Appendix D: Long-Term Heavy-Duty Investment Strategy

Including Fiscal Year 2023–24 Three-Year Recommendations for Low Carbon Transportation Investments

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Executive Summary

The California Air Resources Board's (CARB's) Long-Term Heavy-Duty Investment Strategy (hereafter referred to as the "Strategy") serves as a roadmap for the role of Low Carbon Transportation and Air Quality Improvement Program (AQIP) incentives in transforming the heavy-duty (HD) transportation sector and achieving the State's zero-emission vehicle (ZEV) goals. Each year, CARB updates and refines its priorities for the targeted technologies and project categories that merit investments to help the State reach its climate and air quality goals. In targeting its investments, CARB strives to maximize benefits for priority populations, and the projects funded by these investments include targeted support to the communities most impacted by poor air quality. CARB is increasingly taking steps to shift from broad purchase incentives to more targeted incentives for those who need them most, building on previous efforts to ensure that investments are equitability distributed.

The levels of funding identified in this Strategy represent a critical down payment toward meeting the funding need for advanced technology HD vehicles and off-road equipment but do not approach the entire amount needed to achieve the total transformation of the heavy-duty fleet as outlined in the State's goals (Table D-1). Emphasis is placed on the strategic use of State investments to incentivize the development and advancement of clean HD vehicle and off-road equipment technologies – complementary to CARB's regulatory requirements, in order to support large scale market transformation. Regulations such as the Advanced Clean Fleets regulation are critical to achieve large-scale market transformation of the heavy-duty section, and incentives can play an important complementary role to support early technology advancement and help meet the unique needs of small fleets and small businesses. Sustained progress in implementing these priorities and recommendations will help California continue its role as a national clean vehicle technology leader by achieving this transformation of the HD vehicle and off-road sectors.

In addition to identifying priority focus areas and recommended levels of incentive funding, this document also includes metrics to help assess the performance of Low Carbon Transportation projects. These include targeted metrics that address ways to support healthy communities, grow the green economy, and support technology evolution.

California has made significant progress in its effort to transform the transportation sector to zero-emission (ZE) technologies. Its large portfolio of clean transportation investments covers a variety of programs designed to reduce emissions from on-road and off-road sources. As regulatory requirements approach, CARB's incentive strategy shifts toward a focus on providing financial assistance for smaller fleets that face challenges in qualifying for traditional financing programs.

While there are a variety of statutory drivers and executive orders guiding this effort, the primary driver is Executive Order N-79-20, which calls for a complete transformation of the transportation sector to ZE by 2045 wherever feasible.

Successful deployments of ZE truck and bus technologies from previous investments have been instrumental in advancing the on-road ZEV market to where it is today, with a wide array of vehicles and equipment available on the commercial market. Recent investments in the development and demonstration of heavier and more specialized ZE off-road vehicles and equipment have resulted in a growing list of commercial products in the off-road sector. Continued commitment to these markets in the form of commercial incentives, as well as funding for demonstration and pilot projects, will play a critical role in:

- Meeting California's air quality and climate goals;
- Achieving vehicle and equipment deployment targets;
- Promoting equity by ensuring that investments benefit the communities most impacted by poor air quality and provide assistance to small fleets and owner-operators;
- Supporting high-quality jobs; and
- Enhancing California's leadership role as an incubator and marketplace for clean, ZE technology.

Table D-1: Focused Recommendations for Low Carbon Transportation Investment Priorities[1]

Category	FY 2024–25	FY 2025–26	FY 2026–27
Demos	$55–$95 Million ZE Construction and Mining Equipment, ZE Heavier CHE, ZE Line-Haul Rail, ZE Marine, ZE Aviation, High Power Charging Capable BE Trucks	$65–$100 Million ZE Construction and Mining Equipment, ZE Heavier CHE, ZE Line-Haul Rail, Emergency and Heavy Specialty Equipment, ZE Aviation, High Power Charging Capable BE Trucks	$75–$115 Million ZE Line-Haul Rail, Emergency and Heavy Specialty Equipment, ZE Heavy Aviation
Pilots	$200–$325 Million ZE Ag-Construction-Heavier CHE, ZE/Hybrid Marine, Strategic Range Extenders, ZE Facilities/ Communities/Corridors	$225–$350 Million FC Long Haul Trucks, ZE Ag-Construction-Mining-Heavier CHE, ZE/Hybrid Marine, Strategic Range Extenders, ZE Facilities/ Communities/Corridors	$250–$400 Million FC Long Haul Trucks, ZE Ag-Construction-Heavier CHE, ZE/Hybrid Marine, ZE Facilities/ Communities/Corridors, ZE Light Aviation, High Power Charging Capable BE Trucks
Commercial	$1,147–$1,164 Million ZE Drayage, BE Long Haul Trucks, ZE School/Transit, ZE Heavier CHE, ZE Switcher Rail, ZE/Hybrid Marine, Temp. Fueling, Financing and Insurance Assistance, ePTOs	$1,083–$1,112 Million ZE Drayage, BE Long Haul Trucks, ZE School/Transit, ZE Heavier CHE, ZE Switcher Rail, ZE/Hybrid Marine, Temp. Fueling, Financing and Insurance Assistance, Heavy/Specialty ePTOs	$1,354–$1,399 Million ZE Drayage, BE Long Haul Trucks, ZE School/Transit, ZE Heavier CHE, ZE Construction and Mining Equipment, ZE Switcher Rail, ZE/Hybrid Marine, Heavy/Specialty ePTOs
Total Funding	$1,402–$1,584 Million*	$1,373–$1,562 Million*	$1,679–$1,914 Million*

*The vehicle and equipment types listed in the table above are a prioritized selection of the project types that CARB would invest in, given sufficient available funds. These focus areas are identified utilizing the strategy laid out in this document. This is not an exhaustive list of technologies or applications that Low Carbon Transportation would fund, and total funding recommendations are not limited to existing appropriations.

[1] Acronym key: battery electric (BE), cargo handling equipment (CHE), electric power take-off (ePTO), hydrogen fuel cell (FC)

Introduction

California has invested billions of dollars to date with the goal of accelerating the transformation away from combustion technologies. In just the past few years, the total amount of funding dedicated to incentivizing the transformation of the HD vehicle and off-road sectors has grown substantially.

The Budget Acts of 2021 and 2022 dedicated $10 billion over five years across multiple agencies to support the State's ambitious ZEV deployment goals. Known as the Zero Emission Vehicle Package, the driving policy for this multiyear, multiagency effort is to equitably reduce carbon emissions from the transportation sector and accelerate the adoption of ZEVs for transportation. The transportation sector is the largest contributor to air pollution, and this effort specifically focuses on benefits to priority populations most affected by pollution. The Budget Act of 2023 and associated trailer bills commit $10.1 billion over six years- fiscal year (FY) 2021–22 through FY 2026–27—across multiple agencies to decarbonize transportation and focus on communities most impacted by air pollution. This is applied across a wide variety of sectors including medium- and heavy-duty (MHD) trucks, maritime, aviation, rail, and other off-road applications, as well as infrastructure.

California continues to move toward transforming its communities to become more sustainable and equitable. Working toward sustainability means working toward meeting the State's goal to achieve carbon neutrality no later than 2045 to prevent the adverse impacts of climate change and to provide Californians healthier air to breathe. Addressing equity requires repairing the harms caused by decades of discriminatory transportation, land use, and housing practices to priority populations, and building more inclusive and equitable places that prioritize providing vulnerable communities with opportunities to thrive.

HD vehicles continue to be the largest source of diesel particulate matter (PM), a toxic air contaminant directly linked to a number of adverse health impacts. Replacing HD combustion vehicles with ZEV technology will significantly reduce greenhouse gas (GHG) emissions and diesel PM emissions in low-income communities and communities of color adjacent to ports, distribution centers, and highways. Accelerating the transformation of California's HD vehicle population to ZE technologies and prioritizing investments in underserved areas that have long born the greatest burdens from the legacy HD diesel fleet is a key element of this year's Strategy.

The Strategy serves as a roadmap showing how CARB plans to invest its Low Carbon Transportation and AQIP funding on a variety of transformational technologies for HD vehicles and off-road equipment. Included in this document is a discussion on the overall CARB incentive funding portfolio and the critical role that Low Carbon Transportation and AQIP play in maintaining and increasing adoption of ZE technology. This document also details a strategy for investing these funds, which includes continuing support for previous Low Carbon Transportation and AQIP investments; focusing those investments across ZE

capable technologies; and utilizing the beachhead strategy[2] to map out a path that focuses on the technology applications that will lead to the most rapid transformation.

The types of incentives deployed need to be carefully prioritized between 1) investing in technologies that are just coming to market and are capable of achieving immediate emission reductions, and 2) providing support to emerging advanced technologies to help them bridge the gap between demonstration and commercial status. To reduce the impacts of climate change and to meet air quality standards, California must lead the way by fostering the development of ZE technologies and supporting low-carbon fuel use now. CARB is working closely with other agencies to support a sector-wide low carbon HD vehicle and off-road equipment technology transition, such as through its efforts with the California Energy Commission (CEC) to support the deployment of ZE infrastructure. CARB also continues its history of building a broad suite of regulatory actions, including the Advanced Clean Fleets (ACF) and companion Advanced Clean Trucks (ACT) regulations, the Innovative Clean Transit (ICT) regulation, and the Ocean Going Vessels at Berth regulation, alongside a comprehensive incentive portfolio that supports technologies from the pre-commercial phase all the way through turnover of the legacy fleet (see Figure D-1). State incentives can help spark private sector investment and create partnerships necessary to support the transformation of the HD vehicle and off-road equipment sectors.

This year's Strategy expands on CARB's principles of investment – supporting targeted advanced technologies across the commercialization arc – while generally describing the framework of each of the CARB incentive programs. This document begins by identifying the general parameters of how technologies move through each of the programs, progressing from one program to the next, ultimately leading to a financially sustainable market where technologies are robust enough to no longer be reliant on public investment.

Background

This document represents the seventh update of the Strategy. The first iteration was developed as a companion document to the FY 2017–18 Funding Plan. Its primary focus was on developing a series of criteria for prioritizing incentives for HD projects, but it also included a three-year funding projection of the level of investment needed to stay the course with Low Carbon Transportation and AQIP funding.

In 2018, the governor signed into law Senate Bill (SB) 1403 (Lara, Chapter 370, Statutes of 2018), which directed CARB to produce annually a three-year investment strategy for Low Carbon Transportation and AQIP investments, beginning with FY 2019–20, along with Three-Year Recommendations for Low Carbon Transportation Investments, appearing in this document as Table D-1 and Table D-5. The intention of the Strategy is to:

[2] For additional information on *the beachhead strategy and its applications*, see *https://calstart.org/beachhead-model-background*.

- Describe the role of public investments in supporting the demonstration and deployment of advanced HD and off-road technologies;
- Provide an assessment of the investment needed from Low Carbon Transportation and AQIP funds;
- Describe CARB's portfolio of investments; and
- Include a report on the State's school bus fleet in consultation with CEC, providing information related to milestones achieved by the State's school bus incentive programs and the projected need for funding, taking into consideration the State's school bus inventory, turnover, and useful life (Appendix E of the Funding Plan).

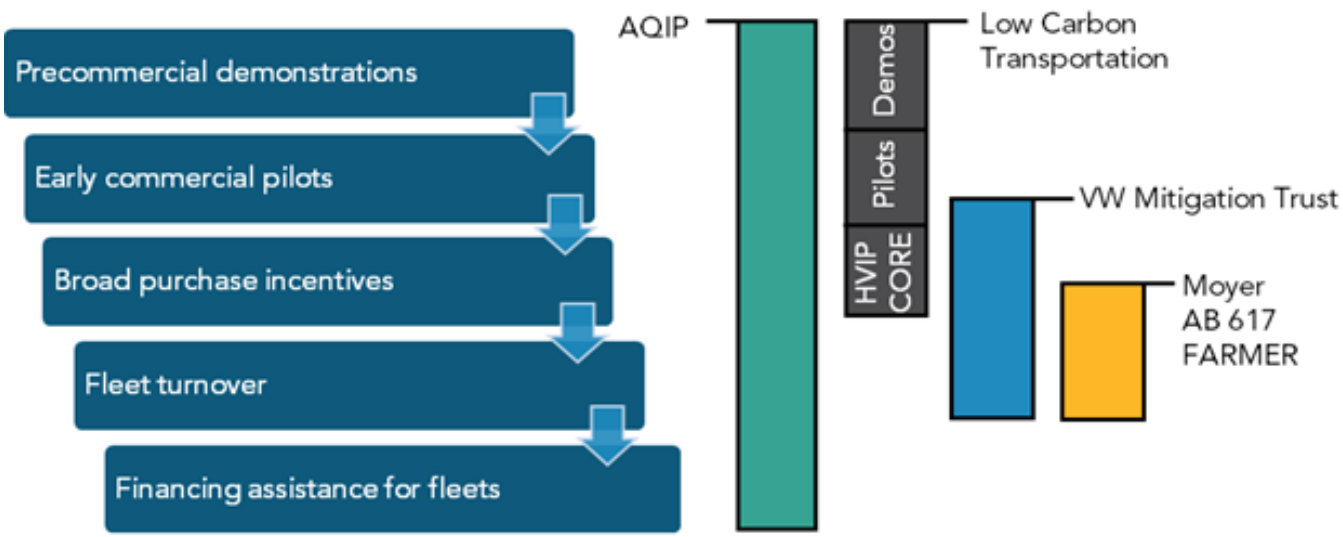
The CARB Portfolio of Funding for Heavy Duty Investments

California has allocated billions of dollars to a multitude of programs, with different but complementary goals, in its ongoing effort to reduce criteria and climate pollutant emissions from the transportation sector. CARB's portfolio emphasizes technology advancement, the deployment of ZE HD vehicles and off-road equipment, turnover of the legacy fleet, and equitably distributed investments. These efforts to incentivize new technologies complement CARB's regulatory efforts that ensure these technologies are deployed in strategic and impactful ways that support the State's climate and low-carbon transportation goals.

CARB's incentive programs work hand-in-hand with its regulatory programs to accelerate the transformation of the HD market for ZEVs. The role of incentives is largely to support early commercialization and market development in advance of regulatory requirements. Incentives help to drive early adopter purchase decisions by reducing incremental costs and supporting vehicle cost reductions over time by building manufacturer economies of scale. Incentives for vehicles and infrastructure are critical, particularly in the early market development years and to help smaller fleets and owner-operators. As regulatory requirements approach, CARB's incentive strategy shifts toward a focus on providing financial assistance for smaller fleets that face challenges in qualifying for traditional financing programs and are not required by existing regulations to switch to ZEVs. In some incentive programs, limited incentives remain available once regulations are in effect for generating emission reductions beyond what is required by the regulations.

Figure D-1below shows how CARB's incentive programs work together. There is a natural progression of support for technologies starting in the pre-commercial demonstration phase all the way through to financing assistance for small businesses who are often unable to qualify for conventional financing. It should be expected that technologies will gradually transition to the next program in the funding succession, and eventually away from incentives completely, as they become more established in the market. This does not mean that CARB does not continue to support or invest in these technologies, but rather that the technology has matured to a high-enough level of commercialization and acceptance in the market to warrant transitioning away from technology advancement incentives.

Figure D-1: Funding Succession



Low Carbon Transportation projects focus on rapidly advancing technology to meet California's long-term climate, air quality, community protection, petroleum reduction, and ZEV deployment goals. These projects fund advanced technologies in their early stages, starting with demonstration and pilot projects and continuing through the early stages of commercialization. These projects focus on deployment of early commercial technologies and generally do not require scrappage.

As a technology reaches market scale, other programs within CARB's portfolio such as the Carl Moyer Memorial Air Quality Standards Attainment Program (Moyer), the Volkswagen (VW) Mitigation Trust, Community Air Protection Program (CAPP), and Funding Agricultural Replacement Measure for Emission Reductions (FARMER) are more appropriate funding sources. These programs focus on achieving cost-effective reductions, especially in disadvantaged communities (DACs). They tend to focus on turning over the existing fleet at an accelerated pace and often require additional measures such as scrappage. Scrappage programs provide additional emission benefits because an older, polluting vehicle must be taken off the road as a condition for funding a clean replacement.

CARB will continue to coordinate its overall investment strategy across the broader portfolio of incentive programs, both within the agency and with other local, state, and federal partners. State and air district programs complement CARB's work with vehicles and other project elements. As a key example, infrastructure investments by CEC, transportation agencies, and utilities are critical to support ZE trucks, buses, and off-road equipment. The Inflation Reduction Act of 2022 provides federal funding that complements CARB and other State agency programs. The federal Infrastructure Investment and Jobs Act also provides funding, particularly for transportation infrastructure projects.

With multiple goals guiding State action on clean HD vehicles and off-road equipment, maintaining multiple programs with different but complementary objectives is necessary. CARB's portfolio of programs is designed for achieving widespread transformation that emphasizes community protection, with investments focused in disadvantaged and low-income communities.

Low Carbon Transportation and Air Quality Improvement Program Specific Investment Strategy

With each annual update of this Strategy, CARB refines the strategy outlined for accelerating the development and market introduction of technologies needed to achieve the State's climate and air quality goals. The State's ongoing investment of Low Carbon Transportation and AQIP funds continue to make this possible, and this Strategy serves as a roadmap, detailing how to accelerate targeted technology advancement through:

- Continuing to invest Low Carbon Transportation and AQIP dollars across the commercialization pathway for various technologies, building on previous investment (which includes supporting technologies through the demonstration, pilot, and commercial phases);
- Focusing investments on the ZE technology pathways needed to meet the State's ZEV adoption and climate and criteria pollutant emission goals; and
- Focusing investments on the expansion of "beachhead" markets—early successful vehicle and equipment applications where technologies can best establish initial market acceptance and then seed additional follow-on market applications (discussed further on page D-25).

This approach has demonstrated success to date: in the seven years since the first Strategy was published, advanced technology growth in the HD industry has accelerated, including continued demand for Hybrid and Zero-Emission Voucher Incentive Project (HVIP) voucher and measurable improvements in the capability of technology displayed in demonstration and pilot projects. The numbers of available platforms and participating manufacturers in the Clean Off-Road Equipment (CORE) Voucher Incentive Project and HVIP are increasing, including global original equipment manufacturers (OEMs) and innovative new manufacturers.

State Air Quality Goals and the Role of Incentives

There are a range of statutory drivers and executive orders that help to guide this Strategy and support the State's goals. These are summarized in Table D-2 below.

Table D-2: California Climate Goals: Statutory Drivers and Executive Orders

Policy Title	Year	Summary
Federal Air Quality Act of 1967	1967	Allows California the ability to set its own more stringent air quality standards.
Assembly Bill 32	2006	Reduce GHG emissions to 1990 levels by 2020 (N??ez, Chapter 488, Statutes of 2006).
Executive Order B-16-2012	2012	Reduce petroleum use in vehicles by 50% by 2030 and reduce GHG emissions from the transportation sector to 80% below 1990 levels by 2050.
Senate Bill 1204	2014	Help accelerate the introduction of the next generation of cleaner HD vehicles and engines with creation of the California Clean Truck, Bus, and Off-Road Vehicle and Equipment Technology Program; prioritize projects that benefit DACs; direct CARB to develop an annual framework and plan to guide these investments (Lara, Chapter 524, Statutes of 2014).
Senate Bill 350	2015	Improve access to clean transportation options (such as cleaner transit bus fleets, passenger trains, and ferries) for low-income residents, including those in DACs (De León, Chapter 547, Statutes of 2015).
Senate Bill 32	2016	Reduce GHG emissions to 40% below 1990 levels by 2030 (Pavley, Chapter 249, Statutes of 2016).

Policy Title	Year	Summary
Assembly Bill 1550	2016	Establish DAC, low-income community, and low-income household targets for the State's Cap-and-Trade auction proceeds investments (Gomez, Chapter 369, Statutes of 2016).
Senate Bill 1403	2018	Must develop the Strategy and Three-Year Recommendations for Low Carbon Transportation and AQIP (Lara, Chapter 370, Statutes of 2018).
Executive Order B-48-18	2018	Deploy 1.5 million ZEVs by 2025 and at least 5 million ZEVs by 2030.
Executive Order B-55-18	2018	Achieve carbon neutrality as soon as possible, and no later than 2045; achieve and maintain net negative emissions thereafter.
Executive Order N-79-20	2020	All new cars and passenger trucks sold in California must be ZEVs by 2035, all drayage trucks to transition to ZE by 2035, all off-road equipment to ZE where feasible by 2035, and the remainder of MHD vehicles to ZE where feasible by 2045.
Senate Bill 44	2021	Allows California to identify MHD vehicle segments that can more quickly reduce motor vehicle emissions, consistent with the Strategy.

Policy Title	Year	Summary
Senate Bill 372	2021	Establishes the Medium- and Heavy-Duty Zero-Emission Vehicle Fleet Purchasing Assistance Program within AQIP to make financing tools and nonfinancial supports available to operators of MHD vehicle fleets to enable those operators to transition their fleets to ZEVs.

Incentives support early adopters to lead commercialization efforts and prove new technologies, but they are also important to expand access to clean vehicles and equipment. CARB is identifying new incentive designs and implementing policy changes that will equitably expand access to fleet operators beyond early adopters as market commercialization of clean technologies continues.

CARB Guiding Documents

In addition to the legislation noted above, there are several other documents that help to guide CARB investments. These include the California State Implementation Plans (SIPs), the 2017 Climate Change Scoping Plan, the 2016 ZEV Action Plan, the ZEV Market Development Strategy, the Cap-and-Trade Auction Proceeds Investment Plan, the California Sustainable Communities and Climate Protection Act 2018 Progress Report, and the SB 350 Low Income Barriers Study, Part B: Overcoming Barriers to Clean Transportation Access to Low Income Residents. Two additional drivers that provide a key focus with specific strategies relevant to the HD vehicle and off-road sectors are the Mobile Source Strategy and the California Sustainable Freight Action Plan.

- **The Mobile Source Strategy** is the State's integrated plan that identified the level of transition to cleaner mobile source technologies needed to achieve California's many air quality, climate, and community risk reduction goals. It is a top-down strategy and generally indicative; CARB regularly refines its approach in specific programs and rulemakings. The 2020 Mobile Source Strategy noted that MHD vehicles with a gross vehicle weight rating (GVWR) of more than 8,500 pounds[3] are responsible for approximately 40% of statewide mobile source nitrogen oxide (NOx) emissions and 21% of statewide mobile source GHG emissions. The 2020 Mobile Source Strategy takes an integrated planning approach to identifying the level of transition to cleaner

[3] For the purposes of this document, the Strategy refers throughout to HD vehicles. However, that designation is meant in the broader sense of commercial vehicle ranges and applications. CARB incentives for commercial vehicles can be used from weight classes starting above 8,500 pounds GVWR.

mobile source technologies needed to achieve California's many targets through 2050.[4] Early investments that accelerate deployment of ZE, hybrid, and the cleanest combustion technologies in the HD and off-road sectors are essential and have already started to play a vital role in transitioning HD vehicles and off-road equipment to cleaner technologies. Vehicles and equipment that are replaced via CARB's scrap-and-replace programs can have a significant impact on each district's individual SIP commitment. Additionally, the State Strategy for the State Implementation Plan, or State SIP Strategy, includes federally enforceable commitments to achieve reductions in NOx, reactive organic gases, and PM2.5 emissions using measures conceptualized in the Mobile Source Strategy.

- **The California Sustainable Freight Action Plan** is designed to integrate investments, policies, and programs across several State agencies to help realize a singular vision for California's freight transport system. To meet the State's 80% GHG emission reduction target by 2050, freight will need to be moved more efficiently, with ZE technologies wherever possible and hybrid or the cleanest combustion technologies, paired with renewable fuel use, everywhere else.[5] The solution will require technology innovation, including development and deployment of ZE, hybrid, and the cleanest combustion trucks, locomotives, cargo handling equipment (CHE), transport refrigeration units (TRUs), and ships. It will also require lower-emission aircraft, parallel development of the necessary supporting fueling infrastructure, and logistical/operational efficiency improvements.

CARB's Mobile Source Strategy and the California Sustainable Freight Strategy rely on a combination of proposed regulations, investments, and incentives that will help move California toward its goal of transitioning 100% of the MHD vehicles to ZE by 2045 everywhere feasible. Together, these strategies are designed to bring about progressively cleaner in-use vehicle and equipment emission levels.

While incentives are designed to help accelerate technology advancement and market penetration, they also function to reward early adopters of these technologies. As the cleaner technologies become commercially available at larger scales, costs will fall, and market adoption will increase.

Supporting Commercialization of Advanced Technologies

There is broad support for HD vehicle and off-road equipment technology advancement at the demonstration, pilot, and commercial deployment stages, spanning all technology

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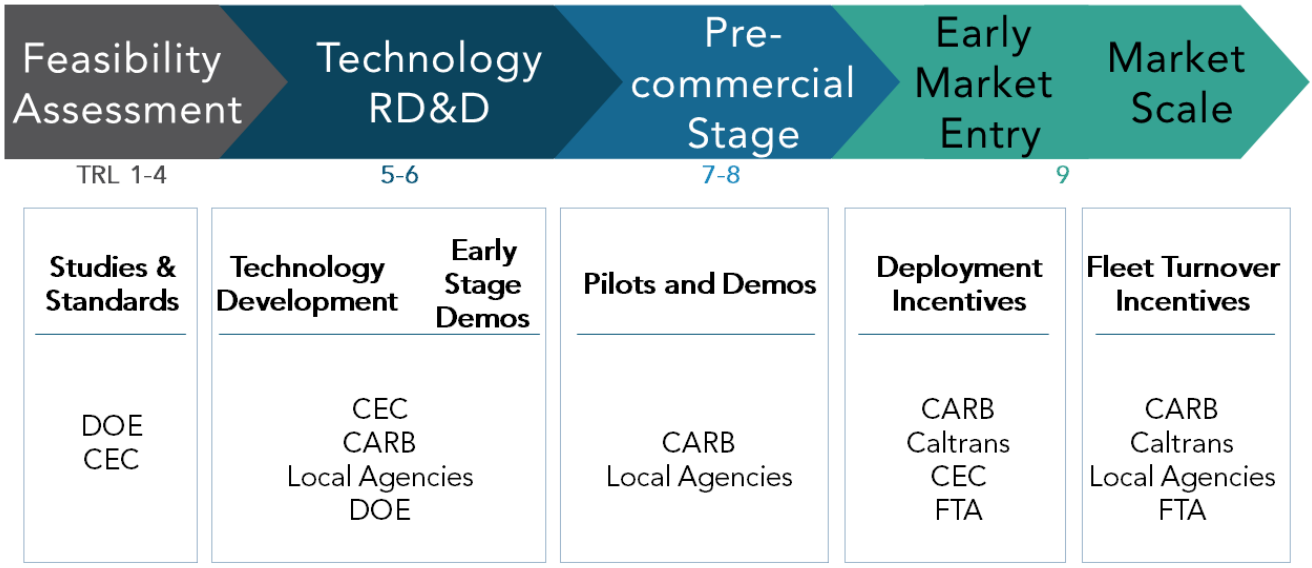
[4] CARB. *2020 Mobile Source Strategy*. *https://ww2.arb.ca.gov/resources/documents/2020-mobile-source-strategy*

[5] *California Sustainable Freight Action Plan*. July 2016. *https://ww2.arb.ca.gov/sites/default/files/2019-10/CSFAP_FINAL_07272016.pdf*

readiness levels (TRLs), at the federal, state, and local levels.[6] (See page D-34 for an explanation of technology readiness and why CARB tracks TRL progress.) Figure D-2 depicts the commercialization path for these technologies along with the public entities that fund key incentives across this path.

Figure D-2: Commercialization Path: Stages and Sources of Public Investment



As Figure D-2 shows, California invests public funds across the entire technology commercialization path, in partnership with many local and federal agencies. This is an important approach because it provides the opportunity to invest not only in the commercial technologies but also ensures the ongoing development, demonstration, and piloting of technologies needed to meet the many State goals and federal mandates.

CARB's portfolio of investment programs focuses on funding beginning with the demonstration phase and following through the subsequent programmatic categories shown above. Relative to this structure, it is important to understand how CARB defines demonstration, pilot, and commercial phases.

In the demonstration phase, manufacturers are typically focused on producing single vehicle and equipment prototypes or small volume demonstration and testing projects. These investments are crucial because they can accelerate the pace of commercializing advanced technology vehicles and equipment by spurring private investment and demonstrating that the technology can meet specific user needs. Demonstration projects

[6] NASA. *Technology Readiness Level*. October 28, 2012. *https://www.nasa.gov/directorates/heo/scan/engineering/technology/txt_accordion1.html*

feed the innovation pipeline and are necessary to ensure the availability of technologies needed to meet the State's goals.

In the pilot phase, projects are typically focused on larger scale deployments where issues around manufacturing design, user acceptance, and support can be assessed. During this phase, per-vehicle incentives remain relatively high because engineering designs are still evolving and manufacturing techniques are not at full volume or capacity, instead focusing on smaller batches of vehicles. Higher levels of incentives per vehicle are needed to help entrepreneurs and early manufacturers cover the costs of this low-volume technology development. Pilots are also critical in solving other challenges, such as infrastructure limitations, user acceptance, and development of a business case.

In the commercialization phase, incentives are provided to encourage user adoption of advanced technologies that may be available at a higher price. The commercialization phase can be broadly separated into lower-volume and higher-volume production phases. In the lower-volume commercialization phase, sales volumes generally start out low but grow over time as user acceptance increases and manufacturing costs decrease with engineering improvement, supply chain competition, and economies of scale. Incentive projects that focus on early commercial deployment tend to support fleet expansion within fleets that are interested in "testing the waters" of technology that is new to their fleet. In higher-volume production, incentives can help support the transition of the technology to wide-scale adoption. Unlike demonstration projects, pilot and commercial incentives are available for vehicles that have obtained a CARB Executive Order or are certified for sale in California.

The continued deployment of incentives assists in speeding up the movement of the market toward financial stability. For the HD on-road and off-road sectors, the deployment of incentives will need to keep increasing over the next three years, and possibly well into the future for some applications, to ensure that market successes are solidified and continue to make progress toward reaching State goals.

Programmatic Metrics for Low Carbon Transportation

In addition to identifying priority focus areas and recommending levels of incentive funding, this document also includes metrics to help assess the performance of Low Carbon Transportation projects in meeting the requirements of SB 1403. These include targeted metrics that address technology advancement, increases in suppliers and supply chain diversity, potential to impact key market segments, and reductions in system costs. CARB has identified three broad categories that define success for these programs with some overlap between the three: (1) Supporting Healthy Communities, (2) Growing the Green Economy, and (3) Supporting Technology Evolution.

For this year's strategy, CARB has continued to work with stakeholders for input on metrics, including holding two public work group meetings and evaluating the available data needed to quantify suggested metrics. For the first time, CARB has surveyed vehicle and equipment manufacturers about their product lines and production volumes, with a focus on HVIP- and CORE-eligible technologies. All program metrics are updated with data through June 2023. As additional project data becomes available from CARB's demonstration and pilot projects, the metrics will be further refined and expanded in future years.

Metrics are summarized into three categories: Supporting Healthy Communities, Growing the Green Economy, and Supporting Technology Evolution. CARB will continue to work with stakeholders to develop, quantify, and implement metrics to communicate the full range of benefits accruing from Low Carbon Transportation Investments.

399
MILLION

MILES TRAVELED

There were 399,110,203 cleaner-than-diesel miles traveled in California by HVIP-funded vehicles between 2010 and 2023.

895+
THOUSAND

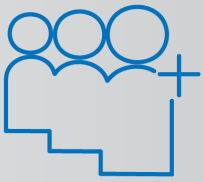
EQUIPMENT RUNTIME

CORE-funded zero-emission off-road equipment has been used for 895,954 hours in California between 2020 and 2023.

26+
THOUSAND

JOBS CREATED

The incentive dollars spent through HVIP and CORE have created over 7,000 jobs and spurred over 19,000 jobs from private investment, totaling over 26,000 jobs.



Supporting Healthy Communities

An essential part of CARB's mission is to protect the health of Californians from the harmful effects of air pollution—particularly for priority populations that are disproportionately impacted. Projects should aim to reduce the health impacts of transportation and improve the air quality of communities.

Current Metrics

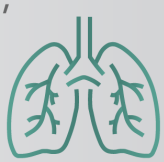
Vehicle and equipment telematics show where emission reductions are occurring, including percentage of operation in DACs. Telematics also provide data on vehicle mileage and equipment runtime. Equity is a very important factor CARB considers when creating incentive programs, and being able to track voucher amounts to small and public fleets is an additional way to show support for small businesses. To date, 58% of vouchers have been used on vehicles or equipment deployed in DACs, totaling 198 million miles traveled.

In future years, CARB will consider comparing clean vehicle miles traveled to total miles traveled by all HD vehicles in California. This will help illustrate the scale of clean vehicle adoption in proportion to the total vehicle population. CARB will also consider breaking down the vehicle miles traveled and equipment runtime metrics further to show both by vehicle/equipment category, GVWR, and more.

58
PERCENT

DAC VOUCHERS

Fifty-eight percent of vouchers (HVIP and CORE combined) have funded vehicles and equipment deployed in DACs, as identified in CalEnviroScreen.



198
MILLION

DAC MILES TRAVELED

HVIP-funded vehicles have traveled approximately 198 million miles in DACs, as identified in CalEnviroScreen.

43
PERCENT

SMALL AND PUBLIC FLEET SUPPORT

Forty-three percent of 2021-2023 HVIP vouchers were given to public or small fleets (private entities with <$10 million annual revenue or fewer than 50 employees).

Industry Example

Increased Support for Small Fleets

As discussed in last year's Strategy, small fleets face unique challenges to deploy ZEVs. CARB has worked to address some of these challenges through the Innovative Small E-Fleets (ISEF) Pilot, which provides funding for emerging ZEV business models that provide operational and financial flexibility to small fleets looking to incorporate ZEVs into their business. Funded by HVIP, ISEF's increased incentives and options like rentals, short-term leases, and Truck-as-a-Service provide opportunities for small fleets to try ZEVs with more flexibility and lower cost compared to traditional ZEV purchases.

ISEF has proven to be very popular, with its initial $25 million quickly oversubscribed in less than three weeks in 2022. In 2023, CARB expanded ISEF, offering $83 million in assistance for small fleets transitioning to ZEVs. The program provides an opportunity to expand ZEV access within the small fleet business community, while exploring innovative mechanisms for small business support with State resources.

ISEF helps address some of the unique financial challenges that small fleets face, but non-financial assistance is also critical to the successful deployment of ZEVs. Fleets have expressed a need for education, understanding of ZEV operations, and assistance with navigating the incentive landscape. To address those needs, CARB launched Cal Fleet Advisor, a free technical assistance service for California fleets, funded by HVIP.

Cal Fleet Advisor provides concierge-style technical assistance tailored to a specific fleet's needs. Advisors can help with education on vehicles, fueling, and regulations; provide technical assistance with total cost of ownership (TCO), duty-cycle analysis, and fueling strategies; and provide referrals to utilities, dealers, OEMs, and incentive programs in order to ensure a fleet's success in their ZEV transition. Officially launched in late June at the CARB ride and drive event in Fresno, Cal Fleet Advisor has assisted over 100 fleets in its first two months, and there are plans to expand capacity to assist thousands in the coming fiscal year.

Growing the Green Economy

CARB's investments are intended to create downstream economic benefits where possible. The presence of consistent funding for clean technology projects helps to attract clean tech manufacturing to California, bringing high-quality jobs and fostering the development of a valuable industry.

Current Metrics

Model availability is expanding rapidly and becoming even more widespread across manufacturers and applications ready to meet fleet demand, as evidenced by the growing number of HVIP- and CORE-eligible models from a growing number of manufacturers. There has been an increase of 21 eligible manufacturers and 188 vehicle or equipment models over the past year.

Leveraging incentive dollars with private investment and complementary public spending supports the commercial viability of advanced technology by tracking the total purchase price and co-funding on HVIP- and CORE-funded vehicles and equipment. To date, for every $1 of voucher investment, there is over $3 of public and private spending toward these purchases.

CARB has qualitative information on the expanding supply chains for advanced technology components. CARB also monitors the number of manufacturers choosing California as a home for manufacturing. Of the 88 current HVIP- and CORE-eligible manufacturers surveyed,[7] 15 have California manufacturing locations and 26 have other California-based administrative, research, or operational locations. Altogether, they total 52 current facilities with 2,186 current jobs dedicated to HD ZE vehicles or equipment.

[7] Surveys were sent out to all HVIP and CORE OEMs, and numbers reflect only those who chose to respond.

$1.2+ BILLION

VEHICLE PURCHASE

HVIP and CORE have funded $1.2 billion toward the purchase of 13,154 clean vehicles and equipment since 2010.

509 MODELS

MANUFACTURERS

There are 88 HVIP- and/or CORE-eligible manufacturers offering 509 vehicle or equipment models.

$3.4 BILLION

TOTAL INVESTMENT

Additional public and private spending toward these purchases totaled $3.4 billion--over $3 for every $1 of voucher investment. Leveraged private spending represents purchases redirected from traditional technologies to clean technologies.

New Metrics

There are many ways to promote growing the green economy in California, and looking at the number of vouchers given to OEMs with in-state manufacturing provides another tool to measure the many ways in which California's investments and initiatives are contributing to economic growth. Since the start of both HVIP and CORE programs, approximately 19% (by dollar value) of all funding has gone to OEMs with California manufacturing facilities. This continues to be an avenue to create high-quality jobs to support the growing industry in California.

Supporting Technology Evolution

Currently available technologies will not be sufficient to meet CARB's long-term air quality and climate change goals. Therefore, investments are needed to spur the development, improvement, and commercialization of additional advanced technologies in more market sectors. CARB tracks technology evolution primarily through the tech readiness snapshots completed as part of the annual updates to this Strategy (see page D-34). Technology evolution continues to be a primary goal for Low Carbon Transportation Investments, as well as a number of CARB's other incentive programs.

In the future, this section of the Strategy could be further expanded to describe metrics that are applicable to a wider array of programs. This will continue to be important as CARB implements the concept of technology transition which will be directly related to the pathway and progress of technology evolution. Defining and quantifying metrics that signal when technologies transition, move on to other incentive programs, or can stand on their own will require an empirical approach for monitoring technology evolution. Further information on technology transition can be found on page D-12.

Current Metrics

CARB tracks expansion of technologies available in its incentive programs. In the past year, one new category of ZEV became HVIP-eligible for the first time: Class 8 hydrogen fuel cell trucks.

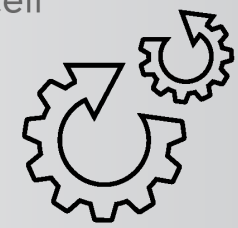
Survey data is valuable for understanding fleet attitudes and perceptions of new vehicle technology and providing valuable feedback from early adopters. One of the best indicators of satisfaction is when a fleet that participated in a demonstration or pilot project or received a voucher continues to express interest in or procure additional advanced technology vehicles. Surveys this year found that 78% of HVIP survey respondents indicated that they plan to purchase additional HD ZEVs within the next five years.

In the future, CARB will consider expanding how technology evolution is tracked. Options could include tracking the number of new HD ZE technology start-ups or activities from innovation hubs and incubators. CARB could also look at the current technologies that are available and track changes year-to-year on attributes such as range, battery capacity, and payload capacity.

1
TYPE

NEW TECHNOLOGY

One new zero-emission vehicle category (new fuel cell trucks) was eligible for vouchers for the first time this past year. New (non-conversion) fuel cell trucks now eligible for HVIP include: Hyundai XCIENT, Hyzon Motors HyHD8, and Nikola TRE FCEV.



78
PERCENT

FUTURE ZEV PURCHASES

Seventy-eight percent of HVIP voucher recipients surveyed plan to purchase additional medium- and heavy-duty zero-emission vehicles within the next five years.

While current criteria for monitoring success across the three metric categories provide some feedback on the effectiveness of CARB investments, there are additional benefits that are not yet reflected. CARB will continue to work with stakeholders to solicit, develop, refine, and implement additional metrics that better communicate the full range of benefits accruing from Low Carbon Transportation Investments, considering the program's unique position in CARB's investment portfolio.

Beachhead Strategy

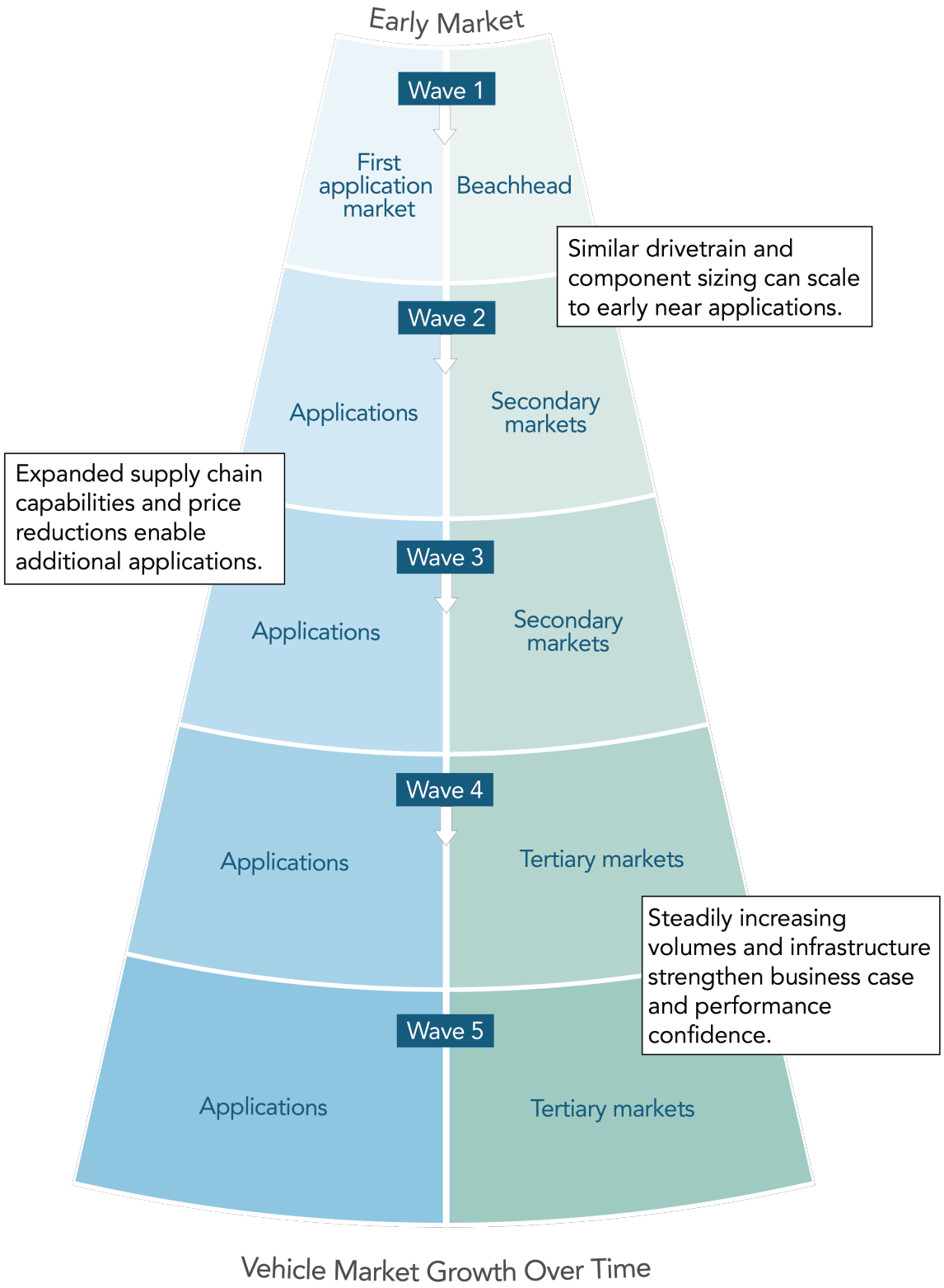
In 2017, CARB developed a visual representation of its focused strategy for technology commercialization based on targeting its investments on strategic "beachheads," or first-success applications, and on the pathways for additional markets or work applications that extend from them.[8] These beachheads are built around applications that can best make early use of one of the pathway technologies based on duty cycle, business case, industrial capacity, and performance. From these initial first-success applications, next-generation vehicle applications can expand by extending the technologies to adjacent markets through the leverage and adoption of similar powertrains, growth of supply chain volumes for common components, expansion of fueling infrastructure, and confidence in performance and business cases.

Beachheads are built around initial first-success applications that can best make early use of one of the pathway technologies based on duty cycle, business case, industrial capacity, and performance. Next-generation vehicle applications can then expand by leveraging similar powertrains, growth of supply chain volumes for common components, and expansion of fueling infrastructure.

With market growth, eventual price reductions based on volume production can expand the technology to additional larger but more price sensitive markets and also make use of opportunities to scale the technology to larger or smaller application sizes. Figure D-3 below depicts the generic beachhead process, highlighting initial applications and suggesting the places where there is likely to be a transfer and extension of the technology to additional vehicle applications and subsequent markets. As the supply chain expands for core components and costs improve, multiple applications of increasingly larger market volumes can be supported, driving steadily larger market penetration.

[8] The term "beachhead" derives originally from military usage and is often connected to the successful Allied amphibious vehicle landings in Normandy during World War II, which started with holding a small strip of beach and expanded to a continent. The commercial definition of beachhead is "a secure initial position that has been gained and can be used for further advancement; foothold." Random House Unabridged Dictionary. Random House, Inc. 2018.

Figure D-3: The Beachhead Strategy



The beachhead concept has helped CARB target and focus Low Carbon Transportation and AQIP investments around applications that have strong potential to transfer and spread to broader applications. An additional consideration is the ability of the beachhead and its follow-on applications to build the expansion of a common supply chain that can provide similar components for powertrains and systems that can reduce costs over time. This in turn helps to build greater production volumes, leading to continued affordability.

This strategy is also being reviewed and adopted by other regions of the world as a useful framework for accelerating technology transformation in HD vehicles. As additional geographic regions adopt similar technologies on a common timeline, it helps to grow a global supply chain and spurs investments. Evidence of this is being seen in the ZE bus application in the United States, Europe, Asia, and South America. The Global Commercial Vehicle Drive to Zero ("Drive to Zero") campaign uses the beachhead model as a foundational principle to drive strategic commercial ZEV proliferation and expansion. Drive to Zero, and by association the beachhead model, has been adopted by the Clean Energy Ministerial's Electric Vehicle Initiative and has been formally signed by 27 nations, including Aruba, Austria, Belgium, Canada, Chile, Croatia, Cura?ao, Denmark, Dominican Republic, Finland, Ireland, Liechtenstein, Lithuania, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Scotland, Saint Maarten, Switzerland, Turkey, Ukraine, the United Kingdom, the United States, Uruguay, and Wales.

The beachhead strategy defines CARB's approach to drive faster technology commercialization through Clean Transportation investments. The beachhead strategy is about focusing resources on a key area or areas—usually a smaller market segment or product to start—and successfully deploying in that market first, or even dominating that market, to help it move into larger markets or other applications.[9]

Given a dynamic market, timing and stages can change and evolve differently. Therefore, the sequences outlined are not intended to be absolute or guaranteed but do provide a guide and focus for investments. They represent a technical assessment of the reasonable potential to progressively scale and transfer components and capabilities to additional applications and platforms. This assessment comes from interviews with manufacturers and suppliers, assessment of component use and commonality across geographical regions and applications, and evaluations of the transferability potential of these components. Technology transfer is considered both from a historical and technological perspective, accounting for how lighter segments and return-to-base operations have supported early deployments, recognizing transfers and tech adoptions in secondary waves, and predicting how manufacturers and fleets will logically incorporate transferable technologies into new applications.

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[9] Berry, Tim. *Don't Underestimate Beachhead Strategy.* Bplans. *http://timberry.bplans.com/the-power-of-beachhead-strategy/*

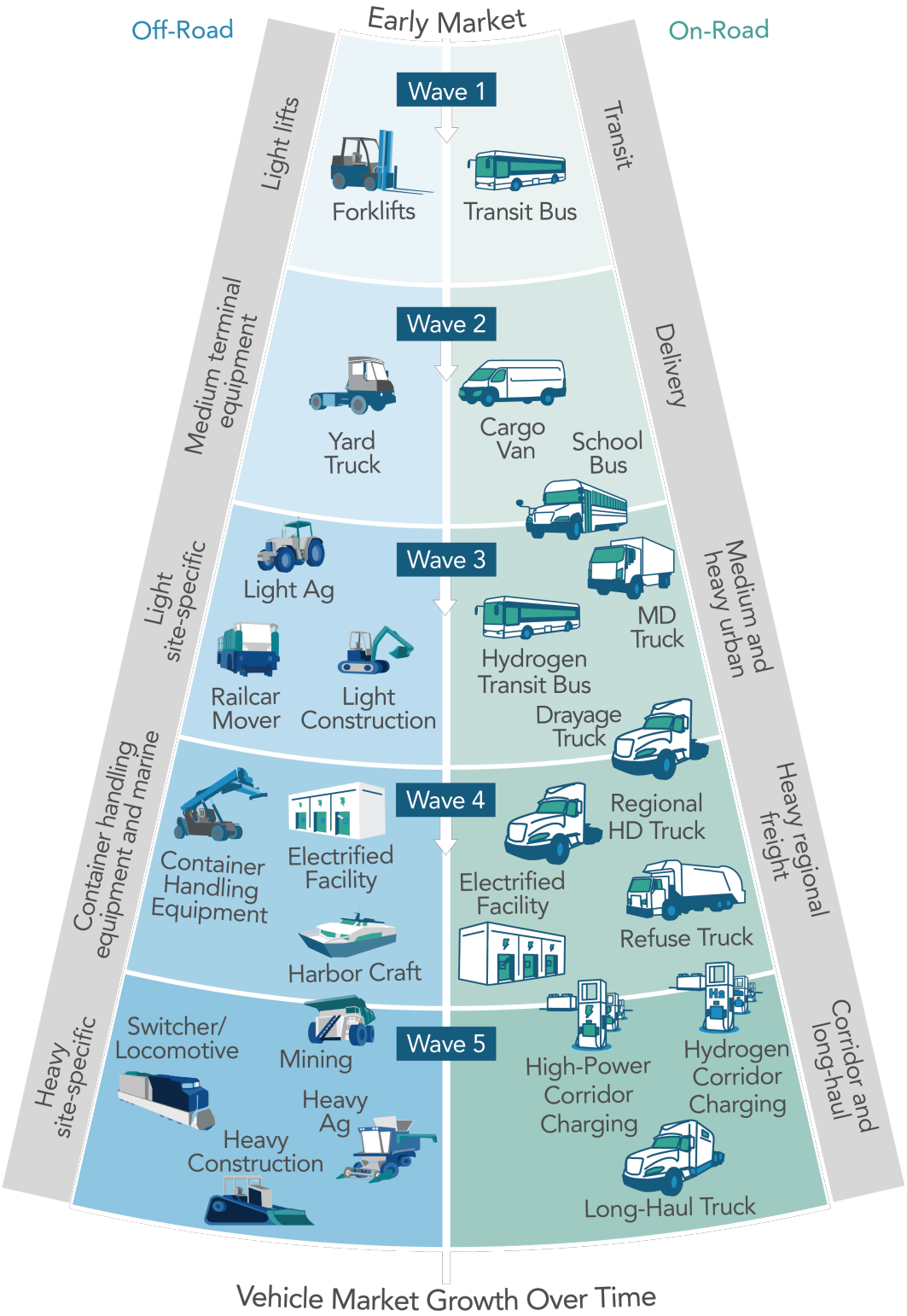
In recognition of the dynamic nature of markets and technology, they remain "works in progress" and are updated and modified as needed to adapt to changing conditions. CARB staff, via workgroup and other industry and stakeholder interactions, initially solicited comments and feedback on these beachheads in 2019 to identify areas where there may be additional leverage to support expanded deployment or areas of technology success. Additionally, the beachhead model shows points of connections between on- and off-road segments, identifying where technology transfer might assist faster off-road technology adoption.

Zero-Emission Beachhead

The most powerful beachhead process to date has been built around the ZE pathway, as illustrated in Figure D-4.[10] It is centered on the first-success application of the battery electric transit bus and how that core market, while relatively small in initial volume, forms the basis for a successful first marketplace and a steppingstone for additional uses of the core component technologies and architectures. A fuel cell electric bus utilizes many of the same powertrain components as a battery electric bus (BEB), which itself was built on the early success of hybrid architectures in the transit bus market. Over time, transit buses began to expand the use of some of these core electric drive components into other bus applications and to expand to truck and van applications. As the technology matures and business cases improve, opening opportunities for manufacturers to meet growing demand, core electric drive components will continue to expand from smaller or reliably return-to-base applications to more diverse, rigorous duty cycles.

[10] Unless designated as hydrogen-powered, all vehicles and equipment highlighted in the ZE beachhead graphic are battery electric.

Figure D-4: The Zero-Emission Beachhead



The development of these core components has had even broader applicability faster than initially expected, and have now served as the launch point for the development and deployment of several other secondary market applications, including:

- Battery electric shuttle and school buses;
- Battery electric delivery vehicles;
- Battery electric terminal tractors;
- Battery electric off-road work trucks designed for site-specific functions (in agricultural, construction, rail, and mining operations);
- Battery electric refuse trucks;
- Battery electric, fuel cell electric, and plug-in hybrid (sometimes operating as range extender systems) drayage trucks; and
- Battery electric, fuel cell electric, and plug-in hybrid (and range extender) regional heavy-haul trucks.

This expansion to other applications is due to:

- Common powertrains and components (motors, power electronics, energy storage) that can be transferred to other applications with similar power and torque needs, or scaled up or down to suit other applications;
- Supply chain expansion partially assisted by hybrid, start-stop, and idle reduction technologies;
- Steadily increasing vehicle volumes and availability of infrastructure, knowledge of the business case, and consumer confidence in performance; and
- Expanded capabilities, including price reductions in energy storage/components enabling HD applications (with some of this energy storage transferring directly from light-duty passenger car production).

Extended range applications are also being developed that use an engine or fuel cell electric generator to augment the range and performance of battery electric HD vehicles. However, the steady and steep improvement in battery energy density and, in prior years, steady reductions in battery price have continued to push the limits of where such systems are needed. From early battery-only ranges of 80–100 miles on a single charge, major manufacturers are now regularly signaling 200 miles, with several manufacturers indicating ranges exceeding 300 miles and a few models anticipated to exceed 600 miles on a single charge.[11] Similarly, fuel cell electric powertrains are beginning their market entry for heavy weight, duration, and longer distance applications, with early commercial deployments operating successfully in on- and off-road applications. While the source of electrical power comes from different sources (batteries, fuel cells, or engine generators), it is important to note that ZEV core components and systems are similar.

[11] CALSTART. *ZETI Analytics. https://globaldrivetozero.org/tools/zeti-analytics/*

Industry Example

Drayage Goes Zero-Emission

CARB has supported the evolution of ZE drayage trucks from their earliest stages, with the first zero-emission projects at California ports launching in 2016. Thanks to this early support, the more recent Project 800 (CARB's initiative to deploy 800 ZE drayage trucks at California's ports), and HVIP funding dedicated to transitioning this industry segment, there have been over 920 ZE drayage trucks sold in California.

In addition to NFI and Schneider's electric drayage trucks discussed on page D-38, many other fleets have transitioned their combustion drayage trucks to ZE options. For example, in 2023, the women-owned Avant Garde Auto Logistics (Agal) deployed four battery electric Class 8 day-cab tractors from Nikola and Kenworth at the Port of Los Angeles (POLA). Agal uses the electric drayage trucks to pick up shipments of imported Nissan vehicles, included the Ariya EV, for onward delivery to dealers in California.

Also in 2023, Hyundai deployed 10 HD hydrogen-powered XCient Fuel Cell trucks at the Port of Oakland as a part of a deployment plan of 30 vehicles.

These ZE drayage truck deployments are supported by a growing number of charging and hydrogen refueling stations at and near ports. In late 2022, the Port of Long Beach opened charging stations at its Clean Truck Program Terminal Access Center, serving the San Pedro Bay Complex. A few months later, TruckNet opened four public chargers at its Otay Mesa location near the Port of San Diego and adjacent to the U.S.-Mexico border. In July 2023, WattEV opened its first public truck charging depot at the Port of Long Beach. The company was also awarded over $40 million to develop additional electric truck charging depots along Interstate 5.

Industry Example

Drayage Goes Zero-Emission

The following month, the Los Angeles Cleantech Incubator (LACI) was awarded grant funding to help install public charging infrastructure for electric drayage trucks at POLA—the first on the Port's property. The new chargers will be capable of providing electric drayage trucks with a full charge in half an hour.

In July 2023, Nikola was awarded over $58 million to develop seven open-network hydrogen refueling stations along California's freight corridors. These public charging and refueling stations can not only supplement "behind-the-fence" depot charging, allowing fleets to extend the range of their vehicles with en-route refueling, but also offer a solution for fleets who do not have or own depots to take advantage of the benefits of ZE technology.

Diesel drayage trucks are a major source of air pollution in the frontline communities adjacent to California's ports and freeways, which is why the State's Advanced Clean Fleets (ACF) regulation stipulates that beginning January 1, 2024, only ZE drayage trucks may register in the CARB Online System. Internal combustion engine (ICE) "legacy" drayage trucks registered with CARB before 2024 may continue to operate through their useful life, but per ACF, all trucks performing drayage operations will be required to be ZE by 2035.[12] ZE drayage trucks are currently eligible for "Early Adopter" 25% voucher enhancements through HVIP, offering up to $150,000 toward the purchase of a battery electric truck and up to $240,000 toward the purchase of fuel cell truck.

Off-road ZE technologies are capitalizing on the growth of drivetrain technologies, extending their operational hours and range. ZE technologies, including battery electric and fuel cell electric systems, have already made significant progress in the industrial lift market. The experience gained from implementing fuel cell electric systems in industrial lifts has proven valuable, as it now contributes to extending the range and operational capabilities of HD vehicles and off-road equipment. These systems are currently undergoing the demonstration phase to showcase their potential.[13] The knowledge base and core technology enables, if not in all cases directly leads to, additional applications, such as:

- Battery electric and fuel cell electric ground support equipment (GSE);
- Battery electric and fuel cell electric site-specific agricultural, rail, and construction applications;

[12] For a *Summary of the Advanced Clean Fleets Regulation*, please visit *https://ww2.arb.ca.gov/resources/fact-sheets/advanced-clean-fleets-regulation-summary*.

[13] For additional information on *ZE off-road technologies and market progress*, see *https://calstart.org/off-road-assessment/*.

- Battery electric, fuel cell electric, and extended operations electric CHE;
- Battery electric, fuel cell electric, and extended operations marine harbor applications; and
- Battery electric and fuel cell electric TRUs.

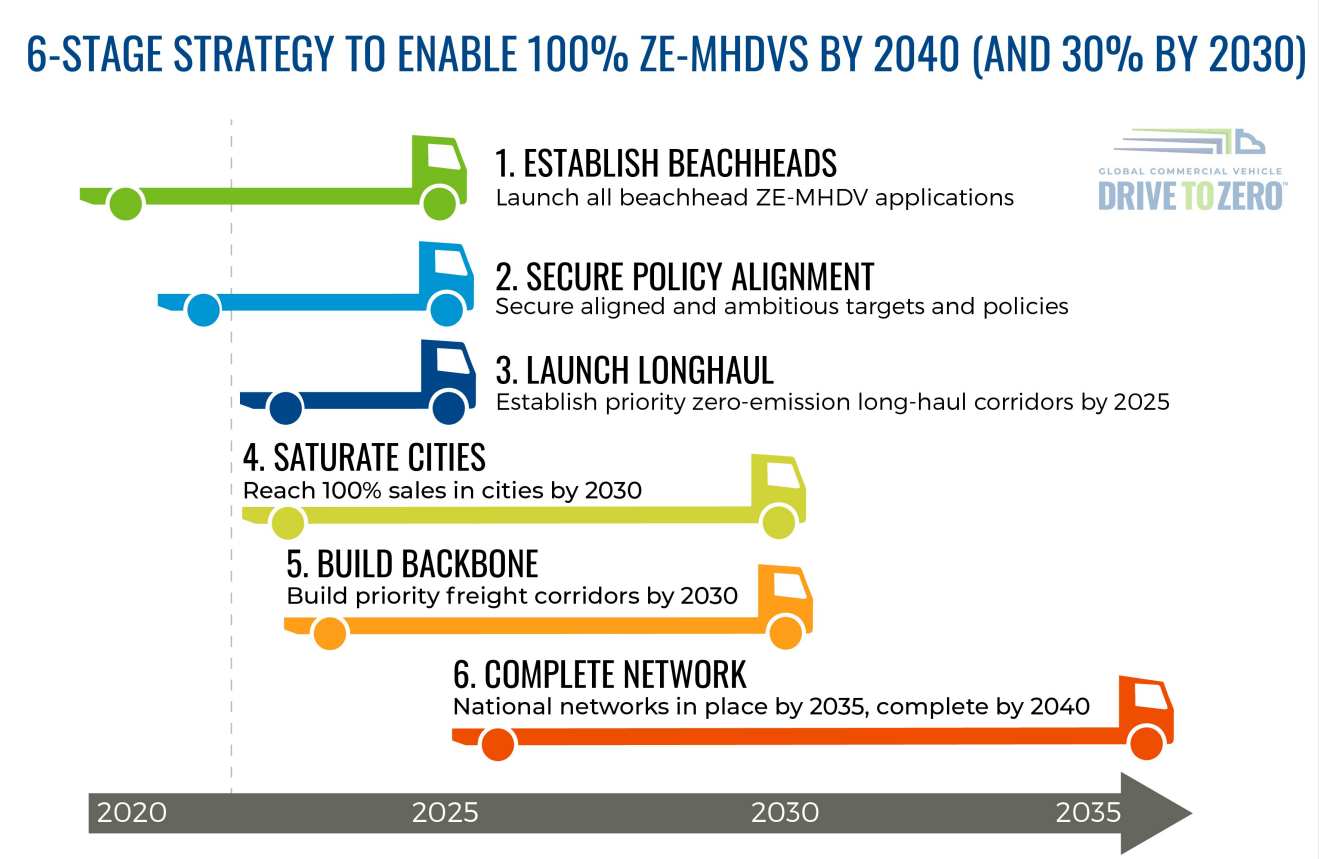
Another key feature is the technology transfer of HD components between the on-road sector and the off-road sector. Technology transfer between sectors has been illustrated in ZE bus components now being used in marine applications (hybrid, battery, and fuel cell) but is also found in common powertrain components that can be used in construction, agricultural, and CHE. Examples of equipment with implemented technology transfer components include wheel loaders, heavy lifts and excavators.

The success of this strategy has been extremely valuable as a framework for planning the introduction timelines of HD electrification. Rather than expecting market launches randomly, there is a clear and sequenced cadence to the growth of ZE capabilities. Utilities, cities, fleets, and government agencies can better plan the timing of infrastructure deployments, supportive policies and incentives, and development of funding knowing that there will be continued expansion and progression of ZE technology. Rapid growth in ZE trucks is expected due in part to the 2020 adoption of CARB's ACT regulation and now the 2023 adoption of CARB's ACF regulation. The new regulations will require large manufacturers to sell qualifying ZEVs as an increasing percentage of their total vehicle sales and priority fleets to deploy ZE MHD vehicles at an increasing percentage of their vehicles starting in 2024. ACT specifically requires an end to combustion truck sales, requiring 100% ZE MHD vehicle sales by 2036. Additionally, 17 U.S. states (accounting for more than 30% of the U.S. commercial vehicle market), the District of Columbia, and Quebec signed a 2020 memorandum of understanding to accelerate the adoption of commercial ZEVs aligned with ACT market penetration goals. Colorado, Maryland, Massachusetts, New Jersey, New York, Oregon, Vermont, and Washington have now adopted ACT as well, and additional states are also considering adopting the regulation. The beachhead model predicted that the earliest successful ZEV applications will take place in transit bus, delivery van, medium-duty (MD) truck, and MD school and shuttle bus markets. These successes will result in lower costs for heavier truck applications by establishing robust supply chains.

With the ZE beachhead firmly in place, the focus for investments must now shift to implementation. Successfully achieving the long-term outcomes established by California's goals requires a front-loaded implementation framework to guide government, industry, and non-profit organizations (NGO) partners and align policy and investment decisions. Working backwards from an end state defined by a complete market transformation to HD

ZEVs, CARB's investment priorities outlined in this document draw from strategies like CALSTART's six-stage Drive to Zero roadmap (Figure D-5).[14]

Figure D-5: Six-Stage Strategy to Enable 100% Medium- and Heavy-Duty Zero Emission Vehicles



Technology Status Updates

Monitoring the status of key technologies is imperative to maintain the effectiveness of the investment strategy and track progress toward set goals. With input from grantees and industry stakeholders, CARB conducts an annual high-level "snapshot" review to assess the generalized status and progress of key technologies. The goal of these analyses is to provide valuable directional guidance on where important technology platforms are in terms of technology readiness for the market. This approach allows CARB to adjust investment recommendations to help further expand market and technology success or to better focus on technologies moving more slowly or facing additional challenges. As in

[14] For additional information on the *Global Roadmap for Reaching 100% Zero-Emission Medium- And Heavy-Duty Vehicles by 2040*, see *https://globaldrivetozero.org/publication/global-roadmap-for-reaching-100-zero-emission-medium-and-heavy-duty-vehicles-by-2040/*.

previous years, for each of the critical pathways and technology categories, staff and CARB's partner, CALSTART, have prepared an updated high-level overview of the technology readiness assessment for ZE HD vehicles and off-road equipment. Building on the baseline approach established in FY 2017–18, applications of the technology are characterized in terms of three general stages on the path to commercialization: demonstration, pilot, and commercial.[15]

For consistency and to track progress, these updated assessments build on the assessments presented in the previous Strategy and are adjusted for changes over the past year. While these assessments were originally built from technology assessments conducted by CARB staff in the past[16] (in conjunction with staff from other agencies and industry stakeholders), the updates here are based on reviews of additional or updated data and information from literature, public information sources, conversations with technology providers, and field data where available.

In tracking this progress, it is important to keep in mind the goals of Low Carbon Transportation projects, as laid out and planned for in this document. Fundamentally, Low Carbon Transportation is tasked with GHG reductions and other co-benefits through strategic investments in advanced technologies. With the end goal of broader market acceptance and a shift toward equity, the Strategy takes a layered approach: beginning first with vehicle technology readiness and then building on that to understand other challenges to market acceptance, such as costs, unique duty cycles, and infrastructure access. (See Market Readiness, page D-50.) Taking these steps to understand the root issues of readiness and challenges greatly assists in formulating more nuanced and effective funding recommendations and priorities, as well as helping to shape regulatory structures.

The charted location of each platform or technology listed is not representative of any one specific product or vehicle but is instead an aggregated average status based on the multiple platforms, vehicles and manufacturers, and different stages at which each may be. Each individual vehicle model that contributes to the platform/technology average is also provided a weighting, based on the type of manufacturer and how long they have been receiving the TRL assessment. For example, the status level of a model from a vertically integrated global OEM would be weighted more heavily than a model from a start-up vehicle integrator. In addition, the status level of a model that has been scored since 2020 is weighted more heavily than a model that is new to market in 2023. This weighting helps provide a realistic assessment of where a platform is in overall progress toward technical and commercial readiness. These platform/technology assessments are displayed as the general weighted average status of known platforms/technologies. This may mean a

[15] For additional information on *technology readiness and market commercialization signals*, see *https://calstart.org/technology-and-market-readiness*.

[16] CARB. *Technology and Fuels Assessment Reports*. June 2015 to December 2016. *https://ww2.arb.ca.gov/resources/documents/technology-and-fuels-assessments*

platform/technology could be shown in the commercial production stage, even when there may be products from some manufacturers that are only in the pilot stage.

Updates and refinements from last year's plan have been incorporated into the technology status charts that follow. Those include:

- Technology categories have been expanded to reflect a growing diversity of off-road equipment. Categories such as concrete pumps and cranes/material handlers are among the many off-road equipment types that have been added to the technology readiness assessment.
- Technology categories that have received a score of TRL 8 or higher for two consecutive years will no longer receive a technology readiness assessment. These categories are considered technologically mature, and CARB's assessments will focus strictly on their market readiness. Categories that have received a score of eight or higher for two consecutive years include all on-road categories, yard trucks, forklifts (light) and several other off-road equipment types.
- The methodology used to grade technology platforms is altered slightly from previous years. The formula now has a new weighting based on how long a model has been assessed for technology readiness. With more models coming to market every year, they will inherently be scored lower, and an influx of new models can skew technology platform scores. This new weighting captures market growth in a platform while also showing a platform's overall technological maturity.

To aid in future assessments of technologies achieving technology transformation and moving into market readiness transition, a demarcation (a gradient shaded area) around TRL 8-9 is placed to identify applications that are transitioning from technology transformation to market transformation. As these technologies mature, they should be more carefully examined for market readiness and transitioning to more appropriate or alternative incentive strategies. See the Market Readiness section for further discussion.

Some categories have seen remarkable progress year-over-year, which is a sign of the early success of the Strategy, particularly in areas where demonstration and pilot funding has helped validate vehicle designs.

Battery Electric Technology Status Snapshot

Battery electric vehicle and equipment technologies are a critical element of the ZE pathway. These platforms have improved continually in technology readiness in the past several years to the point where all on-road vehicles and some off-road equipment platforms have had a score of TRL 8 or higher for two consecutive years, and therefore will solely be assessed in terms of market readiness. These platforms and their two-year averages are displayed in Tables D-3 and D-4.

Off-road battery electric equipment technologies have made great strides over the past year, as heavier equipment has started to move out of the demonstration stage. There are 13 new platforms receiving a technology assessment for the first time this year. Figures D-6

through D-8 depict the achievements made across several off-road battery electric platforms.

Building from previous early success, "beachhead" platforms such as transit buses and HD regional and long-haul trucks have made significant progress in technology readiness over the past year. All major OEMs have started to deliver vehicles in this segment, and deployment of zero-emission trucks (ZETs) has experienced exponential growth: 3,510 HD ZETs were deployed in 2022 alone, surpassing the number of deployments from the previous five years (2017–2021) combined.[17]

[17] CALSTART. *Zeroing In On: ZETs May 2023 Market Update.* May 31, 2023. *https://calstart.org/zio-zets-may-2023-market-update/*

Industry Example

From Demos to Scale

As technology advances and market barriers are overcome, fleets are beginning to deploy ZEVs at scale. Whereas a few years ago fleets would pilot one or two vehicles at a time, they are now purchasing dozens at once, sometimes even electrifying entire depots.

For example, CARB's Zero and Near-Zero Emission Freight Facility (ZANZEFF) program has contributed over $150 million toward 10 transformative projects throughout the state—all located within DACs that are heavily impacted by air pollution from freight facilities. One of these projects awarded over $15 million to Frito-Lay to replace all diesel-powered equipment at its 500,000-square-foot Modesto manufacturing facility. Launched in 2019, the project has deployed 12 Crown battery electric forklifts, three battery electric BYD 8Y yard trucks, 15 HD battery electric Tesla Semis, six battery electric Peterbilt 220EV box trucks, and 38 Class 8 renewable natural gas (RNG) Volvo trucks. The project also includes significant infrastructure buildout, including six dual-port, 125-kilowatt (kW) chargers, four 750-kW chargers, onsite solar panels and battery storage, workplace charging, and an RNG fueling station. PepsiCo views this project as "an operating model for all of [their] facilities across the U.S." and a "catalyst to accelerate adoption of alternative fuel vehicles across the industry."[18]

Meanwhile, CARB contributed over $14.5 million to partner with CEC to showcase large scale ZE HD vehicle and infrastructure deployments via the Joint Electric Truck Scaling Initiative (JETSI).[19] JETSI provided funding for two fleet partners to deploy 50 battery electric Class 8 trucks each. NFI will operate 50 trucks in drayage operations at its Ontario facility, and Schneider will operate 30 trucks in regional haul and 20 in drayage operations at its South El Monte facility. Both fleets have installed fast chargers to support these deployments, and NFI has also installed 1 megawatt of solar and five megawatt-hours of battery energy storage.

[18] Frito-Lay. *Frito-Lay Transforms California Facility into Showcase for Sustainability.* January 18, 2023. *https://www.fritolay.com/frito-lay-transforms-california-facility-into-showcase-for-sustainability/*

[19] CARB. *LCTI: Joint Electric Truck Scaling Initiative (JETSI). https://ww2.arb.ca.gov/lcti-joint-electric-truck-scaling-initiative-jetsi/*

Electric school buses (ESBs) and other BEBs like transit, coach, and shuttle buses continue to show their technological viability, with11 OEMs manufacturing ESBs and 24 OEMs manufacturing BEBs to date.[20] As of December 2022, 3,043 ESBs have been deployed, an increase of 888 from September 2021.[21] As of September 2022, 5,269 BEBs have been deployed, an increase of 2,101 from 2021.[22]

Table D-3: On-Road Battery Electric Technology Status Snapshot: Two Years with Score of TRL 8+

Technology Platform	Two-Year Average
HD Long Haul	8.02
HD Urban Regional Drayage	8.66
MD Truck	8.37
Shuttle Bus	8.43
School Bus	8.46
Transit Bus	8.50
Coach Bus	8.64
Cargo Van	8.39
Refuse	8.57
Work Truck	8.32

[20] Global Drive To Zero. *Zero-Emission Technology Inventory.* August 30, 2023. *https://globaldrivetozero.org/tools/zero-emission-technology-inventory/*

[21] CALSTART. *Zeroing in on Electric School Buses: 2023.* May 3, 2023. *https://calstart.org/zeroing-in-on-esbs-2023/*

[22] CALSTART. *Zeroing in on ZEBs.* February 3, 2023. *https://calstart.org/zeroing-in-on-zebs-2023/*

Table D-4: Off-Road Battery Electric Technology Status Snapshot: Two Years with Score of TRL 8+

Technology Platform	Two-Year Average
Yard Truck	8.56
Rubber-Tired Gantry (RTG) Crane	8.07
Forklift (Light)	8.55
Excavator (Light)	8.58
Compact Track Loader/Skid Steer	8.17
Airport Ground Support Equipment (Light)	8.97
Railcar Mover	8.86
TRU	8.83
GPU/MPU	8.99

For the second year in a row, the technology readiness analysis saw a significant expansion of off-road platforms, as 13 new platforms received scores this year, mainly in the construction and cargo handling segments. With the large expansion of equipment platforms, a total of 345 models were scored this year, an increase of 107 models from last year. There is noticeable progress throughout the technology platforms, with 12 platforms across all off-road categories scoring above TRL 8 for the first time and are therefore being evaluated for market readiness this year. While light off-road equipment (defined differently depending on the application) is generally at high levels of technology readiness and entering commercial production, in some areas heavy off-road technology is also maturing rapidly. Construction and agriculture equipment are following up their initial year in CORE with another good year, showing the viability and demand for electric technology platforms within each category. The most noticeable jumps in TRL scores came from the construction segment which saw telehandlers and light and heavy wheel loaders move from early pilot/late demonstration phase to large scale pilot/early market within the past year. This is mainly due to some major OEMs starting to produce battery electric versions of telehandlers and wheel loaders that are now being piloted and performing well. There have been 264 construction vouchers and 474 agricultural equipment vouchers requested, which

represents roughly 26% of all CORE vouchers that have been requested to date. Demand for equipment in both categories remains high.

Mobile power units (MPUs) are also starting to become more popular for their use in both off-road and on-road applications. There are a handful of OEMs manufacturing these units, and production volumes are higher compared to other categories. A total of 335 vouchers have been requested for MPUs to date, and market demand is increasing. A temporary infrastructure pilot will start near the end of 2023 to help get vehicles into operation sooner, and demand for MPUs is expected to grow.

Figure D-6: Off-Road Battery Electric Technology Status Snapshot: Cargo Handling Equipment

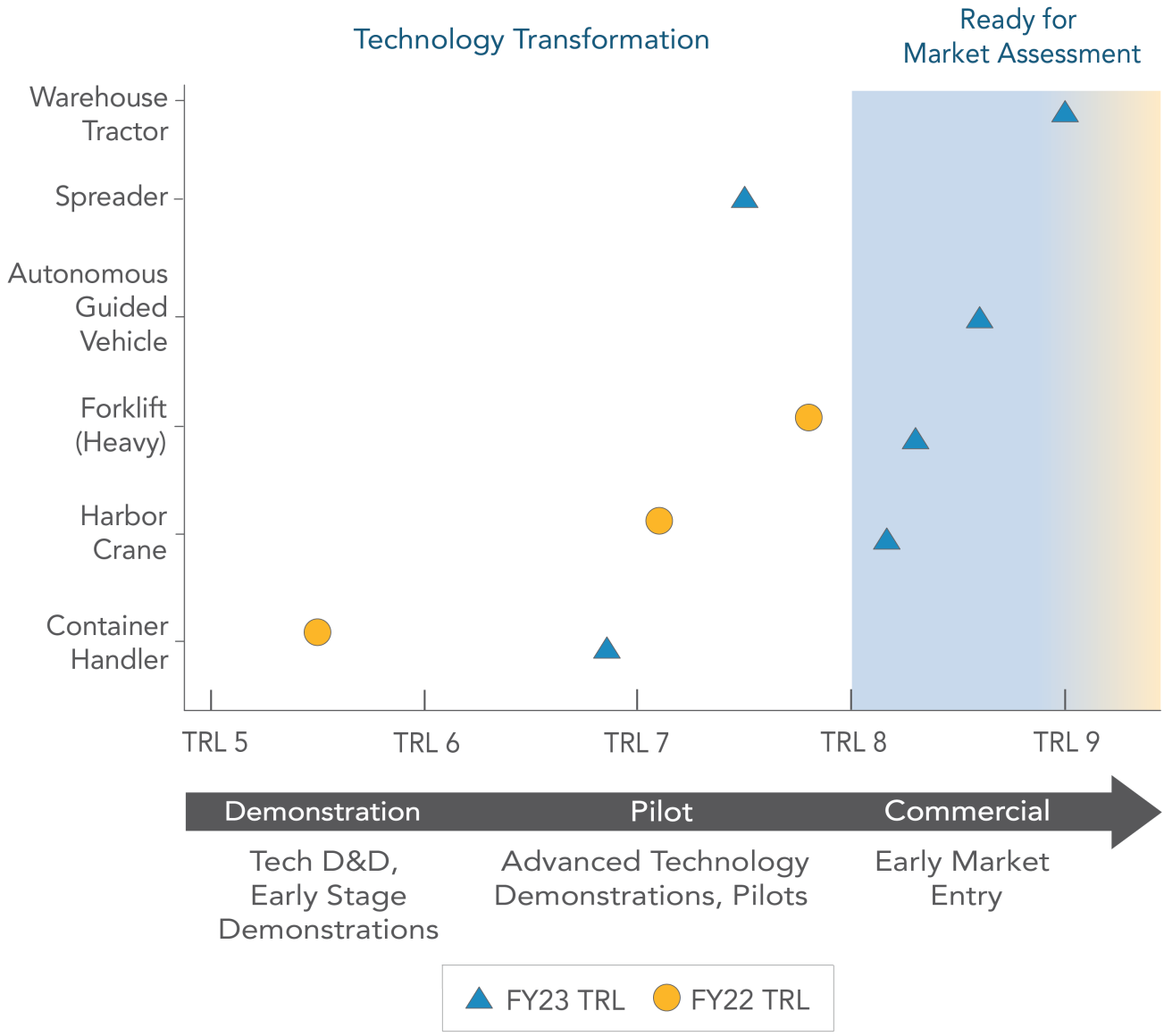


Figure D-7: Off-Road Battery Electric Technology Status Snapshot: Construction

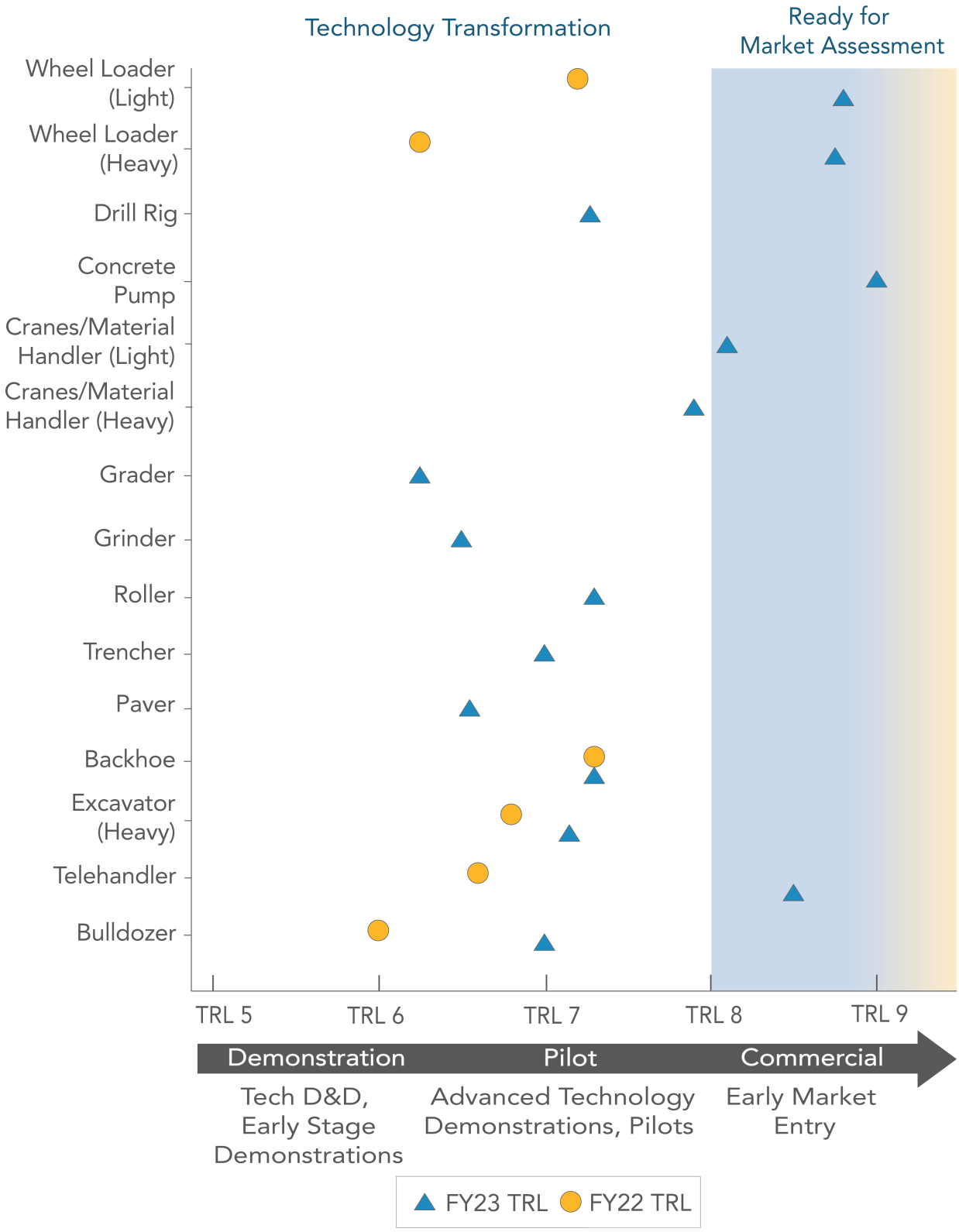
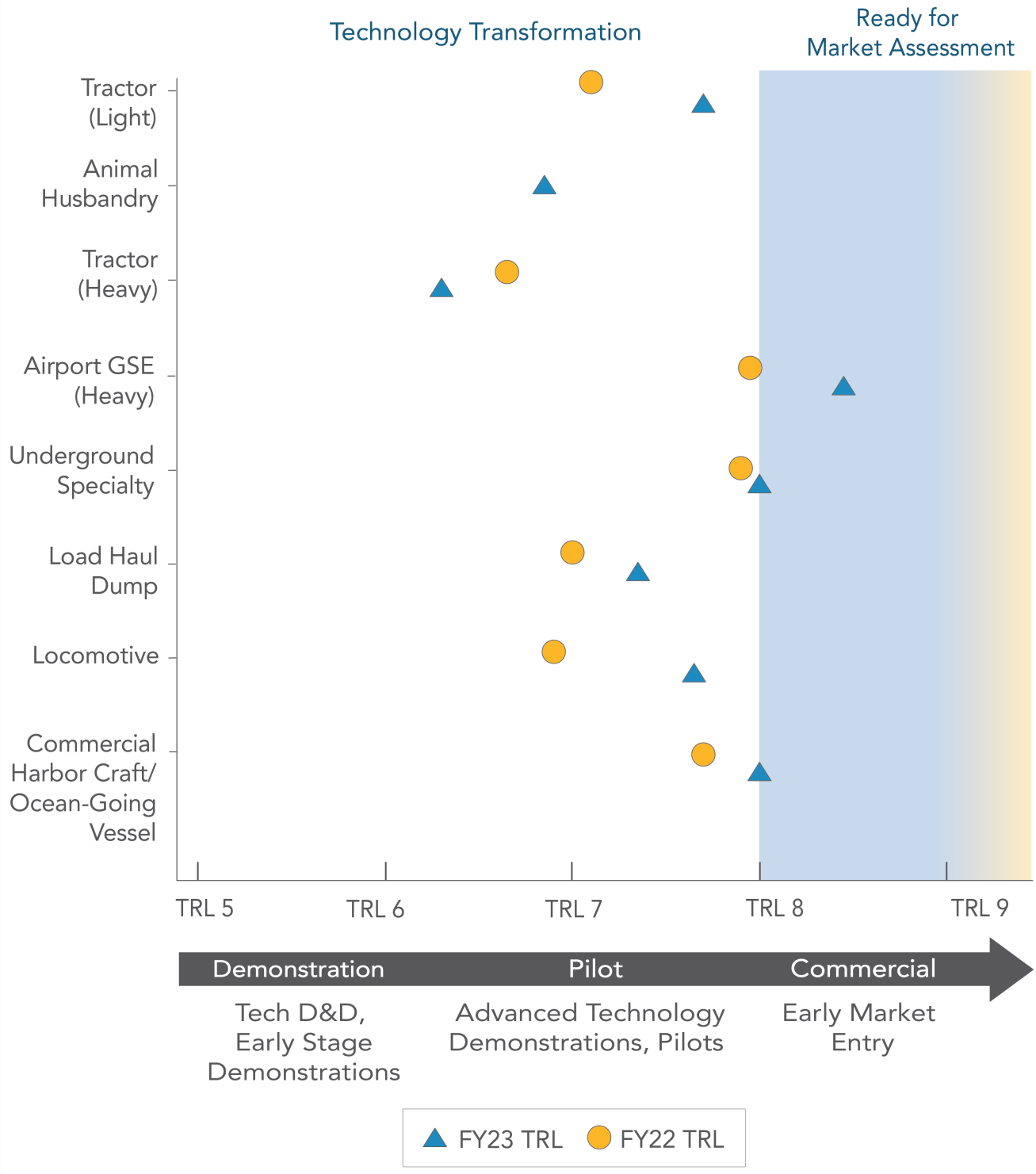


Figure D-8: Off-Road Battery Electric Technology Status Snapshot: Other



Industry Example

Flexibility is Key: Mobile Charging Infrastructure

As utilities and the electrical supply chain work to keep pace with rapidly accelerating electric vehicle (EV) deployments, fleets are seeking interim charging solutions that enable them to take delivery of EVs even before grid infrastructure to the site is upgraded or permanent chargers are installed. Several vehicle and charger manufacturers have interim infrastructure solutions in development, with some already commercially available.

These emerging solutions are categorized as temporary or mobile. Temporary solutions are often skid-based or containerized. These products are brought to the fleet's site, connected to the grid, and utilized until a fully permanent installation is completed. Mobile charging solutions are capable of being used at different locations at a depot but can also be a permanent solution in some cases.

Models are available from FreeWire, Dannar, Nikola, Bp Pulse, XOS, Shyft Group, and Veloce Energy, with more in development. Some of these models are available for purchase outright, while others are available to customers via a lease program.

Often referred to as MPUs in off-road applications, these solutions are vital for enabling the deployment of ZE off-road equipment, which may not have easy access to the electric grid and/or may operate at a different site each day. For example, Volvo Construction Equipment has announced partnerships with both Portable Electric and Beam Global that allow Volvo's extensive North American dealer market to bundle the Voltstack 30k Level 2 e-Charger or the Beam EV ARC off-grid solar charging system, respectively, with a purchase of Volvo electric equipment. These joint offerings enable construction sites to rapidly deploy EV charging without the requirement for electrical work, utility grid connections, or fossil fuel generators, and to power ZE construction equipment such as Volvo's electric wheel loaders and excavators. Together, this equipment produces zero emissions, significantly reduces noise levels, and lowers energy costs, making them ideal

Industry Example

Flexibility is Key: Mobile Charging Infrastructure

for construction sites where emission regulations, noise ordinances, or the risks of indoor air pollution limit the use of diesel generators and construction equipment.

MPUs are already available for CORE funding, and pilot projects for temporary chargers could be a way to expand options for on-road charging.

Fuel Cell Electric Technology Status Snapshot

Fuel cell electric technology has been gaining momentum as a solution for applications with needs for longer range or duration, faster fueling, or demanding duty cycles. Generally, fuel cell electric vehicles and equipment are at the late demonstration/early pilot phase for all on- and off-road platforms with fuel cell electric models available. Figures D-9 and D-10 provide an overview of the technology status of fuel cell electric vehicles and equipment.

Figure D-9: On-Road Fuel Cell Electric Technology Status Snapshot

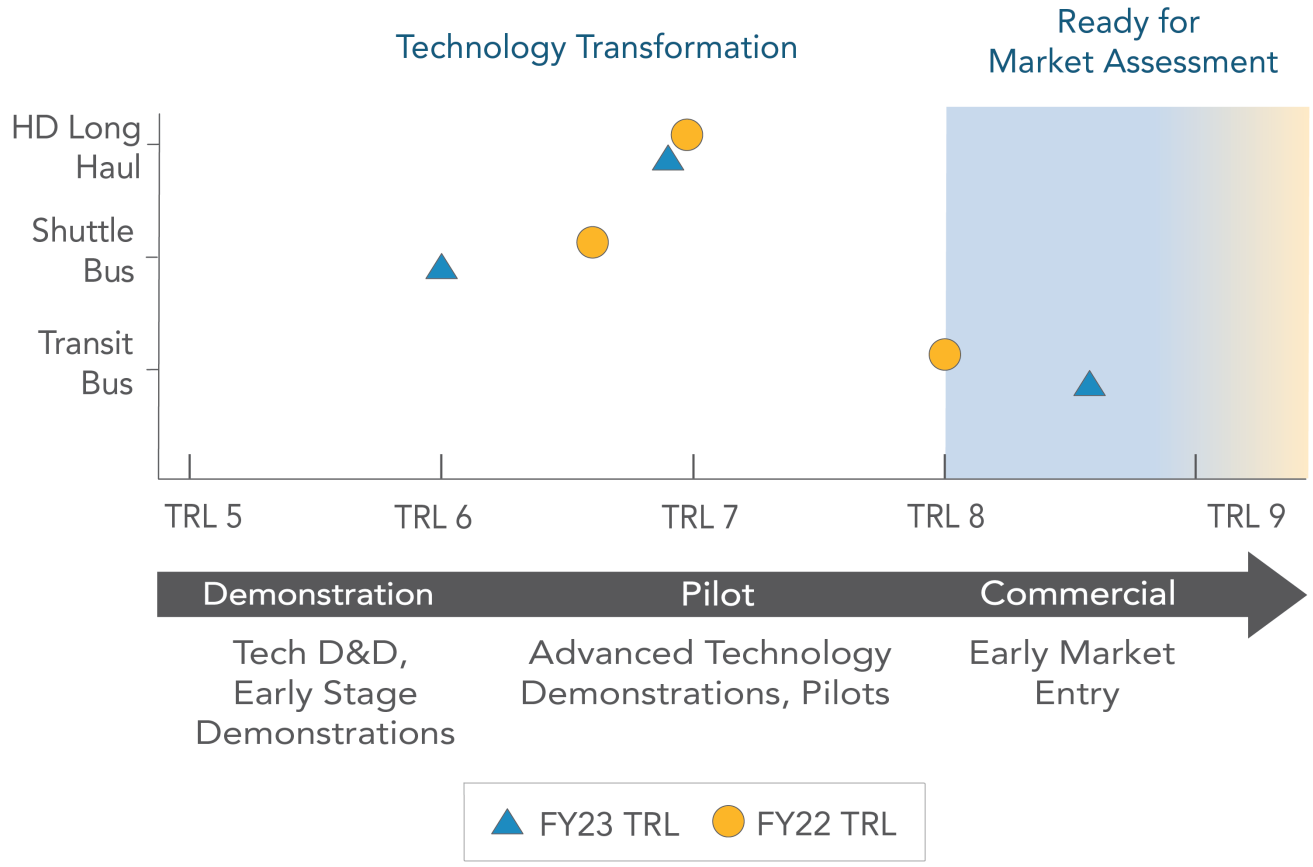
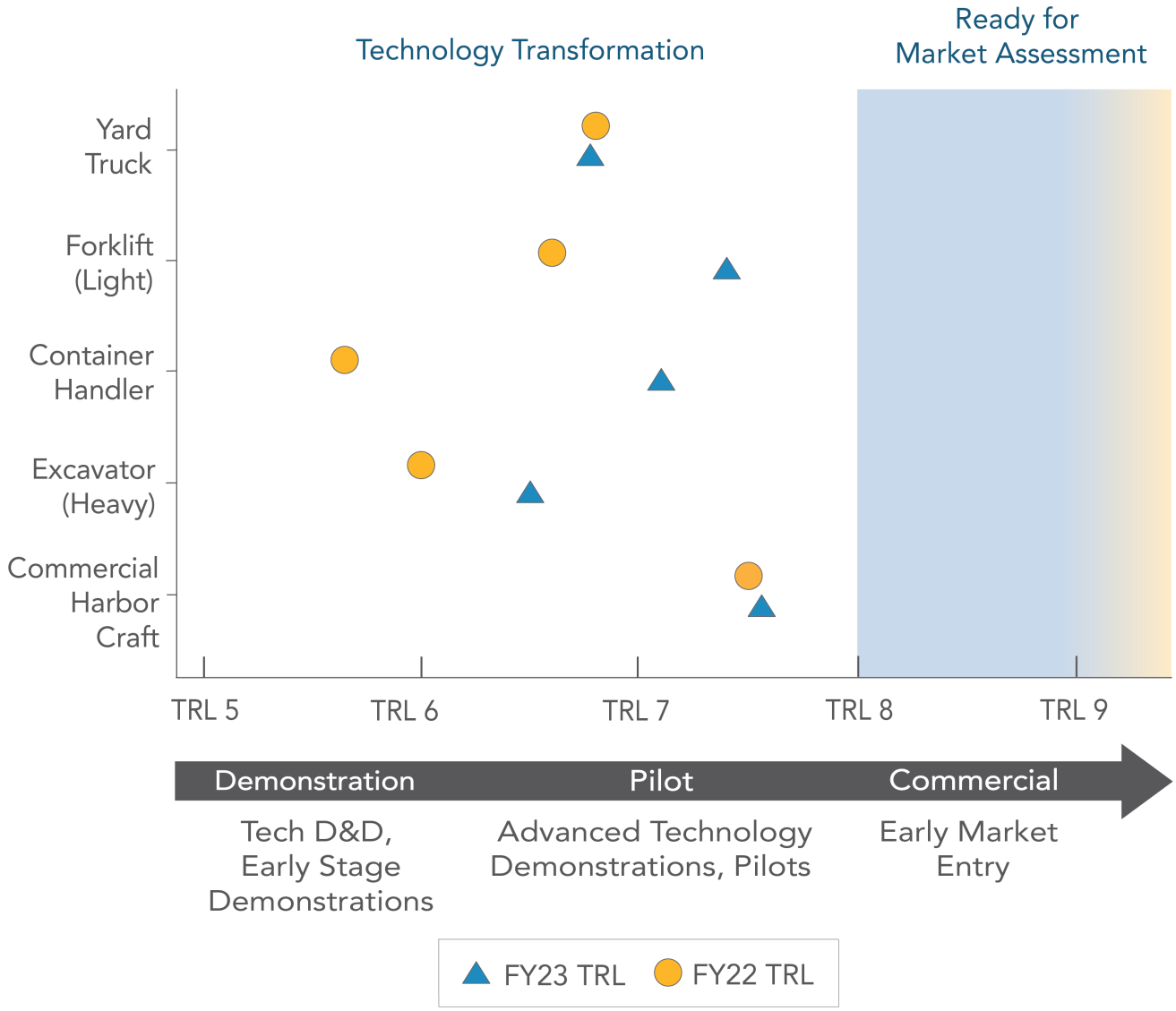


Figure D-10: Off-Road Fuel Cell Electric Technology Status Snapshot



Fuel cell technology has gravitated toward heavier applications in the past several years. HD long-haul delivery and drayage are both prime candidates to take advantage of the benefits of fuel cell technology. These vehicles are the drivers of several large pilot projects at domestic ports supported by global OEMs.

As mentioned previously, one of the reasons behind a growing interest in fuel cell electrification is the capacity for long range or heavier cargo loads where higher capacity on-board energy storage is needed, or for those duty cycles requiring continuous operation or multiple-shift operation where there may be insufficient time for recharging. Such operations can make use of centralized, high-throughput fueling stations that can be sited with on-location, high-capacity hydrogen production facilities. While still in the demonstration phase, such production sites may allow for much cheaper hydrogen

production. Such high-volume, centralized fueling could serve as a base for a range of applications, such as port equipment, marine vessels, transit buses, and drayage trucks, as well as other regional applications.

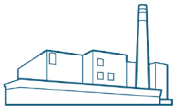
As illustrated in Figure D-10 above, the existing on-road fuel cell electric models tracked here saw minimal movement over the past year. While the technology holds immense promise, these platforms continue to stay in the demonstration and pilot phases. Lack of familiarity and initial high costs have contributed to their slow adoption. However, adoption is trending up, as seen with Nikola's HYLA brand teaming up with Voltera to develop a hydrogen refueling network as well as receiving a California Transportation Commission grant to develop six hydrogen stations in Southern California. There has also been an influx of fuel cell electric transit bus orders placed due in part to successful pilots as agencies' confidence in the technology improves.

Off-road fuel cell electric equipment models did make some gradual improvements, outlined in Figure D-11, as many of the early demonstration platforms have moved into the pilot stage. However, those that were already in the pilot stage have not advanced further. With fuel cell technology being ideal for heavier equipment, there is growing interest in incorporating this technology into demanding platforms such as mining and rail. Those platforms remain pre-demonstration and are not included in these assessments.

Market Readiness

Conducting technology readiness assessments is an important first step in evaluating advanced technologies, but it describes only part of the commercialization story. As technologies move toward full commercial readiness, their commercialization status becomes less about technological readiness and more dependent on market readiness.[23] Being an important factor relative to investment policy, CARB analyzes market readiness, summarized in Figures D-11 through D-14 below.

While the technology status snapshots provide an assessment of the level of technological advancement for emerging technologies, this can make for an incomplete picture. Market and economic factors can hold back what would otherwise be a technologically advanced, commercially viable platform. For this reason, this analysis assesses any technology platforms that have reached a score greater than TRL 8 against the following seven market readiness indicators: production capacity, service network, cost parity, cost parity with incentives, duty cycle capability, infrastructure, and supply chain.



- **Production capacity** is a measure of the ability of manufacturers to produce commercial-ready products. Production capacity for an on- or off-road technology category considers the current and future aggregate production capacities of each manufacturer within that category. This metric also weighs absolute production capacity against the total market size of a technology platform. For instance, although the total industry production capacity for RTG cranes is extremely low compared to on-road vehicles, it is much larger compared to the total annual market size for RTG cranes.

- **Service network** measures the size and capability of the support, repair, and replacement network to service a given technology platform. Technologies in the early commercialization phase may not have established networks when repairs are needed, which can hinder the full utilization of early deployments and disincentivize early technology adoption. This measure also considers the geographic distribution of the service network within California.

- **Cost parity** is the projected TCO of a ZE technology platform purchased in 2025 relative to that of a similar diesel- or gas-powered technology platform. Assumptions for TCO calculations were modeled on assumptions from CARB's "Draft Advanced Clean Fleets Total Cost of Ownership Discussion Document." The TCO analysis assumes a one-to-one replacement of a vehicle or piece of equipment and represents an average case scenario. Because of the many variables associated with TCO, this analysis is not representative

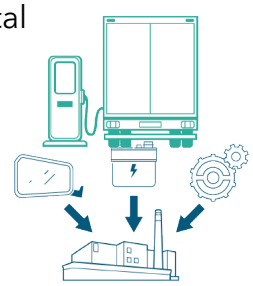
[23] For additional information on *technology and market readiness*, see *https://calstart.org/technology-and-market-readiness*.

of every use case within a particular technology platform but rather provides a high-level estimate of how TCO for ZE technologies compares to that of their diesel– or gas-powered counterparts.

- **Cost parity with incentives**, while similar to the indicator above, is the projected TCO of a ZE technology platform purchased in 2025 relative to diesel- or gas-powered vehicles, plus any base purchase incentives from CARB's HVIP or CORE voucher incentive programs and the federal Commercial Clean Vehicle Credit. HVIP and CORE modifiers that could increase or decrease voucher amounts (e.g., fleet size adjustments, bulk purchase requirements, DAC status, etc.) are not included in the cost parity with incentives analysis, nor are any additional funding sources that could be stacked.[24]

- **Duty cycle capability** measures the applicability of a technology platform's abilities for the wide range of duty cycles required by its applications. On-road technology platforms are measured by their ability to meet range, power, and load capacity requirements, while off-road equipment is measured by ability to meet operating time, power, and lift capacity requirements where applicable.

- **Infrastructure** is an indicator that measures the availability and cost of appropriate charging infrastructure for each technology platform. In addition, challenges to charging infrastructure purchase and installation, such as incremental cost, permitting time, utility upgrades, and unsuitable utility rate structures, are assessed as a part of this indicator.
- **Supply chain** evaluates on-road technology platforms for their vulnerability to ongoing supply chain disruptions and constraints. Trying to incorporate component supply and demand and market volatility of parts and materials, this indicator looks at vehicle delivery timelines by segment as a proxy for supply chain fragility.



Each vehicle and equipment segment are assessed against the above market readiness indicators on a scale of 0 to 100%, with the percentage – scored in 25% increments – representing relative thresholds between being not at all market ready (i.e., having substantial, inhibitory barriers to adoption) and being completely market ready (i.e., having little to no barriers to widespread adoption). These thresholds are determined by internal CALSTART and CARB subject matter experts, vetted with stakeholders, and updated annually (if necessary). Only on-road vehicles are scored against the supply chain indicator due to insufficient data to properly score off-road equipment against this indicator.

Market readiness factors were assessed against a defined rubric by subject matter experts from CALSTART and CARB to arrive at the generalized scores shown in Figures D-11

[24] Stacked refers to the process of combining multiple incentives in a cumulative manner.

through D-14. Detail on the market readiness indicators and derivation of the scores shown in the figures can be found in a dedicated technical white paper.[25]

The market readiness assessment in Figure D-11 reveals on-road technology segments have remained mostly unchanged throughout, with HD long haul experiencing the most aggregate improvement with initial deployments of trucks operating in California successfully. The HD long haul platform still has immediate market barriers with lack of public-facing infrastructure, low production volumes, and payload and range constraints. However, more public-facing infrastructure is being planned, and OEMs have plans for more manufacturing capacity.

There has been consistent growth in the workforce/service network indicator as a high percentage of OEMs offer training to their purchasers. This is only half the battle as more workforce development programs will be needed to equally distribute a workforce throughout California. Numerous obstacles continue to hinder the progress of platforms for specific indicators. These include applications in need of greater range and payload that did not see significant improvements in the past year, as well as persistent infrastructure challenges related to energization, permitting, and high costs. However, innovative solutions such as temporary charging and Charging-as-a-Service are gaining more attention to help fill this gap.

Cost parity remains unchanged throughout each on-road platform, even with increased incentives in HVIP and a new Commercial Clean Vehicle Credit. In an effort to align with CARB's Advanced Clean Fleets (ACF) TCO analysis,[26] the same methodology was used to assess market readiness. CARB acknowledges that some of the underlying assumptions (including battery and overall vehicle pricing) have changed since the original analysis, due primarily to inflation and supply chain constraints. The cost of capital has also increased significantly due to rising interest rates. To better account for these observed changes in the market and reflect current TCO parity, the TCO methodology may be updated in the future.

Furthermore, TCO is analyzed at a high-level for an "average" use case for different technology platforms. The result should be understood as such—as a directional snapshot of the market rather than a specific cost projection representative of all duty cycles within each technology platform. Differences including fleet size, purchase volume, vehicle model, deployment location, annual miles traveled, utility territory, and charging needs may impact the incentive amounts a fleet is eligible for as well as overall TCO.

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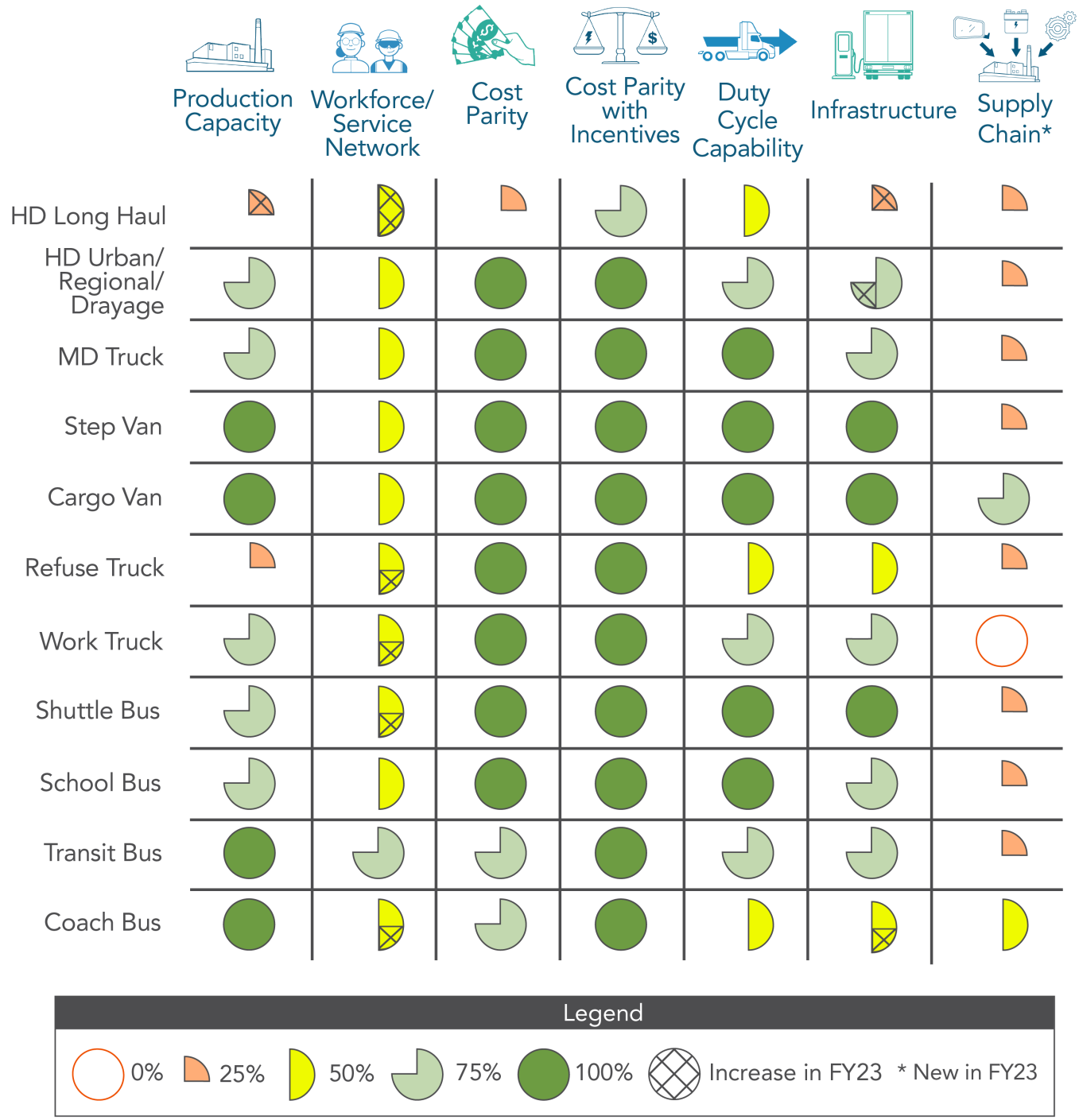
[25] CALSTART. *Methods for Assessing Technology and Market Readiness for Clean Commercial Transportation.* October 2023. *https://calstart.org/technology-and-market-readiness*

[26] For more information on CARB's "*Draft Advanced Clean Fleets Total Cost of Ownership Discussion Document*," visit *https://ww2.arb.ca.gov/sites/default/files/2021-08/210909costdoc_ADA.pdf*.

The only on-road fuel cell EV to achieve a score greater than TRL 8 was the transit bus segment. With order and deployment volumes rising, this segment will be evaluated for market readiness in next year's Strategy.

Figure D-11: On-Road Battery Electric Market Readiness Snapshot



The market readiness snapshot for off-road equipment that have been scored for market readiness in previous years – those not marked with an asterisk in Figures D-12 through D-14 – have shown little movement in market readiness; most platforms scored very high last year. This remains true as many of these platforms, such as yard trucks, forklifts (light), and RTG cranes, have been commercially available for a few years. As a supportive workforce continues to develop and charging infrastructure delays get solved, the main focus will be cost parity. High up-front costs still remain for comparable battery electric equipment without incentives for a few platforms such as switcher locomotives and skid steers. These platforms will need more incentive support to drive broader adoption.

The market readiness snapshot for off-road equipment being scored for the first time – indicated with an asterisk in Figures D-12 through D-14 – shows the diversity in market readiness among the range of off-road equipment platforms. The warehouse tractor platform received 100% in all categories, meaning there are little to no market barriers to adoption and that battery electric warehouse tractors should be the norm for anyone looking to purchase one. Some platforms, such as autonomous guided vehicles and harbor cranes, achieve near cost parity while other segments like commercial harbor craft and large forklifts remain far from reaching cost parity. As platforms new to electrification, they face many of the early adoption market barriers such as lack of service network and needed infrastructure.

Figure D-12: Off-Road Battery Electric Equipment Market Readiness Snapshot: Cargo Handling Equipment

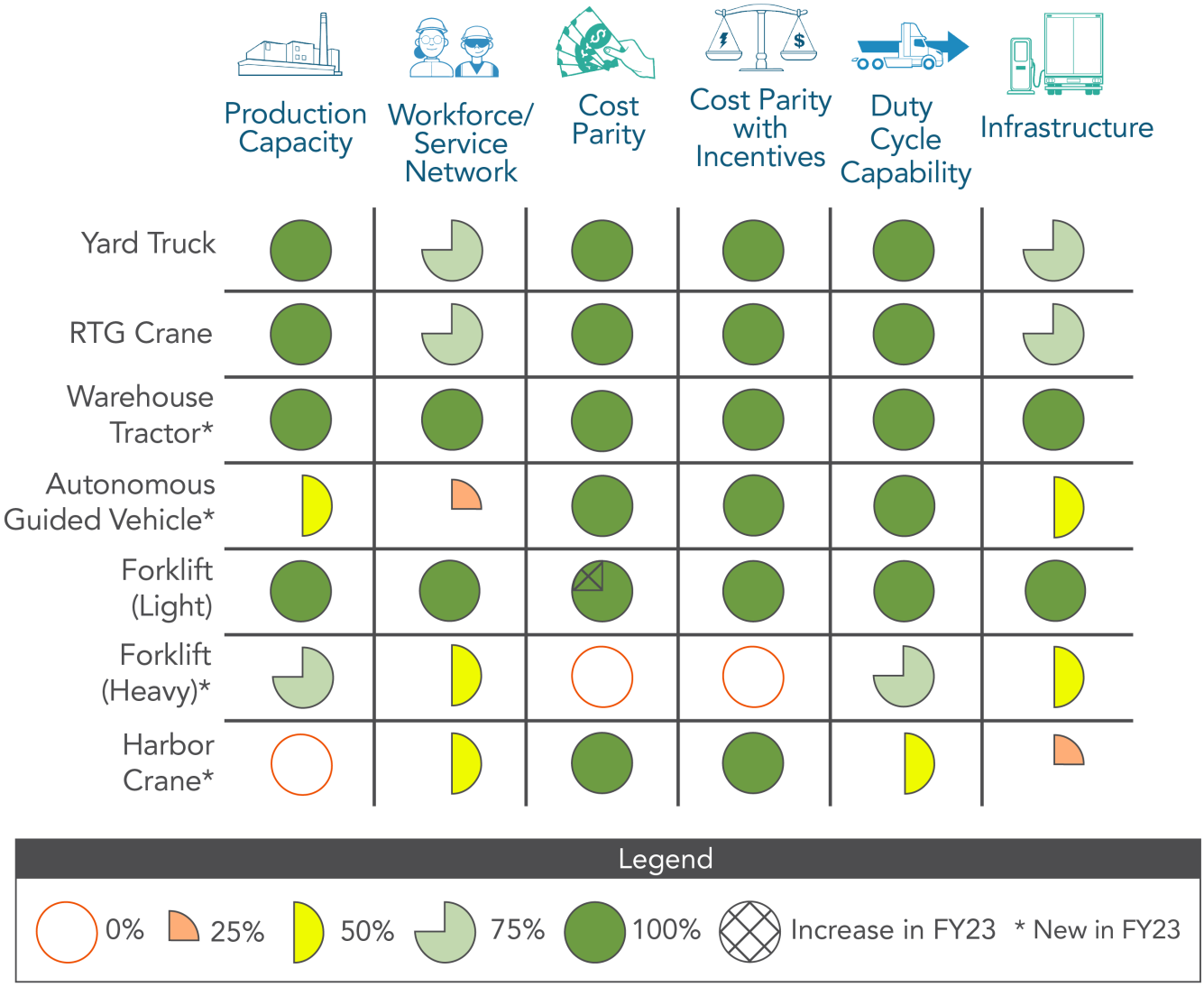


Figure D-13: Off-Road Battery Electric Equipment Market Readiness Snapshot: Construction

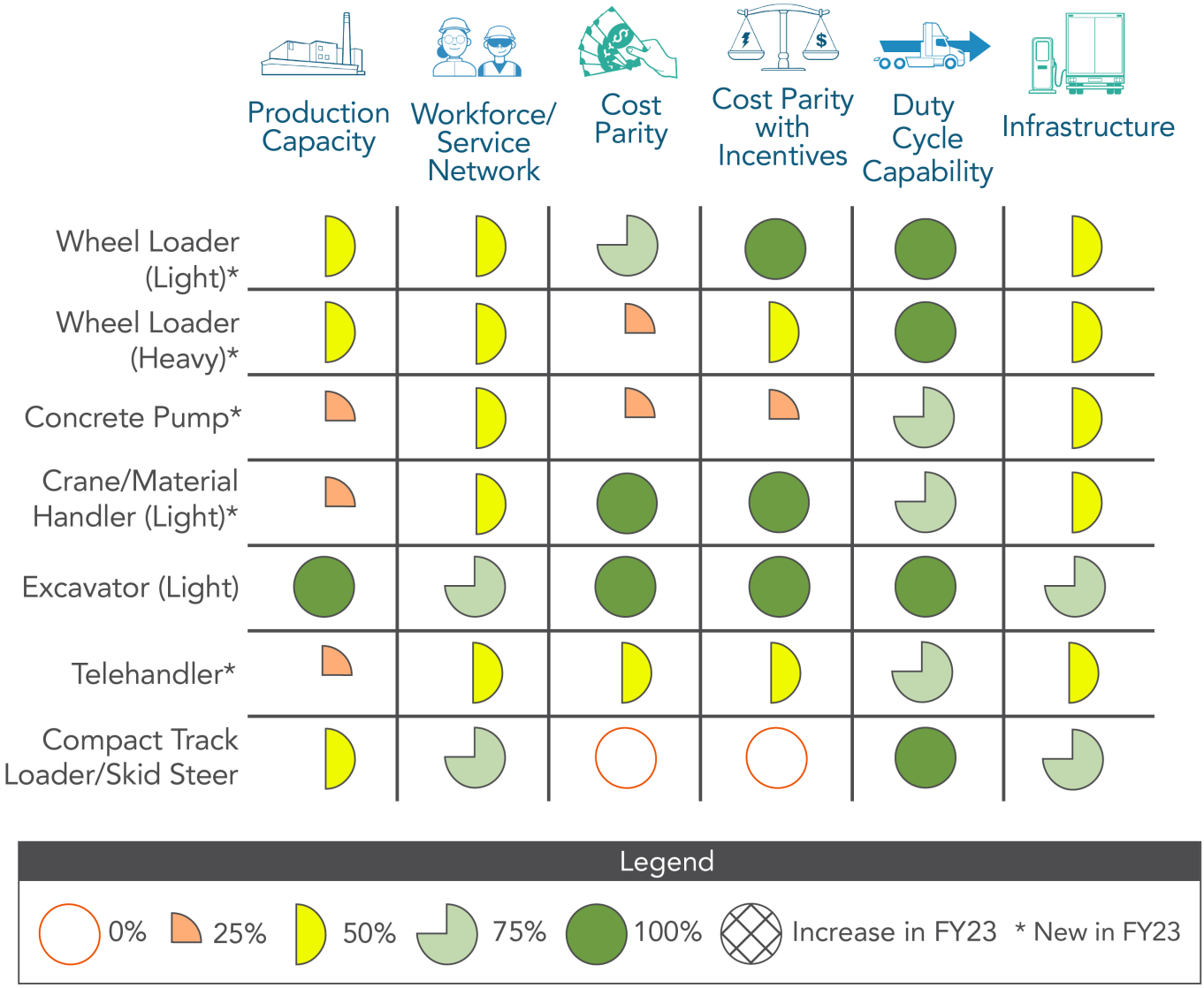
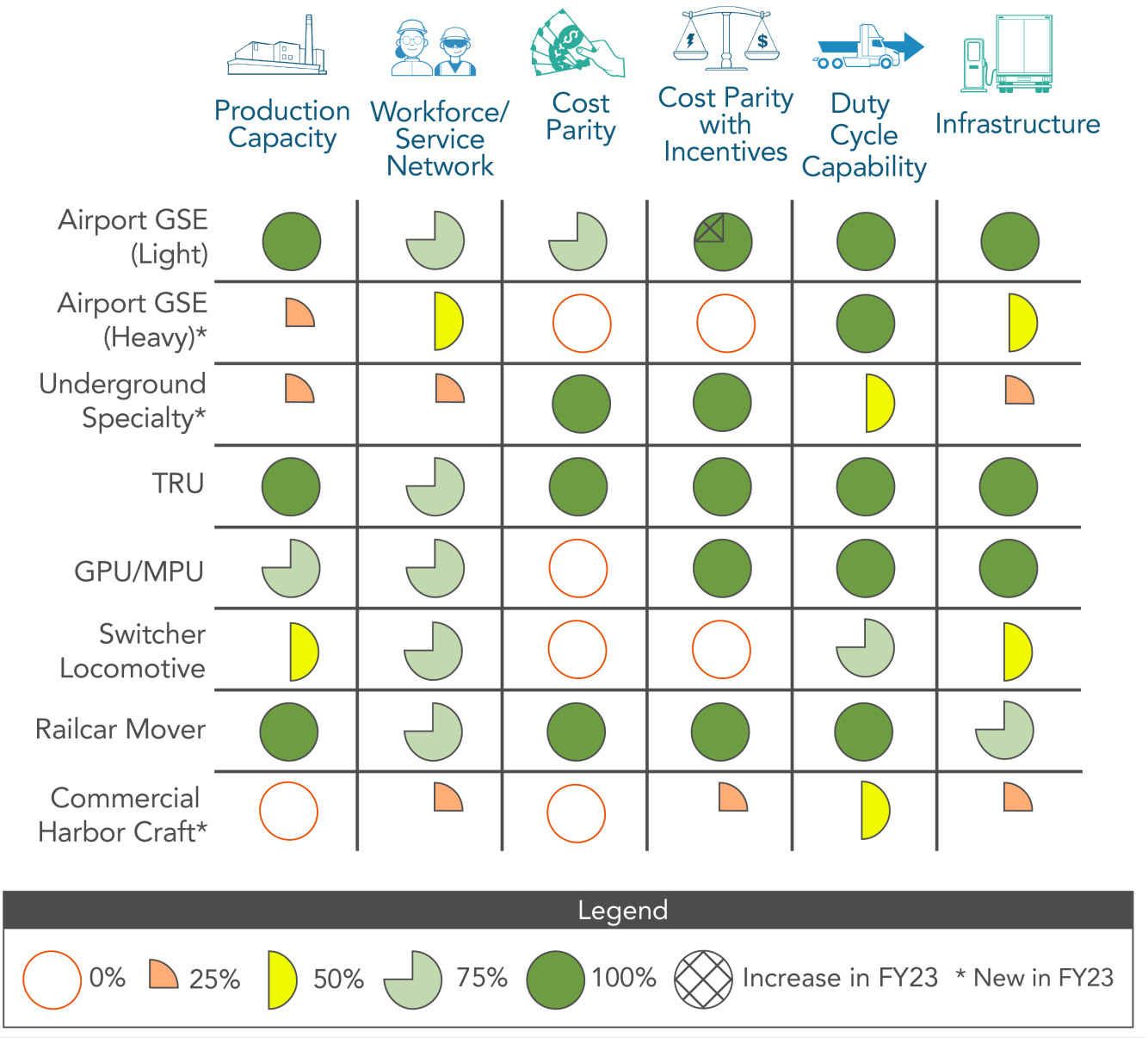


Figure D-14: Off-Road Battery Electric Equipment Market Readiness Snapshot: Other



Industry Example

Supporting Infrastructure Solutions: Energization Roundtable

ZE HD OEMs, truck and bus fleets, charging providers, and government partners are working to improve the timing of utility charging infrastructure energization and vehicle deployment. Supply chains, equipment availability, permitting, workforce, utility coordination/internal resources, and other factors are important considerations being addressed.

To help advance solutions, CARB and CALSTART convened an in-person roundtable series with stakeholders in the EV ecosystem. The series was focused on identifying and implementing process improvements to help streamline and expedite energization, particularly for larger commercial EV projects, to better enable California to meet its ZE targets and climate goals.

As part of this effort, CARB and CALSTART are working to develop a statewide framework that provides solutions aimed at improving the timeliness of deployment for HD vehicle infrastructure. This framework will serve as a replicable product that can support states beyond California as they begin to make the transition to ZE commercial vehicles.

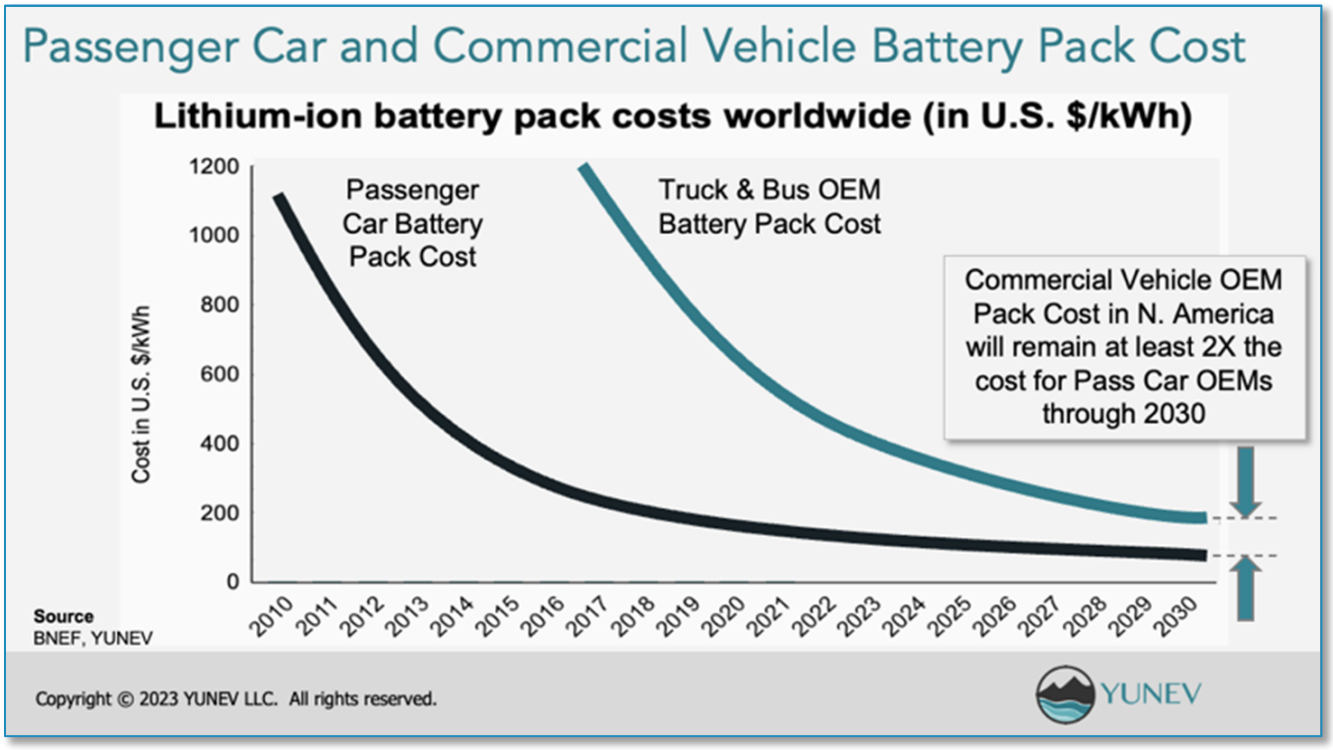
Component cost trends for HD commercial vehicles have remained stable in recent years, despite a significant number of new ZEV offerings from major OEMs and startups alike. For example, the battery portion of incremental EV cost for commercial vehicles remains in the 70% range due to early market production volumes and significant and growing demand from the passenger car industry.[27] As Figure 15 illustrates,[28] while battery pack pricing is expected to continue its downward trend, commercial vehicle OEMs will likely continue paying a premium for the next several years. As such, regulations complemented by

[27] CALSTART. 2022. *Component Costs for Zero-Emission Medium- and Heavy-Duty Commercial Vehicles*. Figure 1 - Interact Analysis, 2021. Retrieved from: *https://calstart.org/zero-emission-component-cost-study/*

[28] Private Research provided by YUNEV. August 2023.

incentives for small fleets remain critical to ensure the rapid adoption of ZEVs in line with climate targets.

Figure D-15: Battery Pack Costs Over Time



From 2010 to 2020, average costs for battery packs fell by 90%, with some variability in the past couple of years.[29] As the global EV industry expands, the battery supply chain may be stretched to keep up with strong demand. As with many sectors of the economy, bottlenecks at points in the supply chain often send ripples through the rest of the value chain, with impacts in pricing like the over 50% increase in cell price from January 2021 to March 2022 followed by a greater than 20% reduction in cell price from March through May 2023. Some continued variability in battery price is expected over the next three to five years as new battery plants come online.

[29] Benchmark Mineral Intelligence (May 2023). "Lithium Ion Battery Cell Price Assessment". Retrieved from private (but not confidential) YUNEV communication sources.

Investments in batteries, EV manufacturing, and EV charger production capacity in the U.S. and Canada have skyrocketed in the past three years, triggered in part by the Bipartisan Infrastructure Law and the Inflation Reduction Act (IRA). According to The White House Briefing Room, companies have invested a total of $85 billion since the beginning of the Biden Administration; with more than $36 billion in EV manufacturing and $48 billion in battery production.[30] According to industry observer, James Turner, the IRA investments have driven more than 60 new projects, created 37,403 jobs, and will enable production of more than 1,000 gigawatt-hours of North American battery capacity.[31] However, according to YUNEV analysis of announced EV and battery production plans in the U.S., pre- and post-IRA, less than 1% of all forecasted battery cell production capacity in North America is allocated for commercial vehicle applications.

While battery pack pricing is expected to continue its downward trend, commercial vehicle OEMs will likely continue paying a premium for the next several years. As such, regulations complemented by incentives for small fleets remain critical to ensure the rapid adoption of ZEVs in line with climate targets.

Fuel cell prices have been falling significantly over the past decade, with Ballard reporting a greater than 65% reduction in the price of fuel cell buses over the past 10 years.[32] Ballard has introduced eight generations of fuel cell technology over the past decade, with each generation reportedly reducing TCO by a third. Further cost reductions of 50%–80% are forecasted by Deloitte-Ballard[33] and McKinsey[34] as production volumes reach 150,000 vehicles per year.

Production capacities for HD vehicles and equipment are improving, and there is strong planned growth in smaller vehicles and equipment platforms like cargo vans, TRUs, and MPUs.

Most OEMs offer vehicle and equipment training to purchasers which can provide some training of the workforce. Over the past few years, CARB has allocated funding for various workforce training and development efforts, including a project in close partnership with

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[30] The White House. *FACT SHEET: President Biden's Economic Plan Drives America's Electric Vehicle Manufacturing Boom.* September 14, 2022. *https://www.whitehouse.gov/briefing-room/statements-releases/2022/09/14/fact-sheet-president-bidens-economic-plan-drives-americas-electric-vehicle-manufacturing-boom/*

[31] Charged. *EV Supply Chain Dashboard.* 2023. https://www.charged-the-book.com/na-ev-supply-chain-map

[32] Ballard. *Fuel Cell Price to Drop 70-80% as Production Volume Scales.* February 11, 2022. *https://blog.ballard.com/fuel-cell-price-drop*

[33] Ballard and Deloitte. *Fueling the Future of Mobility.* 2019. *https://info.ballard.com/deloitte-vol-1-fueling-the-future-of-mobility*

[34] Hydrogen Council and McKinsey. *Path to Hydrogen Competitiveness: A Cost Perspective.* January 20, 2020. *https://www.h2-view.com/story/new-report-from-the-hydrogen-council-says-the-cost-of-hydrogen-will-fall-sharply/* (subscription required for full access).

CEC to implement the IDEAL ZEV Workforce. This project supports large and small training and education community investments for ZEVs, charging and fueling infrastructure, and ZEV-related commercial technologies statewide, including community and employer engagement with pathways toward clean transportation jobs.

Earlier engagement between fleets and utilities is needed to prepare for the infrastructure ahead of time to establish depot charging in a timely manner. If vehicles arrive before infrastructure is ready, remedies like temporary charging and Charging-as-a-Service are a popular alternative or even semi-permanent solution for fleets.

Cost parity remains a top priority among fleets making the transition to ZE. For many vehicle types and vocations, operators are already seeing the lower total cost of ownership of ZEVs compared to conventional alternatives. However, for many smaller fleets, incentives will continue to be needed to offset higher upfront purchase prices. As new technology platforms begin to enter early market adoption, incentives can help to advance market readiness.

Industry Example

Seeing is Believing: Fresno's Zero-Emission Truck and Off-Road Vehicle Showcase and Ride + Drive

Over 500 participants attended the June 2023 Zero-Emission Truck and Off-Road Vehicle Showcase and Ride + Drive event in Fresno. The event featured vehicles and off-road equipment from 30 manufacturers and offered participants the opportunity to get behind the wheel and test drive the ZEVs—for the first time for many of the attendees. The event showcased both battery electric and hydrogen fuel cell vehicles and featured more than 50 ZE MHD trucks, including delivery vans and yard trucks, as well as refrigerated trailers, agriculture and construction equipment, charging equipment, and more.

The event also connected individuals to agencies and resources that can help advance their ZE journey. As part of the Zero-Emission Resource Fair, the local electric utility and state and local government agencies were in attendance to share information about available support to help fleets transition to ZE technology.

CARB and CALSTART will continue to host ZE Ride + Drive events across California to get trucking fleets and independent owner-operators behind the wheel of the latest trucks and equipment, ultimately encouraging cleaner transportation for cleaner air.

Priorities for Low Carbon Transportation Investments

Each year, the Strategy includes an updated assessment of projected funding needs and recommended priority investment areas for Low Carbon Transportation funds. These priorities for investment are shaped by relevant guiding legislation, such as SB 1204 and SB 1403, and also take into account the following:

- Evaluation of the updated technology and market readiness;
- Identification of areas where accelerated progress has been made and additional funding could further support technologies in reaching the market;
- Identification of areas where progress has been slower and a targeted approach to eliminating challenges could help to aid further development; and
- Additional sector-specific research, as well as conversations and feedback from industry as part of this Strategy update, including stakeholder input from public work group meetings and one-on-one discussions.

It is important to note that the levels of funding recommended do not represent the total funding necessary to support the technologies needed for fleet transformation. Rather, these amounts are guided in part by an assessment of OEM and supplier capacity for producing a meaningful number of demonstration and pilot projects during the three-year investment strategy timeframe. These recommendations are designed to ensure that State funds are focused on the technologies that need to advance in commercialization over the next three years in order to impact 2030 and 2050 outcomes while also providing benefits today. If additional resources were to become available, the transformation of the HD and off-road sectors could happen more quickly, and significantly increased funding could help spur manufacturers to increase production capacity and provide additional fleet support, training, and infrastructure.

Keep Expanding Successful Beachheads and Pathways

The beachhead markets continue to show success and have been establishing footholds in other areas. For instance, advances in ZE drayage and regional delivery have developed from the progress made with the transit bus beachhead, which continues to experience year-over-year growth. It will continue to be important that the first beachhead market successes noted here be further expanded upon.

Priorities for the on-road sector include:

- Building on the success of 'Project 800,' which secured over 800 ZE drayage truck purchase commitments, and further expanding to include additional deployments of ZE drayage trucks, transit buses, school buses, and refuse trucks;
- Continuing to support ZE transit buses, including hydrogen fuel cell buses. This includes helping to develop larger scale infrastructure, service, and component volumes to move these products closer to full market readiness;
- Continuing to support the transformation of school bus fleets to ZE; and

- Beginning to support commercial deployments of battery electric long-haul trucks.

Priorities for the off-road sector include:

- Deploying heavier applications of ZE CHE;
- Continuing to develop ZE and hybrid marine applications;
- Continuing to deploy electric power takeoff (ePTO) equipment, increasingly focused on heavier and specialty equipment;
- Continuing advancements in lighter construction and agricultural applications while supporting the development of heavier applications; and
- Innovating and supporting early advances in rail and mining equipment.

CARB will also explore ways to minimize market barriers by offering assistance for financing, insurance, and potentially infrastructure as well.

Target Promising Next Pathway Markets

Subsequent technology applications in the development pipeline need to continue to be supported and brought through the development stages to early production. Ensuring that consistent and robust funding is available will ensure that these beachhead technologies keep expanding.

Key pilot stage priorities include:

- Continuing to build out larger ZE ecosystems at the facility, corridor, and/or community level;
- Deploying more ZE construction and agriculture equipment;
- Supporting development of longer-range goods movement applications, including long-haul fuel cell trucks;
- Developing strategic range extenders for applications where ZE options are not yet feasible;
- Building on recent successes of ZE rail technology and growing industry interest; and
- In outer years, beginning to support ZE light aviation technologies.

Focus on and Expand the Innovation Pipeline

Maintaining momentum in the "innovation pipeline" for a number of early-stage technologies will be necessary for meeting State climate and air quality goals for 2030 and beyond. California companies are among the world leaders in developing advanced component and vehicle solutions, providing tangible economic and job benefits to the State. Leveraging the work and funding of those companies with Low Carbon Transportation demonstration funding can act as a powerful driver of change. This year's Strategy update includes a focus on the following technology demonstration areas:

- Advancing high power charging-capable ZE truck technologies;

- Applying ZE technologies to construction and emergency and heavy specialty equipment, including those used in mining;
- Advancing ZE marine demonstrations;
- Advancing heavier ZE CHE;
- Developing longer distance/regional ZE rail applications; and
- Applying ZE technologies to aviation.

Innovation may also involve increased coordination between CARB and other state agencies and departments toward shared goals.

Industry Example

Harmonizing Vehicle and Infrastructure Incentive Funding

The HVIP Public School Bus (PSB) Set-Aside and Energy Infrastructure Incentives for Zero-Emission (EnergIIZE) Commercial Vehicles Project pairs vehicle funding through CARB's HVIP with infrastructure funding from CEC. In FY21–22, the project awarded funding for 296 ZE school buses across 74 applicants. For FY22–23, the HVIP PSB Set-Aside and EnergIIZE Joint Application connected outreach efforts and offered participants a streamlined approach to obtain paired vehicle and infrastructure funding. In FY22–23, the HVIP and EnergIIZE teams launched the Joint Application in three distinct phases.

Joint Application Part A:

Basic Eligibility Questions

HVIP PSB Set-Aside-required vehicle information

EnergIIZE preliminary EV charging infrastructure questions

The HVIP PSB Set-Aside team reviews Joint Application Part A submissions and confirms which applicants proceed to the next step based on eligibility and priority factors designated in the HVIP Implementation Manual, Appendix G. The HVIP PSB Set-Aside gives priority to eligible applicants in DACs and low-income communities. The Joint Application Part A centers on the vehicle eligibility side, as eligible applicants must also have an eligible school bus(es) to scrap. Joint Application Part A also prepares participants to move forward with infrastructure planning in Application Part B, after applicants are notified of a tentative award.

The preliminary infrastructure questions on Application Part A allow school districts and other eligible entities to provide the EnergIIZE team with preliminary information, and allow them to begin gathering the requisite information for infrastructure planning ahead

Industry Example

Harmonizing Vehicle and Infrastructure Incentive Funding

of Application Part B. In addition, the HVIP PSB Set-Aside and EnergIIZE teams conduct outreach to eligible applicants to ensure they engage with their utility early.

Joint Application Part B:

HVIP PSB Set-Aside-required old bus documentation.

EnergIIZE-required infrastructure information.

In Joint Application Part B, eligible participants move on to the next phase—submitting documentation for additional vehicle eligibility verification and infrastructure planning. Applicants are also encouraged to begin outreach to OEMs, dealers, contractors, and vendors and begin selecting vehicles and chargers from the approved lists.

Joint Application Part C:

Vehicle Dealer(s) Selection

Spending plan: designation of vehicle and charger selections

Joint Application Part C requires participants to designate their vehicle and charger selections. Once participants make their final vehicle and charger selections, funding is allocated to participants via an HVIP voucher and an EnergIIZE Conditional Award.

As administrator of both CEC's EnergIIZE and CARB's HVIP, CALSTART will continue to work with both agencies to identify additional opportunities for synchronized funding processes, reduce administrative burden on fleets, and speed up deployments.

Focus on Small Fleet Support

Across its portfolio of investments, CARB is intentionally shifting the focus from deployments at large fleets toward helping a greater number of smaller fleets. With ACF going into effect for large on-road fleets, CARB is directing its resources to undercapitalized small fleets in greatest need of assistance to ensure equitable access to ZE technology. Small fleets are eligible for larger HVIP incentives, along with new innovative incentive options available through the Innovative Small eFleets Pilot Project. Similarly, CORE will prioritize funding for small businesses as well. Changes to program eligibility and voucher amounts will be reflected in the Funding Plan and individual program implementation manuals.

Low Carbon Transportation Three-Year Investment Recommendations

The Strategy includes a set of funding recommendations that function as a snapshot in time, incorporating a rolling three-year funding horizon. This year's update to the Strategy builds on the funding levels identified in the FY 2022–23 report, addresses FY 2024–25 and FY 2025–26, and adds a new third year, FY 2026–27. Based on the updates to the technology status snapshots and the refinements to the beachhead strategies, CARB has reevaluated and updated the projected levels of investment needed to move technologies toward meeting State goals over the new three-year funding period.

The recommended levels of funding have been developed around a central core of established priorities, as well as the updated priorities, strategies, and segment opportunities identified in the discussion above. For example, continuing to support hydrogen fuel cell technologies will be important to advancing those vehicle and equipment platforms that have the potential to considerably extend the range of operations for ZE technologies. Building on further development of ZE ecosystems helps to prove the ability of these technologies to function at the more expansive facility, corridor, or community deployment levels. While many prior demonstrations and pilots have focused on deployments in port environments, newer projects have also been conducted at railyards and distribution centers. Ongoing demonstrations of ZE rail and marine technologies are underway and show great potential for further deployment. While the application of ZE technologies in the areas of HD construction and agriculture has not advanced as rapidly as most on-road applications, they are now starting to be ready for further deployment. And finally, going forward, CARB will apply an equity overlay to all of these investments that looks at ways to target funding to small fleets, priority populations, and underserved communities.

The aggregated results of these funding projections are shown in Table D-5. The table summarizes key focus areas and frames the range of investments ideally needed each year over the course of the next three fiscal years. Both low and high funding levels are shown to suggest the range of investment needed to maintain progress. At the lower funding levels, not all of the priorities can be achieved. The higher levels represent aggressive levels of investment sufficient to drive all of the identified priorities, potentially allowing additional applications within a pathway to advance.

These recommendations focus on creating the critical technology capability and product mix needed for transformation without fully funding that transformation. As has been highlighted in prior Strategy documents and by way of input from public meetings, the need for incentives geared toward meeting California's GHG and air quality goals continues to exceed the recommended funding levels shown here.

Table D-5: Focused Recommendations for Low Carbon Transportation Investment Priorities

Category	FY 2024–25	FY 2025–26	FY 2026–27
Demos	$55–$95 Million ZE Construction and Mining Equipment, ZE Heavier CHE, ZE Line-Haul Rail, ZE Marine, ZE Aviation, High Power Charging Capable BE Trucks	$65–$100 Million ZE Construction and Mining Equipment, ZE Heavier CHE, ZE Line-Haul Rail, Emergency and Heavy Specialty Equipment, ZE Aviation, High Power Charging Capable BE Trucks	$75–$115 Million ZE Line-Haul Rail, Emergency and Heavy Specialty Equipment, ZE Heavy Aviation
Pilots	$200–$325 Million ZE Ag-Construction-Heavier CHE, ZE/Hybrid Marine, Strategic Range Extenders, ZE Facilities/ Communities/Corridors	$225–$350 Million FC Long Haul Trucks, ZE Ag-Construction-Mining-Heavier CHE, ZE/Hybrid Marine, Strategic Range Extenders, ZE Facilities/ Communities/Corridors	$250–$400 Million FC Long Haul Trucks, ZE Ag-Construction-Heavier CHE, ZE/Hybrid Marine, ZE Facilities/ Communities/Corridors, ZE Light Aviation, High Power Charging Capable BE Trucks
Commercial	$1,147–$1,164 Million ZE Drayage, BE Long Haul Trucks, ZE School/Transit, ZE Heavier CHE, ZE Switcher Rail, ZE/Hybrid Marine, Temp. Fueling, Financing and Insurance Assistance, ePTOs	$1,083–$1,112 Million ZE Drayage, BE Long Haul Trucks, ZE School/Transit, ZE Heavier CHE, ZE Switcher Rail, ZE/Hybrid Marine, Temp. Fueling, Financing and Insurance Assistance, Heavy/Specialty ePTOs	$1,354–$1,399 Million ZE Drayage, BE Long Haul Trucks, ZE School/Transit, ZE Heavier CHE, ZE Construction and Mining Equipment, ZE Switcher Rail, ZE/Hybrid Marine, Heavy/Specialty ePTOs
Total Funding	$1,402–$1,584 Million*	$1,373–$1,562 Million*	$1,679–$1,914 Million*

*The vehicle and equipment types listed in the table above are a prioritized selection of the project types that CARB would invest in, given sufficient available funds. These focus areas are identified utilizing the strategy laid out in this document. This is not an exhaustive list of technologies or applications that Low Carbon Transportation would fund, and total funding recommendations is reflective of ideal appropriations and are not limited to existing appropriations.

Conclusion

California has committed to reducing carbon emissions from every sector of the economy, laying the foundation for a more equitable and sustainable future in the face of the climate crisis and ensuring that this transformation benefits those communities that have historically been hardest hit by the ongoing use of fossil fuels. With the transportation sector accounting for roughly one-third of all domestic GHG emissions, the need to transform the sector to ZE is as urgent as ever. At the federal level, the U.S. Departments of Energy, Transportation, Housing and Urban Development, and the U.S. Environmental Protection Agency (EPA) jointly released the U.S. National Blueprint for Transportation Decarbonization, a landmark interagency framework of strategies and actions to remove all emissions from the transportation sector by 2050.[35]

In California, the path to achieve this goal has meant the complementary pursuit of both regulations and incentives. On the incentives side, the State has allocated billions of dollars across a multitude of programs, with different but complementary goals. CARB's incentives portfolio places an emphasis on technology advancement, the deployment of HD ZEVs, and turnover of the legacy fleet. These efforts to incentivize the development and market adoption of new technologies complement CARB's regulatory efforts that ensure these technologies are deployed in strategic and impactful ways that support the State's climate and low-carbon transportation goals. Incentives accelerate the transition of small fleets to ZE as well as support equitable, community-driven clean transportation approaches. Additionally, incentives promote economic growth, job training, and apprenticeship opportunities, and continue to build on successes of previous investments.

[35] *The U.S. National Blueprint for Transportation Decarbonization.* 2023. *https://www.energy.gov/sites/default/files/2023-01/the-us-national-blueprint-for-transportation-decarbonization.pdf*

Vehicle and Equipment Classification Descriptions

Airport GSE (Light) – Ground support equipment used by airports to service aircraft before departures and after landings; light refers to baggage tractors, belt loaders, cargo loaders, lavatory service equipment, passenger stairs, and smaller pushback tractors.

Airport GSE (Heavy) – Ground support equipment used by airports to service aircraft before departures and after landings; heavy refers to larger pushback tractors capable of moving aircraft over 50 tons.

Animal Husbandry – Machines used for the management and care of animals for purposes like farming, breeding, and production.

Autonomous Guided Vehicle – A self-operating vehicle programmed to move goods without human intervention.

Backhoe – Excavating machine, or digger, that has a digging shovel attached to a two-part articulated arm that can be drawn toward the equipment on which it is mounted.

Bulldozer – Motorized machine on large tires or continuous tracks fitted with a metal dozer blade on its front.

Cargo Van – Class 2b–6 cargo vans and step vans.

Coach Bus – Buses used for longer-distance service; often used for touring, intercity, and international bus service; also used for private charter for various purposes; includes double-decker buses.

Commercial Harbor Craft – Marine vessels, including passenger ferries, tugboats, towboats, and fishing boats.

Compact Track Loader/Skid Steer – Lightweight machine used primarily for digging.

Concrete Pump – A machine used to transfer liquid concrete, typically from a mixer to a construction site.

Container Handler – Material handling equipment that moves intermodal containers.

Cranes/Material Handlers (Light) – Machinery designed to lift, move, and position heavy materials and objects on construction sites; light refers to cranes/material handlers that weigh less than 35 tons.

Cranes/Material Handlers (Heavy) – Machinery designed to lift, move, and position heavy materials and objects on construction sites; light refers to cranes/material handlers that weigh more than 35 tons.

Drill Rig – Equipment utilized for drilling holes in the ground, often used in construction, mining, and geothermal projects.

Excavator (Light) – Large construction machine designed to excavate earth with its shovel to make holes, trenches, and foundations; light refers to excavators that weigh less than 14,000 pounds.

Excavator (Heavy) – Same as above; heavy refers to excavators weighing over 14,000 pounds.

Forklift (Light) – Industrial truck with rear-wheel steering used to lift and transport materials for short distances via forks/blades; light refers to forklifts with lift capacity under 7 tons.

Forklift (Heavy) – Same as above; heavy refers to forklifts with lift capacity over 7 tons.

Grader – Machinery employed to level and smooth surfaces, commonly used in road construction and maintenance.

Grinder – A machine used for cutting, grinding, or polishing materials like metal, wood, or concrete.

Harbor Crane – Dockside gantry crane found at container terminals for loading and unloading intermodal containers from container ships (e.g., container crane, container handling gantry crane, or ship-to-shore crane).

HD Long Haul – Class 8 trucks, including both sleeper cabs and day cabs, with a range of at least 300 miles.

HD Urban/Regional/Drayage – Class 7–8 day-cab tractors with a range less than 300 miles.

Load Haul Dump – Equipment used to load, haul, and dump materials in mining operations.

Locomotive – A train's power unit equipment that pulls railroad cars, coaches, and wagons but does not carry freight or passengers itself.

MD Truck – Class 3–7 trucks.

Mobile and Ground Power Units (MPU/GPU) – Fixed or mobile off-grid power units.

Paver – Machinery used in road construction to lay asphalt or concrete in a smooth and even manner.

Railcar Mover – Equipment capable of traveling on both rail tracks and roads fitted with couplers for moving railroad cars and service equipment around small yards or rail sidings.

Refuse – Class 6–8 trucks used for hauling refuse.

Roller – A heavy machine used to compact surfaces, such as soil, asphalt, or concrete, to enhance stability and smoothness.

RTG Crane – Mobile cranes built on a gantry.

School Bus – Buses used for transporting children to and from school.

Shuttle Bus – Buses used for transporting people, typically under 30 feet in length; typically privately owned, such as by airports, hotels, retirement villages, etc.; includes cutaways.

Spreader – A device for evenly distributing materials like fertilizer or asphalt across a surface.

Switcher Locomotive – A small locomotive, geared to produce high torque, used for moving railroad cars short distances within a railyard.

Telehandler – Similar to a forklift but with a telescopic cylinder/boom (e.g., telescopic handler, lull, telehandler, teleporter, reach forklift, or zoom boom).

Tractor (Light) – Low-speed, high-powered piece of equipment with large rear wheels made to pull farming implements, trailers, and other machinery; light refers to tractors with capabilities equivalent to a diesel tractor with less than 100 horsepower.

Tractor (Heavy) – Same as above; heavy refers to tractors with capabilities equivalent to a diesel tractor with horsepower equal to or greater than 100.

Transit Bus – Class 6–8 buses used for transportation within a single metropolitan region, typically 30 feet in length and above; includes articulated buses.

Trencher – Equipment designed to dig trenches in the ground, often used for laying pipes, cables, or drainage systems.

TRU – Refrigeration systems designed to refrigerate or heat perishable products that are transported in various containers, including truck vans, semi-truck trailers, shipping containers, and railcars.

Underground Specialty – Equipment designed to be used in underground environments such as mines; includes drill rigs, concrete mixers and sprayers, bolting rigs, and more.

Warehouse Tractor – A specialized vehicle for moving heavy loads within warehouses and industrial settings.

Wheel Loader (Light) – Wheeled type of tractor ordinarily utilized to organize and load loose materials; light refers to wheel loaders with a lift capacity of less than 5 tons.

Wheel Loader (Heavy) – Same as above; heavy refers to wheel loaders with a lift capacity of 5 tons or more.

Work Truck – Class 4–8 trucks designed for job sites (e.g., utility bucket trucks, concrete mixers, etc.).

Yard Truck – Semi-tractors intended to move trailers within a cargo yard, warehouse facility, nearby warehouses, an intermodal facility, a large manufacturing facility, or similar location (e.g., yard tractor, yard spotter, terminal tractor, yard dog, yard goat, yard hostler, mule, etc.).

Acronym List

ACF – Advanced Clean Fleets

ACT – Advanced Clean Trucks

Agal – Avant Garde Auto Logistics

AQIP – Air Quality Improvement Program

BE – Battery Electric

BEB – Battery Electric Bus

CAPP – Community Air Protection Program

CARB – California Air Resources Board

CEC – California Energy Commission

CHE – Cargo Handling Equipment

CORE – Clean Off-Road Equipment Voucher Incentive Project

DAC – Disadvantaged Community

EnergIIZE – Energy Infrastructure Incentives for Zero-Emission Commercial Vehicles Project

EPA – U.S. Environmental Protection Agency

ePTO – Electric Power Takeoff

ESB – Electric School Bus

EV – Electric Vehicle

FARMER – Funding Agricultural Replacement Measures for Emission Reductions

FC – Fuel Cell

FY – Fiscal Year

GHG – Greenhouse Gas

GSE – Ground Support Equipment

GVWR – Gross Vehicle Weight Rating

HD – Heavy-Duty

HVIP – Hybrid and Zero-Emission Voucher Incentive Project

ICT – Innovative Clean Transit

ICE – Internal Combustion Engine

IRA – Inflation Reduction Act

ISEF – Innovative Small E-Fleets

JETSI – Joint Electric Truck Scaling Initiative

kW – Kilowatts

LACI – Los Angeles Cleantech Incubator

MD – Medium-Duty

MHD – Medium- and Heavy-Duty

Moyer – Carl Moyer Memorial Air Quality Standards Attainment Program

MPU – Mobile Power Unit

NOx – Nitrogen Oxides

OEM – Original Equipment Manufacturer

PM – Particulate Matter

PM2.5 – Fine Particulate Matter

POLA – Port of Los Angeles

PSB – Public School Bus Set-Aside

RNG – Renewable Natural Gas

RTG – Rubber-Tired Gantry (Crane)

SB – Senate Bill

SIP – State Implementation Plan

TCO – Total Cost of Ownership

TRL – Technology Readiness Level

TRU – Transport Refrigeration Unit

VW – Volkswagen

ZANZEFF – Zero and Near-Zero Emission Freight Facility

ZE – Zero-Emission

ZET – Zero-Emission Truck

ZEV – Zero-Emission Vehicle