Appendix D:
Long-Term Heavy-Duty Investment Strategy

Including Fiscal Year 2022-23 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 "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 meet the entire amount needed to achieve the State's goals (see Table D-1 below). 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 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. More recent investments in the development and demonstration of ZE off-road vehicles and equipment have resulted in a growing list of commercial products in the off-road sectors. 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: Recommendations for Low Carbon Transportation Investment Priorities

	FY 2023-24	FY 2024-25	FY 2025-26
Demonstrations	$50-$90 Million Focus: ZE Construction Equipment, ZE Heavier Cargo Handling Equipment, ZE Line-Haul Rail, ZE Marine, ZE Aviation, High Power Charging Capable ZE Trucks	$55-$95 Million Focus: ZE Construction and Mining Equipment, ZE Heavier Cargo Handling Equipment, ZE Line-Haul Rail, ZE Marine, ZE Aviation	$65-$100 Million Focus: ZE Construction and Mining Equipment, ZE Heavier Cargo Handling Equipment, ZE Line-Haul Rail
Pilots	$175-$300 Million Focus: ZE Ag-Construction-Heavier Cargo Handling Equipment, ZE/Hybrid Marine, Strategic Range Extenders, ZE Facilities/ Communities/Corridors	$200-$325 Million Focus: ZE Ag-Construction-Heavier Cargo Handling Equipment, ZE/Hybrid Marine, Strategic Range Extenders, ZE Facilities/ Communities/Corridors	$225-$350 Million Focus: ZE Longer Range Trucking, ZE Ag-Construction-Heavier Cargo Handling Equipment, ZE/Hybrid Marine, Strategic Range Extenders, ZE Facilities/ Communities/Corridors, ZE Aviation
Commercial	$1,210-$1,815 Million Focus: ZE Drayage, ZE Long-Haul Trucks, ZE Transit, ZE Heavier Cargo Handling Equipment, ZE/Hybrid Marine, ZE Switcher Rail, ePTOs, ZE Work Trucks, ZE Small Fleets	$1,210-$1,815 Million Focus: ZE Drayage, ZE Long Haul Trucks, ZE Transit, ZE Heavier Cargo Handling Equipment, ZE Switcher Rail, ZE/Hybrid Marine, ePTOs	$1,460-$2,170 Million Focus: ZE Drayage, ZE Long Haul Trucks, ZE Transit, ZE Heavier Cargo Handling Equipment, ZE Switcher Rail, ZE/Hybrid Marine, ePTOs
Total Funding	$1,435-$2,205 Million*	$1,465-$2,235 Million*	$1,750-$2,620 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.

Introduction

California has invested over $2 billion to date with the goal of accelerating the transformation away from combustion technologies. In just the past few years, the amount of funding dedicated to incentivizing the transformation of the HD and off-road sectors has been steadily increasing.

This year, the Governor's proposed State budget for fiscal year (FY) 2022-23 includes the strongest support ever for the ZE transformation. The proposal includes $6.1 billion over five years to accelerate the State's transition to ZEVs and make them more affordable, especially in underserved communities. The ZEV package builds on last year's $3.9 billion over three years ($1.8 billion in 2021-22), for a total of $10 billion. This is applied across a wide variety of sectors including medium- and heavy-duty (MHD) trucks, light-duty, maritime, aviation, rail, and other off-road applications, as well as infrastructure. These investments will focus on an equitable ZEV transition by continuing to support priority populations.

California continues to address challenges in 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 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 trucks 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 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 the State's HD fleet to ZE technologies and prioritizing investments in underserved areas that have long born the greatest burdens from the legacy HD 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 combination 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 continued support for previous Low Carbon Transportation and AQIP investments; focusing those investments across ZE capable technologies; and utilizing

the beachhead strategy[1] 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 emissions 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 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 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 Truck (ACT) regulation, to the Innovative Clean Transit (ICT) regulation, to 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 and off-road sectors.

This year's Strategy expands on CARB's principles of investment—supporting targeted advanced technologies across the commercialization path—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—graduating and 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 sixth 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

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

2019-20, along with Three-Year Recommendations for Low Carbon Transportation Investments, appearing in this document as Table D-1 and Table D-3. The intention of the Strategy is to:

- 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 the 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 HD Investments

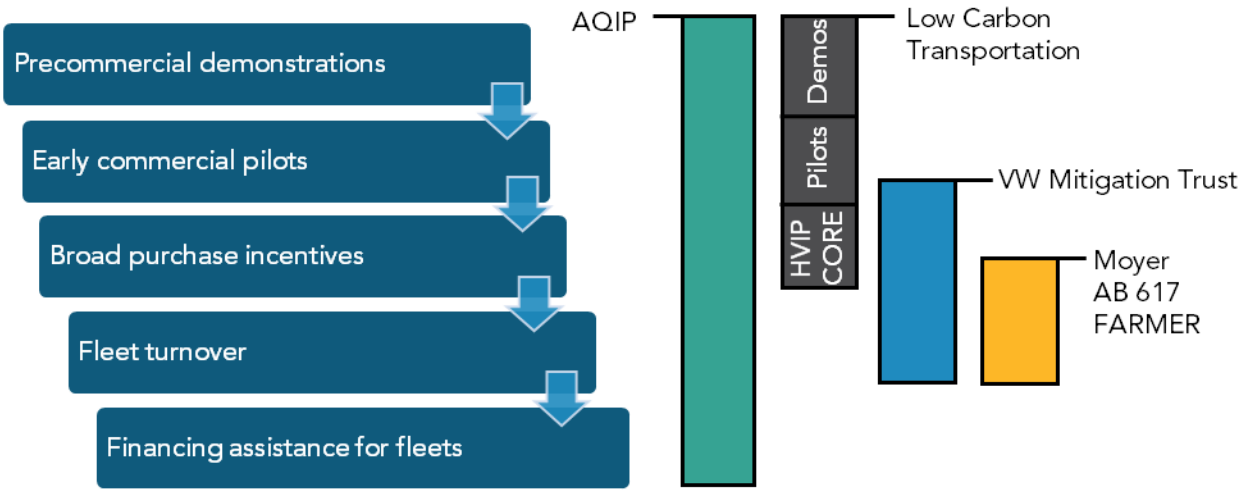
California is allocating billions of dollars annually to a multitude of programs, with different but complementary goals, in its ongoing effort to reduce criteria and climate pollutant emissions from the transportation sector. CARB's portfolio emphasizes technology advancement, the deployment of HD ZEVs, turning over the legacy fleet, and ensuring that investments are equitably distributed. 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. 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-1 below 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 unable to qualify for conventional financing. It should be expected that technologies will eventually "graduate" or progress to the next program in the

funding succession, or 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 and achieved a high enough level of commercialization and acceptance in the market to warrant a graduation from technology advancement incentives.

Figure D-1: Funding Succession



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. Infrastructure investments by CEC, transportation agencies and utilities, as a key example, are critical to supporting ZE trucks, buses, and off-road equipment.

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

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. 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.

Low Carbon Transportation and AQIP Specific Investment Strategy

With each annual update of this Strategy, CARB continues to refine the strategy 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-24).

This approach has demonstrated success to date: in the six years since the first Strategy was published, growth in the advanced technology HD industry has accelerated, including a continued increase in Hybrid and Zero-Emission Voucher Incentive Project (HVIP) voucher requests, 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	Allow California the ability to set its own more stringent air quality standards.
Assembly Bill 32	2006	Reduce GHG emissions to 1990 levels by 2020 (Núñez, Chapter 488, Statutes of 2006).
Executive Order B-16-2012	2012	Reduce petroleum use in vehicles by 50 percent by 2030 and reduce GHG emissions from the transportation sector to 80 percent 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 percent below 1990 levels by 2030 (Pavley, Chapter 249, Statutes of 2016).
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	CARB 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 expanding 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 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 2016 Mobile Source Strategy noted that HD trucks with a gross vehicle weight rating (GVWR) of more than 8,500 pounds[2] were the fastest growing transportation sector in the United States, are responsible for about 33 percent of the total statewide nitrogen oxide (NOx) emissions and approximately 25 percent of the total statewide diesel PM emissions, and are a significant source of GHG emissions. The 2020 Mobile Source Strategy takes an integrated planning approach to identifying the level of transition to cleaner mobile source technologies needed to achieve

[2] For the purposes of this document, this investment 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.

California's many targets through 2050.[3] 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 percent 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.[4] 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 percent of the MHD vehicle fleet to ZE by 2045 everywhere feasible. Together these strategies are designed to bring about progressively cleaner in-use fleet 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, costs continue to fall and market adoption increases.

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[3] CARB. 2020 Mobile Source Strategy.

https://ww2.arb.ca.gov/resources/documents/2020-mobile-source-strategy

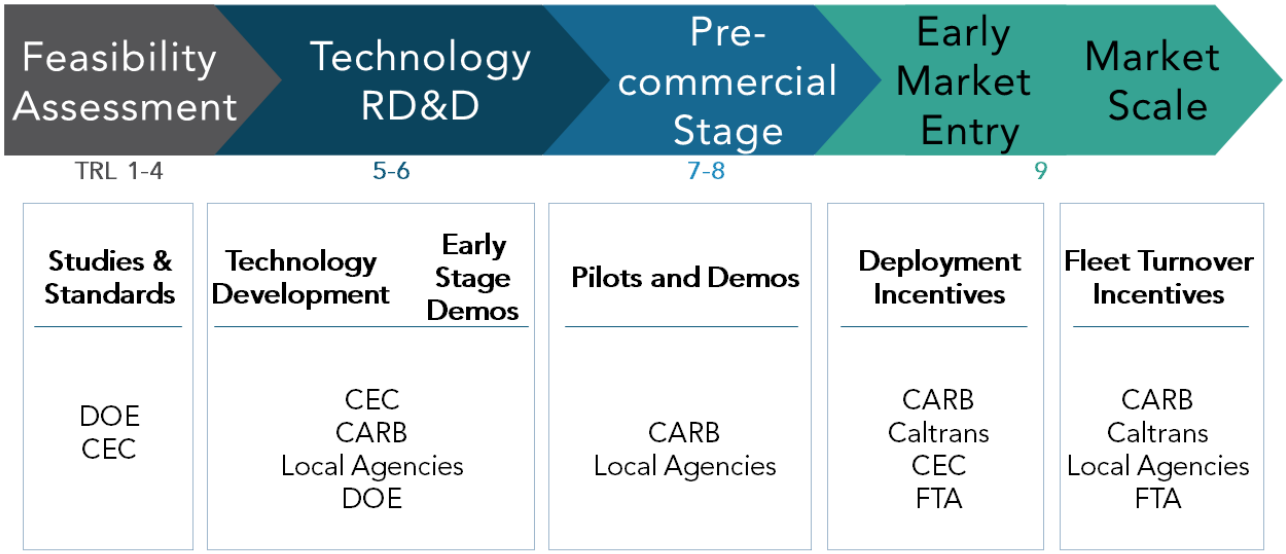
[4] California Sustainable Freight Action Plan. July 2016.

https://ww2.arb.ca.gov/sites/default/files/2019-10/CSFAP_FINAL_07272016.pdf

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, or across all technology readiness levels (TRLs), at the federal, state, and local levels.[5] 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 prototypes or small volume vehicle 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

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

demonstrating that the technology can meet specific user needs. Demonstration projects 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 building 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.

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 recommended levels of incentive funding, this document also includes metrics to help assess the performance of Low Carbon Transportation projects, 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.

Metrics are summarized into three categories: Supporting Healthy Communities, Building 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.

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. In previous years, metrics have focused exclusively on HVIP, but many of this year's metrics include data from the CORE as well. CORE was closed to new voucher requests from August 2020 to July 2022, but program metrics have been updated where possible with data through June 2022. As additional project data becomes available from CARB's demonstration and pilot projects, the metrics will be further refined and expanded in future years.

345
MILLION

MILES TRAVELED

There were 345,000,000 cleaner-than-diesel miles traveled in California by HVIP-funded vehicles between 2010 and 2022.

465+
THOUSAND

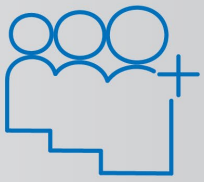
EQUIPMENT RUNTIME

CORE-funded zero-emission off-road equipment has been used for 465,261 hours in California between 2020 and 2022.

15+
THOUSAND

JOBS CREATED

The incentive dollars spent through HVIP have created nearly 3,500 jobs and spurred ~12,000 jobs from private investment, totaling nearly 15,500 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.

Other public health metrics CARB considered include health risk assessments and exposure studies. Health risk assessments, while a measure of the potential health benefits of displacing conventional technologies, would not capture impacts from many existing demonstration and pilot deployments, which are definitionally limited in size. Exposure studies for vehicle and equipment operators, while likely valuable in demonstrating near-source exposure improvements, are currently not conducted as part of Low Carbon Transportation data collection.

56
PERCENT

DAC VOUCHERS

Fifty-six percent of vouchers (HVIP and CORE combined) have funded vehicles and equipment deployed in DACs, as identified in CalEnvironScreen 3.0.

174
MILLION

DAC MILES TRAVELED

HVIP-funded vehicles have traveled approximately 174 million miles in DACs, as identified in CalEnvironScreen 3.0.

41
PERCENT

SMALL AND PUBLIC FLEET SUPPORT

Forty-one percent of 2022 HVIP vouchers were given to public or small fleets (private entities with <$10 million annual revenue or fewer than 50 employees).

Industry Examples
ZE Trucks Deliver for Drivers Too

HD trucks powered with internal combustion engines pollute the communities in which they operate with carcinogens, GHGs, and noise. But the drivers of those trucks are closest to the source. Truck engines expose drivers and others working in or around the vehicle to harmful levels of noise. Studies have found noise exposure, like inside a truck cab, leads to reduced job performance, hypertension and cardiovascular disease, fatigue, and hearing loss.[6] In addition, the constant rumble of the engine exposes drivers to whole body vibration, associated with deteriorated psychomotor performance and increased fatigue.[7]

Pat, a driver with Napa-based trucking company Biagi Bros., immediately noticed the improved comfort of operating a ZE truck. "It's quiet. I can hear everything in this," he said pointing out the added comfort and safety behind the wheel of a battery electric truck. Biagi operates its Peterbilt 579EV in the Napa and Sonoma Valleys, largely on country roads and through small towns. Pat loves driving the truck, in part because the reduced noise is appreciated by others around it. The electric truck is not just making his job easier, he feels good about it, too. "What a great feeling to know you're not polluting," he said, "that you're doing something for the future."

Biagi recently began using a Nikola Tre hydrogen fuel cell electric truck, giving more drivers the chance to benefit from the comfort and safety of ZE trucking.

[6] Basner M, Babisch W, Davis A, Brink M, Clark C, Janssen S, Stansfeld S. Auditory and non-auditory effects of noise on health. Lancet. 2014 Apr 12;383(9925):1325-1332. doi: 10.1016/S0140-6736(13)61613-X. Epub 2013 Oct 30. PMID: 24183105

[7] Troxel WM, Helmus TC, Tsang F, Price CC. Evaluating the Impact of Whole-Body Vibration (WBV) on Fatigue and the Implications for Driver Safety. Rand Health Q. 2016 May 9;5(4):6. PMID: 28083416.

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 supporting a nascent and valuable industry.

Current Metrics

- Model availability is expanding rapidly, becoming even more widespread across manufacturers and applications ready to meet fleet demand, as evidenced by the growing number of HVIP- or CORE-eligible models from a growing number of manufacturers.
- Leveraging of incentive dollars with private investment and complementary public spending to support the commercial viability of advanced technology, by tracking the total purchase price and co-funding on HVIP- and CORE-funded vehicles and equipment.
- 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 67 current HVIP- and/or CORE-eligible manufacturers, 12 have California manufacturing locations and another 13 have other California-based administrative or operational locations.

  In the future, CARB plans to track and report on the amount of HVIP and CORE incentives that have gone to the entities with in-state manufacturing locations.

$900+ MILLION

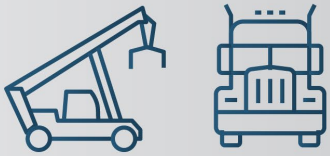
VEHICLE PURCHASE

HVIP and CORE have funded $904+ million toward the purchase of nearly 11,617 clean vehicles and equipment since 2010.

320 MODELS

MANUFACTURERS

There are 67 HVIP- and/or CORE -eligible manufacturers offering 321 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.

Supporting Technology Evolution

Currently available technologies will not be sufficient to meet CARB's long-term air quality and climate change goals. Therefore, investments should spur the development, improvement, and commercialization of additional advanced technologies in more market sectors for the future. Technology evolution continues to be a direct goal or ancillary outcome 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 graduation, which will be directly related to the pathway and progress of technology evolution. Defining and quantifying metrics that signal when technologies graduate, move on to other incentive programs, or can stand on their own, will require an empirical approach to monitoring technology evolution. Further information on technology graduation can be found on page D-6.

Current Metrics

CARB is collecting observations that technologies from one application are being transferred to and used in others—a phenomenon being accelerated by CARB investments and an example of CARB's beachhead theory of technology transfer, as further discussed on page D-24.

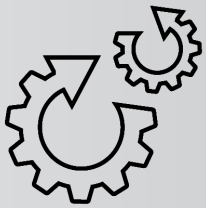
New Metrics

- Four new categories of ZEVs or ZE equipment were eligible for vouchers for the first time this past year, including Class 2b on-road vehicles, agricultural tractors, construction equipment, and CHE.
- Survey data is valuable for discovering attitudes and perceptions of new vehicle technology and providing valuable feedback from first deployers. HVIP has expanded its survey questions to now collect data on vehicle acceptance and behavior change. 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. Three-quarters of HVIP-survey respondents indicated that they plan to purchase additional MHD ZEVs within the next five years. CARB will also work to improve survey response rates as future annual surveys are conducted.

4
TYPES

NEW TECHNOLOGY

Four new categories of zero-emission vehicles/equipment were eligible for vouchers for the first time this past year.



75
PERCENT

FUTURE ZEV PURCHASES

Seventy-five 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 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.

Industry Examples
California CORE Expands to Offer New Equipment Types and Models

After a one-year hiatus due to less available funding throughout the pandemic, California's CORE Voucher Incentive Project opened its second round on July 18, 2022, with $125 million, tripling the amount of allocated funding from the previous round for equipment used in agriculture, airport, railyard, port, construction, and marine operations.[8] Demonstrating the growing excitement around ZE off-road equipment, all available funding was fully requested that day.

CORE funding supports nine categories of ZE equipment, including:

- On- and off-road terminal tractors
- Truck- and trailer-mounted TRUs
- Large forklifts and cargo-handling equipment
- Airport ground-support equipment
- Railcar movers and switcher locomotives
- Mobile power units (MPUs) and mobile shore-power cable management systems
- Construction equipment
- Agricultural equipment
- Commercial harbor craft

Since its first tranche of funding in 2020, CORE has added 100 new models to its equipment catalog, offered by more than 60 new dealers.

[8] For additional information on California's CORE Voucher Incentive Project, see https://californiacore.org/.

Beachhead Strategy

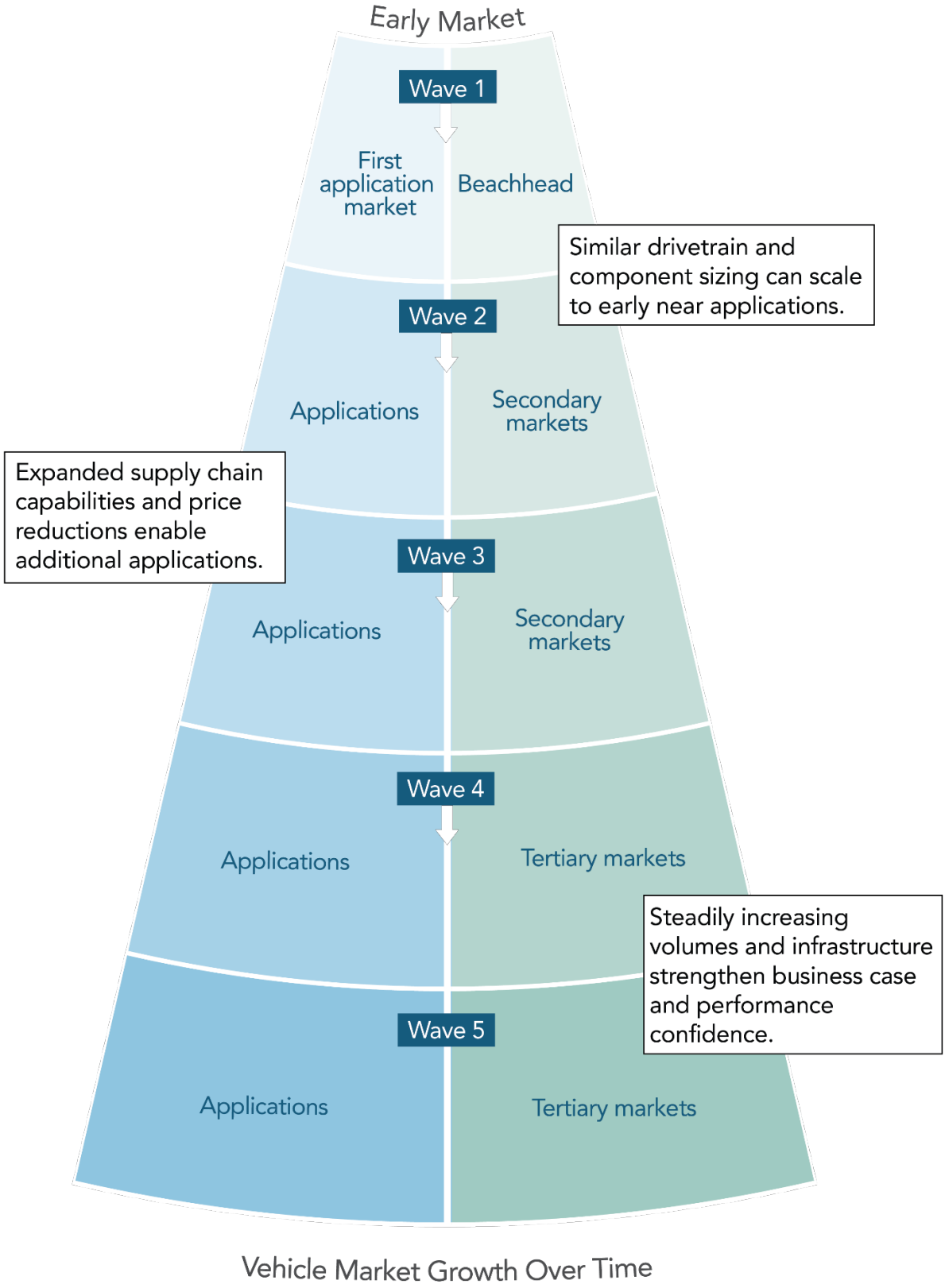
In 2017, CARB developed a visual representation of its focused strategy for technology commercialization based on targeting its investments on strategic "beachheads," or first-success applications, and on the pathways for additional markets or work applications that extend from them.[9] These beachheads 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 leveraging 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.

[9] 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 cost 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 MHD 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 recognized by 16 national governments, including Austria, Canada, Chile, Denmark, Finland, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Scotland, Switzerland, Turkey, the United Kingdom, Uruguay, and Wales.

The Global Commercial Vehicle Drive to Zero ("Drive to Zero") campaign uses the beachhead model as a foundational principle for commercial ZEV proliferation. 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 recognized by 16 national governments, including Austria, Canada, Chile, Denmark, Finland, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Scotland, Switzerland, Turkey, the United Kingdom, Uruguay, and Wales.

The beachhead strategy defines CARB's approach to driving 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.[10]

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

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

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.

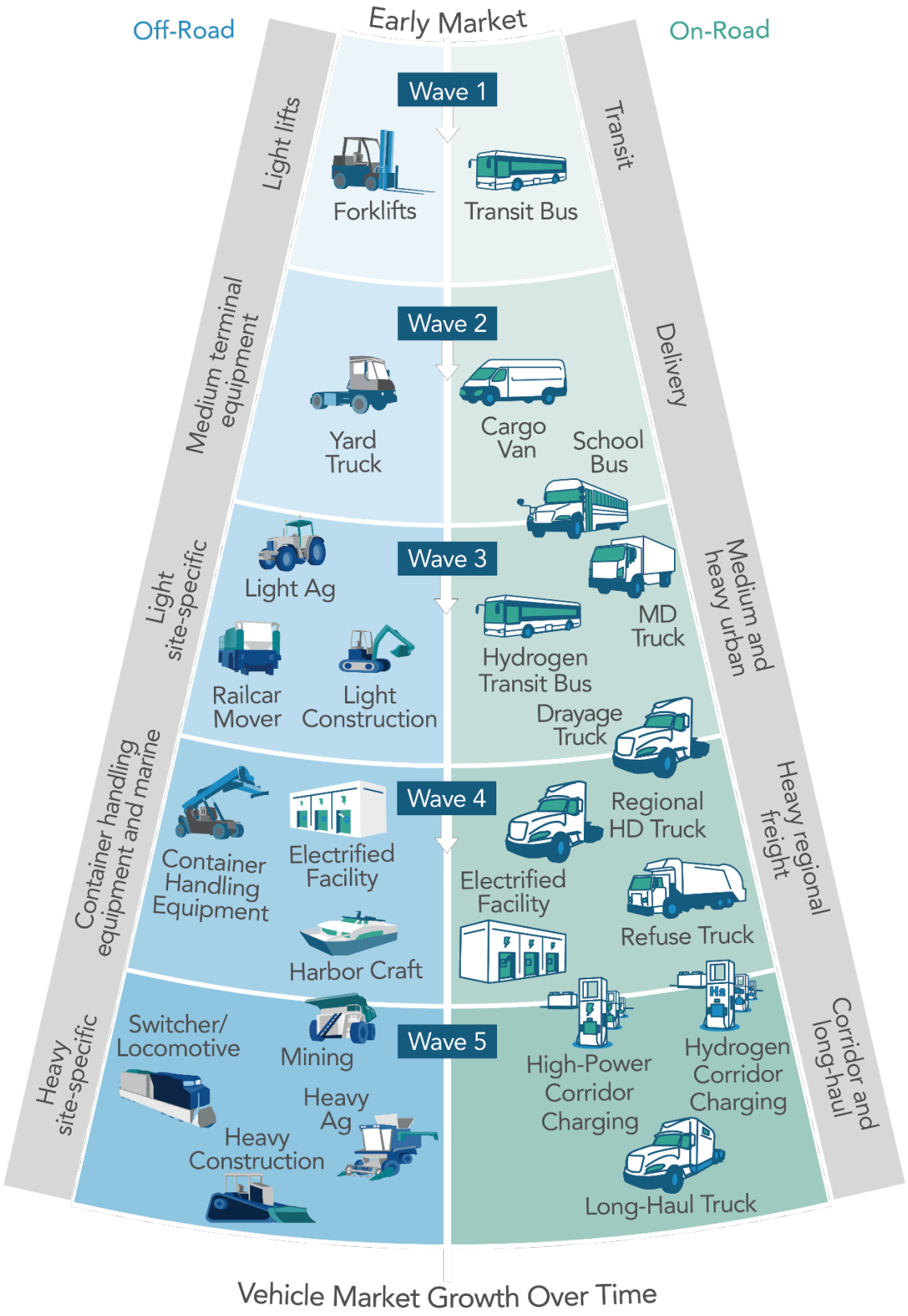
In recognition of the dynamic nature of markets and technology, they remain "works in progress" and are updated and modified as needed to adapt to changing conditions. CARB staff, via workgroup and other industry and stakeholder interactions, initially solicited comments and feedback on these beachheads in 2019 to identify areas where there may be additional leverage to support expanded deployment or areas of technology success. Additionally, last year CARB gave renewed focus to the off-road sector. With a rapidly developing segment poised for further CARB investments, to the Strategy highlighted where the on-road and off-road points of connection might be for certain technologies, identifying where technology transfer might assist faster off-road technology adoption.

ZE Beachhead

The most powerful beachhead process to date has been built around the ZE pathway, as illustrated in Figure D-4. [11] It is centered on the first-success application of the ZE 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, 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.

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

Figure D-4: The ZE 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 MHD 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 capacity and 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.[12] Similarly, fuel cell electric powertrains are emerging as a potential market entrant for heavy weight, duration, and longer distance applications by 2023, with early commercial deployments operating successfully in on-road and off-road applications.

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

Fuel cell electric trucks are being developed by an increasing number of major manufacturers and partnerships including Hyzon, Hyundai, Hino (in partnership with Toyota), Kenworth (in partnership with Toyota), Navistar (in partnership with GM), and Nikola. 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.

Industry Examples
Rapid Transit Bus Electrification

Leading the way and setting an example for other California transit agencies, the Antelope Valley Transit Authority (AVTA) in Los Angeles County this past year became the first transit agency in the U.S. to electrify its entire fleet of 87 buses. AVTA achieved fully electric service 18 years ahead of the State deadline set forth under California's ICT regulation. "Projects like this require a lot of coordination and work and leadership. It's absolutely 100 percent doable, and it will become routine over time," said Liane Randolph, CARB Chair.[13]

AVTA's electrification project, which kicked off in 2014, relied on the Transit and Intercity Rail Capital Program and over 70 HVIP vouchers, in addition to funding from various federal and local sources and the agency's capital reserve. AVTA now operates the electric buses at approximately half the cost of comparable diesel buses, even before considering Low Carbon Fuel Standard (LCFS) credits. Including LCFS, the agency is able to more than cover the cost of electricity, thereby getting paid for each electric mile driven and insulating itself from the risk of volatile fuel prices.

As of August 2022, California transit agencies have ordered or deployed over 930 ZE transit buses (Class 4-8 buses).[14] Of these, approximately 87 percent are battery

[13] Spector, Julian. How one California transit agency electrified its fleet 18 years ahead of schedule, Canary Media. March 22, 2022. https://www.canarymedia.com/articles/clean-fleets/how-one-california-transit-agency-electrified-its-fleet-18-years-ahead-of-schedule

[14] California Air Resources Board. Innovative Clean Transit Reporting Tool. September 2022. https://ww2.arb.ca.gov/our-work/programs/innovative-clean-transit/reporting-tool-data

electric, while the remaining 13 percent are hydrogen fuel cell electric buses. Rollout Plans submitted to CARB pursuant to ICT show increasing interest in fuel cell electric options with some agencies choosing to comprise their future fleets of mostly fuel cell electric buses.

Momentum for ZE buses is expected to increase with the wide availability of funding. For example, federal funding for ZE transit buses has dramatically increased under the Infrastructure Investment and Jobs Act passed by Congress in 2021. A key funding provision was a significant increase to the Low and No Emission Grant Program (Low-No). This program, previously funded at a level of $55 million annually, has gradually increased to over $1 billion annually in 2022. This influx of money made federal opportunities very attractive and much more attainable than in previous years.

In addition to federal funding developments, CARB is always considering ways to improve Low Carbon Transportation Investments to help fleets leverage federal funds to increase the impact of State funds. For example, certain HVIP program adjustments, fleet ZE transition planning, and workforce development programs can more rapidly and economically aid the transition of the State's transit agencies in order to meet the deadlines set forth under the State's ICT rule. Allowing flexibility with HVIP vouchers to be temporarily committed without a purchase order could allow HVIP to be counted as a "local match" requirement under a program such as Low-No, which does not allow for reimbursements of anything purchased prior to award. This could multiply the effectiveness of California dollars within the State. CARB will consider such program adjustments going forward.

Off-road ZE technologies leverage the expansion of drivetrain technologies, operating times and distances. Industrial lifts have been an important market for ZE technologies such as battery electric and fuel cell electric systems. Fuel cell electric systems from the industrial lift application are becoming an asset for extended range and extended operation capabilities in on-road trucks and HD off-road equipment. Such systems are in the demonstration phases.[15] 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 sight-specific agricultural, rail, and construction applications;
- 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.

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

As important, though, is the technology transfer of HD components between the on-road sector and segments of 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 here include wheel loaders and heavy lifts. Technology transfer has also been accomplished by utilizing ZE truck components for ZE 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 phased timing of infrastructure deployments, supporting policies, incentives, and development of funding and use regulations based on this steady expansion and progression. Rapid growth in ZE trucks is expected due in part to the 2020 adoption of CARB's ACT regulation. The new regulation will require large manufacturers to sell qualifying ZEVs as a percentage of their total vehicle sales starting in 2024. Additionally, 17 U.S. states (accounting for more than 30 percent of the U.S. commercial vehicle market), DC, and Quebec signed a 2020 memorandum of understanding to accelerate the adoption of commercial ZEVs aligned with ACT market penetration goals. Massachusetts, New Jersey, New York, Oregon, and Washington have now adopted ACT as well, and Colorado, Vermont, and Maine 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 enable heavier truck applications by reducing costs and 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 NGO partners and align policy and investment decisions. Working backwards from an end state defined by a complete market transformation to MHD ZEVs, CARB's investment priorities outlined in this document draw from strategies like CALSTART's six-stage Drive to Zero roadmap.[16,17]

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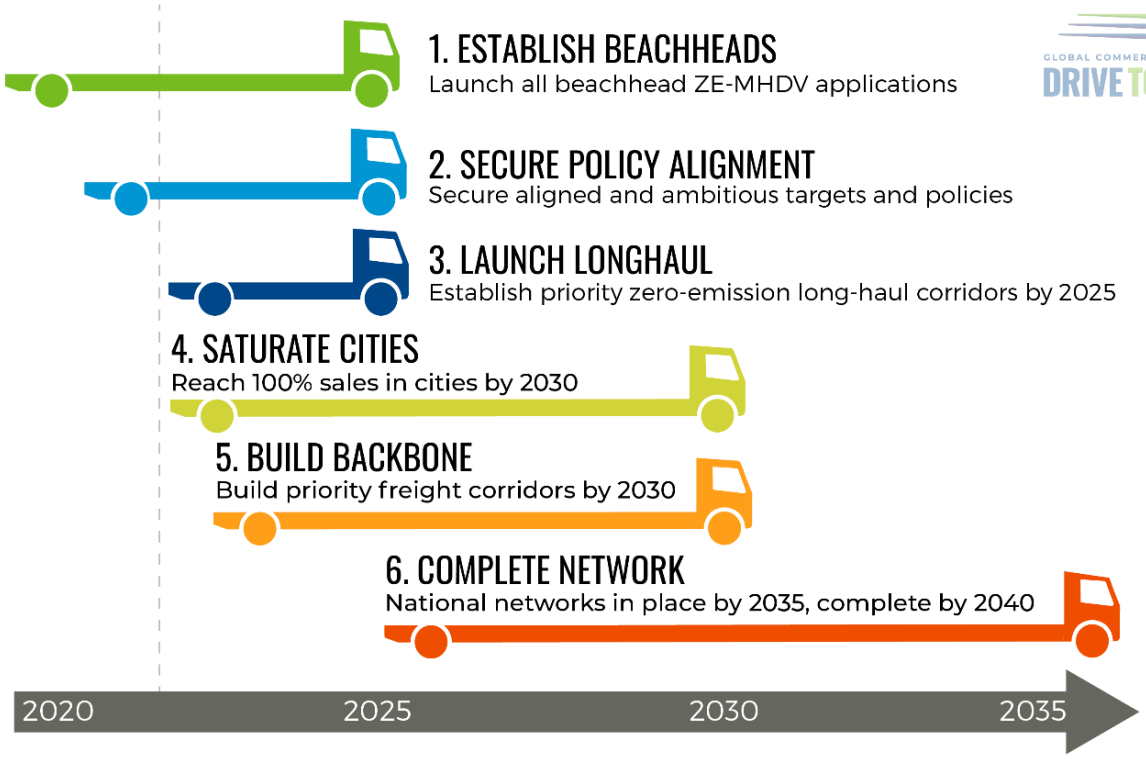
[16] For additional information on the Global Roadmap for Reaching 100% Zero-Emission Medium- And Heavy-Duty Vehicles by 2040, see https://globaldrivetozero.org/publication/global-roadmap-for-reaching-100-zero-emission-medium-and-heavy-duty-vehicles-by-2040/

[17] Global Roadmap for Reaching 100% Zero-Emission Medium- and Heavy-Duty Vehicles by 2040. June 2022. https://globaldrivetozero.org/publication/global-roadmap-for-reaching-100-zero-emission-medium-and-heavy-duty-vehicles-by-2040/

Figure D-5: Six-Stage Strategy to Enable 100% MHD ZEVs



Technology Status Updates

Monitoring the status of key technologies is imperative to maintain the effectiveness of the investment strategy and track progress against set goals. With input from grantees and from 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 further assist technologies moving more slowly or facing additional challenges.

As in 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 of the technology as it pertains to MHD 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.[18]

For consistency and to track progress, these updated assessments build on the assessments presented in the previous Strategy documents and adjust them for changes in the intervening year. While these assessments were originally built from technology assessments conducted by CARB staff over previous years[19] (in conjunction with staff from other agencies and industry stakeholders), the updates 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 the Low Carbon Transportation projects as laid out and planned for in this document.

With input from stakeholders, CARB conducts an annual high-level technology snapshot review to assess the generalized status and progress of key pathway technologies and representative platforms using each technology, providing directional guidance on technology readiness for the market.

Fundamentally, Low Carbon Transportation is tasked with GHG reductions through strategic investments in technologies that provide GHG and other co-benefits. 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 work site rules, unique duty cycles, and infrastructure costs. 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.

These technology status "snapshots" are also unique in their design. They are broadly guided by the general framework of TRLs, or technology readiness levels.[20] However, the approach used in these assessments is an adaptation of the TRL process that is applied not to a component but to a full vehicle platform. Therefore, the technology

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

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

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

readiness portrayed is not intended to be absolute, but rather directional, to provide information on where pathway technologies generally reside and what supporting tools or funding could then benefit them.

The charted location of each platform or technology listed is not representative of any one specific product or vehicle, but is an aggregated average status based on the multiple platforms, vehicles and manufacturers, and the 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. 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. 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 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 to last year's plan have been incorporated into the technology status charts that follow.

- As part of this year's update, with the statewide focus now on ZE technologies, consistent with the Governor's Executive Order (N-79-20) and the recent adoption of new regulations (ICT, ACT, ZE shuttles, and development of Advanced Clean Fleets), CARB's focus for the Long-Term Heavy-Duty Investment Strategy remains on ZE and ZE enabling technologies for Low Carbon Transportation investments. Therefore, CARB is no longer including a separate combustion beachhead. Fleets and equipment operators choosing to invest in combustion technologies may be able to access available funding from other programs within CARB's larger incentives portfolio.
- Technology readiness categories have been expanded to reflect the growing diversity of on-road vehicles and off-road equipment. Categories such as coach buses and work trucks have been added to on-road technology snapshots, while additional construction, cargo-handling, and agricultural equipment platforms have been added to off-road technology snapshots.

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 graduation to more appropriate or alternative incentive strategies. See the Market Readiness section on page D-45 for further discussion.

Some of the progress noted is very solid year-over-year and is one signal of the early success of the investment strategy, particularly in areas where pilot and demonstration funding has helped validate vehicle designs.

Battery Electric Vehicles Technology Status Snapshot

Battery electric vehicle (BEV) technologies and key platforms are a critical element of the ZE pathway. They have improved continually in technology readiness in the past several years across most of the platforms assessed. Many on-road BEV technologies are beginning to reach TRL 8-9, signifying early or mature commercial readiness, and therefore will begin to be assessed in terms of market readiness indicators. Off-road BEV technologies are more diverse in their technology readiness, with many lighter duty applications being technologically ready and many HD applications still in the demonstration and pilot stages. Figure D-6 through Figure D-9 depict the progress made across several on- and off-road BEV 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 manufacturers and several new innovators are now in active sales and product development stages. Several large OEMs have begun production: Kenworth and Peterbilt have begun deliveries of their HD truck models to early customers and have plans to increase production. Altogether, there are 14 OEMs producing HD truck models and close to 100 Class 7 and 8 HD trucks that have been deployed in the U.S. as of Q1 2022.[21,22]In the latest round of HVIP funding, which opened in March 2022, 775 vouchers were approved for battery electric HD trucks, mostly for use in urban, regional, and drayage applications. In 2021, Project 800 was launched to help jump-start the ZE drayage truck market by supporting the purchase of 800 drayage truck orders in California. While we have now surpassed the original goal of 800 truck orders, transitioning drayage trucks to ZE remains an important priority, supporting Executive Order N-79-20 and providing benefits in California's priority populations.

Similarly, battery electric school buses have expanded their market size and technological viability, reaching 1,738 total deployments, awards, and orders as of September 2021. School buses will be assessed in the following Market Readiness section.

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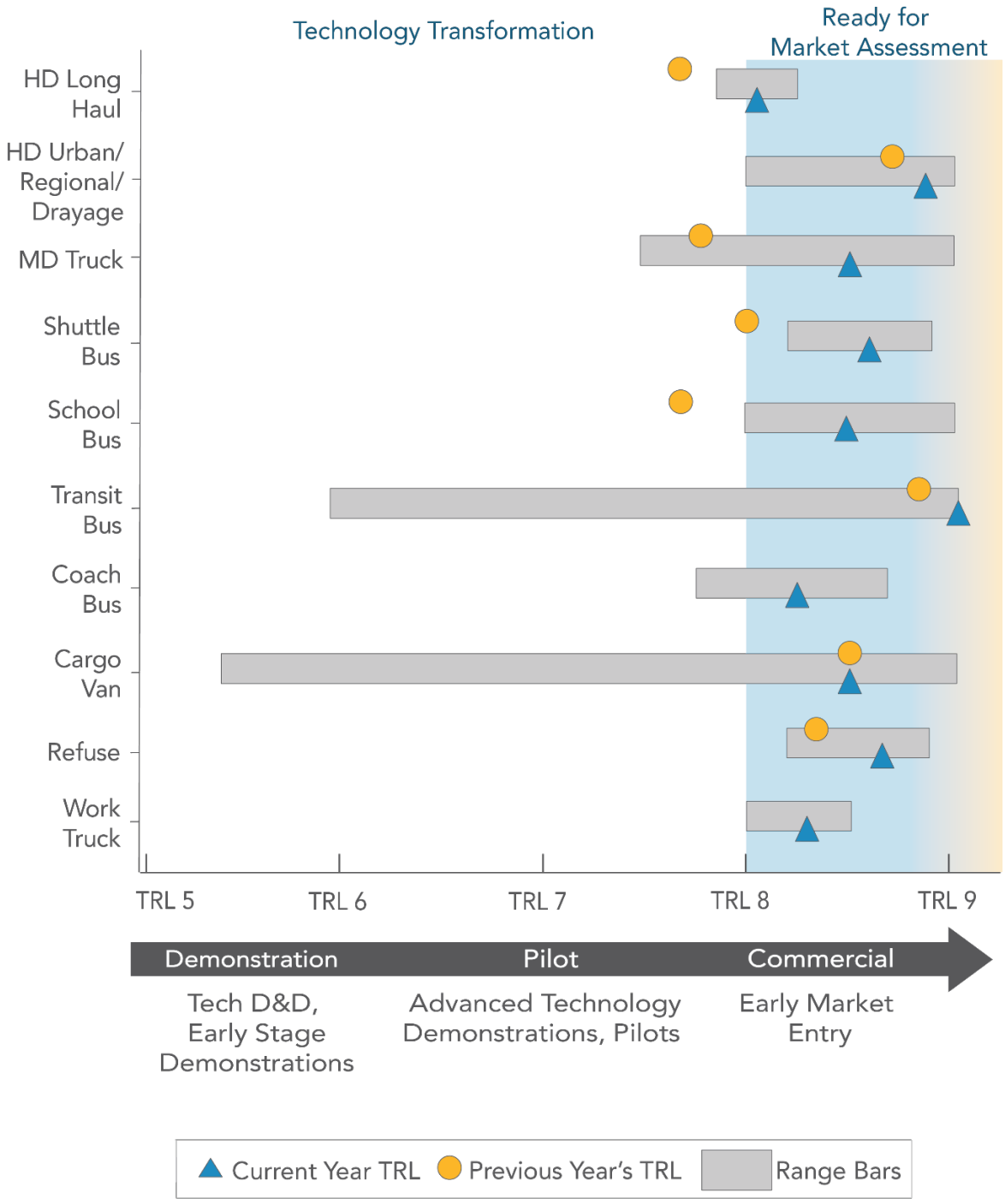
[21] Global Drive To Zero. Zero-Emission Technology Inventory. July 12, 2022. https://globaldrivetozero.org/tools/zero-emission-technology-inventory/

[22] CALSTART. Zeroing in on ZETs – June 2022 Market Update. July 21, 2022. https://calstart.org/zio-zets-june-2022-market-update/

Figure D-6: On-Road BEVs Technology Status Snapshot [23]



[23] Range bars are present for each technology platform where there is variation in TRL scores. Where TRL scores are consistent across all models, no range bar was included.

Figure D-7: Off-Road BEVs Technology Status Snapshot – CHE

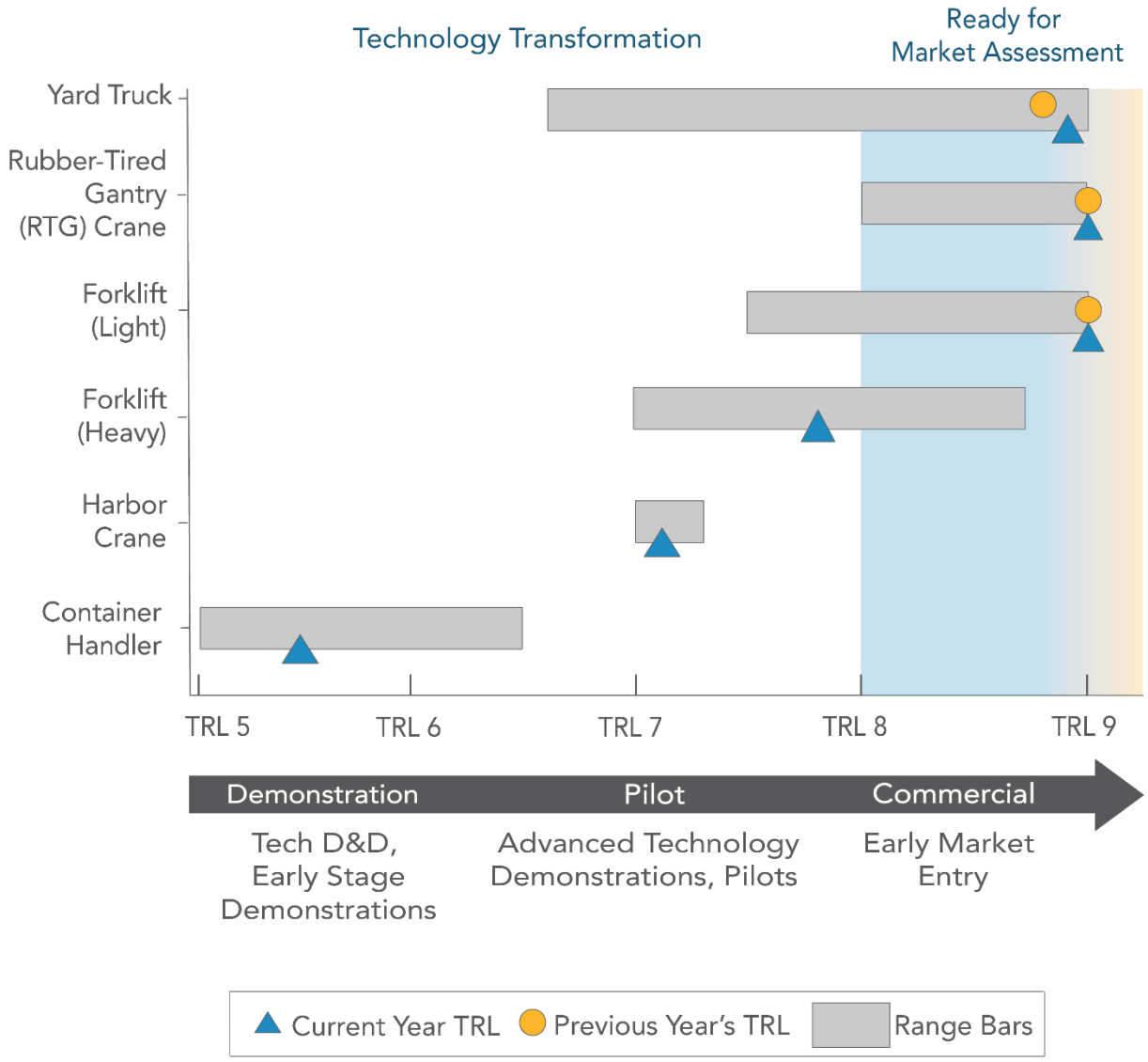


Figure D-8: Off-Road BEVs Technology Status Snapshot – Construction

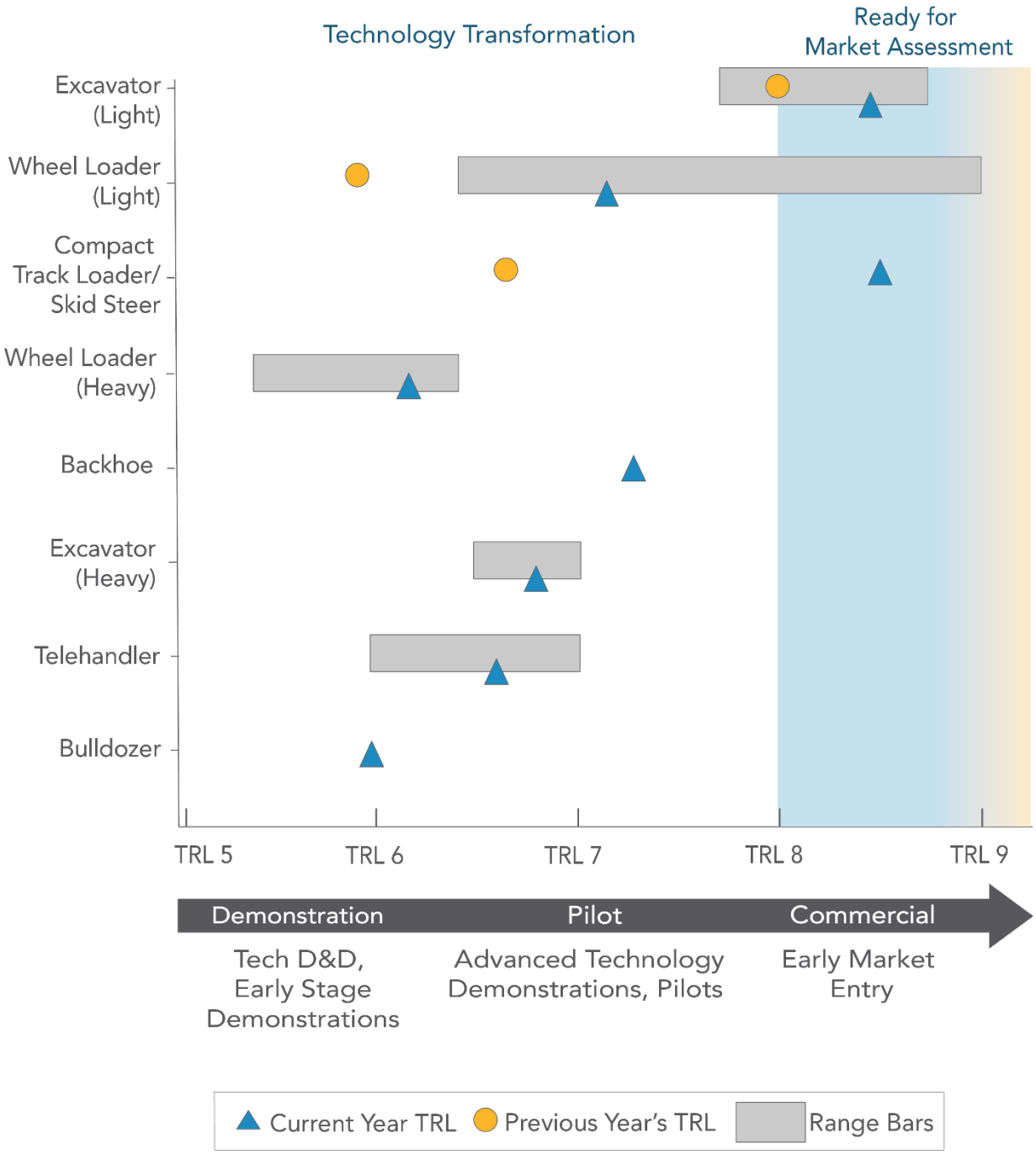
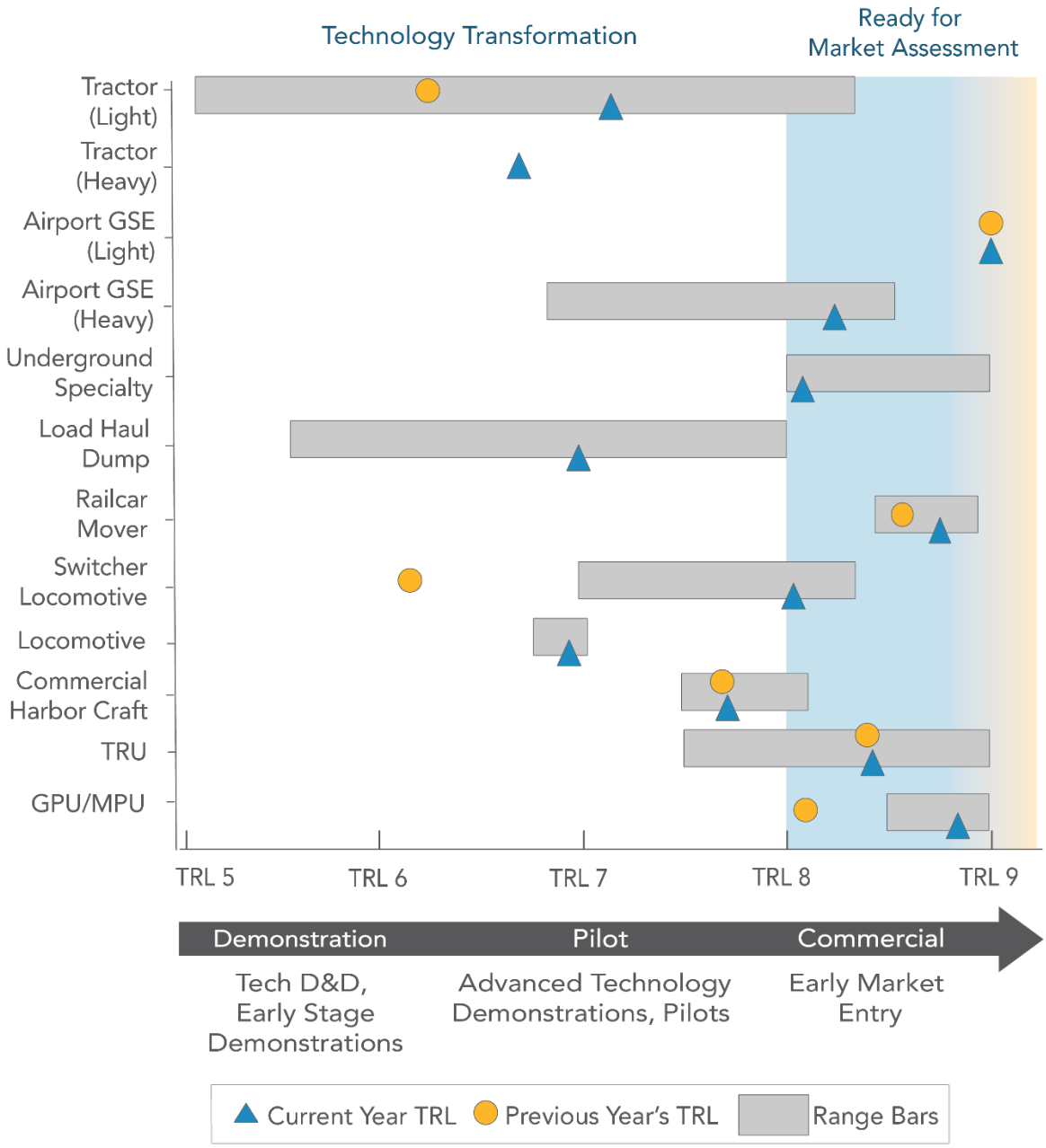


Figure D-9: Off-Road BEVs Technology Status Snapshot – Other



This year's technology readiness analysis featured a significant expansion of the off-road categories considered for technology readiness, including additional categories in the construction, CHE, rail, and mining segments. In general, Figure D-7 through Figure D-9 exemplify the substantial diversity in technology readiness of off-road equipment, reflecting the underlying diversity of off-road applications, technology development, and market conditions. 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 HD technology is also maturing rapidly.

Construction and agricultural equipment have had breakout years with many major OEMs beginning production of battery electric equipment platforms. Light battery electric excavators (less than or equal to 8 tons) are being produced by 23 OEMs internationally including some major construction equipment OEMs: Komatsu, JCB, and Bobcat. These excavators are showing an increasing ability to replace diesel excavators at job sites while reducing air pollution, carbon emissions, and cost.[24] Skid steers and compact loaders are entering early commercialization stages and reaching mature levels of technological readiness. One notable advancement is the battery electric compact track loader from Bobcat, which has purchase commitments from rental company Sunbelt Rentals.

This year also featured advancements in light agricultural tractor technology, especially from OEMs such as Monarch Tractor, Hummingbird EV, and Solectrac. While still not in the stages of early commercialization, heavier agricultural tractor technology is moving forward and is expected to be commercially available in the next few years.

Another notable technological advancement is in switcher locomotives used in railyards, which will be offered vouchers through CORE for the first time this year. These locomotives, which can have batteries as large as 14.5 megawatt-hours (MWh), are primarily for use in switching shunting operations in rail yards, regional service, or for use in an otherwise diesel consist.[25] Demonstrating the commercial readiness of switcher locomotives, freight hauler Union Pacific has committed to purchasing 10 of them and Australian mining company Fortescue is purchasing two of them, to be delivered in 2024.

[24] Government Fleet. JCB Electric Mini Excavator Ideal for Urban Job Sites. January 21, 2020. https://www.government-fleet.com/347273/jcb-electric-mini-excavator-ideal-for-urban-job-sites

[25] A consist is a term for the group of rail vehicles that make up a train.

Industry Examples
ZE Rail Builds Steam

Freight rail, particularly line haul with long routes and large energy demands to pull thousands of tons, is a challenging application for ZE technology. But in 2021, Wabtec Corporation, with support from CARB and the San Joaquin Air Pollution Control District, deployed a 4,400 horsepower, fully battery electric freight locomotive (BEL) for use in line haul transport. Operated in revenue service by BNSF Railway on a 400-mile route through California's Central Valley, it was the first such demonstration in the world. The "FlexDrive" BEL was used in conjunction with two conventional Tier IV diesel-electric locomotives, together called a consist, to turn the train into a battery hybrid capable of storing energy rather than braking and reducing strain on diesel locomotives when accelerating or climbing hills. The result was an average 12 percent, with a maximum 19 percent, reduction in fuel consumption each trip – a substantial savings for railroads whose operating costs are multiplied by the millions of miles their trains travel annually.

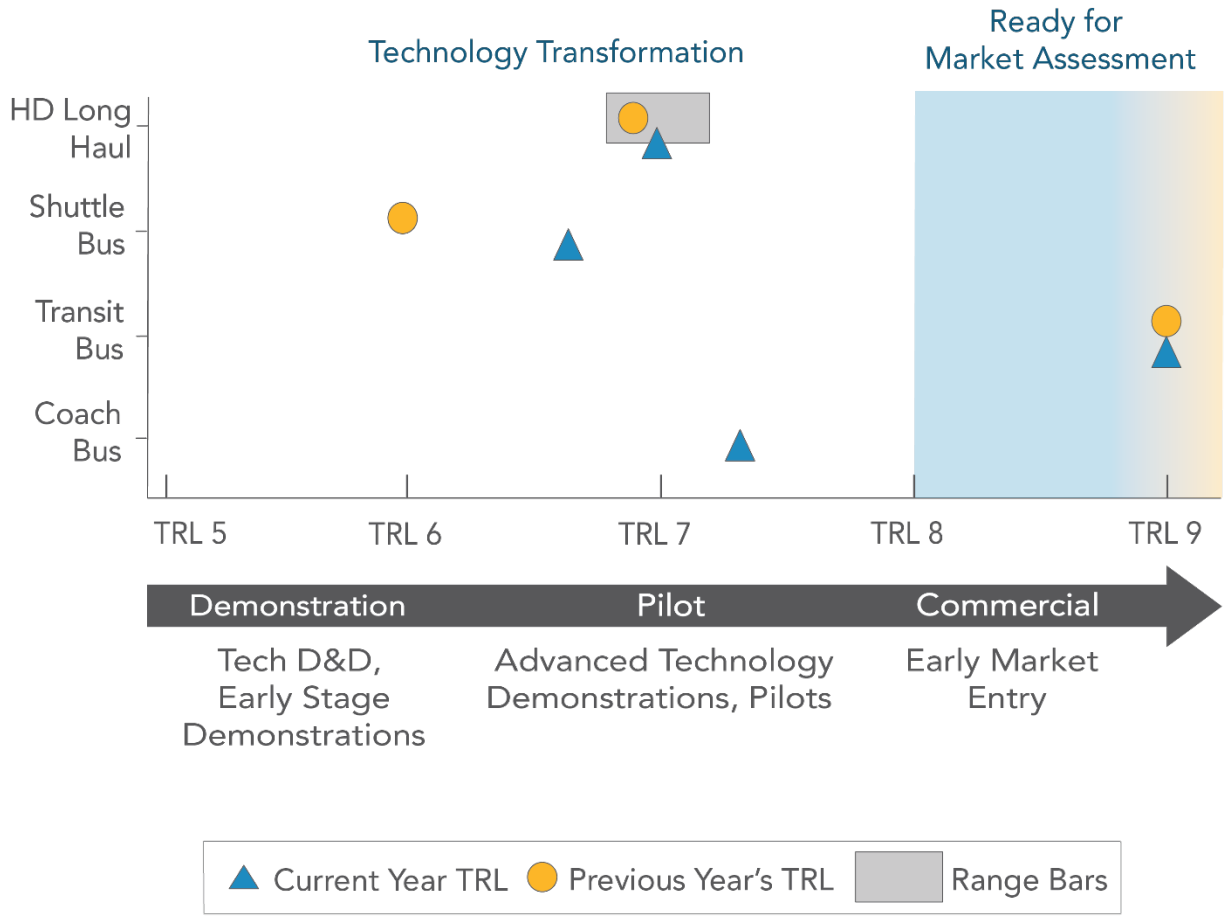
The year following the demonstration saw unprecedented interest in ZE rail, including orders for dozens of BELs from railroads in North America, South America, and Australia. Wabtec and competitor Progress Rail are fulfilling most of those orders. Due to data gathered by Wabtec during the demonstration of its first BEL, the next generation FlexDrive BELs delivered to customers, starting next year, will be even more advanced. Lessons learned are being incorporated to improve several aspects of performance. Notably, modified energy storage architecture and technology transfer from light-duty cars will allow the new units to carry three times more energy than the demonstration BEL. Wabtec has partnered with GM to use their Ultium batteries, leveraging decades of battery improvements made by the automotive industry. Ultium provides the energy density required for Wabtec to fit its BELs with up to 8 MWh of storage.

As the industry signals greater interest in ZE options, Wabtec is looking further into the future. They see many likely applications for BELs and are investigating hydrogen fuel cell electric options as well, also in partnership with GM. Though Wabtec believes hydrogen-powered rail to be about eight years behind battery technology, they think a line-haul fuel cell electric demonstration is possible in the next few years. With continued investments by government and industry, the ZE transformation of rail is on track.

Fuel Cell Electric Vehicles Technology Status Snapshot

Fuel cell electric vehicle (FCEV) technology has been gaining momentum as a solution for applications with needs for longer range or duration, faster fueling, or other demanding duty cycles. Generally, FCEVs are at the late demonstration/early pilot phase for heavy trucks and pilot/early commercialization phase for transit buses. Forklifts continue to expand as a successful commercial product, and demonstration activity in heavier lift and CHE progresses. Figure D-10 and Figure D-11 provide an overview of the technology status of FCEVs.

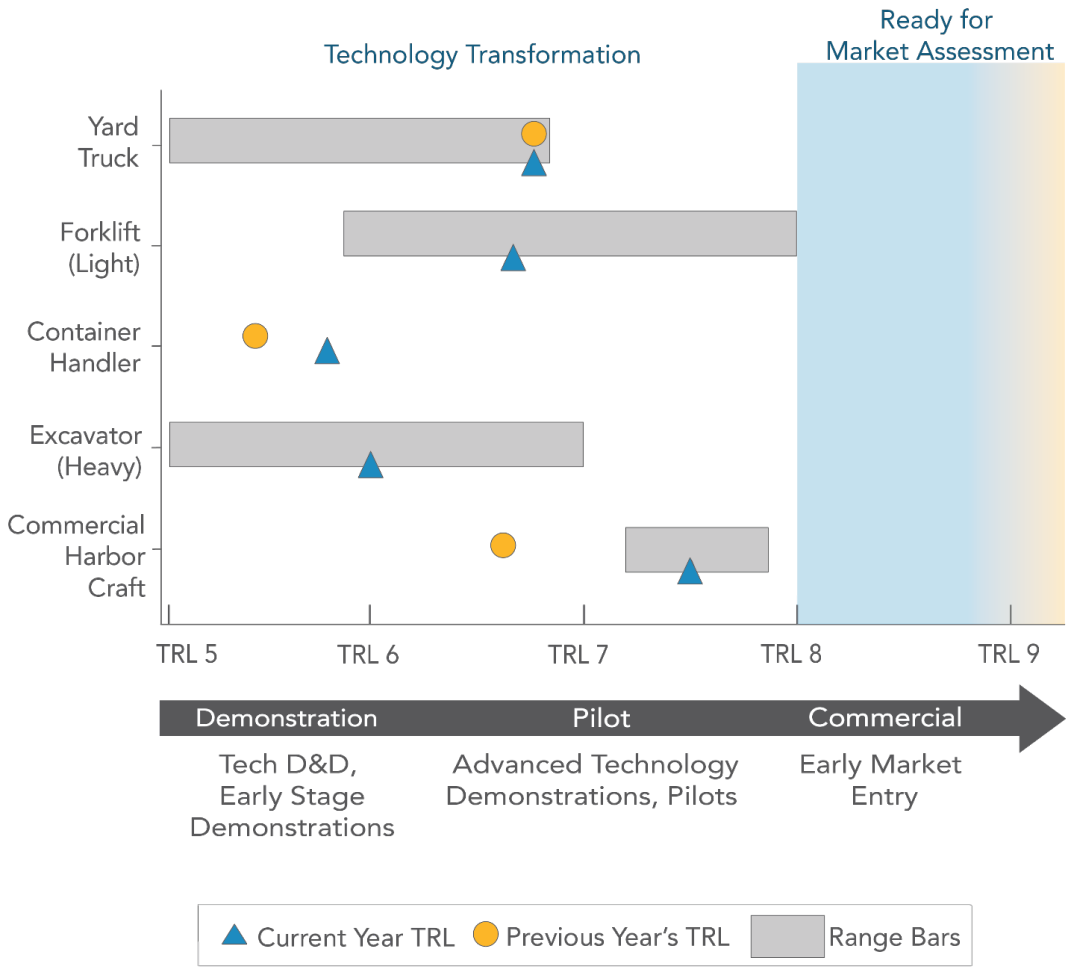
Figure D-10: On-Road FCEVs Technology Status Snapshot



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. The European market has begun large-scale pilot projects, creating a strong market signal for HD FCEV delivery and drayage manufacturers.

As mentioned previously, one of the reasons behind a growing interest in fuel cell electrification is the potential for quickly providing sufficient energy for long range or heavier cargo loads where higher capacity on-board energy storage is needed, or those work cycles requiring continuous operation or multiple-shift operation where time for recharging may not be an option. Such operations can make use of centralized, high throughput fueling stations that can be sited with on-location higher capacity hydrogen production facilities. While still in the prove-out phase, such production sites may allow for much lower cost hydrogen fuel 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.

Figure D-11: Off-Road FCEVs Technology Status Snapshot



As illustrated in Figure D-11above, the existing off-road FCEV models tracked here sustained minimal movement over the past year, with the exception of commercial harbor craft, which have seen increasing demonstration projects seeking to prove out fuel cell technology for typical harbor duty cycles. New FCEV equipment being

tracked this year are examples appearing in the construction, mining, and rail categories.

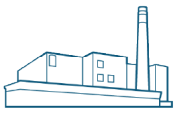
FCEVs have had their most successful break-out application to date with industrial forklifts. This core capability is exploring scaling to higher fuel use and weight applications, including potentially heavy lifts, CHE, and the marine sector. Such applications could make strong use of centralized fuel production and fueling infrastructure in locations such as port sites.[26]

Market Readiness

Conducting technology readiness assessments are an important first step in evaluating advanced technologies, but one that describes only part of the commercialization story. As technologies move toward full technical readiness, their commercialization status becomes more dependent on market readiness.[27] Being an important factor to investment policy, CARB analyzes market readiness, summarized in Figure D-12 and Figure D-13 below.

While the technology status snapshots provide an assessment of the level of 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 TRL greater than 8 against the following six market readiness indicators: production capacity, service network, cost parity, cost parity with incentives, duty cycle capability, and infrastructure.

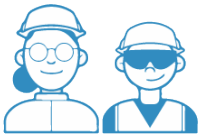
- **Production capacity** is a measure of the ability of manufacturers to produce commercial-ready products. Production capacity for an on- or off-road technology category considers the current aggregate production capacities of each manufacturer within that category. This metric also weighs absolute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



[26] For additional information on off-road technology readiness for various applications, see https://calstart.org/off-road-assessment.

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

- **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.

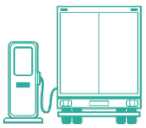


- **Cost parity** is the projected 2025 total cost of ownership (TCO) of a ZE technology platform relative to that of a similar diesel technology platform. Assumptions for TCO calculations were modeled on assumptions from CARB's "Draft Advanced Clean Fleets Total Cost of Ownership Discussion Document." One notable assumption is that the TCO in this category includes revenue generated from LCFS, but no purchase incentives.

- **Cost parity with incentives**, while similar to the indicator above, is the projected 2025 TCO relative to diesel, plus any purchase incentives from CARB's HVIP or CORE voucher incentive programs.

- **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.



Each vehicle and equipment segment is assessed against the above market readiness indicators on a scale of zero to 100 percent, with the percentage – scored in 25 percent increments – representing a relative measure between being not at all market ready (having substantial, inhibitory barriers to adoption) and being completely market ready (having little to no barriers to widespread adoption).

Charging and Refueling Infrastructure

ZEVs and ZE equipment are feasible when fleets are able to access appropriate, functional, and affordable charging (in the case of battery electric) or refueling (in the case of hydrogen fuel cell electric) equipment.

As such, the CEC has launched a first of its kind infrastructure incentive program, Energy Infrastructure Incentives for Zero-Emission (EnergIIZE) Commercial Vehicles.[28] Administered by CALSTART, EnergIIZE provides incentives for ZEV infrastructure equipment for MHD battery electric and hydrogen fuel cell electric vehicles in California. The project provides a user-friendly and streamlined process for participation through four funding lanes to support the unique infrastructure needs of each commercial fleet user: EV Fast Track, EV Jump Start, EV Public Charging Station, and Hydrogen.

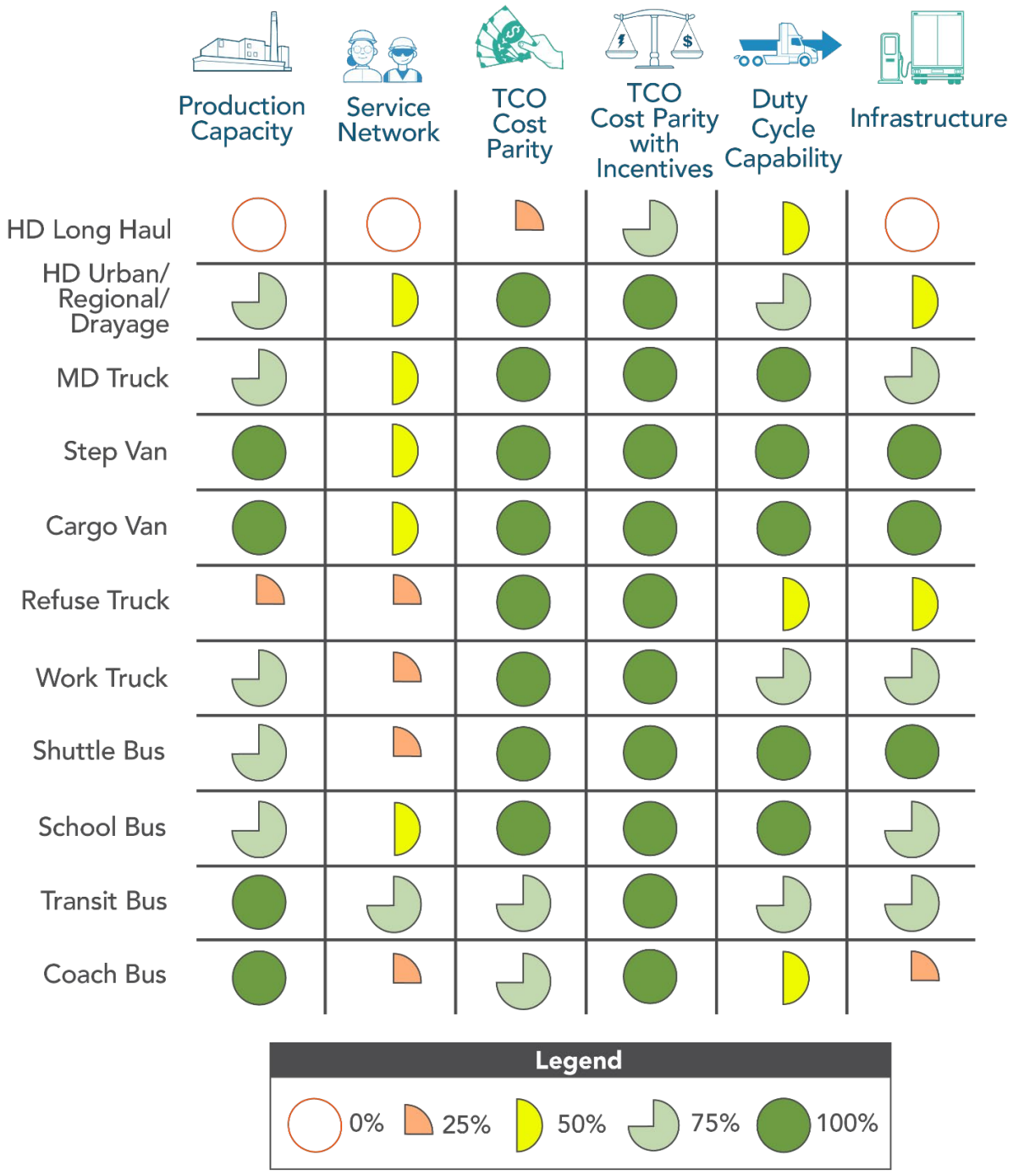
In addition to providing funding for infrastructure, EnergIIZE also offers an Infrastructure Readiness Center (IRC), which includes tools and resources to assist fleets with their ZE vehicle and infrastructure deployment needs. The IRC includes infrastructure planning guides, site plan checklists, charging best practices, a catalogue of eligible technology, approved and preferred vendors, a LCFS Fleet Estimator Tool, and workshop slides and recordings.

EnergIIZE was created in conjunction with feedback and continued support of government, industry, and community stakeholders. Various advisory committees and workgroups meet regularly to make incentives more inclusive and far-reaching for all potential applicants.

In addition to providing incentive funding for customer-side infrastructure, California also offers pilot funding for grid-side infrastructure upgrades (in some locations) and ZEV-friendly electricity rates. Fleets with facilities in the service territories of Pacific Gas and Electric, San Diego Gas and Electric, Sacramento Municipal Utility District, or Southern California Edison are able to access funding for "make-ready" infrastructure such as electrical system upgrades, switchgear, meters, wiring and conduit to ensure their site has the adequate capacity to operate their ZEV infrastructure. Many other California utilities offer financial, material, or consultative support to fleets considering electrification.

[28] For additional information on the Energy Infrastructure Incentives for Zero-Emission (EnergIIZE) Commercial Vehicles program, see https://www.energiize.org/.

Figure D-12: On-Road BEVs Market Readiness Snapshot



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 Figure D-12 and Figure D-13. Detail on the market readiness indicators and derivation of the

scores shown in the figures can be found in a dedicated technical white paper.[29] The market readiness assessment in Figure D-12 reveals on-road technology segments that have relatively few market challenges for adoption and are therefore poised for full-scale market adoption (e.g., cargo vans, step vans, transit buses, and school buses). In contrast, this analysis also reveals technology segments that face some market challenges and should be the focus of policy, such as HD urban/regional/drayage trucks and HD long-haul trucks. Naturally, all details can't be included in the abstract figure. For example, though HD long haul certainly has immediate market barriers in service and infrastructure, substantial progress and investment is being made in both, improvements that should be visible in upcoming assessments.

The only on-road FCEV to achieve a TRL greater than 8 was the transit bus segment. However, due to relatively low volumes of FCEV transit buses deployed to date, market readiness indicators for this segment will be evaluated and included in next year's Strategy.

[29] CALSTART. Methods for Assessing Technology and Market Readiness for Clean Commercial Transportation. October 2022. https://calstart.org/technology-and-market-readiness

Long-Haul Trucking: On the Road to ZE

Compared to the relatively small proportion of on-road vehicles that they represent, long-haul HD trucks, thanks to their high utilization and low fuel efficiency, have a disproportionate impact on climate change and air quality. Transitioning to ZE will be a key part of the solution to reducing both criteria emissions and GHGs.

Due to their challenging duty cycles, including large daily energy requirements, these trucks are proving to be the most difficult to bring to market. Market challenges include attaining a reasonable total cost of operation, established interstate refueling and maintenance networks, and integration with existing business models. These challenges affect sleeper cabs more than day cabs.

To electrify these vehicles, significant challenges remain. To compete with their diesel counterparts, which are able to refuel in under 10 minutes with 200 gallons of fuel for a range of over 1000 miles between fill up and typically average over 500 miles per day in operation,[30] battery electric versions would need access to on-route recharging or would have to carry over 1 MWh of batteries on-board to travel the same 500 miles per day. Although battery prices continue to decline, a battery of this size today would likely cost more than $100,000 and add 12,000 pounds to the truck. Although those numbers are expected to decrease over time, they make it a challenge to provide a truck with a TCO close to a diesel vehicle.

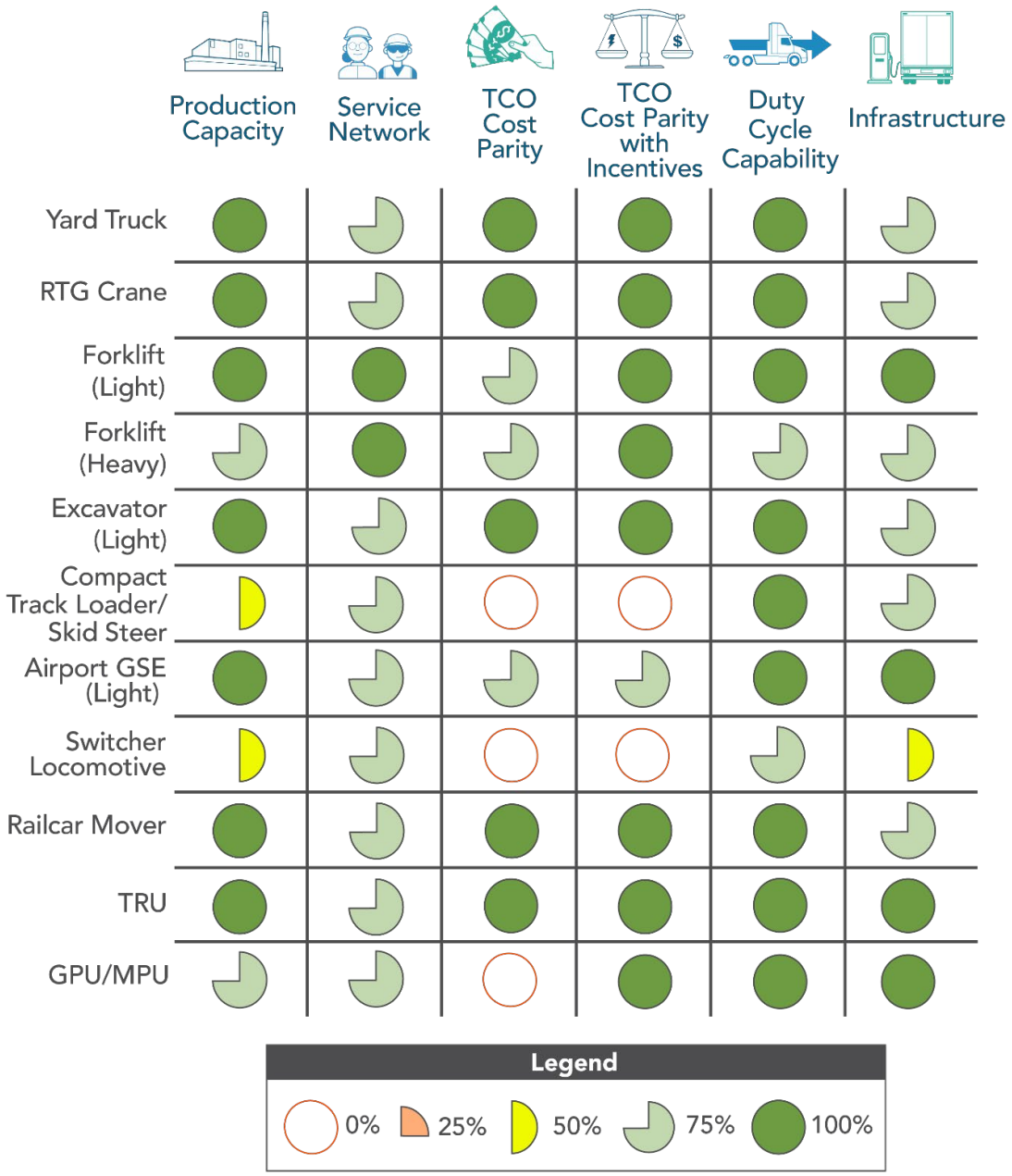
The alternative to large on-board batteries would be a high-power on-route charging system or megawatt charging system (MCS) that could quickly extend the daily range of the vehicles. MCS-capable trucks and charging systems are under development now. On-route, public MCS networks need to be deployed nationally and solutions are being developed now, particularly in California.

Another option for ZE long-haul trucking is FCEVs. Propulsion systems exist today that can provide the power and energy needed for daily duty cycles. These systems have the ability to provide the necessary on-board energy storage with quick refuel times and lower weight solutions. A remaining hurdle for these trucks is the availability of low-cost renewable hydrogen along interstate routes.

Both battery electric and hydrogen fuel cell electric long haul capable trucks also lack established maintenance networks as well as high-capacity manufacturing support at this time, but progress is being made. All established truck manufacturers as well as many newer ZE truck manufacturers are quickly making these trucks available at the volumes needed by operators and establishing maintenance and dealer networks necessary for interstate and national operation. Volume production of necessary truck systems, supporting maintenance and dealer networks, along with established interstate charging networks is expected to be available by 2030.

[30] Davis, S. C.; Boundy, R. G. Transportation Energy Data Book (Edition 37); Oak Ridge National Laboratory: Oak Ridge, TN, 2019.

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



The market readiness snapshot for off-road equipment, Figure D-13, displays a wide diversity in market readiness for ZE equipment. In general, yard trucks, RTG cranes, light forklifts, railcar movers, light airport GSE, and TRUs show broad market readiness, which is reflected in the fact that these equipment platforms are already experiencing early to late commercial adoption. Equipment platforms with greater market readiness challenges include compact track loaders/skid steers and switcher locomotives, which both have large incremental purchase prices over diesel.

Expanding Access to ZEV Incentives to Small Fleets

Small fleets face unique challenges to deploying ZEVs,[31] such as:

- Lack of awareness of ZEVs;
- Insufficient access to capital; and
- Lack of access to charging infrastructure.

Additionally, minority fleet stakeholders are more than twice as likely as white fleet stakeholders to have never heard about nor explored ZEVs.

Due to the challenges listed above, California recognizes that in the transition away from diesel, smaller fleets require an increase in funding, resources, and assistance in contrast to larger fleets who possess a greater awareness of the funding and technology available in their transitions to ZE, along with easier access to capital and financing.

In summer 2022, CARB launched the Innovative Small E-Fleets (ISEF) pilot program, setting aside $25 million to implement a range of innovative solutions to help small privately owned and nonprofit trucking fleets make the transition to ZEVs.[32] These solutions include flexible financing, short-term rentals, and full-service leases, such as all-inclusive truck-as-a-service options with enhanced incentives and charging/fueling support. The pilot is within HVIP.

By dedicating this set-aside funding for small fleets, CARB will position itself to better understand and meet the specific needs of this traditionally underserved group and support their transition to ZEVs.

To minimize application barriers and streamline the process for small fleets, CARB and the CEC developed a joint drayage application where fleets were able to apply for ZE incentives for vehicles and infrastructure in one place, similar to the ZE truck loan pilot. Additionally, the drayage joint application provided investments into public truck charging infrastructure, addressing a huge barrier for small trucking fleets—the lack of access to capital and real estate to invest into charging infrastructure. CARB anticipates doing similar joint solicitations in the future.

CARB proposes to allocate an additional $35 million toward ISEF in FY 2022-23.

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[31] Dream Corps. Green for All, Taking Charge: Supporting Small Fleets in the Transition to Zero-Emission Trucks. April 21, 2022.

https://dream.org/wp-content/uploads/2022/08/Dream.Org_SmallFleet_1.pdf

[32] For additional information on the Innovative Small E-Fleets set-aside, see https://ww2.arb.ca.gov/news/new-pilot-program-help-small-trucking-fleets-transition-zero-emission-technologies.

Industry Examples
Strong Start for ZE TRUs

Although engines used in TRUs are relatively small, because of the significant population of TRUs in California and how they congregate at distribution centers, truck stops, and other facilities, the emissions from TRUs result in local and regional health risks and contribute to climate change. To complement other ZE efforts at CARB, ZE TRUs have been included as an eligible equipment category in CORE since the Implementation Manual was first published in 2019.

- Since CORE began accepting voucher requests in February 2020, CORE has funded more than 150 TRUs totaling over $11 million in funds. All TRUs funded through these vouchers were or will be deployed in a disadvantaged or low-income community.
- On July 18, 2022, CORE reopened with new funding, and the ZE TRU category became over-subscribed in less than two hours, with received voucher requests for more than 400 units totaling over $28 million.
- At program inception, only two TRU manufacturers applied to participate in CORE, with a combined total of six configurations. As of July 18, 2022, four TRU manufacturers are participating in CORE, offering 16 different configurations, which include options for straight and local-delivery trucks for the first time.
- The eligible equipment in this category includes many unique and innovative technological features, such as integrated trailer solar panels and waste energy capture.

The increase in participation from CORE's initial launch to this latest iteration shows strong and continued demand with an almost three-fold increase in the number of voucher requests received for the category. With more manufacturers entering the market and businesses looking to reduce fuel and maintenance costs, demand is expected to continue to grow.

Overall, key focus areas in both on- and off-road market readiness are infrastructure, production capacity, and service network.

Lower-power charging for on-road vehicles – often overnight at a depot – is more technologically mature but still faces market challenges related to easy and cost-effective installation. Meanwhile, higher-power, faster charging for vehicles requiring

on-route or opportunity charging – particularly HD vehicles – is less technologically mature and available. However, California is actively working to provide solutions and technical assistance to fleets looking to access ZEV charging and refueling infrastructure. For example, the EnergIIZE program (detailed on page D-47) launched in 2021 to provide financial support to fleets for infrastructure. Fleets are also able to access technical assistance, including infrastructure guidance, through the Medium- and Heavy-Duty Zero-Emission Vehicle Fleet Purchasing Assistance Program created by SB 372 (Leyva, Chapter 639, Statutes of 2021). Many utilities and nonprofits also offer technical assistance to fleets looking to procure charging or refueling infrastructure for ZEVs. And the state is working to streamline permitting for this infrastructure via new legislation.[33] In addition, recent advances in high-power charging standards are expected to accelerate the development and deployment of megawatt charging and above, which will further support fleets that rely on publicly accessible charging. Related to this, the CEC has partnered with the Electric Power Research Institute (EPRI) and CALSTART to jump start California's high-power charging infrastructure for MHD vehicles. Through the Research Hub for Electric Technologies in Truck Applications (RHETTA) project, California will launch the country's first ZE freight-charging corridor network.

Hydrogen refueling infrastructure remains costly, though advancements are expected here as well. And Governor Newsom's administration has announced California's intention to leverage federal investment from the Infrastructure Investment and Jobs Act (IIJA) to establish an environmentally and economically sustainable and expanding renewable hydrogen hub in the state.

Production capacities, while currently low for many on- and off-road vehicles and equipment, are rising rapidly and expected to increase to levels that can satisfy market demand in the near future. While a service network is available in some capacity through OEMs and dealers for many on- and off-road vehicles, a well-developed and evenly-geographically-distributed service network is not yet mature.

Importantly, for those vehicles and equipment studied in terms of market readiness, cost parity and duty cycle capability are performing well. On- and off-road ZEVs and equipment studied are technologically mature and able to complete most of the duty cycles required by their applications. In addition, TCO is expected to reach parity by 2025 for many on- and off-road ZEVs in California, assuming users take advantage

Higher incremental costs will persist for the immediate near-term. In this context, incentives will remain integral to bridge the gap to commercialization for HD ZEVs and to support the growth of and investments in the commercial ZEV sector.

[33] AB 1236 (Chiu, Chapter 598, Statutes of 2015) and AB 970 (McCarty, Chapter 710, Statutes of 2021)

of LCFS credits. It should be noted, however, that TCO is only one component of a purchasing decision. Upfront purchase price is equally important and still significantly higher for ZE technologies than diesel technologies for most platforms studied, a particular challenge for small fleets that typically have less access to capital.

While over time, component costs, and therefore total upfront purchase price, is expected to continue to decline as manufacturers achieve economies of scale, current supply chain challenges – in large part due to COVID-19 – have resulted in increased component costs and competition between technologies for limited resources, driving vehicle and equipment prices up in the short-term.[34] Cost increases aren't limited to ZE technology, however, and volatile conventional vehicle and fossil fuel costs are closing the gap.

[34] For additional information on component costs, supply chains, and other factors impacting low-carbon technology costs, see https://calstart.org/zero-emission-component-cost-study.

Industry Examples
Electrification-as-a-Service Business Models Help Fleets Realize Operational Savings of ZEVs Without Upfront Purchase Cost

Although TCO of ZEVs is often favorable compared to diesel vehicles, upfront purchase price remains a challenge, particularly for smaller fleets who lack access to capital. For some fleets, even voucher incentives like those offered through HVIP may be insufficient to make ZEV ownership feasible. However, innovative business models like Electrification-as-a-Service (EaaS) can make ZEV operation a reality for these fleets.

Under a traditional procurement model, the high capital expenditure costs exclude less capitalized fleets from acquiring ZEVs. However, under an EaaS business model, all costs are bundled together and spread out over time, making the technology and operational savings accessible to everyone.

A variety of EaaS offerings are springing up across California, including:

- In 2022, Zeem Solutions opened the first commercial electric vehicle transportation-as-a-service depot near Los Angeles International Airport (LAX). The depot has 77 fast charging ports, 53 Level 2 chargers, a driver lounge, and the capacity to charge and park more than 200 MHD vehicles on-site and support hundreds more for opportunity charging. Fleets currently operating out of Zeem's LAX depot include tour buses, airport shuttles, last-mile delivery vans and trucks, third-party logistics, mobility services, ridesharing, and drayage operations.[35]
- WattEV offers ZE HD trucks through their as-a-service model. WattEV has locations in Bakersfield, San Bernardino, and Gardena, and plans to open an additional location at the Port of Long Beach by mid-2023.[36]
- Forum Mobility has partnered with port drayage services operator, Hight Logistics, to provide five BEV trucks from three OEMs and charging infrastructure for one monthly price.[37]

[35] For additional information on Zeem Solutions, see https://zeemsolutions.com/.

[36] For additional information on WattEV, see https://www.wattev.com/.

[37] For additional information on Forum Mobility, see https://forummobility.com/.

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 800 ZE drayage truck purchase commitments, and further expanding to include commitments for additional ZE drayage trucks, transit buses, school buses, and refuse trucks;
- Shifting focus from deployments at a few large fleets to helping out a greater number of smaller fleets;

- Continuing to support ZE transit buses, including hydrogen fuel cells. This includes helping to develop larger scale infrastructure, service, and component volumes to move these products closer to full market readiness; and
- Continuing to support the transformation of school bus fleets to ZE.

Priorities for the off-road sector include:

- Deploying heavier applications of ZE CHE;
- Continuing to develop ZE and hybrid marine applications;
- 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.

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;
- Developing strategic range extenders for applications where ZE options are not yet feasible; and
- Building on recent successes of ZE rail technology and growing industry interest.

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 longer-haul truck demonstrations;
- Advancing high power charging capable ZE truck technologies;
- Applying ZE technologies to construction equipment;
- Advancing ZE marine demonstrations;

- Developing longer distance/regional ZE rail applications; and
- Applying ZE technologies to aviation

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 2021-22 report, addresses FY 2023-24 and FY 2024-25, and adds a new third year, FY 2025-26. 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 pathway 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 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-3. 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, while not 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-3: Recommendations for Low Carbon Transportation Investment Priorities

	FY 2023-24	FY 2024-25	FY 2025-26
Demos	$50-$90 Million Focus: ZE Construction Equipment, ZE Heavier Cargo Handling Equipment, ZE Line-Haul Rail, ZE Marine, ZE Aviation, High Power Charging Capable ZE Trucks	$55-$95 Million Focus: ZE Construction and Mining Equipment, ZE Heavier Cargo Handling Equipment, ZE Line-Haul Rail, ZE Marine, ZE Aviation	$65-$100 Million Focus: ZE Construction and Mining Equipment, ZE Heavier Cargo Handling Equipment, ZE Line-Haul Rail
Pilots	$175-$300 Million Focus: ZE Ag-Construction-Heavier Cargo Handling Equipment, ZE/Hybrid Marine, Strategic Range Extenders, ZE Facilities/ Communities/Corridors	$200-$325 Million Focus: ZE Ag-Construction-Heavier Cargo Handling Equipment, ZE Switcher Rail, ZE/Hybrid Marine, Strategic Range Extenders, ZE Facilities/ Communities/Corridors	$225-$350 Million Focus: ZE Longer Range Trucking, ZE Ag-Construction-Heavier Cargo Handling Equipment, ZE/Hybrid Marine, Strategic Range Extenders, ZE Facilities/ Communities/Corridors, ZE Aviation
Commercial	$1,210-$1,815 Million Focus: ZE Drayage, ZE Long-Haul Trucks, ZE Transit, ZE Heavier Cargo Handling Equipment, ZE/Hybrid Marine, ZE Switcher Rail, ePTOs, ZE Work Trucks, ZE Small Fleets	$1,210-$1,815 Million Focus: ZE Drayage, ZE Long Haul Trucks, ZE Transit, ZE Heavier Cargo Handling Equipment, ZE/Hybrid Marine, ePTOs	$1,460-$2,170Million Focus: ZE Drayage, ZE Long Haul Trucks, ZE Transit, ZE Heavier Cargo Handling Equipment, ZE Switcher Rail, ZE/Hybrid Marine, ePTOs
Total Funding	$1,435-$2,205 Million*	$1,465-$2,235 Million*	$1,750-$2,620 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.

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 greatest existential threat we face, and ensuring that this transformation benefits those communities that have historically been hardest hit by the ongoing use of fossil fuels. The combustion of these fuels has polluted California's air, particularly in low-income communities and communities of color, for far too long, and is the root cause of climate change. The centerpiece of this transformation will be the aggressive reduction of fossil fuels wherever they are currently used in California, building on and accelerating carbon reduction programs that have already been in place for a decade and a half. This means rapidly moving to ZE transportation, electrifying the cars, buses, trains, and trucks that now constitute California's single largest source of planet-warming pollution.

The State has been allocating billions of dollars annually to 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 turning over the legacy fleet. 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. Furthermore, incentives accelerate the transition of fleets to ZE as well as support equitable, community-driven clean transportation and multi-sector approaches. Additionally, incentives promote economic growth, job training and apprenticeship opportunities, and continue to build on successes of previous investments.

Nevertheless, the State continues to face challenges. Problems with the global supply chain that began during the pandemic continue to impact the availability of parts, equipment, and vehicles needed to transform the HD and off-road sectors, and economists anticipate these issues will persist for at least another year.[38] In addition, truck driver shortages continue to increase across the globe. Even rising wages have not been able to stop this trend, which will be compounded by the impending retirement of much of the existing workforce.[39] California's economy has continued to see sustained and rapid job growth over the past year, but it has recovered only about 90 percent of the jobs that were lost at the start of the pandemic. Furthermore, California experienced its first decline in population in over 100 years. If this trend

[38] Newscenter - University of Rochester. "Expect Another Year of Supply Chain Problems." June 27, 2022. https://www.rochester.edu/newscenter/what-is-supply-chain-issues-explained-525302/

[39] IRU. "Driver Shortages Surge, Expected to Jump up to 40% in 2022: New IRU Survey." June 16, 2022. https://www.iru.org/news-resources/newsroom/driver-shortages-surge-expected-jump-40-2022-new-iru-survey

were to continue, or even if population levels were to remain unchanged, the State could eventually find itself facing declines in revenue and other economic outputs.[40]

Despite these challenges and uncertainties, at least one OEM is forecasting TCO parity for BEVs as early as 2025 and TCO parity for FCEVs by 2027.[41] Many locations in the Netherlands will begin enforcing ZE-only zones starting in 2025, which has led to the development of a wide range of ZEV and ZE equipment offerings in that country. Norway is also seeing considerable success in its move to ZE through a combination of regulations and incentives, reaching the highest ZE sales share worldwide. China, which has adopted a ZE manufacturing mandate, is already positioned to capture 40 percent of the world market.[42] Here in California, Los Angeles and San Francisco have both signed onto the C40 mayors' Clean Construction Declaration with a near-term deadline for electrifying construction equipment.

As the range of commercialized ZE Class 8 tractors grows, some trucking companies are seeking ways to plan their operations to utilize the available range in a way that still gets drivers home at night. And while there are some long-range direct custom shipping routes that do not match up well to existing range options, there are many more typical routes that could be set up for electrification or utilize "pony express" type relay trailer handoffs. Initial feedback from the trucking industry shows that roughly a third of large fleets do not exceed 100 miles in a day and two thirds do not exceed 200 miles in a day. Many Class 8 tractors are ready to electrify now and should be prioritized before dealing with more challenging longer-range situations.

Many of these ZE trucks were on display at CARB and CALSTART's Zero-Emission Truck Showcase + Ride and Drive on the grounds of the Auto Club Speedway in Fontana on June 8, 2022. Nearly 500 fleet owners and operators, policy makers, and industry professionals came out to test drive a wide range of ZE trucks available for purchase and deployment. Throughout the event, attendees completed 729 ride and drives behind the wheel of 23 different vehicles, ranging from MD delivery vans to HD tractors and refuse trucks. "We urgently need cleaner MHD vehicles on the road, especially in DACs that are overburdened by truck pollution. Today's event

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[40] Bank of the West. "California Economic Outlook Report – April 2022." April 20, 2022. https://www.bankofthewest.com/alpha/wealth-management/insights/economic-report/california-economic-outlook-report-april-2022.html

[41] Daimler Truck Roadshow Presentation. May 2022. https://www.daimlertruck.com/dokumente/investoren/berichte/zwischenberichte/daimler-truck-ir-roadshowpresentation-q1-2022.pdf

[42] Cornell SC Johnson College of Business, Emerging Markets Institute. "In the Electric Vehicle Race, China is Coming First." March 2022. https://business.cornell.edu/hub/2022/03/25/in-electric-vehicle-race-china-coming-first/

demonstrates that industry is ready to meet this challenge – the vehicles here are available for purchase today," said Tom Brotherton, CALSTART's director of market acceleration. "When fleet managers and drivers experience these vehicles firsthand, they are impressed. The success of and interest in this ZE truck showcase further emphasizes that the ZE truck market is poised for significant growth – both here in California and across the country."

Industry Examples
California's First Zero-Emission Truck Showcase + Ride and Drive Highlights
Plethora of Commercial ZE Truck Options on the Market Today

In June 2022, CARB and CALSTART partnered to host California's first Zero-Emission Truck Showcase and Ride and Drive at the Auto Club Speedway in Fontana. Nearly 500 fleet owners and operators, policymakers, and industry professionals came out to test drive a wide range of commercially available ZE trucks. Throughout the event, attendees:

- Completed 729 ride and drives behind the wheel of 23 different vehicles, ranging from MD delivery vans to HD tractors and refuse trucks;
- Got under the hood of 17 additional trucks on display for the showcase;
- Attended five in-person training sessions on technology, incentives, financing, and charging and refueling infrastructure;
- Heard remarks from CARB, U.S. National Highway Traffic Safety Administration (NHTSA), and Environmental Protection Agency (EPA) officials; and
- Engaged in conversations with partners representing 13 infrastructure partners in the Charging and Infrastructure Zone.

The vast majority of the vehicles on-site were eligible for funding under HVIP. Similarly, all participating off-road equipment – including ZE terminal tractors and TRUs – was eligible for funding under CORE. Two hydrogen fuel cell electric trucks – the Hyundai Xcient Fuel Cell and the Hyzon Class 8 – were the only vehicles not yet eligible for voucher funding. Fleet and policymaker interest in fuel cell electric trucks has grown considerably over the last year, particularly as the industry grapples with how best to reduce emissions from long-haul, HD trucks and the federal government launches a competitive $8 billion program for clean hydrogen hubs across the U.S.

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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

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

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

Container Handler – material handling equipment that moves intermodal containers

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 but 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 but heavy refers to forklifts with lift capacity over 7 tons

Harbor Crane – dockside gantry crane found at container terminals for loading and unloading intermodal containers from container ships (aka 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 – the 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

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

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

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 (aka 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 but 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

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

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 but 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 (aka yard tractor, yard spotter, terminal tractor, yard dog, yard goat, yard hostler, mule, etc.)

Acronym List

ACT – Advanced Clean Truck

AQIP – Air Quality Improvement Program

AVTA – Antelope Valley Transit Authority

BEV – Battery Electric Vehicle

BEL – Battery Electric Locomotive

CAPP – Community Air Protection Program

CARB – California Air Resources Board

CEC – California Energy Commission

CHE – Cargo Handling Equipment

CORE – Clean Off-Road Equipment

EaaS – Electrification-as-a-Service

EnergIIZE – Energy Infrastructure Incentives for Zero-Emission

FARMER – Funding Agricultural Replacement Measures for Emission Reductions

FCEV – Fuel Cell Electric Vehicle

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 Program

ICEF – Innovative Small E-Fleets

ICT – Innovative Clean Transit

LCFS – Low Carbon Fuel Standard

Low-No – Low or No Emission Vehicle Program

MCS – Megawatt Charging System

MD – Medium-Duty

MHD – Medium- and Heavy-Duty

MWh – Megawatt-Hour

NOx – Nitrogen Oxides

OEM – Original Equipment Manufacturer

PM – Particulate Matter

PM2.5 – Fine Particulate Matter

SB – Senate Bill

SIP – State Implementation Plan

TCO – Total Cost of Ownership

TRL – Technology Readiness Level

TRU – Transport Refrigeration Unit

VW – Volkswagen

ZE – Zero-Emission

ZEV – Zero-Emission Vehicle