paper will summarize California's experience in creating an ecosystem of success

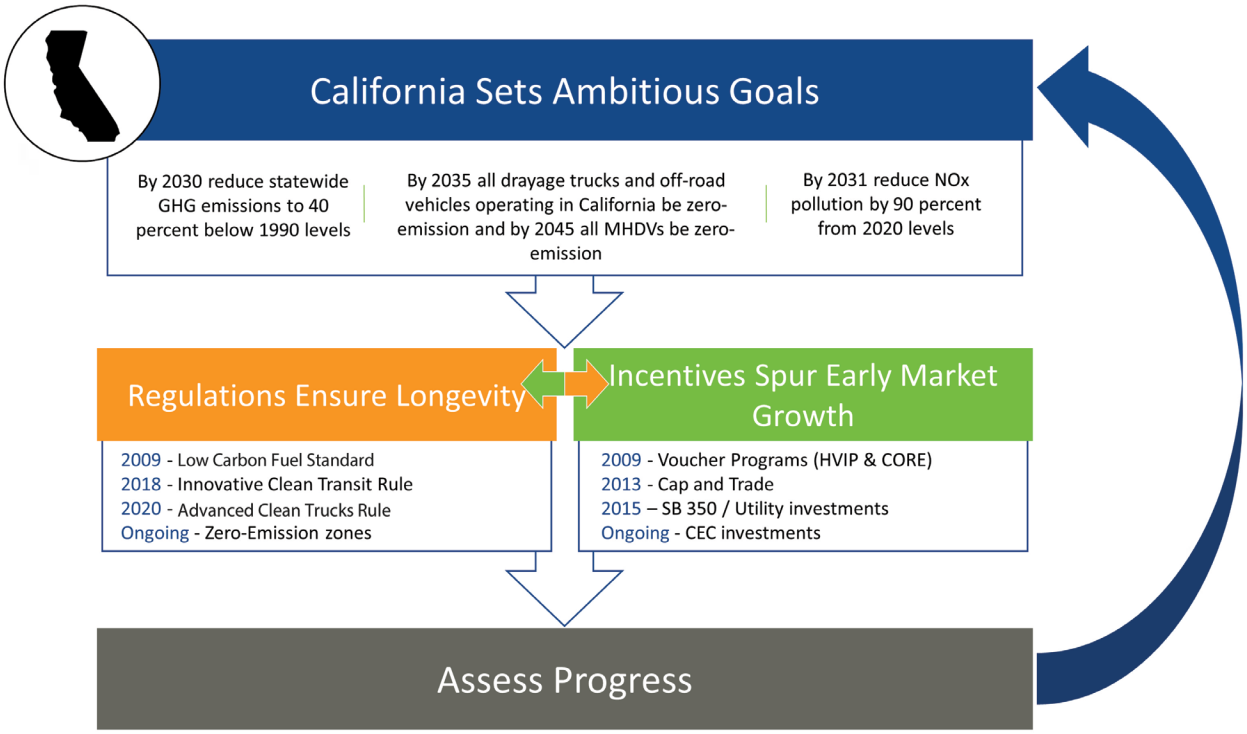
to accelerate the deployment of ZECVs. Chapter 3 describes California's ZECV ecosystem in more detail with a discussion of each of the key programs supporting and enabling ZECV deployment, grouped into regulations, incentives, and supporting investments. Chapter 4 summarizes California's current ZECV market, and progress to-date in achieving the state's ZECV goals and targets. Finally, Chapter 5 examines the path ahead, with a discussion of California's continued innovation and support for ZECV deployment, and implications for other leading regions.

CHAPTER 3

CALIFORNIA'S ZECV ECOSYSTEM

The following approach has established California as an early innovator in clean vehicle market acceleration. Guided by clear and progressively more ambitious targets, California has used a mix of incentives and regulations to catalyze and sustain ZECV market transformation, supported by dedicated public investment and continual assessment. Programmatic elements represent different policy levers that government and industry partners can utilize to advance ZECVs (Figure 3.1). In the following section, each of these key elements—clear and ambitious goals, regulations, and incentives—are described in more detail.

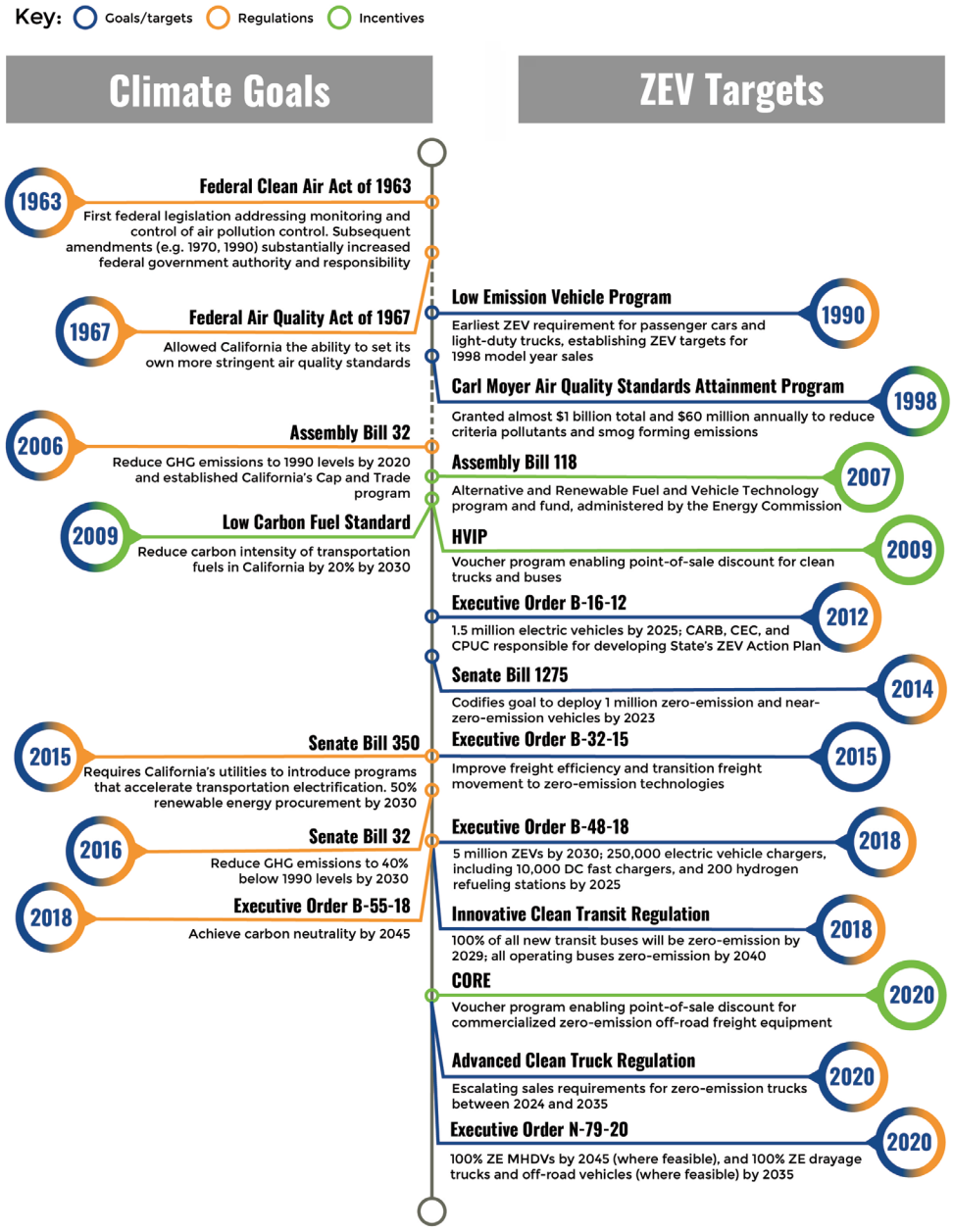
Figure 3.1. California's Approach to Market Transformation



A. GOALS & TARGETS

In addition to reducing local air pollution, California's efforts to accelerate ZECVs are underpinned by the state's climate goals, which were first established in 2006 through the adoption of AB 32. The state has since expanded these targets through subsequent policy (Figure 3.2), with the ultimate goal of achieving carbon neutrality by 2045 under Executive Order B-55-18, signed by former Governor Jerry Brown in 2018. Moreover, the state has adopted several related and supporting goals to expedite the deployment of ZEVs (Figure 3.2). These goals have scaled over time and in tandem with zero-emission technology readiness, demonstrating rising levels of commercial viability and market progress.

Figure 3.2. California Climate Goals & ZEV Targets



B. REGULATIONS

To achieve these climate goals and ZEV targets, California has developed several technology-driven regulations that provide strong market signals and a clear, long-range path towards market transformation. The following section describes California's key regulatory programs, as well as complimentary local-level vehicle access and operating restrictions supporting zero-emission technology deployment.

LOW CARBON FUEL STANDARD (LCFS)

The LCFS is a market-based mechanism that works by reducing the carbon intensity of transportation fuel over time. California's LCFS created the first market of its kind when it was approved in 2009 by CARB and implemented in 2011. The program has been revised and re-implemented several times, most recently in 2018, to create smoother benchmarks and to set regulations to meet the state's 2030 GHG emissions targets. The current LCFS target is a 20% carbon intensity (CI) reduction by 2030 from 2010 levels, which will continue in the years following 2030.

A Revenue-Generating Regulation: Earning Income through ZECV Use

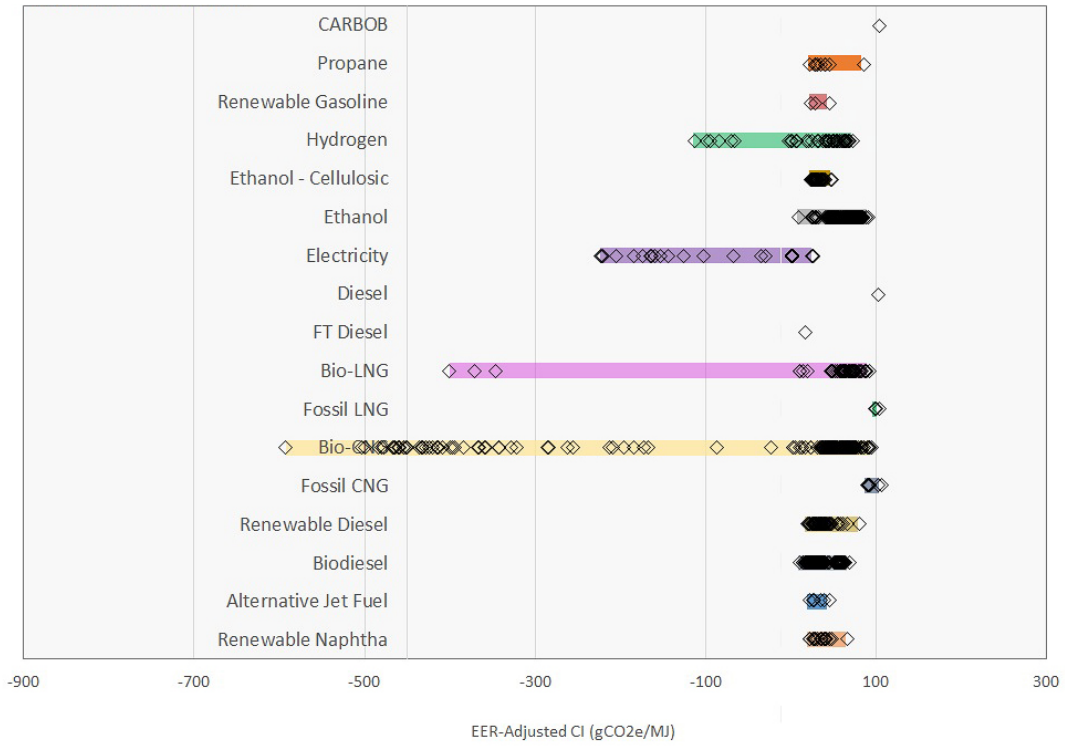
The LCFS is designed to encourage the production and use of cleaner low-carbon transportation fuels in California, thereby reducing GHG emissions and decreasing petroleum dependence in the transportation sector. The program acts as a regulation to ensure that the state's GHG performance and air quality improve, but it also creates incentives and funding streams to support clean fuel development. Parties that generate surplus credits for clean fuel production can sell them to non-compliant regulated parties or bank the credits for future use. Electricity generates credits when it passes through a charger, at which point it is considered a transportation fuel (Witcover and Murphy, 2019). The charger owner receives the LCFS credit for non-residential applications, making charging station ownership a potentially valuable commodity in a growing market. In 2019, the LCFS generated over approximately $2.7 billion in credit trading (PG&E, 2020).

The policy has several features that make it a powerful tool for balancing business interests and environmental goals. First, it is incredibly flexible, providing covered entities with multiple ways to comply. Compliance measures can include investing on-site to reduce emissions, supporting clean fuel or transportation electrification projects, blending biofuels into existing products, or a range of other options. This gives business actors freedom to choose compliance measures that work best for their operations. In addition, the policy is technology neutral, allowing the market to determine which combination of technologies are appropriate to reach established targets cost effectively. This drives innovation, as industry reacts to find practical strategies for compliance. Reducing GHGs from fuels is a necessary component to reducing sectoral emissions, which are collectively the result of vehicle

efficiency, the carbon content of fuels, and the vehicle miles traveled of a fleet. The LCFS therefore works in conjunction with other regulations and policies to reduce GHG and local air pollutant emissions from the entire transportation sector.

The LCFS reduces the GHG content of fuels by creating a market-based cap on the CI of each fuel type and ensuring that the state's overall fuel carbon-intensity decreases over time. Fuel types include standard fossil fuels (e.g., gasoline, diesel, etc.), as well as a range of alternative fuels such as natural gas, renewable natural gas, hydrogen, electricity, and a range of biofuels. Each of these fuels is given a CI rating based on a lifecycle assessment of the production, transportation, and use of a given fuel. High-carbon fuels must purchase credits on the market to cover their emissions, whereas low-carbon fuels generate credits that are sold to earn revenue. The lifecycle assessment includes direct emissions associated with producing, transporting, and using the fuels, in addition to significant indirect effects on GHG emissions, such as changes in land use for some biofuels. Because of the variability of producing, refining, and transporting fuels, multiple pathways with different CI assessments often exist for a single fuel type. CARB regularly adjusts these CI scores, which are publicly available and are used to determine regulated parties' compliance obligations (Figure 3.3) (CARB, 2021f).

Figure 3.3. Carbon Intensity Values of Certified Pathways, EER-Adjusted (CARB, 2021f)[2,3]



2 The alternative fuel's CI value is divided by its Energy Economy Ratio (EER) – the distance an alternative-fueled vehicle travels divided by the distance an internal combustion engine vehicle travels using the same amount of energy – in order to obtain the EER-adjusted CI value, representing the emissions that occur from the use of alternative fuel per MJ of conventional fuel displaced.

3 CARBOB represents the average crude oil supplied to California refineries and average California refinery efficiencies.

The LCFS sets a CI cap on the average fuel supply that regulated parties, typically large petroleum importers, refiners, and wholesalers, sell into California. Approved alternative fuel project operators may opt into the program and sell their credits in the market. These projects include actions to reduce GHG emissions in the petroleum supply chain, including carbon capture and storage. Additionally, CARB allows ZEV infrastructure, including hydrogen and DC fast charging, to generate credits based on the capacity of the stations minus the fuel dispensed (CARB, 2021a). California utility PG&E estimates that a fleet operating Class 8 electric trucks can earn $33,000 per vehicle per year in LCFS credits (PG&E, 2020). This represents a major source of revenue for ZECV adopters, who can use these funds to offset other costs. California is designing a loan program to allow fleets to leverage these future credits and help buy down vehicle costs up front.

The CI cap is designed to lower over time, requiring improvements in the GHG performance of regulated parties' fuel supplies. Each regulated party generates credits or deficits based on the CI of its fuels sold in California—fuels that do not meet the CI cap generate deficits, and fuels that exceed (have lower emissions than) the threshold generate credits. A regulated party must track its quarterly fuel credits and deficits, and at the end of the year, must have purchased sufficient credits to cover its deficits and meet the state's CI target for the calendar year.

Greater improvements beyond the CI cap yield greater numbers of credits. Electricity and hydrogen have some of the best CI scores in the LCFS program, depending upon their production and refining methods. California's ZEV targets will expand markets for electricity and hydrogen producers while allowing ZECV fleets to generate revenue at non-residential charging or fueling locations.

FLEET MANDATES

As a core approach to ZECV regulation, California has adopted, or is in the process of developing, several ZEV purchase mandates for commercial vehicles fleets. Following the Beachhead Strategy, these regulations have initially focused on early wave vehicle technologies, such as transit buses.

Innovative Clean Transit (ICT) Rule

One of California's first ZECV-focused regulations was the ICT rule, reflecting the first-wave technological and commercial (i.e., beachhead) viability of zero-emission buses (ZEBs). The ICT, adopted by CARB in 2018, requires public transit agencies in California to gradually transition their bus fleets to be 100% zero-emission by 2040. With this rule, the main provisions outlined in the ICT fall into two vitally important categories: deployment plans and purchase requirements.

The ICT requires all transit agencies to provide a ZEB rollout plan that demonstrates how they will achieve a full transition by 2040 (CARB, 2020b). The rule differentiates between large and small transit agencies, with large transit agencies required to submit rollout plans in 2020 and to adopt ZEBs starting in 2023, and small agencies required to submit plans by 2023 and to begin adoption of ZEBs by 2026. According to the regulation, large transit agencies are defined by one of two criteria: 1) those operating either in the South Coast or the San Joaquin Valley Air Basin with more than 65 buses in

annual maximum service; or 2) those operating outside of these areas, but in an urbanized area with a population of at least 200,000 and at least 100 buses in annual maximum service. Small transit agencies encompass all other transit operators that do not meet these criteria.

The purchase mandate component of the ICT drives demand for ZEBs and thus signals to producers to increase production, which will lower costs over time as supply chains and manufacturing increase in scale. The following table outlines the percent of total new buses required to be zero-emission by the corresponding year.

Figure 3.4. ZEB Purchase Schedule (ZEB Percentage of Total New Bus Purchases)

YEAR	LARGE TRANSIT	SMALL TRANSIT	PURCHASE WAIVER THRESHOLD
2023	25%	-	Waved if 850 ZEBs purchased by end of 2020
2024	25%	-	Waved if 1,250 ZEBs purchased by end of 2021
2025	25%	-	
2026	50%	25%	
2027	50%	25%	
2028	50%	25%	
2029	100%	100%	

As shown in Figure 3.4, the ICT gradually increases the mandate, giving agencies time to plan and prepare for this rule in order to ensure a successful rollout (CARB, 2020b). There is a built-in incentive for agencies to initiate this shift sooner. The earliest purchase requirement, beginning in 2023, will be waived if 850 ZEBs have been purchased by the end of 2020. A similar rule applies to the 2024 purchase requirement; if 1,250 ZEBs are purchased by California transit agencies by the end of 2021, the next binding purchase requirement will not occur until 2025 (California Transit Association, 2020). This caveat to the ICT incentivizes early adopters and fleets to push ahead of schedule and get ZEBs on the road as quickly as possible. Further, funds commonly available to transit agencies through California's Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP)—discussed below—will only be administered before the requirements established by the regulation come into effect. This approach is an important aspect of California's approach to ZECV market transformation linking incentives and regulations, utilizing incentives as a way to stimulate early market growth and introduce subsequent regulation.

Consistent with California's commitment to clean air and the battle against climate change, the ICT provides real tangible change in reducing congestion and emissions, efficiently transporting large volumes of users, and shifting point source pollution away from vulnerable communities. Projections based on CARB's models and analytics indicate that the full implementation of ICT will bring major benefits, reducing GHGs by 19 million tons from 2020 to 2050—equivalent to taking 40 million cars off

the road—while also reducing other harmful tailpipe emissions such as PM and NOx by 40 and 7,000 tons respectively (CARB, 2018a). These reductions, particularly of PM and NOx, are critical to improving public health and providing direct benefits to surrounding communities reliant on public transit. Beyond the social and environmental benefits, transit agencies are expected to save $1.5 billion by 2050 due to lower total cost of ownership of ZEBs (Green Car Congress, 2018). CALSTART has observed that many large and small transit agencies began purchasing ZEBs far ahead of the mandated schedule in the rule. California also passed a law, AB 784 of 2019, giving transit agencies an exemption from state sales taxes until 2024.

Other Fleet Mandates

In addition to the ICT rule, California has implemented additional fleet mandates for the purchase of ZECVs. The **Zero-Emission Airport Shuttle Regulation** was adopted in June 2019, and requires a 100% transition to ZEV technologies by 2035 for airport shuttles with GVWR of 8,501 pounds or greater at California's 13 largest airports (CARB, 2019a). In January 2021, CARB announced a **Transport Refrigeration Unit (TRU) rulemaking**, which would require truck TRU fleets to begin transitioning to zero-emission technologies in 2023, with all truck TRUs operating in California required to be zero-emission by 2029 (CARB, 2021b). Finally, in 2021 CARB announced the development of an **Advanced Clean Fleets regulation** focused on medium- and heavy-duty fleets, in support of the state's goal for 100% of MHDVs to be zero-emission by 2045.

ADVANCED CLEAN TRUCKS (ACT) REGULATION

Recognizing that trucks are responsible for a disproportionate share of harmful emissions in California, CARB's ACT regulation requires manufacturers to meet minimum ZEV sales as a percentage of their total MHDV sales in the state between 2024 and 2035. Despite the name of the regulation, it includes other non-truck categories of MHDVs. CARB divided regulated trucks and other vehicles into three categories, each with distinct fleet sales percentage targets. The categories separate vehicles by weight class based on GVWR and by vehicle platform (i.e., tractors and straight trucks), as defined below:

- **Class 2b-3 pickup trucks and vans**: Weighing between 8,501 and 14,000 pounds, this group includes full-size pickup trucks, smaller utility trucks, delivery trucks, step vans, cargo vans, and passenger vans. Examples include heavier versions of popular pickup trucks, such as the Ford F-250 and the Chevrolet Silverado 2500, but not the lighter F-150 or Silverado 1500, which are considered light-duty.
- **Class 4-8 rigid trucks and buses**: Starting from 14,001 pounds, this group includes on-road straight trucks ranging from delivery step vans and trucks to refuse trucks, heavy utility trucks, coaches, and school and shuttle buses.
- **Class 7-8 tractor trucks**: Weighing from 26,001 pounds, this group is isolated to tractors, which are defined as trucks that are designed to haul the weight of other vehicles (e.g., trailers). These vehicles consist of regional and long-distance freight tractors used for goods movement.

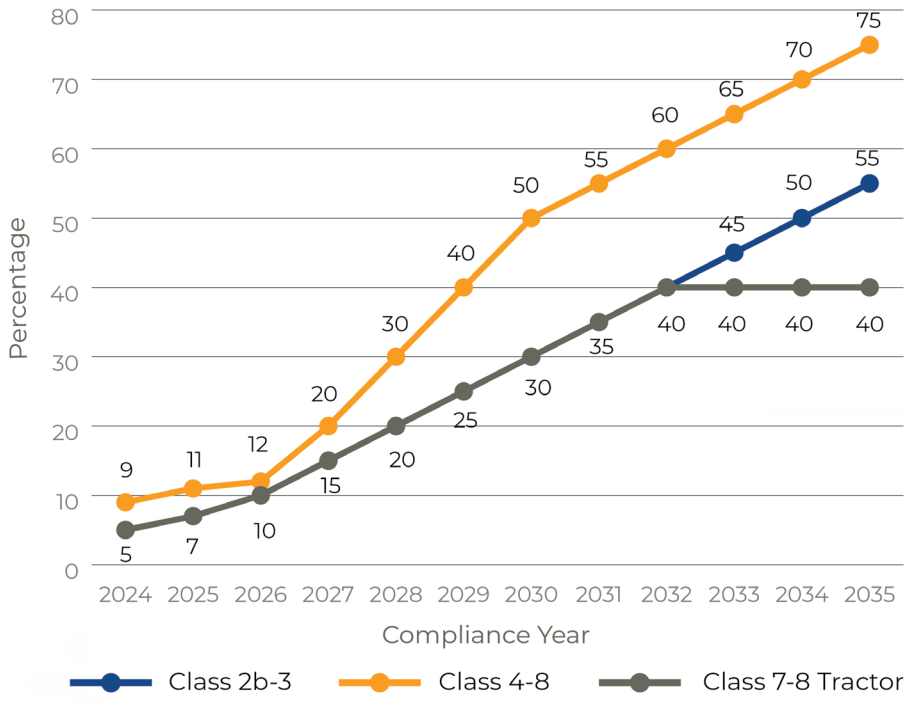
The ACT regulation rapidly transitions new medium- and heavy-duty vehicle sales in California toward ZEVs and near-zero-emission vehicles (NZEVs).[4] This transition requires manufacturers to earn credits by selling ZEVs and NZEVs as a percentage of their total fleet sales. Eligible ZEV and NZEV sales earn credits through Model Year 2030, when NZEV credit eligibility will sunset. Vehicle manufacturers that are obligated to comply or choose to participate will begin generating credits in 2021 and will be required to meet sales requirements by 2024.

Each of the three vehicle categories in the ACT have separate targets that accommodate current and projected vehicle markets and technological advancements. Sales targets increase over time to allow both manufacturers and fleets to adjust their practices and adapt to the new vehicle technologies. By 2035, all manufacturers must earn enough ZEV credits to account for at least 40% of their fleet sales (Figure 3.5).

Continued Internal Combustion Engine Regulation

In tandem with ZEV policy, California continues to increase the stringency of tailpipe emissions standards for all remaining non-zero-emission, internal combustion engine vehicles—an important additional step to improving air quality and achieving climate goals in the transition to ZECVs. CARB has proposed a Heavy-Duty Omnibus Regulation that would reduce NOx pollution 75% below current standards beginning with Model Year 2024 vehicle sales, and 90% below current standards for Model Year 2027 sales.

Figure 3.5. ZEV Truck Sales Percentages by Year and Vehicle Category



4 Near-zero-emission vehicles (NZEVs) are defined as hybrid electric vehicles or plug-in hybrid electric vehicles that achieve a minimum all-electric range for vehicles exceeding 8,500 pounds as defined by 17 CCR section 95663(d).

CARB has also indicated a goal of achieving 100% ZE-MHDV operations by 2045 "everywhere feasible" as part of the state's policy of carbon neutrality by 2045. Certain market segments have been identified for a potential early 100% ZEV transition, including:

- Drayage trucks, last-mile delivery, and government fleets by 2035;
- Refuse trucks and specified bus types by 2040; and
- Utility fleets (zero-emission capable, which may include NZEVs) by 2040.

Governor Newsom reinforced targets these for drayage trucks and on-road trucks in Executive Order N-79-20, signed in September 2020. This order also created a new California target for new off-road vehicles and equipment, which must be zero-emission by 2035 where feasible.

PORT ACCESS RESTRICTIONS & ZEV MANDATES

In tandem with statewide climate goals, and consistent with the ACT regulation, California's major seaports have adopted ambitious goals of their own around emissions reductions and ZEV requirements. Through their joint 2017 Clean Air Action Plan, the neighboring Ports of Los Angeles and Long Beach will increasingly require zero-emission goods movement via the following targets (Vock, 2019):

- Reduce GHG emissions to 40% below 1990 levels by 2030;
- Reduce GHG emissions to 80% below 1990 levels by 2050;
- Transition all cargo-handling equipment within the ports to ZEVs by 2030; and
- Require all trucks servicing the ports to be zero-emission by 2035.

To achieve these goals, terminal operators are required to submit equipment inventories and a 10-year procurement schedule for new cargo handling equipment, with the requirement that any equipment purchased after 2020 must be zero-emission if feasible, or the cleanest available technologies (The Port of Long Beach, 2019).

In addition to requiring 100% zero-emission trucks serving the ports by 2025, the ports have developed interim diesel engine phase-out and near-zero-emission deployment strategies. This includes banning access to trucks older than Model Year 2007 starting in 2012, which is well ahead of the zero-emission drayage truck requirement.

Zero-Emission Delivery Zones

Accompanying state-wide ZECV regulations and port terminal access restrictions for diesel-powered trucks, California cities are implementing ZECV requirements of their own. In partnership with the Los Angeles Cleantech Incubator, the City of Santa Monica is piloting a one-square mile downtown zero-emission delivery zone for all goods—from food to packages—with priority loading zones, curb management, and infrastructure for ZEVs.

Through its Green New Deal 2019 Sustainability Plan, the City of Los Angeles is developing a Fossil Fuel Free Zone, and is aiming for 100% zero-emission school buses by 2028 and 100% zero-emission urban delivery vehicles by 2035.

C. INCENTIVES

Complementing the zero-emission regulations detailed in the previous section, California has implemented a variety of incentive and investment programs to spur demand and early market growth for ZECVs, as well as enable early introduction of regulations. As discussed in the Fleet Mandate section above, California's approach to market transformation has strategically linked incentives and regulations, utilizing incentives to stimulate early market growth and introduce subsequent regulation. This section describes some of the key investment strategies and incentive programs that California has adopted to support ZECV market transformation and broader climate goals.

CAP-AND-TRADE INVESTMENTS

Stemming from AB 32, California's Cap-and-Trade program sets a statewide limit on emissions from major GHG sources. Administered by CARB, this program is aligned to the state's goal of returning to 1990 levels of GHG emissions before 2020. The Cap-and-Trade program is a market-based mechanism that motivates major polluters to curb emissions while rewarding those who have already begun to adopt cleaner practices in their operations (CARB, 2015). The program sets a statewide upper limit on emissions generated by various industry sectors responsible for significant shares of GHGs. This cap provides incentive for polluters to reduce emissions through operational or technical advancement; otherwise, polluters must purchase additional emission allowances in order to carry out operations and remain in compliance. The program sets a limit on roughly 80% of emissions from the 450 largest polluters in the state (CARB, 2015).

California's Cap-and-Trade program is the fourth largest in the world and is the first of its kind in North America as a multi-sector program. Through Cap-and-Trade, yearly free allowances are allocated to compensate part of the emissions from major polluters while the remaining must be covered by purchasing additional offset credits, investing in cleaner operations, or funding carbon sequestration

projects to meet compliance.

As shown in Figure 3.6, proceeds from California's Cap-and-Trade allowance auctions have totaled over $16.9 billion cumulatively, with $2.6 billion generated in FY2020-21 (CARB, 2021c). These proceeds create the state's Greenhouse Gas Reduction Fund (GGRF), which in turn funds California Climate Investments programs via legislative appropriations to administering agencies, including CARB and CEC. California Climate Investments projects funded by GGRF are used to directly reduce GHGs from transportation and other sectors, benefit disadvantaged communities, and provide other environmental, economic, and public health benefits. These revenues are the primary funding source for clean vehicle incentive programs. Through 2020, California Climate Investments have totaled $8.3 billon (CARB, 2021d). The law requires 35% of these funds to be directed towards low-income and environmental justice communities that have been historically marginalized and exposed to a disproportionate amount of pollution (CARB, 2020a).

Figure 3.6. California GGRF Proceeds from Cap-and-Trade Program Auctions

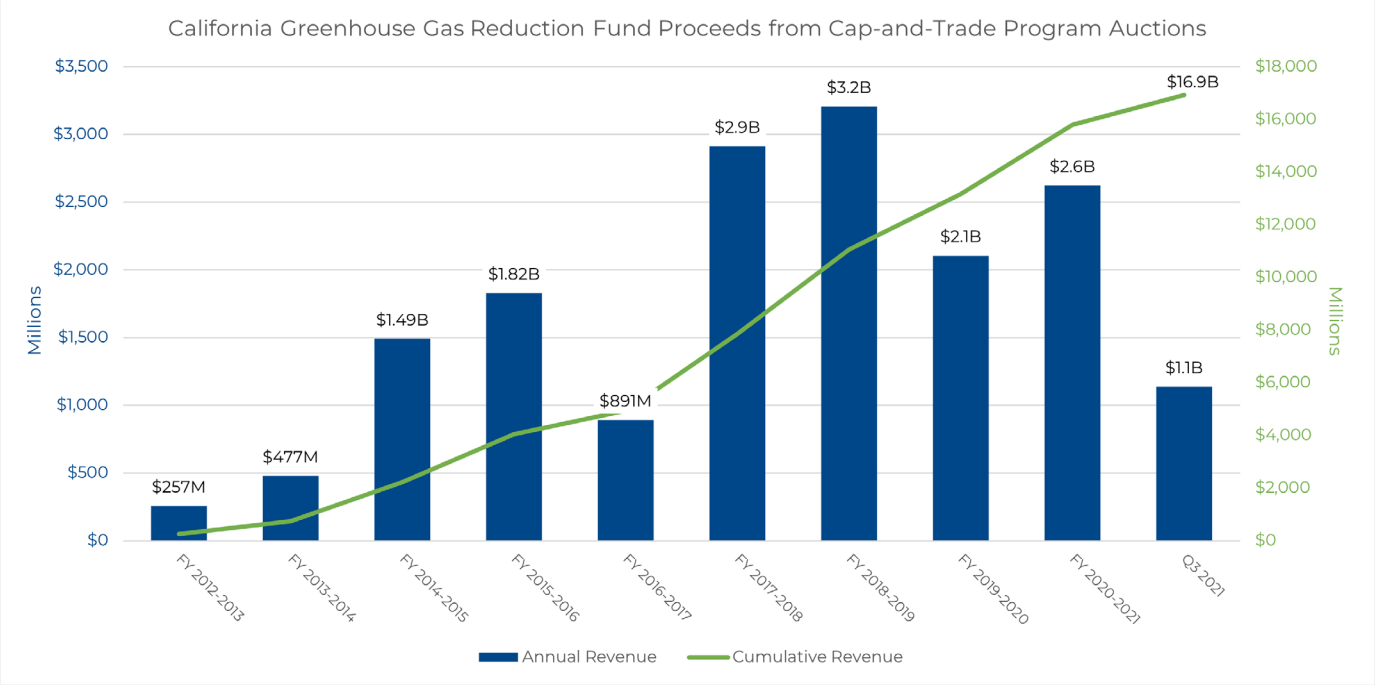
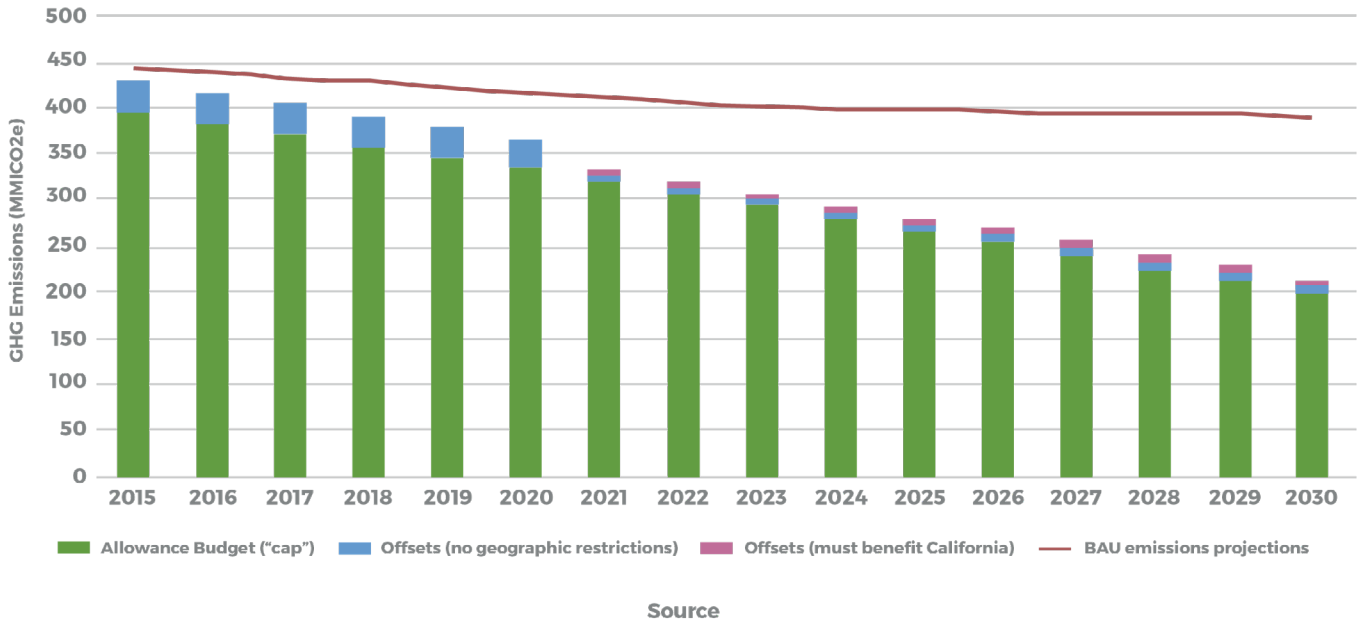


Figure 3.7 demonstrates the Cap-and-Trade program's design to reduce GHG emissions through 2030, as compared to business-as-usual (BAU) emission projections. While GHG emissions do diminish in the BAU scenario, the projected rate of reduction will not meet California's 2030 GHG emission targets. Covering approximately 80% of all GHG emissions, the Cap-and-Trade program is designed to achieve California's 2030 emissions reduction target in tandem with other measures, and is a critical component of the state's emissions reduction strategy. As illustrated below, the program's overall GHG emission cap declined by 3% annually from 2015 through 2020 and will continue to decrease an additional 5% from 2021 through 2030 (Center for Climate and Energy Solutions, 2020).

Figure 3.7. California's GHG Cap and Business-as-Usual (BAU) Projections



Source

Regulation for the California Cap on Greenhouse Gas Emissions and Market-based Compliance Mechanisms (April 2019) and California's 2017 Climate Change Scoping Plan (CARB 2017)

From 2013 through 2017, statewide GHGs decreased by 5.3%, a figure that is difficult to connect directly to one policy considering California's multifaceted approach to combating climate change and the diverse ecosystem of policies and actions in place (Center for Climate and Energy Solutions, 2020). Despite the difficulty in isolating the effectiveness of a single program, the revenue that California's Cap-and-Trade program has raised marks tremendous success in finding innovative ways to fund programs committed to GHG reduction. By capping emissions and making it costly to pollute, this policy is a valuable tool to curb emissions while raising significant funding for ZECV programs, such as the Zero and Near Zero Emission Freight Facility (ZANZEFF) program, and other initiatives to improve air quality and fight climate change.

Zero and Near Zero Emission Freight Facility (ZANZEFF) Pilot and Demonstration Projects

Funded largely by revenues from California's Cap-and-Trade program, CARB's ZANZEFF program has provided $205 million in grants for pilot and demonstration projects that accelerate the adoption of clean freight technologies and reduce air pollution caused by goods movement. The goal of the program is to pilot transformative zero-emission technologies that can be adopted by other freight facilities and accelerate the commercialization of these technologies throughout the state. Through ZANZEFF, several of the state's Air Districts have received funding for ZECV deployment projects, including:

- San Joaquin Valley Air Pollution Control District (SJVAPCD)
    - **Flexible Solutions for Freight Facilities**: SJVAPCD received $22.6 million to demonstrate a battery electric locomotive, zero-emission drayage truck, hybrid cranes, and other equipment at intermodal rail yards in Stockton and San Bernardino. Project partners will provide $22.9 million in matching funds.
    - **Frito Lay Transformative Zero and Near-Zero Emission Freight Facility Project**: SJVAPCD also received $15.4 million to help replace all diesel-powered equipment at Frito-Lay in Modesto, including deployment of 15 heavy-duty Tesla battery electric tractors, 38 low NOx trucks fueled with renewable natural gas, and six Peterbilt 220EV battery-electric trucks. Project partners will match $15.4 million (CARB, 2018b).
- South Coast Air Quality Management District (SCAQMD)
    - **Volvo LIGHTS (Low Impact Green Heavy Transport Solutions)**: SCAQMD, the Volvo Group, and 12 other organizations collaborated to develop an end-to-end blueprint to successfully introduce battery-electric trucks and equipment into the market at scale (Volvo Trucks, 2020). The CARB-funded program was conceived to speed the development and deployment of zero-emission heavy-duty trucks, charging infrastructure, and workforce development, and to demonstrate operations between regional ports and freight distribution centers. SCAQMD contributed a $1.7 million grant for charging infrastructure, while the U.S. EPA contributed an additional $20 million grant through the Targeted Air Shed Grant Program, a national program to assist local air pollution control authorities to reduce air pollution in areas with the highest levels of ozone and PM pollution (Fuller, 2020).

VOUCHER INCENTIVE PROGRAMS (HVIP & CORE)

CARB, in collaboration with CALSTART and industry partners, developed point-of-sale voucher incentive programs (VIPs) to make fleet purchases of ZEVs more affordable and overcome one of the most significant barriers to commercial ZEV adoption—the high upfront costs. A VIP is a well-structured, highly transparent tool that government agencies can use to attract industry participants; engage fleets; and distribute public funding efficiently, equitably, and directly to clean vehicle projects by reducing technology costs at the point of purchase. As adopted by CARB and other State programs, such as New York's Truck Voucher Incentive Program (NYTVIP), the VIP model's strengths include:

1. Transparency: Making abundantly clear how the program operates and the available level of funding.
2. Simplicity: Laying out up front the streamlined responsibilities and processes for manufacturers, vendors, and fleets.
3. Cost-effectiveness: Providing support and certainty of outcome for participants while reducing the administrative burden on sponsoring agencies.

More specifically, public funds are used to reduce the cost difference of a conventionally fueled vehicle and an alternative fuel vehicle. Caps for each category of vehicle may set an upper limit of public funds

for each vehicle project. Dealer networks then help fleets navigate the VIP process and take on the financial responsibility of completing voucher redemptions. Consequently, fleets see a lower purchase cost while dealers receive full price for the vehicles, as public funds make up the difference between the original price and the reduced voucher price.

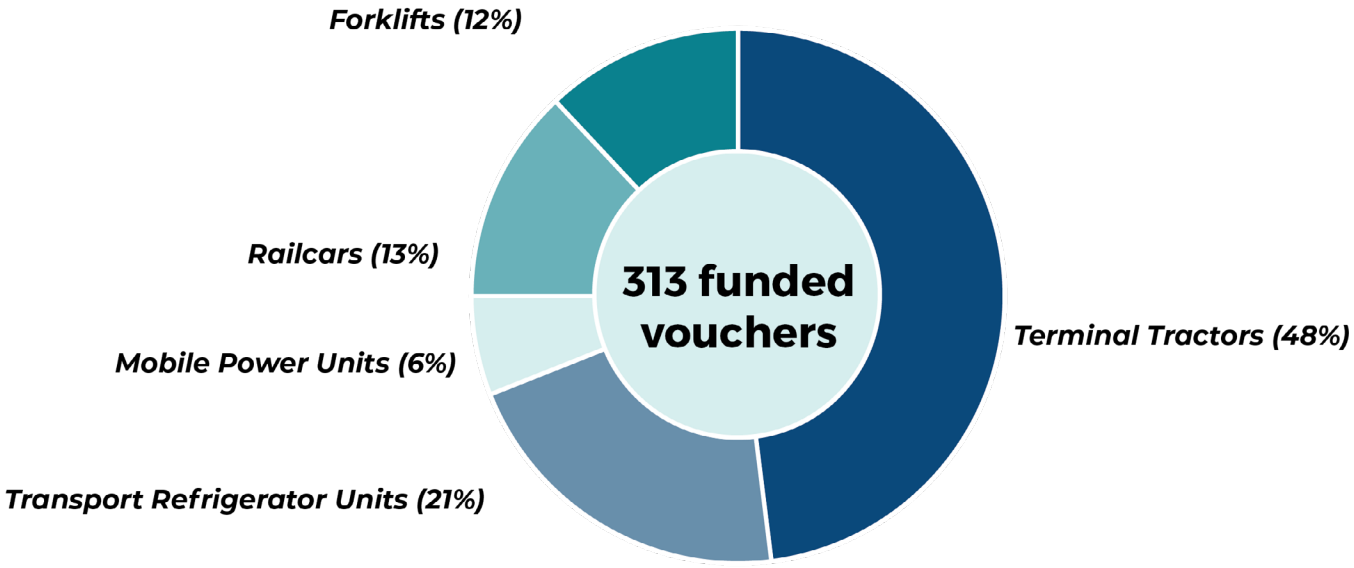
The earliest model to demonstrate the function, flexibility, and effectiveness of a voucher-based incentive program for commercial vehicles was California Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP). The project started in February 2010, using state funds from license fees specifically dedicated to supporting advanced vehicle and fuel demonstration and deployment. Since 2012, HVIP has been funded by auction proceeds from California's statewide GHG Cap-and-Trade program, designed pursuant to California AB 32. HVIP is a key component of CARB's Low Carbon Transportation Investments and AQIP, which is focused on supporting development and deployment of the advanced technologies needed to meet California's longer-term, post-2020 air quality goals. Its success as a powerful tool for rapid deployment has encouraged regional adaptations of the voucher model in other states and on a more localized basis, such as within Air Districts in California.

In its first year of operation, HVIP disbursed its funds faster than any program in CARB history and was recognized as the number one emerging state energy project by the American Council for an Energy Efficient Economy. The HVIP program has deployed over 9,000 all-electric and hybrid vehicles and low-NOx engines, with total voucher funding over $622 million through November 2021 (California HVIP, 2022). In 2021 alone, the HVIP program received 2,014 truck and bus voucher requests through $247 million in available funding.

The Clean Off-Road Equipment (CORE) program, borrowing from the HVIP design, was launched in 2020 to encourage California fleets to purchase or lease cleaner off-road equipment. CORE provides a streamlined voucher process by which potential purchasers can receive funding to help offset the higher cost of off-road equipment. Pursuant to AB 134 and the FY2017-18 Funding Plan, CORE is currently applicable only to freight equipment powered exclusively by zero-emission technology. While the goal of CORE is to help purchasers overcome the incremental cost barrier of cleaner off-road equipment, the methodologies developed for determining voucher amounts also consider other factors, such as current market penetration and the projected need for incentives. The distribution of funds is separated by vehicle platforms and technologies, ensuring that available funding is used to support a broad suite of clean off-road technologies.

CORE distributed $44 million for clean off-road vehicles, technologies, and charging equipment in its first year of operation (Clean Off-Road Equipment Voucher Incentive Project, 2022). More than 70% of vouchers support vehicle deployments in communities disproportionately impacted by air pollution. Terminal tractors and yard trucks, the most market-ready eligible ZEV technology, have been completely subscribed and represent 48% of initial funded vouchers (Figure 3.8), but vouchers have supported diverse ZEV applications that will continue clean off-road innovation.

Figure 3.8. CORE Voucher Funding by Equipment Type



CEC PROGRAMS

The CEC supports California's ZEV and broader climate goals through a range of programs and investments focused on ZEV technologies, charging infrastructure, clean fuels, vehicle efficiency, energy system planning, and vehicle-grid integration. Across this portfolio, two programs in particular support California's ZE-MHDV transition: the Clean Transportation Program and the School Bus Replacement Program.

Clean Transportation Program

As part of over $1 billion in Clean Transportation Program invested since 2009, the CEC's 2020-2023 Investment Plan directs $129.8 million for medium- and heavy-duty ZEVs and infrastructure, along with funds to support California's broader ZEV industry and ecosystem, including $70 million for hydrogen fueling infrastructure, $9 million for ZEV manufacturing, and $7.5 million for ZEV-related workforce development. In addition, California's landmark 2021 climate budget bill, SB 129, provides the CEC with additional one-time funding of $628 million for ZEV infrastructure. Of this, up to $428 million could go to ZE-MHDV infrastructure, with $133 million in guaranteed MHDV funding.

Complementing vehicle incentive and demonstration projects supported by CARB, regional Air Districts, and California's major ports, CEC investments have supported 54 advanced technology freight and fleet vehicle demonstrations, and the deployment of 150 zero-emission and near-zero-emission trucks (Brecht, 2020).

Clean Transportation Program investments are also guided by input from two key external stakeholder

advisory groups. The Clean Transportation Program Advisory Committee reflects a broad array of stakeholders from community organizations, social and environmental justice advocates, alternative vehicle technologies, and workforce and labor interests. The CEC's Disadvantaged Communities Advisory Group is an 11-member group created by SB 350 to review and ensure CPUC and CEC clean energy programs and policies benefit low-income and disadvantaged communities.

Clean Transportation Program funds are distributed to projects through a mix of funding mechanisms, including the following (Brecht, 2020):

- **Competitive Solicitation for Grants**: These grants are the most common Clean Transportation Program funding mechanism. It allows for flexibility in adapting project requirements and scoring criteria to a broad range of commercial and technological maturity levels. Competitive grants also require significant investment in time and resources for application review and project oversight.
- **First-Come, First-Served**: This mechanism is used by the Clean Transportation Program for vehicle and infrastructure incentives. Once eligibility requirements are established, funding can be administered quickly and provide greater market certainty for a given technology.
- **Production or Operation Incentives**: This type of incentive has been used for hydrogen refueling station operation and maintenance, with the primary aim of providing greater market certainty and subsequent private investment.
- **Loan Loss Reserve/Loan Guarantees**: This funding mechanism aims to leverage private financing for zero-emission vehicles and infrastructure.
- **Block Grants**: These grants are used to distribute Clean Transportation Program funding through other organizations such as local and regional governments, academic institutions, or NGOs. This enables grant recipients to administer Clean Transportation Program funding while following CEC procedures for project and applicant eligibility.
- **Federal Cost Sharing**: With this mechanism, the CEC provides the required matching funds to project applicants seeking federal funding opportunities.

Recent Clean Transportation Program investments have sought to support and incentivize ZE-MHDV technology deployment through a variety of innovative mechanisms. Through a first-of-its-kind $50 million block grant, the CEC is funding the design and implementation of the Energy Infrastructure Incentives for Zero-Emission Commercial Vehicles (EnergIIZE Commercial Vehicles), which will provide incentives for electric charging and hydrogen fueling infrastructure to support fleets with zero-emission MHDV acquisitions. EnergIIZE is intended to close a critical infrastructure funding gap for fleets looking to transition to ZEV technology, and will ultimately support the deployment of 600 zero-emission trucks, transit buses, and school buses (Ward, 2020).

The Clean Transportation Program has also funded California's network of hydrogen fueling stations (often referred to as California's "Hydrogen Highway"), allocating up to $20 million annually to support planning, development, and construction of the first 100 publicly available hydrogen fueling stations, with the ultimate goal of establishing 200 hydrogen fueling stations by 2025 as outlined in Executive Order B-48-18 (Brecht, 2020).

Volkswagen Diesel Emissions Settlement

In addition to Clean Transportation Program funding, the CEC's ZEV investments are funded by proceeds from California's settlement with Volkswagen over the sale of diesel vehicles equipped with illegal emission testing defeat devices in violation of federal and state law. Stemming from this settlement, California was awarded over $400 million from a national Environmental Mitigation Trust to remedy the harm caused by these defeat devices through projects to eliminate the lifetime excess of NOx emissions. CARB's Beneficiary Mitigation Plan, approved in May 2018, outlines that, of California's total allotment of Environmental Mitigation Trust Funds, $130 million was approved for the deployment of zero-emission school, shuttle, and transit buses, administered on a first-come, first-served basis. An additional $90 million was approved for zero-emission Class 8 freight and port drayage trucks and $70 million for zero-emission freight and marine projects (Brecht, 2020a).

School Bus Replacement Program

The CEC-led School Bus Replacement program is helping schools throughout California to replace older, polluting diesel school buses with newer zero- or low-emission vehicles. In addition to supporting ZEV technology and deployment, the program seeks to improve children's health by reducing exposure to transportation-related air pollution, with priority given to disadvantaged, low-income communities that are disproportionately impacted by air pollution and negative health outcomes resulting from the state's fossil fuel-powered transportation system. As of March 2021, the School Bus Replacement Program has funded the replacement of 235 school buses, covering almost 100% of the costs for qualifying school districts.

California SB 110 of 2017 allocated $75 million for the School Bus Replacement Program, utilizing funds appropriated from the California Clean Energy Jobs Act, which was approved by California voters via ballot initiative in 2012 (Proposition 39) to fund projects that improve energy efficiency, expand clean energy production, and create clean jobs via the state corporate income taxes revenue. More than $94 million has since been made available to public school districts, county offices of education, and joint power authorities for the purchase of ZEBs to replace old diesel buses.

Through Clean Transportation Program grants and other funding sources, the CEC provides complementary funding and support for school bus charging infrastructure and workforce training and development for school bus drivers and maintenance technicians (CEC, 2018).

UTILITY INVESTMENTS IN CHARGING INFRASTRUCTURE AND NOVEL RATE DESIGN

The CPUC is California's primary electrical utility regulator. With regulatory authority over the state's six IOUs, the CPUC oversees rate-setting and electric generation and distribution infrastructure investment planning. The CPUC plays a key role in advancing California's clean energy and climate goals, and has increasingly required investment in infrastructure for a zero-emission transportation system.

SB 350, passed in 2015, requires the CPUC to direct IOUs to file applications for programs that "accelerate widespread transportation electrification." These programs are required to reduce dependence on petroleum, increase the adoption of ZEVs, help meet air quality standards, and reduce GHG emissions (CPUC, n.d.).

SB 350 recognized that transportation electrification was critical to the state's clean air and GHG reduction goals, and that the state's disadvantaged communities lacked equitable access to charging and clean vehicles. As such, the CPUC ruled[5] in 2016 that the three largest IOUs—SCE, PG&E, and SDG&E—should file applications within the following year to promote widespread electrification, including for MHDVs. Applications were required to show how IOUs will balance competing objectives and not unfairly compete with other actors, while also demonstrating how they will forecast demand for electric MHDVs.

Four years later, these processes have generally been accomplished through utility "applications" approved via CPUC proceedings. Each of the IOUs has filed, and had approved, a stand-alone make-ready program for MHDV charging. In total, these programs will encompass nearly $700 million in make-ready investments to support commercial fleets. Specific budgets were approved as follows:

- SCE: $343 million
- PG&E: $236 million
- SDG&E: $115 million

In total, the CPUC expects these programs to support over 2,000 new make-ready installations that could serve nearly 20,000 ZE-MHDVs.

All of the California IOU programs enable utilities to cover 100% of the distribution side upgrades for commercial fleet charging, while also offering comprehensive advisory services for fleets and some level of customer-side infrastructure incentives. The programs vary in what they offer customers regarding incentives or reimbursements for customer-side upgrades and charging equipment. For example, SCE's program offers to cover up to 50% of customer-side infrastructure costs for sites located in disadvantaged communities or those that support public transit or school buses. Some utilities are requiring a minimum "commitment" from the fleet to a certain number of vehicles over a 5-year period, in order to guarantee some level of cost efficiencies and to ensure that the grid upgrades will in fact be utilized. Utilities and stakeholders have observed that when fleets are willing to make bigger commitments, this produces much more cost efficiencies for the entire market. Thus, larger scope projects (as opposed to more programs with fewer vehicles) create a bigger impact. Many of the programs also offered sector specific pilot projects, such as for school buses or transit buses to demonstrate vehicle-grid-integration capability.

Each of the utilities has also filed (with two approved) new electric vehicle rate tariffs that are specifically designed for commercial fleets, which do away with demand charges in favor of time-of-use (TOU)

5 Rulemaking issued in OIR 13-11-007 on 9/14/16, "Regarding the Filing of Transportation Electrification Applications pursuant to SB 350."

rates that will benefit the grid. Demand charges can be extremely detrimental to ZE-MHDV adoption because they charge users a monthly fee that is based, in large part, on their peak usage for the month. Most notably, PG&E has implemented a novel rate design that involves a lower subscription charge and a TOU rate component. The new PG&E tariff creates a new rate class for commercial electric vehicle charging and aims to provide a more affordable and simple structure for electric vehicle charging with a new subscription charge based on connected charging capacity, plus a TOU volumetric rate that encourages charging overnight and during mid-day hours. Rate analysis demonstrated that charging electricity at this new rate should be significantly cheaper than using diesel for all vehicle and customer types analyzed.

AQMD GRANT PROGRAMS

California's 35 regional Air Districts are responsible for regional air quality planning, monitoring, and stationary source and facility permitting. The districts administer air quality improvement grant programs and are CARB's primary partners in efforts to ensure that all Californians breathe clean air. At a local and regional level, California's Air Districts play a key role in supporting the transition to ZECVs. Some of the key ZECV-focused programs led by California's Air Districts include the Carl Moyer Program, Volkswagen Environmental Mitigation Trust funding, and other grant programs and incentives for ZECV deployment.

Carl Moyer Program

In partnership with CARB, California's 35 Air Districts implement the Carl Moyer Memorial Air Quality Standards Attainment Program, providing grant funding for the upgrade or replacement of heavy-duty on- and off-road diesel vehicles and equipment that go beyond regulatory requirements. Eligible on-road vehicles include heavy-duty trucks and buses, school buses, transit vehicles, drayage trucks, public agency and utility vehicles, emergency vehicles, and solid waste collection vehicles. Eligible off-road equipment includes construction and farm equipment, marine vessels, locomotives, stationary agricultural equipment, forklifts, light-duty vehicles, airport ground support equipment, lawn and garden equipment, and emergency vehicles. The program also supports electrical charging infrastructure projects for light, medium, and heavy-duty trucks.

Funded through tire fees and smog impact vehicle registration fees, the Carl Moyer Program provides around $60 million per year, with over $1 billion in cumulative funding since the program's inception in 1998. Grant funding is administered by individual Air Districts, which have considerable flexibility in implementing the program and focusing grant funds on specific pollution sources and projects that meet local air quality objectives. Public and private entities are eligible for Carl Moyer Program funding, and funded projects must not provide "early or extra" emissions reductions that are not otherwise required by existing regulation.

Other Programs

In addition to the Carl Moyer Program, California's Air Districts implement a number of district-level

grant programs to support clean air and climate goals. For example, within the Bay Area Air Quality Management District (BAAQMD), the Mobile Source Incentive Fund provides supplemental grants to public and private sector projects eligible for Carl Moyer Program funding via revenues collected from a $2 fee on vehicles registered in the Bay Area (which generates around $11 million per year). Likewise, BAAQMD's Transportation Fund for Clean Air generates revenues from a $4 surcharge fee on vehicles registered in the Bay Area, providing around $22 million per year in additional funds for cost-effective projects that reduce on-road motor vehicle emissions within the Air District's jurisdiction.

PORT INITIATIVES

In addition to the port access restrictions discussed previously, California's ports have also implemented a number of clean energy and zero-emission technology demonstration projects to facilitate the transition to zero-emission goods movement, often through funding from CARB and the CEC via programs discussed above. For example, as of October 2018, the Port of Long Beach has received nearly $80 million in total grant funding from the CEC and CARB to implement several zero-emission demonstration projects, including (Port of Long Beach, n.d.):

- **Zero-Emissions Terminal Equipment Transition**: The CEC awarded a $9.7 million grant towards the $13.7 million total project cost for the demonstration and deployment of nine electric rubber-tire gantry cranes, 12 zero-emission yard tractors, and four hybrid and electric drayage trucks, as well as workforce development training programs.
- **Sustainable Terminals Accelerating Regional Transformation Project (START)**: CARB awarded a $50 million grant for a transformative demonstration of a near-zero and zero-emission supply chain, funding 34 pieces of zero-emission cargo handling equipment, two of the cleanest container ships to call on the West Coast, an electric-drive tugboat, five electric trucks at an off-dock container yard, and two HDT charging outlets.
- **Port Advanced Vehicle Electrification (PAVE)**: TThe CEC provided $8 million out of a total project cost of $16.8 million to design, install, and deploy electrical charging infrastructure, including electrical conduit, wires, switchboards, transformers, and switchgears, to support battery-electric yard tractors and forklifts at Total Terminals International's facility at Pier T.
- **C-PORT Zero-Emissions Demonstration**: Supported by $5.3 million grant from CARB, the Port of Long Beach and terminal operators SSA Marine and Long Beach Container Terminal demonstrated five zero-emission cargo handling vehicles, including three never-before-tested battery-electric top handlers and a head-to-head comparison of a hydrogen fuel truck and a battery-electric yard truck.

Continued Innovation to Meet California Goals

California's planners and regulators are always innovating and finding new opportunities to support regional ZECV growth. The recent examples below demonstrate targeted new and/or proposed approaches to improving clean commercial vehicle adoption.

Project 800

CARB has launched an aggressive effort to financially support early regional Class 8 zero-emission drayage truck adoption. The Project 800 initiative, launched in January 2021, aims to improve the health of residents near California ports by setting a goal of 800 zero-emission drayage truck orders in 2021. To accomplish its goals, CARB is working directly with drayage operators to ensure funding availability and providing carve-outs from HVIP. These 800 trucks represent a pathway toward jump-starting the sector and paving the way for more zero-emission trucks in the near future.

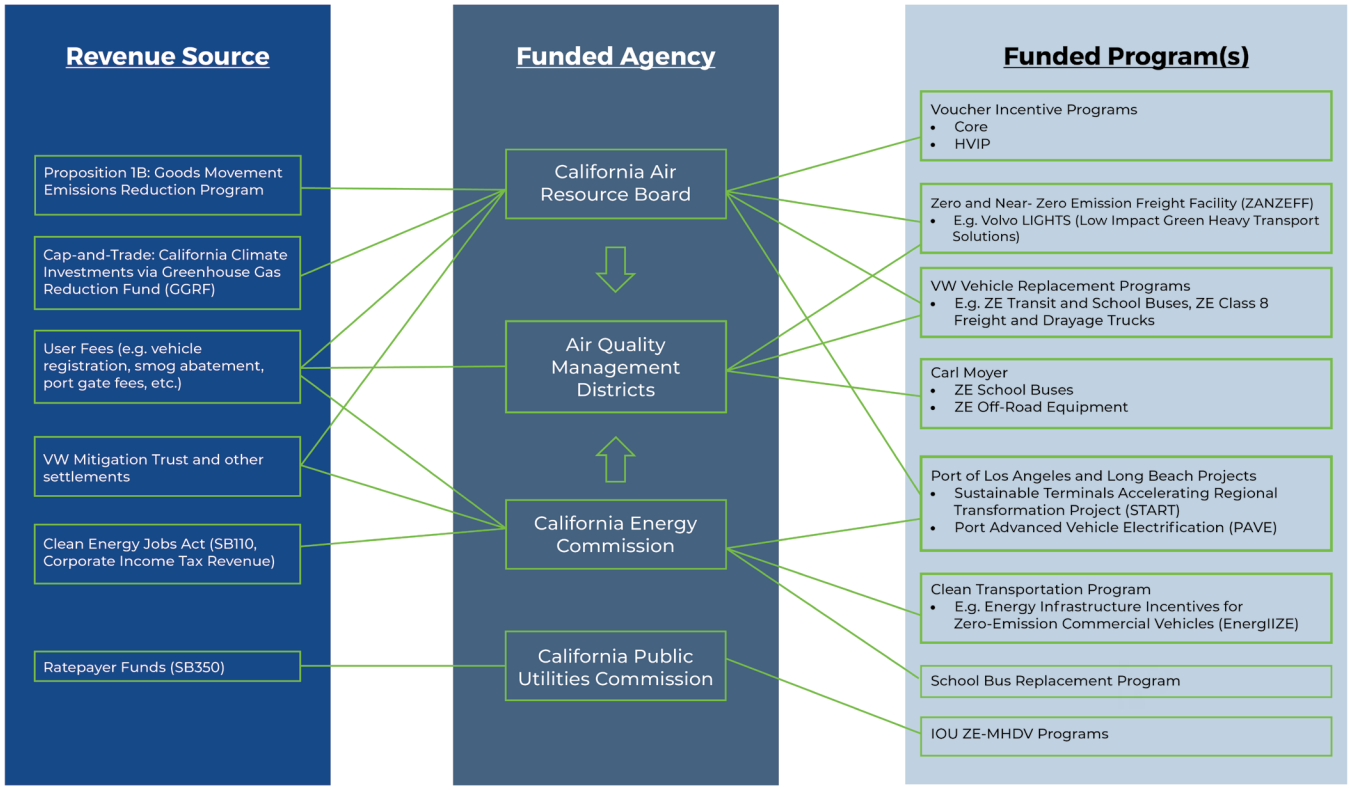
Warehouse Actions and Investments to Reduce Emissions (WAIRE)

The SCAQMD's proposed WAIRE regulation may introduce a points-based system encouraging large warehouse operators to use zero- or net-zero-emissions trucks at their facilities. Under the proposed rule, large warehouses would be required to accrue points based on annual zero-emission truck or charging use. Warehouse facilities that don't earn sufficient points through emissions-curbing actions would be required to purchase points, with proceeds benefiting SCAQMD's clean vehicle programs (Fuller, 2021).

SUMMARY OF ZECV FUNDING AND INVESTMENTS

Figure 3.9 provides a non-exhaustive and illustrative overview of California's major public investments in zero-emission commercial vehicles and infrastructure, summarizing the primary funding streams, implementing agencies, and investment programs supporting the state's ZECV transition through vehicle and infrastructure pilots, demonstration projects, purchase incentives, and make ready requirements. Coupled with regulatory "sticks" requiring the sale and deployment of ZECVs through the ICT rule, ACT rule, and forthcoming Advanced Clean Fleet rule, these investment programs have helped to lower vehicle purchase and infrastructure implementation costs; support fleet operational understanding; and accelerate commercial readiness through a sustained and multi-pronged market transformation strategy.

Figure 3.9. Major Funding Sources and Programs for ZECVs



CHAPTER 4

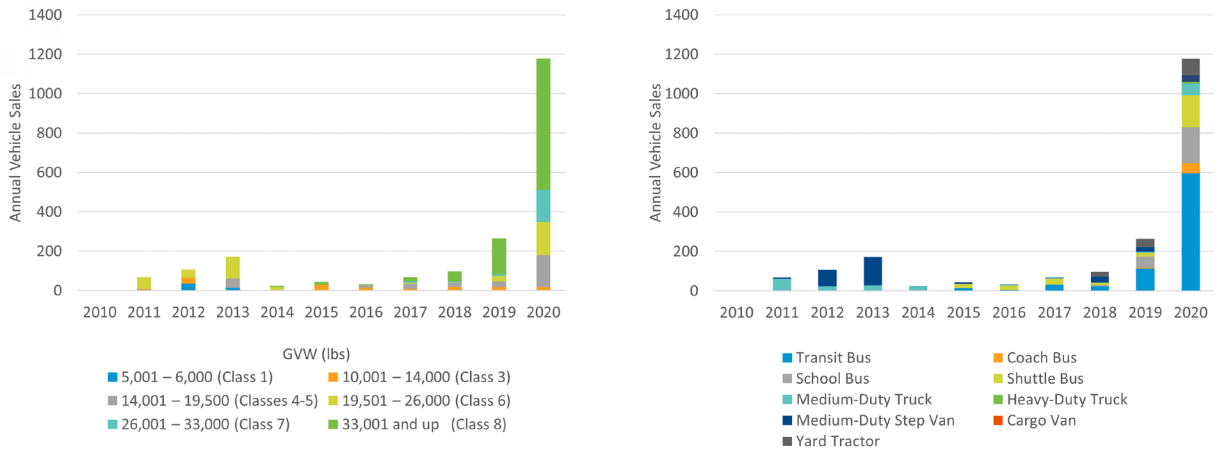
ZECV MARKET PROGRESS IN CALIFORNIA

The diversity of programs and robust policy mechanisms implemented in California have played a major role in accelerating the adoption of ZECVs. Through ambitious goals, backed up by targeted policy regulations and innovative financial mechanisms, California has become a leader in the global effort to reduce the impact of emissions on the environment and public health. In understanding California's progress, other regions can begin to explore the impact that various policies and actions might have in their regions.

A. HISTORICAL PROGRESS

California's progress can be seen through a decade of delivered sales of ZECVs (Figure 4-1). Following an initial ramp up between 2011 and 2013 – largely due to corporate interest in zero-emission urban logistics – there was a sharp drop in sales in 2014 due to inadequate real-world performance in meeting fleet expectations. The overall trend since 2014 has been a more encouraging snapshot of ZECV deployments, with a significant uptake in identified beachhead segments like transit, shuttle, and school buses.

Figure 4.1. Delivered Vehicle Sales in California by Weight Class and Vehicle Type

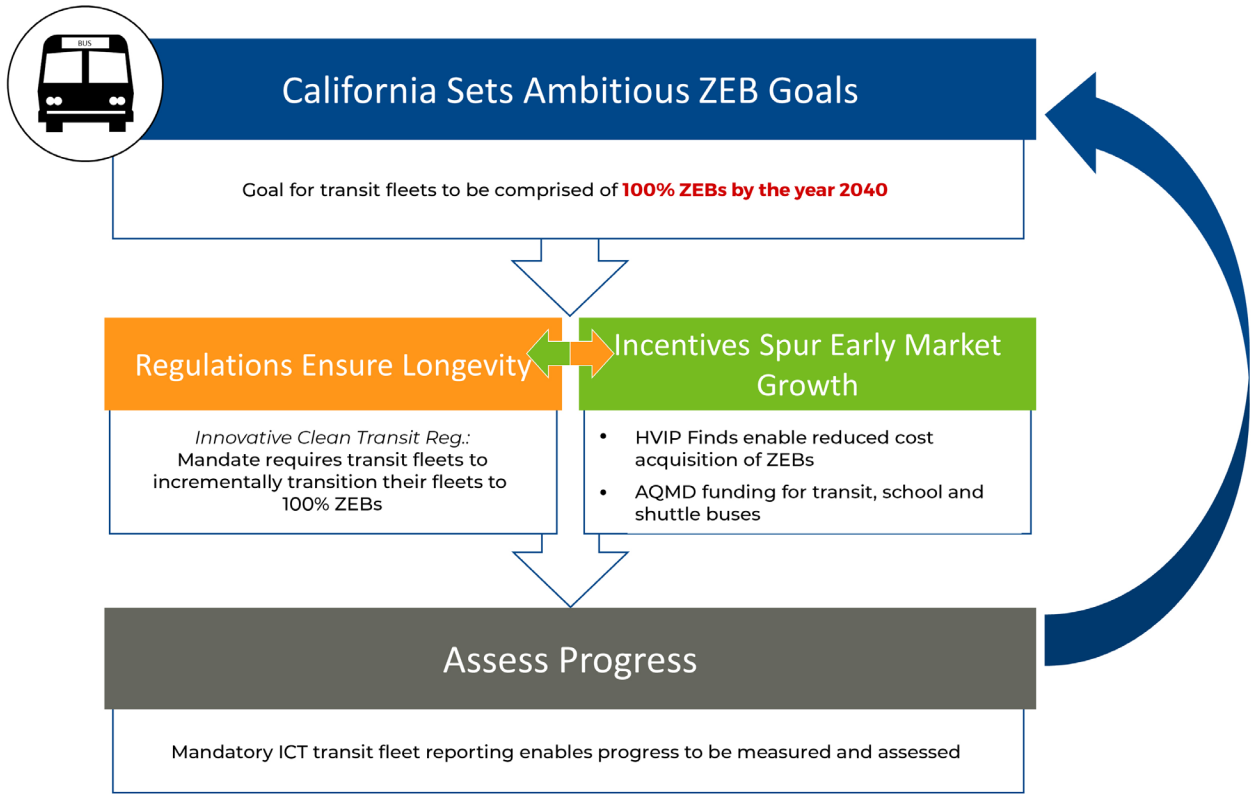


Though these vehicles were funded in part by California's HVIP program, other mechanisms may be responsible for the significant increases in volumes after 2018. Outlined previously, California's ICT regulation also went into effect in 2018, which may impact transit agencies' decisions to begin acquiring ZEBs before funding is no longer available through vouchers. The CEC's School Bus Replacement program also opened in 2018, which could allow for further cost reductions in this segment.

The progress made in California aligns with the Drive to Zero program's identified beachhead segments. Large orders of zero-emission transit, school, and shuttle buses, as well as parcel delivery vehicles used in last-mile applications, have given a significant boost to ZECV sales numbers. Looking at transit buses specifically, California leads the country with 1,371 full-size ZEBs deployed or on order across the state, out of a total of 3,533 deployed or on order nationally as of 2021—representing 38.8% of the total U.S. market for ZEBs (Hamilton et al. 2021).

Though California represents a small share of the total global bus market, the state's success with ZEBs relative to rest of the U.S. is a result of California's strategy of goal setting, regulations, incentives, and continuous assessment of progress applied to ZEBs (Figure 4-2). Following the Beachhead Strategy introduced in Chapter 2, transit buses are typically the first foothold for zero-emission technologies for commercial vehicles, and California has structured their policies and incentives to match technology readiness and transfer as the market evolves. Most importantly, ZEB investment lays the foundation for technology transfer to zero-emission trucks as technology evolves.

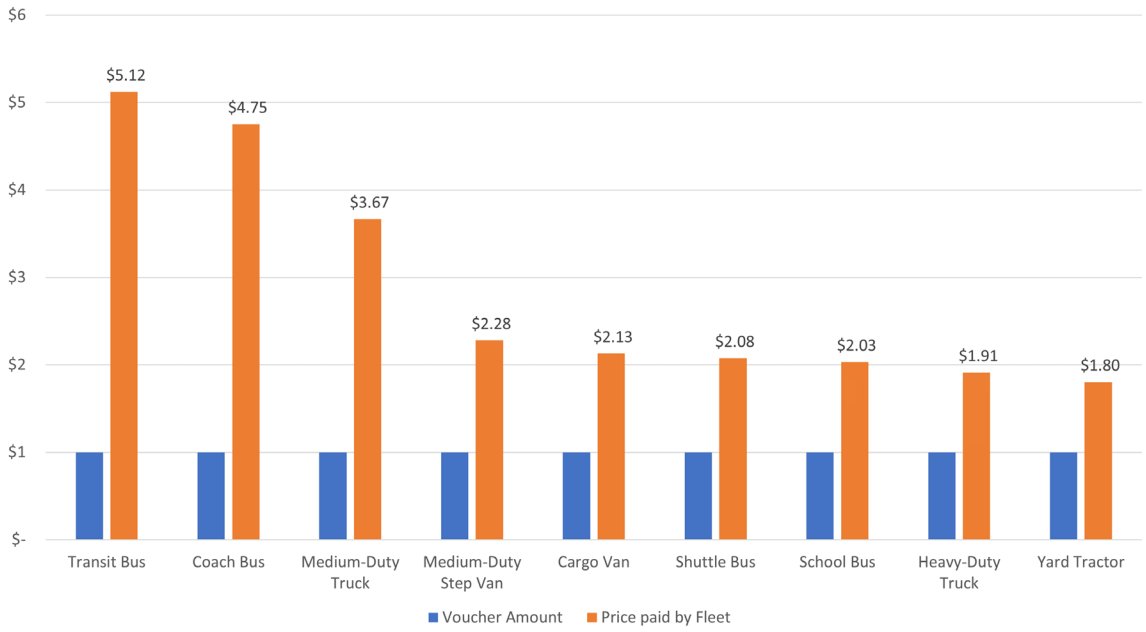
Figure 4.2. Framework for Zero-Emission Bus Transformation



B. PRIVATE INVESTMENT

In California, financial incentives and programs that reduce the cost of vehicles for the end-user have been critical to scale up production and achieve price parity. California's programs such as HVIP have shown remarkable returns in their ability to leverage private funding from fleets (Figure 4-3). In aggregate, from the roughly $400 million administered by HVIP through 2020, about $1.4 billion has been spent towards these vehicles by fleet operators. Fleet investments in this early stage of the market transition lead not only to technology innovation, but also help other fleets and freight users understand the benefits and challenges of incorporating ZECVs into their fleets. In addition, fleet investments also enable manufacturers to ramp up production and accelerate economies of scale.

Figure 4.3. Fleet Investments Leveraged per Dollar of HVIP Funding



C. FUTURE OUTLOOK

With more stringent purchase and sales requirements coming into effect soon due to CARB regulations, as discussed above, and other fleet purchase mandates underway, ZECV deployment is expected to rapidly accelerate in the next three to ten years. To be successful, these regulations need to be complemented by strong vehicle incentives and infrastructure investments, which has been the case

in California. Assuming that these regulations are implemented effectively, approximately 4,000 ZE-MHDVs are expected to be deployed in California by 2024, and 103,000 will be deployed in 2030 (CARB 2020c).

Economic Development Benefits

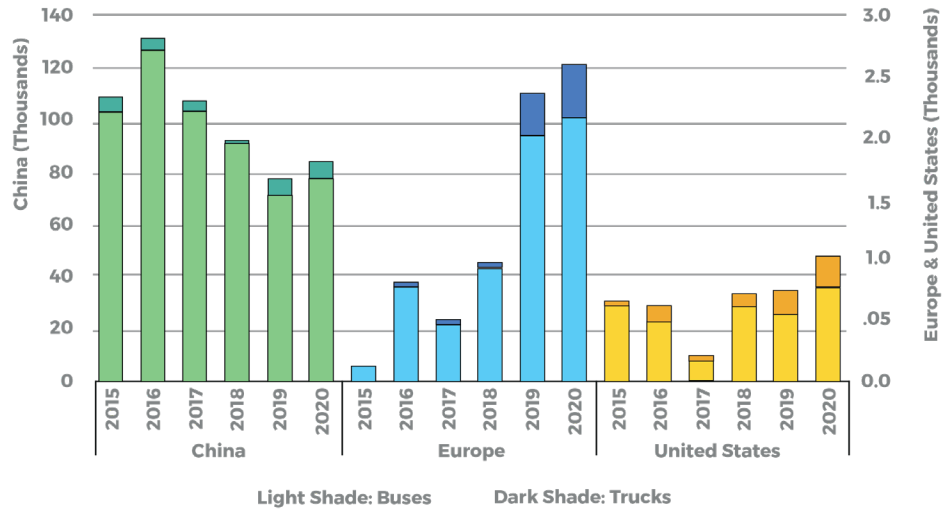
In addition to advancing clean air and climate goals, California's sustained focus on clean transportation and ZEVs has created a vibrant ZEV industry within the state and important economic development benefits. According to the Los Angeles County Economic Development Corporation, California is now home to "over 60 company headquarters related to the electric vehicle and charging industry and over 20 manufacturing sites have made California their home. The state's ZEV industry provided 275,600 jobs in 2018 alone across a variety of equipment manufacturing and service-providing segments with an average annual wage of $91,300. California's ZEV industry is also contributing to a growing share of the state's exports, with transportation equipment exports accounting for 13%, or $22.7 billion, of California's global exports in 2019, and an 18% increase from 2018" ("Energizing the Ecosystem: The Electric Mobility Revolution in Southern California," 2020).

CHAPTER 5

GLOBAL CONTEXT

Though California has led the U.S. in ZECV sales, sales of ZECVs in China and Europe have greatly exceeded total U.S. sales. Since 2015, China has dominated global ZECV sales through a combination of financial incentives and local traffic restrictions (Figure 5-1). China's ZECV sales have largely consisted of ZEBs, like other regions, but also reflect a relatively large zero-emission truck market. Chinese ZECV sales have been buoyed by substantial national and local subsidies that were implemented in 2013 and reduced gradually starting in 2016. These subsidies have been extended through 2022, but the impact on China's ZECV sales is clear, with lower sales volumes mirroring the reduced value of financial incentives. This further exemplifies the need for a strong policy ecosystem of incentives and regulations to ensure market longevity and stability in ZECV sales.

Figure 5.1. Electric Bus and Truck Registrations by Region, 2015-20 (IEA, 2021)



ZECV sales in the European Union (EU) are much closer in scale, but still exceed U.S. sales volumes. The EU lacks a single, cohesive program such as China's incentives scheme to help advance the ZECV market, but several programs and regulations have helped advance the regional ZECV market:

- Regulations on manufacturers' CO_2 performance have rewarded ZECV sales with "super-credits" that double the number of credits earned through 2024.

- The Clean Vehicles Directive assigns member states a target date and number of clean commercial vehicle deployments, which include ZECVs, but leaves implementation open to member states. This approach provides flexibility for how each member state can most efficiently meet its targets while working toward collective EU clean commercial vehicle goals.
- Many EU member states (e.g., Germany, Spain, Italy, France) offer ZECV purchase incentives, ranging from €9,000 to €50,000.
- European cities and nations have announced their intention to implement zero-emission zones, such as the many signatories to C40's Green and Healthy Streets Declaration that will create significant zero-emission zones in central business districts. The Netherlands requires 30-40 of its largest cities to create medium-sized zero-emission zones. These efforts support a better outlook for ZECVs while adding uncertainty in the business case of diesel-powered vehicles.
- In June 2019, the EU amended its regulations to allow zero-emission trucks to exceed standard weight classes by two tons, taking a similar approach to California whose weight exemptions allow zero-emission trucks to exceed strict weight restrictions by up to 2,000 pounds. Because batteries weigh more than diesel combustion technologies, such weight exemptions to zero-emission trucks aim to avoid potential payload restrictions.

The regulations and incentives that have emerged from California's early-market ZECV innovations have led to new solutions and similar efforts in other U.S. jurisdictions:

- The HVIP program, originally implemented in 2010, devised an innovative solution for addressing the common barrier of upfront purchase or lease costs being too high for fleets to afford ZECVs. HVIP has disbursed more than $120 million for ZECVs since the program launched and opened a new tranche of funding worth $160 million in June 2021. The voucher design inspired the New York State Energy Research and Development Authority to launch its own voucher incentive program, NYTVIP, which uses similar methods to distribute clean vehicle funding. The City of Chicago also operated a voucher program to distribute federal funding. Newer programs that follow the voucher incentive design continue to emerge across the U.S., including the recently announced New Jersey ZIP program and the Massachusetts MOR-EV program.
- California's LCFS since launching in 2006 has since been adopted in Oregon and British Columbia, and Washington state adopted an LCFS in 2021. Though the programs are not fully merged, clean fuels programs that generate revenue for ZECV operators will soon stretch along the West Coast.
- The ACT rule is a first-of-its-kind regulation that uses market mechanisms to require regulated truck manufacturers to sell ZECVs as a percentage of their total vehicle sales. Following adoption of the regulation in 2020, 15 U.S. states and the District of Columbia signed an MOU to join forces to accelerate bus and truck electrification (NESCAUM, 2020). As of January 2022, five of these states had adopted ACT regulations modelled upon California's: Massachusetts, New Jersey, New York, Oregon, and Washington.
- Similarly, the New York state legislature passed legislation in 2021 to adopt the same targets outlined by Governor Newsom's Executive Order N-79-20.

The experiences of California demonstrate that ZECV market growth is the result of careful planning and coordination, including conspicuous targets, strategies (such as incentives or regulations) that best fit their goals, and continuous revisions to ensure market progress. California's framework for market transformation is flexible to allow each jurisdiction to create its own goals based on the outcomes it seeks. Targets may be set to generate cleaner air and improve human health, to meet climate goals, or to stimulate economic opportunity. Setting appropriate targets and monitoring progress toward goals are perhaps the most important steps. Well-known programs and regulations like HVIP and ACT exist to execute specific functions that meet California's climate and ZECV goals. Though the programs are celebrated, they represent purposeful organization, goal setting, and collaboration that ultimately determine how successful these programs will be. The California framework has helped build a regional ZECV beachhead and is a valuable tool for other jurisdictions looking to do the same.

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