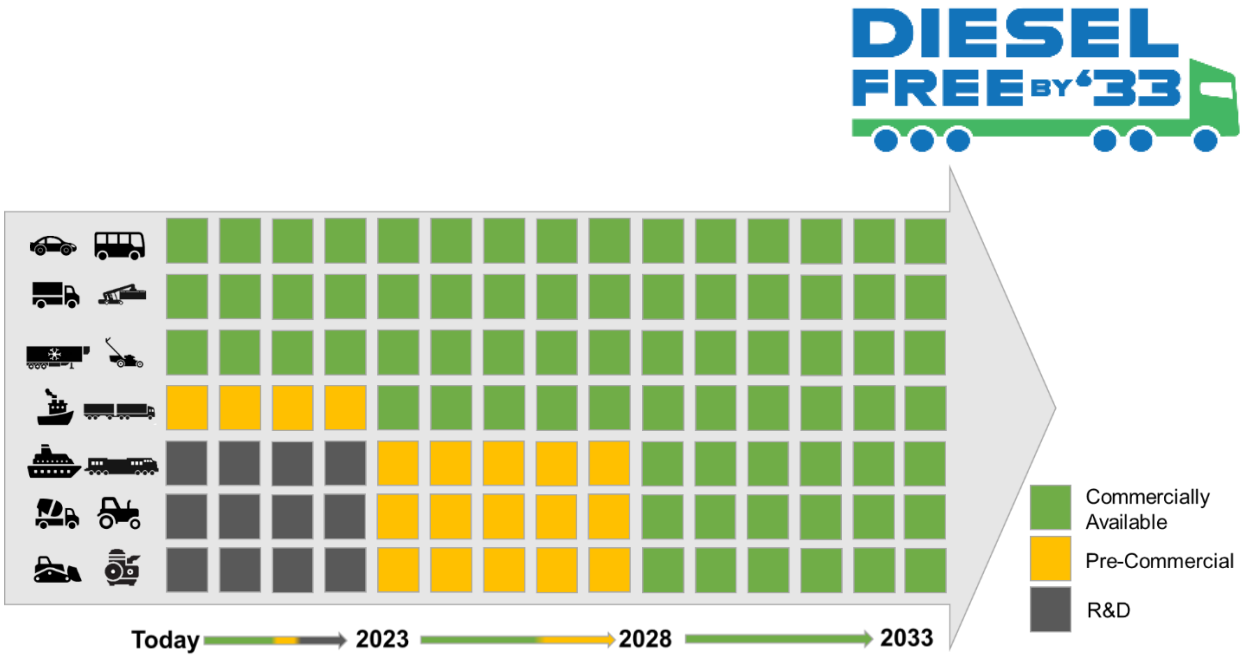
Summary of Available Zero-Emission Technologies 2.0



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I. Introduction

Diesel exhaust causes significant public health effects and accelerates climate change. The California Air Resources Board (CARB) estimates that on-road diesel and off-road mobile engines comprise 54 percent of the state of California's total black carbon emissions, a short-lived climate pollutant that is contributing significantly to global climate change. Petroleum diesel air pollution is also highly toxic and can have an immediate impact on the health of residents in communities where emissions are most concentrated.

The **Diesel Free by '33** initiative, adopted by the Bay Area Air Quality Management District (BAAQMD) in 2018 establishes an aspirational goal and framework for how the region may eliminate diesel emissions and black carbon from our communities. Signatories from city and county governments, and industry and business leaders, have joined the BAAQMD and the state of California to showcase collective leadership in identifying and adopting innovative solutions to eliminate diesel emissions.

A key component in developing pathways toward eliminating diesel emissions is the phased-in replacement of diesel-fueled vehicles and equipment with zero-emission alternatives as these new technologies become commercially available. In early 2018, the BAAQMD completed an assessment of zero-emission technology options for replacing diesel combustion vehicles and equipment ("Diesel Free by '33: Summary of Available Zero-Emission Technologies and Funding Opportunities"). ***The zero-emissions technology landscape is advancing rapidly; based on the initial and updated assessments zero-emissions options may be commercially available for all equipment and vehicle category types by 2033.***

The purpose of this 2.0 update is to identify what zero-emission technology options are currently available and what may be available within the short-, medium-, or longer term in order to help equipment owners and operators, fleet managers, policy makers, and other interested parties in developing their own pathway towards phasing-in zero-emission technologies, and therefore achieving Diesel Free by '33. This 2.0 update is a 2019 snapshot of commercially-available and demonstration-phase zero-emission technologies for mobile source vehicles and equipment and stationary source engines and a discussion of applicable regulations and incentives that are supporting the accelerated drive to a zero-emissions future.

The report is structured by general equipment category, headed by a table with information on the technology readiness level status. For technologies that are **commercially available**, considerations and challenges of extensive deployment (e.g. limited offerings; operational constraints; cost parity; infrastructure availability) are briefly discussed. Readers can also find a table listing the manufacturers of zero-emission vehicles and equipment in **Appendix D**. For technologies that are still in the **demonstration stage**, selected case studies of current pilots and testing activities are described based on publicly available information.

The BAAQMD will continue to provide regularly updated assessments and is currently working to expand this assessment to include zero-emission technologies that replace stationary engines and light-duty vehicles. The next phase of this work is anticipated to be completed by early 2020. It is BAAQMD's hope that the Diesel Free by '33 initiative and the information in this report will be used to spur the development and adoption of zero-emission technologies and improve air quality in both the Bay Area and globally.

II. Overview of Regulatory Framework & Incentives

Regulations and incentives are significant drivers of zero-emission technology innovation and adoption. While some regulations mandate certain sectors transition to zero-emission technologies (e.g., the Innovative Clean Transit Rule), others can have more diverse effects, such as creating new markets for innovative technologies (e.g. Low Carbon Fuel Standard) or reducing barriers for adopting new technologies.

Incentive programs reduce financial and other barriers of adoption, spur the development of prototypes and test pilots, help current owners and operators offset the incremental cost of deploying zero-emission technologies, and accelerate broader adoption of new cleaner technologies.

Regulations and incentives applicable to transitioning different equipment and vehicle types to zero-emission are shown in **Table 1** below. For a summary of these rules and regulations, see **Appendix B**. For further information on each incentive program that can fund the development and adoption of zero-emission technologies, see **Appendix C**.

Table 1. Equipment/Vehicle Type and Applicable Regulation and Incentives[1]

<table>
<tr><th rowspan="2">Category</th><th rowspan="2">Type</th><th rowspan="2">Applicable Regulation</th><th colspan="6">Incentive Source</th></tr>
<tr><th colspan="2">Infrastructure only</th><th colspan="2">Infrastructure & Equipment/Vehicle</th><th colspan="2">Equipment/ Vehicle only</th></tr>
<tr><td rowspan="2">On-Road</td><td>Buses</td><td>Innovative Clean Transit Rule</td><td rowspan="8">LCFS</td><td rowspan="5">PG&E</td><td rowspan="4">California Climate Investments</td><td rowspan="2">TFCA</td><td>HVIP</td><td rowspan="8">DERA</td></tr>
<tr><td>Trucks</td><td>Drayage Truck Regulation</td><td rowspan="6">CORE</td></tr>
<tr><td rowspan="6">Off-Road</td><td>Cargo Handling</td><td>Cargo Handling Equipment Regulation</td><td rowspan="6"></td><td rowspan="6"></td></tr>
<tr><td>Airport Ground Support</td><td rowspan="2">Off-Road Regulation & LSI Fleet Regulation</td><td>CEC ARFVTP</td></tr>
<tr><td>Construction</td><td rowspan="3">Carl Moyer</td></tr>
<tr><td>Locomotive</td><td>Statewide Rail Yard Agreement</td></tr>
<tr><td>Commercial Harbor Craft</td><td>Commercial Harbor Craft Regulation</td><td rowspan="2">VW Mitigation Trust</td></tr>
<tr><td>Ocean Going Vessels</td><td>At-Berth Regulation & Annex VI</td></tr>
</table>

[1] See Appendix B and C for further discussion of applicable regulations and incentive sources.

III. Technology Readiness Levels of Zero-Emission Vehicles and Equipment

With recent advances in battery and fuel cell technologies, a greater number of zero-emission vehicle and equipment types are becoming feasible. Table 2 summarizes the status of zero-emission technology readiness (Technology Readiness Level) for selected equipment and vehicle categories. Further information about each equipment category is discussed later in this report. For a definition of each vehicle and equipment category, see Appendix A. Technology Readiness Level stages are classified as: Technology Readiness Level stages are classified as:

- **Commercially Available:** A zero-emission technology for the particular vehicle or equipment category has been proven through successful operations and is available for purchase by relevant industry sectors with defined delivery dates.
- **Demonstration:** Either a prototype has been developed or there exists a fully-developed system that is currently going through a process of testing and demonstration in an actual operation environment.
- **Research:** Initial scientific research of a zero-emission technology has been conducted for the particular vehicle or equipment category. Elements of the technology or system components are being evaluated, and/or the potential of the zero-emission technology has been confirmed and established as feasible.
- **No Information Available:** No public information was found regarding zero-emission technologies for the given equipment or vehicle.

Table 2. Summary Status of Zero-Emissions Technologies in the Heavy-Duty Sector

Technology Readiness Level	Vehicle or Equipment Category
Commercially Available	Airport Ground Support Equipment Buses Cargo Handling Equipment Construction Equipment: *Stationary Cranes* *Light Payloads* On-Road Trucks
Demonstration	Cargo Handling Equipment: *Reach Stackers* *Heavy-Duty Forklifts* *Top Handlers* Commercial Harbor Craft Locomotives
Research	Ocean-Going Vessels
No Information Available	Construction Equipment: *Crawler Cranes* *Heavy Payloads* *Specialized Equipment*

Buses

The recent advancement of battery electric technology in the light-duty on-road vehicle sector can broadly be transferred to similar applications in medium- and heavy-duty buses. As of August 2019, there are fifteen bus manufacturers and fifty-four bus models that the state of California funds as eligible zero-emission vehicles through the HVIP program[2]. These zero-emission buses have gained CARB certification/approval, comply with all-electric range requirements, and provide warranty provisions and definitive Manufacturer Suggested Retail Price sheets.

Table 3. Technology Readiness Level of Buses and Considerations for Widespread Adoption

Equipment	Technology Readiness Level	Considerations for Widespread Adoption
School Bus Shuttle Bus Transit Bus	Commercially Available	Cost premiums

Cargo Handling Equipment

Zero-emission alternatives are commercially available for most stationary cargo handling equipment or for equipment that operated on strictly fixed paths (due to the ability to plug-in); and for equipment that is intended to exclusively transport containers horizontally (i.e., terminal tractors and automated guided vehicles) or to vertically move only empty containers (i.e., side handler).

Table 4. Technology Readiness Levels of Cargo Handling Equipment and Considerations/ Challenges

Equipment Type	Technology Readiness Level	Considerations / Challenges
Automated Guided Vehicles Ship-to-Shore Gantry Cranes Side Handlers Straddle Carriers Terminal Tractors Yard Cranes	Commercially Available	Limited Offerings Demanding Duty-Cycles High Premium
Heavy-Duty Forklifts Reach Stackers Top Handlers	Demonstration	Battery Capacity Charging Infrastructure Electricity Upgrades

Top Handler Pilot: *Port of Los Angeles*
CARB and California Climate Investments (CCI) are partially funding a demonstration of the first three battery-electric top handlers and one fuel-cell electric range-extended top loader at the Port of Los Angeles. The three battery-electric top handlers are manufactured by Hyster Yale Group and are expected to be in operation in spring 2020. The overall project at the Port of Long Beach also includes a

[2] California Air Resources Board Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP). Eligible Vehicle Catalog. www.californiahvip.org

battery-electric yard truck and a hydrogen fuel cell (HFC) yard truck[3]; the total cost of the project is $8.3 million. The batteries will be lithium-ion and charge by wireless fast charger. The fuel-cell range extended top loader, which includes two 45-kW fuel cell engines built by Nuvera Fuel Cells, and its associated 250 kW wireless inductive charger built by Wireless Advanced Vehicle Electrification (WAVE) are expected to be operating in spring 2020[4] and will cost $8.8 million, with up to $6.5 million of funding provided by CCI. Project partners for these pilots include the Center for Transportation and the Environment and the City of Long Beach Harbor Department.

Reach Stacker Pilot: *Port of Valencia, Spain*
An electric reach stacker with HFC a range extender is being developed for the Port of Valencia and manufactured by Hyster Yale Group Inc., with funding from the Fuel Cells and Hydrogen Joint Undertaking and European Horizon 2020 program and additional support from the H2Ports project[5]. The reach stacker is scheduled to begin operation in 2021.

Heavy-Duty Forklift Pilot: *Port of Stockton*
CARB and CCI are partially funding a demonstration of two 30,000-pound capacity battery-electric forklifts manufactured by DANNAR[6]. The total project cost for the two forklifts is $1.2 million, of which $770,000 is funded by CARB and CCI. The two forklifts will also be testing additional cargo handling attachments, including a scissor lift and dump truck bed. The batteries will be lithium-ion and charged by ChargePoint DC fast chargers. The project is expected to be complete in spring 2020.

Construction Equipment

Construction Equipment is a broad category with many types of equipment serving specialized tasks. Equipment types that are generally stationary and can be easily connected to the grid currently have zero-emission options commercially available. Other types of equipment that are more mobile or that may be deployed in remote locations lacking infrastructure typically rely on conventional (petroleum) fuel, although there are some early demonstrations of zero-emission technologies. With this in mind, urban applications are the most promising.

Stationary applications with the ability to plug electric equipment into the grid are uncommon for construction-type activities, with the exception of tower-cranes, which are typically electric. The most significant restriction with battery-electric equipment is the power-demand during heavy lifting or excavating/earth-moving activities. Hybrid applications have been developed where equipment utilize lithium-ion batteries to move the equipment wheels but use a diesel engine to operate the hoist, lift, bucket, arm, etc.

[3] California Air Resources Board. "C-PORT: The Commercialization of Port of Long Beach Off-Road Technology Demonstration Project" https://ww3.arb.ca.gov/msprog/lct/pdfs/longbeachoffroad.pdf?_ga=2.244551500.896765447.1565191950-520522063.1534345374
[4] California Air Resources Board. "Demonstration of Zero-Emission Technologies for Freight Operations at Ports: Fuel Cell Hybrid Electric Top Loader" https://ww3.arb.ca.gov/msprog/lct/pdfs/fuelcelltoploader.pdf?_ga=2.242920267.896765447.1565191950-520522063.1534345374
[5] Hyster Yale Group. Inc. Press Release. https://www.hyster.com/emea/en%E2%80%90gb/press/press%E2%80%90releases/hyster-electric-container-handlers-progress/
[6] California Air Resources Board. "San Joaquin Valley Zero-Emission Cargo Handling Demonstration Project" https://ww3.arb.ca.gov/msprog/lct/pdfs/sjcargohandling.pdf?_ga=2.138649850.896765447.1565191950-520522063.1534345374

Table 5. Technology Readiness Levels of Construction Equipment and Considerations/ Challenges

Equipment Type	Technology Readiness Level	Considerations / Challenges
Boom Lifts Concrete Mixers Dumpers Loaders Mini Cranes Mini Excavators Tippers Tower Cranes	Commercially Available	Charging Availability in Remote Locations Battery Size Limited Applications
Dozers Excavators Graders	Demonstration	High Power Demands Highly Specialized Equipment Types
Crawler Cranes Crushers Pavers Rollers Scrapers Trenchers	No Information Available	High Power Demands Highly Specialized Equipment Types

Early stage demonstration projects are taking place in North America and Europe. Two of these demonstrations are described below:
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Grader Demonstration: *Borden Lake Mine, Canada*
In spring 2018, as part of a larger effort at GOLDCORP's Borden Lake Mine in Canada to transition to 100% electric, MacLean Engineering commissioned MEDATECH to manufacture a retrofit to an existing motor grader to convert the equipment to battery-electric[7].

Excavator Demonstration: *Gjellerasen, Norway*
Norway's Pon Equipment retrofitted a 26-ton Caterpillar 323 Hydraulic Excavator to an entirely battery-electric power system[8,9]. The excavator has a 3.4-ton, 300 kwh battery. Norwegian company Veidekke placed an order for eight retrofitted electric excavators.

Airport Ground Support Equipment (GSE)

The relatively light payloads of GSE, along with the short distances travelled and availability of electrical infrastructure where these equipment types operate mean most equipment in this category are good candidates for electrification. However, airport tarmacs are highly trafficked and charging equipment will need to be wireless and/or located away from areas where they may be inadvertently damaged. GSE can also be highly specialized, which means many different prototypes and demonstrations may be needed to prove to operators that their needs are met for each application.

[7] MEDATECH. Press Release. https://medatech.ca/battery-electric-retrofit-of-diesel-grader-for-goldcorp-borden-lake/
[8] https://insideevs.com/news/342491/pon-equipment-reveals-electric-caterpillar-excavator/
[9] https://electrek.co/2019/01/29/caterpillar-electric-excavator-giant-battery-pack/

Table 6. Technology Readiness Levels of Airport Ground Support Equipment and Considerations/ Challenges

Equipment Type	Technology Readiness Level	Considerations / Challenges
Air Conditioners Baggage Tractors Belt Loaders Hydrant Carts Lavatory Trucks Passenger Stands Pushbacks Water Trucks	Commercially Available	Demanding duty cycles Battery size
Cargo Tractors Catering Trucks Fuel Truck Sweepers	Demonstration	Highly specialized equipment types
Air Starts De-Icers Service Trucks	No Information Available	Highly specialized equipment types

On-Road Trucks

As of 2019, there are three models of zero-emission on-road heavy-duty trucks available. Lion Electric Co. and BYD offer battery-electric tractors and a refuse truck. The tractors have an advertised range of up to 250 miles and 125 miles (full-load), and are advertised as appropriate for short-haul or local operations but not for long-haul trucking[10,11].

For long-haul operations, four other manufacturers have released prototypes and are testing zero-emission Class 8 trucks. Tesla is accepting orders along with financial deposits for their vehicles. However, no manufacturer has released a specified delivery date. Several companies are already in a testing phase for their zero-emission long-haul trucks in operational environments. Publicly announced information about vehicle availability is summarized in **Table 8**.
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[10] Lion Electric Co. website. https://thelionelectric.com/documents/en/LION8_specsheet.pdf
[11] BYD website. https://en.byd.com/truck/#models

Table 7. Technology Readiness Levels of On-Road Trucks and Considerations/ Challenges

Equipment Type	Technology Readiness Level	Considerations / Challenges
Refuse Tractor Trucks	Commercially Available	Limited offerings Range Recharging times
Long-haul Trucks	Demonstration	Range Charging / fueling infrastructure

Table 8. Summary of Class 8 Long-Haul Trucks in Development

Manufacturer Model	Estimated Range	Powertrain	Production Date Target
Tesla Semi[12]	500 miles	Battery Electric	End of 2020
Daimler eCascadia[13]	250 miles	Battery Electric	End of 2021
Nikola One and Two[14]	500-750 miles	Fuel Cell Electric	2022
Toyota/Kenworth Project Portal[15]	300 miles	Fuel Cell Electric	No information announced

Commercial Harbor Craft

There are multiple early demonstrations of zero-emission commercial harbor craft currently taking place and commercial availability is expected to occur quickly following successful completion of these demonstrations. Demonstrations include both battery-electric and HFC technologies; battery electric systems are being tested for shorter duration, high-power applications, while HFC are being applied to longer routes.

Table 9. Technology Readiness Levels of Commercial Harbor Craft and Considerations/ Challenges

Equipment Type	Technology Readiness Level	Considerations / Challenges
Commercial Fishing Ferries Tugboats Workboats	Demonstration	Cost Fueling
Excursion Vessels Pilot Boats Research Vessels	Research	Space constraints
Crew and Supply Vessels Charter Fishing	No Information Available	

[12] Tesla Semi website. https://www.tesla.com/semi
[13] Daimler/Freightliner website. https://www.daimler.com/innovation/case/electric/electric-buses-and-trucks.html
[14] Nikola Motor website. https://nikolamotor.com/motor
[15] Motor Authority. "Toyota and Kenworth Reveal First Fuel Cell Electric Truck Ready to Haul Cargo." https://www.motorauthority.com/news/1122730_toyota-and-kenworth-reveal-first-fuel-cell-electric-truck-ready-to-haul-cargo

There are currently multiple zero-emission ferries and tugboats, an inland barge, and a fishing vessel, under development in California, Alabama, New York, Europe and Japan[16]. California and the European Union demonstrations of HFC vessels, utilizing compressed gas and liquid hydrogen, are described below.
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HFC Ferry Demonstration- California: *Water-Go-Round*
CARB and BAAQMD have awarded $3 million for the development and testing of an HFC ferry that will demonstrate both passenger and freight services in the San Francisco Bay. The 70-foot vessel was designed by Incat Crowther and built by Bay Ship & Yacht; the three 120 kW fuel cells were from Hydrogenics; and the fuel cell electric propulsion system was manufactured by BAE Systems. Golden Gate Zero Emission Marine provided project management, and Sandia National Laboratories will provide data analysis and hydrogen safety training. The Water-Go-Round is expected to have enough hydrogen storage capacity to power up to two days of normal operations. The project began in May 2018 and is expected to begin operations in Fall 2019[18].

HFC Ferry Demonstration- Europe: *FLAGSHIPS*
The E.U.'s Research and Innovation program awarded 5 million Euros ($5.6 million) for the development and testing of two liquid-hydrogen-powered vessels. In Norway, the HFC ferry will carry up to 299 passengers and 80 cars in the local public transit network; in France, the HFC push boat will operate under commercial shipping conditions. The vessels will be designed by LMG Marin and manufactured by ABB; fuel cell technology will be provided by Ballard Europe; and energy monitoring and management will be provided by PersEE. The HFC ferry is expected to have enough capacity for over three tons of liquid hydrogen, fueling three weeks of normal operations. The project started on January 1, 2019 with operations expected to start in 2021[19].

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[16] California Air Resources Board. "Technology Assessment: Commercial Harbor Craft"
https://ww3.arb.ca.gov/msprog/tech/techreport/draft_chc_technology_assessment.pdf?_ga=2.72114195.1642215430.1563896364-592388194.1562085676
https://www.electrive.com/2019/05/23/ballard-abb-developing-fc-tugboat/
https://alabamanewscenter.com/2019/02/15/gees-bend-has-the-nations-first-electric-ferry/
https://www.electricandhybridmarineworldexpo.com/en/industry-news.php?release=de7f47e09c8e05e6021ababdf6bc58e7&utm_source=mailing&utm_medium=email
https://corvusenergy.com/projects/karoline-2/
https://safety4sea.com/japan-toyota-to-build-fishing-boat-powered-with-hydrogen-fuel-cells/

[17] California Air Resources Board. "Technology Assessment: Commercial Harbor Craft"
https://ww3.arb.ca.gov/msprog/tech/techreport/draft_chc_technology_assessment.pdf?_ga=2.72114195.1642215430.1563896364-592388194.1562085676
https://www.electrive.com/2019/05/23/ballard-abb-developing-fc-tugboat/
https://alabamanewscenter.com/2019/02/15/gees-bend-has-the-nations-first-electric-ferry/
https://www.electricandhybridmarineworldexpo.com/en/industry-news.php?release=de7f47e09c8e05e6021ababdf6bc58e7&utm_source=mailing&utm_medium=email
https://corvusenergy.com/projects/karoline-2/
https://safety4sea.com/japan-toyota-to-build-fishing-boat-powered-with-hydrogen-fuel-cells/

[18] California Air Resources Board. "Zero-Emission Hydrogen Ferry Demonstration Project"
https://ww3.arb.ca.gov/msprog/lct/pdfs/hydrogenferry.pdf

[19] https://www.maritime-executive.com/article/hydrogen-fuel-cell-vessels-destined-for-france-and-norway

Ocean Going Vessels

The current conversation on zero-emission technologies for ocean going vessels going completely zero-emission is focused on first proving technologies for smaller zero-emission marine vessels. Reducing the use of the auxiliary engines while at berth (shore power) or the electrification of at-berth operations has been in commercial operations for approximately a decade.

Based on research calculations, a large containership has available space for an HFC powerplant, and the necessary power and energy requirements for cross-ocean routes can be met using liquid hydrogen[20].

Table 10. Technology Readiness Level of Ocean Going Vessels and Considerations/ Challenges

Equipment Type	Technology Readiness Level	Challenges
Cargo ships Container ships	Research	Infrastructure Transportation and storage of hydrogen fuel

For current demonstrations of HFC powered ferries and tugboats, see section *Commercial Harbor Craft*.

Locomotives

Although varieties of electric passenger trains are currently commercially available, including over-head catenary electric locomotives and self-propelled electric trains, these technologies are not currently functional in freight applications, due to the necessary overhead clearance or, in the case of self-propelled cars, the lack of power necessary for freight locomotive applications. Additionally, the high cost per mile of deploying electric rail and catenary systems inhibits these applications for long haul operations.

Table 11. Technology Readiness Level of Locomotives and Considerations/ Challenges

Equipment Type	Technology Readiness Level	Considerations / Challenges
Locomotive for Long-haul Switcher Locomotive	Demonstration	Limited applications High cost of infrastructure

Though no full zero-emission prototype for long haul freight and passenger service was found, CARB is demonstrating a zero-emission local (switchyard) locomotive, as well as a single battery-electric locomotive paired with diesel locomotives (a consist) for line-haul operations.
Though no full zero-emission prototype for long haul freight and passenger service was found, CARB is demonstrating a zero-emission local (switchyard) locomotive, as well as a single battery-electric locomotive paired with diesel locomotives (a consist) for line-haul operations.

Switchyard: *Zero-Emission Track-Miles Locomotive Project*
In October 2018, CARB and the South Coast Air Quality Management District (SCAQMD) announced $2.7 million of funding for a zero-emission switcher locomotive at the San Pedro Ports. Originally slated as a natural gas-powered project, the transition to battery electric will demonstrate a zero-emission locomotive repower[21]. VeRail Technologies will build the 2,100 hp six-axle switcher locomotive, which features a redesigned cooling system, a new battery mounting system and control computer, and 2.89 MWh of battery storage capacity anticipated to be capable of working a full 12-hour shift before needing to charge. Testing is expected to run through 2020[22].

Consist Long Haul Freight: *San Joaquin Valley Zero and Near-Zero Emission Enabling Freight Project*
In March 2019, CARB and the San Joaquin Valley Air Pollution Control District (SJVAPCD) announced funding for a battery-electric locomotive (BEL), which will power a freight train between Stockton and Barstow. The BEL will be paired with diesel locomotives in a "consist", or a sequence of connected locomotives, and is expected to result in overall fuel savings of 10-15%. The unit is anticipated to maintain full horsepower for 30 minutes per given charge, allowing zero-emission operations in populated areas where air quality impacts are of concern.

GE Transportation will develop and build the BEL, which will include a new cooling system, 2.4 MWh of battery storage, trip-optimizing software with automated cruise control, and AC Traction System Inverters capable of recharging the battery[23]. Demonstration is expected to begin in 2020.

[21] San Pedro Ports Clean Air Action Plan. "2018 ANNUAL REPORT AND 2019 PRIORITIES Technology Advancement Program" http://www.cleanairactionplan.org/documents/2018-tap-annual-report.pdf/
[22] California Air Resources Board. "Zero-Emission Track-Miles Locomotive Project" https://ww3.arb.ca.gov/msprog/lct/pdfs/zelocomotive.pdf?_ga=2.96202332.1103824982.1564087744-1670947689.1557852817
[23] GE Transportation. Press release. https://www.ge.com/reports/leading-charge-battery-electric-locomotives-pushing-us-freight-trains/

Appendix

Appendix A: Descriptions of Vehicle or Equipment Type

Below are brief descriptions of each of the vehicle or equipment types discussed in this report.

Airport Ground Support Equipment

Airport Ground Support Equipment (GSE) are portable equipment that operate at airports and service the various needs of aircrafts. Examples of GSE include baggage tractors, belt loaders, cargo lifts, pushback tractors, catering trucks, fuel trucks, lavatory trucks, sweepers, water trucks, de-icers and other service vehicles. Conventional GSE are diesel, gasoline or compressed natural gas (CNG) powered.

Buses

Buses are typically 35 to 45 ft. in length (or longer) and are primarily used to transport passengers. Buses can range in size from small shuttles with seating for 10 to 20 passengers, to school and transit buses that can seat 40 to 80 passengers, to articulated and double-decker buses that can carry over 200 passengers.

Cargo Handling Equipment

Cargo handling equipment (CHE) move containers, materials, and other cargo at ports and intermodal facilities to and from various container storage areas and transport modes. Examples of CHE include terminal tractors (aka yard hostlers/yard goats) that ferry containers around a facility; top handlers, side handlers, reach stackers and heavy-duty forklifts, which are all used to lift, stack, and load empty and full cargo containers; yard cranes (such as rubber-tired and rail-mounted gantry cranes); straddle carriers which transport, stack, and load containers; and ship-to-shore gantry cranes which load and unload containers onto and off of vessels. CHE has historically been powered by diesel combustion engines.

Commercial Harbor Craft

Commercial harbor craft means any private, commercial, government, or military marine vessel, including, but not limited to: passenger ferries, excursion vessels, tugboats, ocean-going tugboats, towboats, push-boats, crew and supply vessels, pilot vessels, fishing vessels, research vessels, U.S. Coast Guard vessels, hovercraft, emergency response harbor craft, and barge vessels that do not otherwise meet the definition of ocean-going or recreational vessels.

Construction Equipment

Construction equipment broadly consists of equipment that is used to erect and demolish buildings; grade and pave roads; dig, excavate, and mine; transport earth and other materials; and many other activities. Construction equipment varies widely in size, payload capacity, power, and application, and includes equipment such as dozers, graders, excavators, scrapers, loaders, trenchers, cranes, rollers, mixers, crushers, lifts, tippers and dumpers. Construction equipment is largely powered by diesel combustion engines.

Locomotive

A locomotive is a self-propelled vehicle used to push or pull trains. The combination of locomotive(s) pulling freight or passenger railcars forms a train. Coupled self-propelled cars that form a train (i.e., Electric Multiple Units) are not locomotives.

Ocean Going Vessel

An ocean-going vessel is a commercial ship that is equal to or greater than 400 feet in length, is equal to or greater than 10,000 gross tons, is propelled by a marine compression ignition engine with a displacement of greater than or equal to 30 liters per cylinder, or is any combination of the above.

Trucks

Heavy-duty trucks are large motor vehicles that are primarily used to transport goods and equipment and have a GVWR of 26,001 lbs. and above (class 7 and 8).

Appendix B: Applicable Regulations

Below are brief summaries of applicable regulations for vehicles and equipment discussed in this report operating in California.

Mobile Cargo Handling Equipment Regulation

California Code of Regulations, title 13, section 2479 (13 CCR 2479)

Adopted by CARB in 2005, the Mobile CHE Regulation was fully implemented at the end of 2017. The Mobile CHE Regulation requires newly purchased yard trucks (aka terminal tractors, yard hostlers, yard goats) and other equipment brought onto a port or intermodal rail yard to have either a Tier 4 Final off-road engine or a Model Year (MY) 2010 or newer on-road engine. CARB is considering changes to the Mobile CHE Regulation that would require a transition to new zero-emission technologies and facility infrastructure as guided by CARB resolution 17-8, which directed CARB staff to develop new regulatory requirements for CHE that will require up to 100% zero-emissions technologies at ports and intermodal railyards by 2030.

In-Use Off-Road Diesel-Fueled Fueled Fleets Regulation

California Code of Regulations, title 13, section 2449 (13 CCR 2449)

In 2007, CARB adopted the Regulation for In-Use Off-Road Diesel-Fueled Fleets (Off-Road Diesel Regulation) to reduce diesel-particulate matter (PM) and oxides of nitrogen (NOx) emissions from construction, mining, industrial, and other sectors. The Off-Road Diesel Regulation applies to a) vehicles with off-road engines of 25 bhp or greater and b) 2-engine cranes, drilling rigs, and vehicles with auxiliary engines greater than 50 bhp. The regulation restricts idling and requires all new engines to be Tier 3 or higher for large and medium fleets. Small fleets must add tier 3 or higher starting January 1, 2023.

Off-Road Large Spark-Ignition Engines Regulation

California Code of Regulations, title 13, section 2431 (13 CCR 2431)

CARB adopted rules in 2006 (and amended them in 2010 and 2016) for large spark-ignited-engine powered equipment 25 hp or greater, including but not limited to: forklifts, industrial tow tractors and sweepers/scrubbers, and airport GSE. The Off-Road Large Spark-Ignition Engines Regulation requires operators of in-use fleets to achieve fleet average emission level (FAEL) standards that become more stringent over time. FAEL standards vary and are specific to large, mid-size and non-forklift fleets.

Statewide Rail Yard Agreement to Reduce PM at California Rail Yards

CARB, Union Pacific Railroad Company, Burlington Northern, and Santa Fe Railway Company entered into the Statewide Rail Yard Agreement to Reduce Diesel PM at California Rail Yards (Rail Yard Agreement), effective June 30, 2005. The purpose of the Rail Yard Agreement is to reduce diesel emissions in and around rail yards in California by implementing idle-reduction programs and through the evaluation and development of measures to further reduce impacts on local communities. The regulation also requires that parties maximize locomotive use of ultra-low sulfur diesel, and establish a visible emissions reduction and repair program.

Commercial Harbor Craft Regulation

California Code of Regulations, title 13, section 2299.5 (13 CCR 2299.5)

The Emission Limits and Requirements for Diesel Engines on Commercial Harbor Craft Operated within California Waters and 24 Nautical Miles of the California Baseline Regulation (Commercial Harbor Craft Regulation) was adopted in 2007 to reduce emissions of diesel PM, NOx and reactive organic gases

(ROG) from diesel engines used on commercial harbor craft in California waters (within 24 nautical miles of the California coast). The rule was amended in 2010 and will be fully implemented by the end of 2022. The Regulation requires that all newly-acquired engines for in-use harbor craft meet the Tier 2 or Tier 3 marine or off-road standards; New ferries with capacity of 75 or more passengers are required to install best available control technology (BACT) on the propulsion engines or meet Tier 4 standards. Harbor craft with existing Tier 1 and earlier must meet Tier 2 or Tier 3 standards based on their compliance schedules.

Low Carbon Fuel Standard Regulation

California Code of Regulations, title 17, sections 95480-95503 (17 CCR 95480-95503)

The Low Carbon Fuel Standard (LCFS) was first adopted in 2009 (re-adopted in 2015 and amended in 2018) with the purpose of reducing the full fuel-cycle carbon intensity (CI) of the fuel used for transportation in California by at least 20% by 2030. The LCFS sets well-to-wheels CI benchmarks for fuel production, distribution and consumption. Fuels either generate credits or deficits depending on their CI, relative to the benchmark. LCFS credits can also be earned by increasing zero-emission vehicle (ZEV) infrastructure capacity (hydrogen or ZEV fast charging). Electric vehicles, trucks, electric transit systems, electric forklifts, electric CHE, electric transportation refrigeration units (TRUs), and shore power are all eligible to generate credits. Electric Distribution Utilities (EDU) can also earn "base" credits for all residential charging accomplished using the grid average CI, and the load-serving entity, auto manufacturer, or another entity may generate "incremental" credits for supplying metered, low-CI electricity or smart charging to those residences. The person who owns the hydrogen fueling supply equipment or the hydrogen forklift fleet is eligible to generate credits for hydrogen fueling.

Innovative Clean Transit Rule

California Code of Regulations, title 13, section 2023 (13 CCR 2023)

Adopted by CARB in December 2018, the Innovative Clean Transit Rule (ICT) requires all public transit agencies to transition to 100% zero-emission bus fleets by 2040, with transition requirements varying by transit agency fleet size, utilization, and location. The rule requires zero-emission buses to be 25% of new purchases beginning in 2023 for large transit agencies, and 100% of transit agency new bus purchases beginning in 2029, including standard, articulated, over-the-road, double-decker, and cutaway buses over 14,000 gross vehicle weight rating (GVWR).

Drayage Trucks Regulation

California Code of Regulations, title 13, section 2027 (13 CCR 2027)

The In-Use On-Road Diesel-Fueled Heavy-Duty Drayage Trucks Regulation (Drayage Truck Regulation) was adopted by CARB in December 2017. The existing regulation applies to all drayage trucks in California that transport cargo to and from ports and intermodal rail yards in the state. Drayage trucks are class 7 or 8 vehicles with GVWR greater than 26,000. The existing regulation requires the registration of drayage trucks in the Drayage Truck Registry and requires Class 7 and 8 truck owners to either have trucks with an engine model year 2010 or newer, or meeting 2010 engine emission standards, by 2022, in order to enter ports and rail yards in the state. CARB is currently considering adopting a new regulation or amending the existing regulation to direct a transition to zero-emission operations beginning in 2026-2028.

California At-Berth Regulation

California Code of Regulations, title 17, section 93118.3 (17 CCR 93118.3)

The Airborne Toxic Control Measure for Auxiliary Diesel Engines Operated on Ocean-Going Vessels At-Berth in a California Port (California At-Berth) regulation was approved by CARB in December 2007.

Beginning January 1, 2014, the regulation requires onboard auxiliary diesel engines for fleets visiting the Port of Hueneme, Port of Los Angeles, Port of Long Beach, Port of Oakland, Port of San Diego, or Port of San Francisco to meet increasingly stringent operational time limits and reductions of their vessels' on-board power generation. Fleets can achieve compliance with the regulation by plugging their vessels into shower power, also known as cold-ironing, or otherwise utilizing alternative control technology to achieve equivalent emission reductions.

Appendix C: Applicable Incentives

Below are brief summaries of some available incentives, as of August 2019, for zero-emission vehicles and equipment discussed in this report.

Local

Transportation Fund for Clean Air (TFCA): *San Francisco Bay Area*
Transportation Fund for Clean Air (TFCA) revenues are collected from a $4 surcharge fee on vehicles registered in the Bay Area, to fund cost-effective projects that reduce on-road motor vehicle emissions. BAAQMD administers the program, providing incentives for clean air vehicle projects and trip reduction programs. For further detail, visit:
http://www.baaqmd.gov/funding-and-incentives/funding-sources/regional-fund

PG&E Clean Fleets: *Northern California (PG&E Service Areas)*
PG&E provides rebates for eligible customers developing on-site charging for heavy duty vehicles and equipment. Rebates vary at up to 50% or $42,000 for 150kW and above chargers, or up to $9,000 per vehicle or equipment for infrastructure upgrade (25 vehicle limit per site). For further information, visit: https://www.pge.com/en_US/large-business/solar-and-vehicles/clean-vehicles/ev-fleet-program/ev-fleet-program.page

State of California

HVIP
The Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP) provides point-of-sale discounts to vehicle purchasers. HVIP works directly with dealers to apply the voucher incentive at the time of purchase. Eligible funding recipients are any commercial vehicle user in California. Commercial vehicles include but are not limited to: municipal fleets, smalls businesses, school districts and more. Incentive levels for zero-emission vehicles with a GVWR >26,000 lbs range from $71,000 to $220,000. For further detail, visit: https://www.californiahvip.org/

Carl Moyer Program
Carl Moyer Program
The Carl Moyer Memorial Air Quality Standards Attainment Program (Carl Moyer Program) provides grant funding for cleaner-than-required engines, equipment, and other sources of air pollution. The Carl Moyer Program is implemented as a partnership between CARB and California's 35 local air districts. Eligible equipment includes medium and heavy-duty on-road and off-road vehicles and equipment, marine vessels, and locomotives. For more information, visit: https://ww2.arb.ca.gov/our-work/programs/carl-moyer-memorial-air-quality-standards-attainment-program

AB617 Community Air Protection Incentives
The Community Air Protection Program (CAPP) was established after the passage of Assembly Bill 617 and focuses on the reduction of exposure to air pollution in the most vulnerable communities. Strategies to address poor air quality in impacted communities include providing incentives for mobile sources. CAPP incentives are administered by local air districts through the Carl Moyer Program. For further information, visit: https://ww2.arb.ca.gov/our-work/programs/community-air-protection-program

Clean Off-Road Equipment (CORE) Voucher Incentive Project
The CORE project is a $40 million market acceleration program to advance the deployment of zero-emission off-road freight equipment. CORE provides equipment purchasers and lessees with attractive point-of-sale discounts toward the purchase of zero-emission off-road freight equipment, making costs comparable to their traditional fossil-fueled counterparts.
https://ww2.arb.ca.gov/news/california-air-resources-board-announces-new-incentive-program-clean-road-freight-and-cargo

California Climate Investments
CCI is a statewide initiative that invests proceeds from cap-and-trade into greenhouse gas emission reductions. SB 862 established continuous appropriations of 60 percent of the available proceeds to certain transportation and sustainable communities programs, including local and regional public transit and low carbon transportation. For further information, visit:
http://www.caclimateinvestments.ca.gov/sustainable-communities-clean-transportation.

Alternative and Renewable Fuel and Vehicle Technology Program
The California Energy Commission (CEC) strategically invests to close gaps in the development and deployment of alternative and renewable fuels, and advanced transportation technologies, through the Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP). Solicitations vary and are posted periodically, rather than on an ongoing basis. For further detail, visit:
https://ww2.energy.ca.gov/contracts/transportation.html

US Federal

FTA Low or No Emission Vehicle Program
The Federal Transportation Authority's (FTA) Low or No Emission Competitive program provides funding to state and local governmental authorities for the purchasing or leasing of zero-emission transit buses, as well as acquisition, construction, and leasing of required supporting facilities, such as fueling infrastructure. For further details, visit: https://www.transit.dot.gov/funding/grants/lowno

EPA Clean Diesel and DERA Funding
The Environmental Protection Agency's (EPA) Clean Diesel Program provides funding for projects that reduce harmful emissions from diesel engines. This program includes grants and rebates funded under the Diesel Emissions Reduction Act (DERA). The 2020 request for applications is planned to open in December 2019. For further information, visit: https://www.epa.gov/cleandiesel

Congestion Mitigation and Air Quality Improvement Program
Administered by the Federal Highway Administration (FHWA), the Congestion Mitigation and Air Quality Improvement Program (CMAQ) program provides funding to areas that face nonattainment for the National Ambient Air Quality Standards (NAAQS). Eligible activities include diesel retrofits, installation of diesel emission control technology on nonroad diesel equipment or on-road diesel equipment that is operated on highways.

Appendix D: Manufacturers of Zero-Emission Vehicles and Equipment

Below are tables listing the manufacturers of zero-emission vehicles and equipment. All information below was obtained from CARB's Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP) eligible vehicle catalogue.[24]

On-Road

Buses, School Manufacturer and Number of Models by Length			
OEM	**<30 feet**	**30-40 feet**	**>40 feet**
Blue Bird		4	1
Green Power		1	
Lion Electric		4	
Micro Bird	1		
Motiv Power System	1	1	
Thomas Built		1	
Phoenix	1		

Buses - School Manufacturer and Number of Models by Length			
OEM	**<30 feet**	**30-40 feet**	**>40 feet**
Blue Bird	-	4	1
Green Power	-	1	-
Lion Electric	-	4	-
Micro Bird	1	-	-
Motiv Power System	1	1	-
Thomas Built		1	-
Phoenix	1	-	-
TOTAL	**3**	**11**	**1**

Buses- Shuttle, Coach, and Transit Manufacturer and Number of Models by Length			
OEM	**<30 feet**	**30-40 feet**	**>40 feet**
BYD Motors	1	5	3
El Dorado National		2	
Gillig	1	2	
GreenPower Motor Company	1	3	1

[24] HVIP Eligible Vehicle Catalogue. https://www.californiahvip.org/how-to-participate/#Eligible-Vehicle-Catalog

Lightning Systems	2		
Micro Bird	1		
Motiv Power Systems	1		
New Flyer		3	2
Phoenix	2		
Proterra		5	7
SEA Electric	1		
Zenith Motors	1		
TOTAL:	11	20	13

Tractor and Yard Tractor Manufacturer and Number of Models by Gross Cargo Weight Rating			
OEM	**54,600 Lbs.**	**81,000 Lbs.**	**>100,000 Lbs.**
BYD Motors	-	-	2
Kalmar Ottawa	-	1	-
Lion Electric	1	-	-
Orange EV	-	2	-
TOTAL	**1**	**3**	**2**

Trucks and Refuse Trucks Manufacturer and Number of Models by Gross Vehicle Weight			
OEM	**<14,000**	**14,000-26,000**	**>26,000**
BYD Motors		3	2
Lightning Systems		1	
Motiv Power Systems		3	1
Phoenix		2	
SEA Electric		1	
Workhorse Group		1	
Xos		1	
Zenith Motors	2		
TOTAL:	2	12	3

Tractor and Yard Tractor Manufacturer and Number of Models by Gross Cargo Weight Rating (lbs)			
	54,600	**81,000**	**>100,000**
BYD Motors			2
Kalmar Ottawa		1	
Lion Electric	1		
Orange EV		2	
TOTAL:	1	3	2

Off-Road

Equipment Type	Technology Readiness Level	Manufacturer or Further Detail
Airport Ground Support		
Air Conditioner	Commercial	TLD[25]
Baggage Tractor	Commercial	Charlatte, Harlan, TUG Technologies Corporation, Eagle[26]
Belt Loader	Commercial	Charlatte, TLD, Hercules[27]
Cargo Loader / Lift	Commercial	TLD, JBT Corporation[28]
Cargo Tractor	Demonstration	A 90-day pilot was completed on an electric cargo tractor by Charlatte America in 2011[29].
Catering Truck	Demonstration	A demonstration electric catering vehicle by Doll[30]
Hydrant Cart	Commercial	Westmor[31]
Lavatory Truck	Commercial	Charlatte[32]
Passenger Stand	Commercial	TLD[33]

[25] Aero Specialties Ground Support Equipment https://www.aerospecialties.com/aviation-ground-support-equipment-gse-products/pre-conditioned-air-service/tld-ace-302-emp-24-ton-air-conditioning-unit/

[26] National Renewable Energy Laboratory. "Electric Ground Support Equipment at Airports" https://afdc.energy.gov/files/u/publication/egse_airports.pdf

[27] Ibid.

[28] Ibid.

[29] TLD. https://www.tld-group.com/news/part-green-strategy-klm-awarded-tld-replacement-lower-deck-loader-full-electric-fleet-recognizing-performance-txl-838-regen/

[30] National Renewable Energy Laboratory. "Electric Ground Support Equipment at Airports" https://afdc.energy.gov/files/u/publication/egse_airports.pdf

[31] Westmore. https://westmor-ind.com/wp-content/uploads/2017/10/Hydrant-Servicers-WMLT2081ENWB-02.pdf

[32] National Renewable Energy Laboratory. "Electric Ground Support Equipment at Airports" https://afdc.energy.gov/files/u/publication/egse_airports.pdf

[33] TLD.

Equipment Type	Technology Readiness Level	Manufacturer or Further Detail
Pushback	Commercial	Charlatte, TLD, Lektro, Jetporter, TUG Technologies, Eagle[34]
Water Truck	Commercial	Charlatte[35]
Cargo Handling		
Automated Guided Vehicles	Commercial	Konecrane, Kalmar[36,37]
Heavy-Duty Forklift	Demonstration	Kalmar piloting an electric forklift with Cargotec[38]
Reach Stacker	Demonstration	Hyster Europe developing an electric reach stacker using hydrogen fuel cells. Kalmar is also demonstrating an electric reach stacker with Cabooter[39,40].
Ship-to-shore gantry crane	Commercial	Electric gantry cranes are the most common ship-to-shore gantry cranes at California ports.
Side Handler	Commercial	Kalmar[41]
Straddle Carriers	Commercial	Kalmar[42]
Top Handler	Demonstration	Battery powered electric container handler at Port of LA with a wireless fast charger.
Yard Cranes	Commercial	Both RMG and RTG's have commercially available grid-electric technologies developed.
Yard Hostler (i.e., Yard Goat)	Commercial	Electric Orange EV, Kalmar Ottawa, BYD[43]

https://www.tld-group.com/products/passenger-steps/bbs-580-e/

[34] National Renewable Energy Laboratory. "Electric Ground Support Equipment at Airports" https://afdc.energy.gov/files/u/publication/egse_airports.pdf

[35] Ibid.

[36] Konecrane. https://www.konecranes.com/equipment/container-handling-equipment/automated-guided-vehicles

[37] Kalmar. https://www.kalmarglobal.com/equipment/automated-guided-vehicles/

[38] Kalmar. https://www.kalmarglobal.com/pressroom/press_releases/2019/kalmar-forges-ahead-on-its-electrification-journey-with-industrys-first-fully-electric-reachstacker-for-cabooter/

[39] Hyster. https://www.hyster.com/emea/en%E2%80%90gb/press/press%E2%80%90releases/hyster-electric-container-handlers-progress/

[40] Kalmar. https://www.kalmarglobal.com/pressroom/press_releases/2019/kalmar-forges-ahead-on-its-electrification-journey-with-industrys-first-fully-electric-reachstacker-for-cabooter/

[41] Kalmar. https://www.kalmarglobal.com/equipment/masted-container-handlers/electric-empty-handler-ecg70-35e3e4/

[42] Kalmar. https://www.kalmarglobal.com/equipment/straddle-carriers/fastcharge-straddle/

[43] California HVIP. https://www.californiahvip.org/how-to-participate/#Eligible-Vehicle-Catalog

Construction Equipment		
Boom lift	Commercial	JLG[44]
Concrete Mixers	Commercial	Small portable electric concrete mixers are common.
Dumpers	Commercial	Wacker Neuson[45]
Excavators	Demonstration	Caterpillar piloted an all-electric 25-ton excavator with a 300 kWh battery pack[46]. Smaller "mini" electric excavators are commercially available by Volvo, NASTA, Kobelco, and Wacker Neuson[47].
Loaders	Commercial	Wacker Neuson, Kramer[48,49]
Small Cranes	Commercial	UNIC Spydercrane, MAEDA, ZEE Crane[50,51, 52]
Tippers	Commercial	Epiroc[53]
Tower Cranes	Commercial	Electric tower cranes are commonly available.
Commercial Harbor Craft		
Ferries	Demonstration	Norwegian shipyard Fjellstrand and Siemens, AG are demonstrating a BE car ferry. Golden Gate Zero Emission Marine and CA Climate Investments are demonstrating a FCE passenger ferry in the San Francisco Bay Area. Alabama's Gee's Bend Ferry was retrofitted to be all electric. SWITCH maritime is designing an all-electric ferry in NYC.
Locomotive		
Locomotive switch (yard)	Demonstration	CARB / SCAQMD pilot with Port of LA and VeRail Technologies through 2020
Locomotive line haul	Demonstration	CARB / SJVAPCD to demonstrate a battery electric locomotive late 2019 through fall 2021
Ocean Going Vessel		
Ocean-Going Vessel	Research	Smaller vessels (commercial harbor craft ferries, tugboat/towboat) are being built and piloted with ZE HFCs in the Bay Area, France and Norway. European pilots expect operational date of 2021.

[44] JLG.
https://www.jlg.com/en/equipment/electric-hybrid-boom-lifts/articulating/e450-m450-series/e450aj?Cookie=language
[45] Wacker Neuson.
https://www.wackerneuson.eu/en/products/dumpers/track-dumpers/model/dt10e/
[46] Electrek. "Caterpillar unveils an all-electric 26-ton excavator with a giant 300 kWh battery pack"
https://electrek.co/2019/01/29/caterpillar-electric-excavator-giant-battery-pack/
[47] Bellona Europa. "Zero Emission Construction Sites: The Possibilities and Barriers of Electric Construction Machinery"
https://network.bellona.org/content/uploads/sites/3/2018/06/ZEC-Report-1.pdf
[48] Wacker Neuson.
https://www.wackerneuson.eu/en/products/wheel-loaders/articulated-wheel-loaders/model/wl20e/
[49] Kramer.
https://www.kramer-online.com/en/discover-kramer/zero-emission/the-kramer-5055e/
[50] Spydercrane.
https://spydercrane.com/compare-spydercrane
[51] ZEE Crane.
https://www.zeecrane.com/
[52] MAEDA Mini Cranes.
https://www.maeda-minicranes.com/
[53] Epiroc.
https://www.epiroc.com/en-us/applications/mining/zero-emission