CARB Heavy-Duty & Off-Road Hydrogen and Fuel Cell Activities

2019 DOE FCTO Annual Merit Review

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CALIFORNIA
AIR RESOURCES BOARD

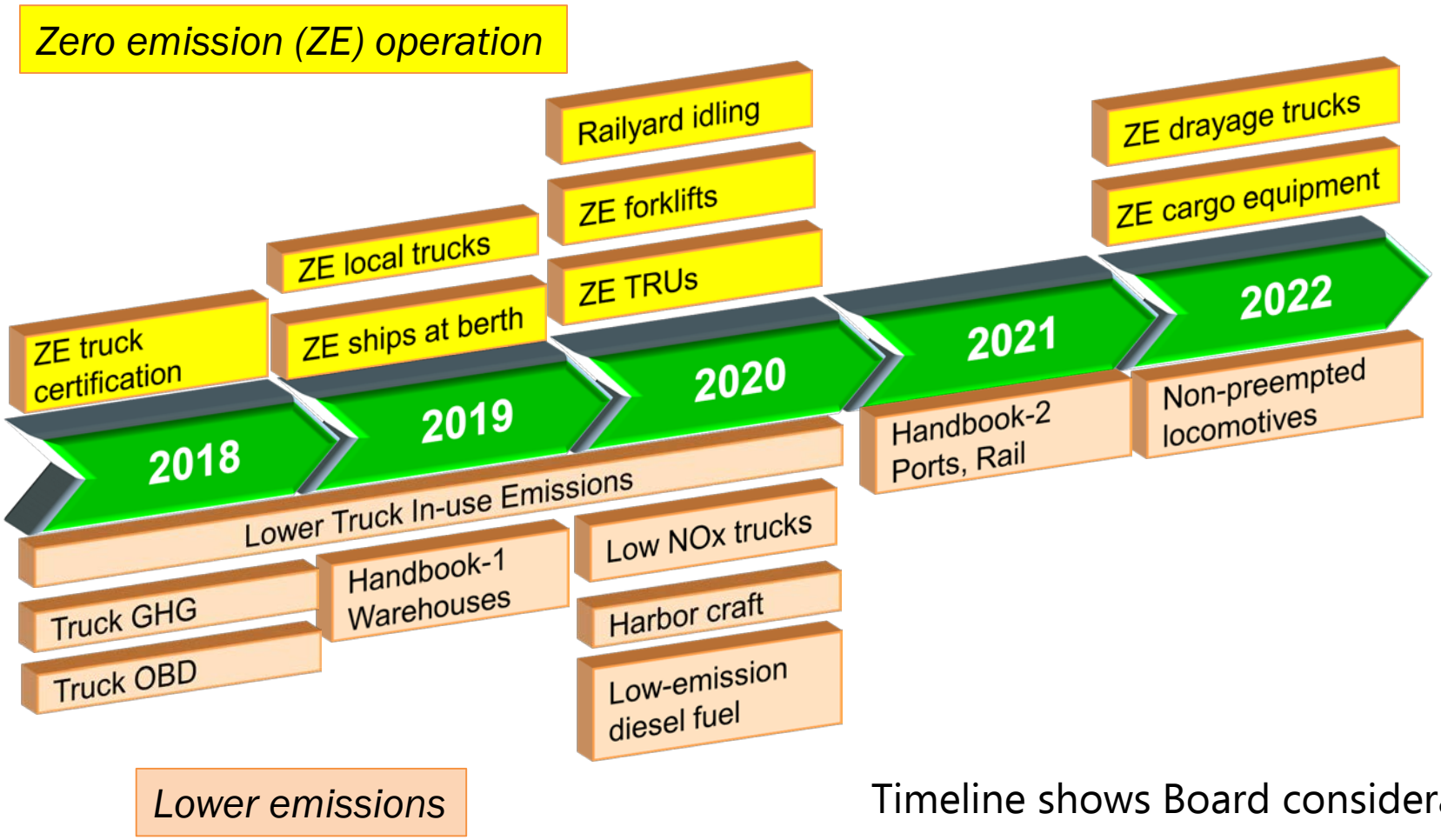
Innovative Clean Transit Rule

- Approved December 2018
- Zero-Emission Bus Roll-out Plans due:
  - Large transit agencies: June 30, 2020
  - Small transit agencies: June 30, 2023
- Early ZEB purchases count towards future compliance

https://arb.ca.gov/msprog/ict/ict.htm

Year	ZEB Percentage of Annual Total New Bus Purchases	
	Large Transit Agency	Small Transit Agency
2023	25%	-
2024	25%	-
2025	25%	-
2026	50%	25%
2027	50%	25%
2028	50%	25%
2029 & after	100%	100%

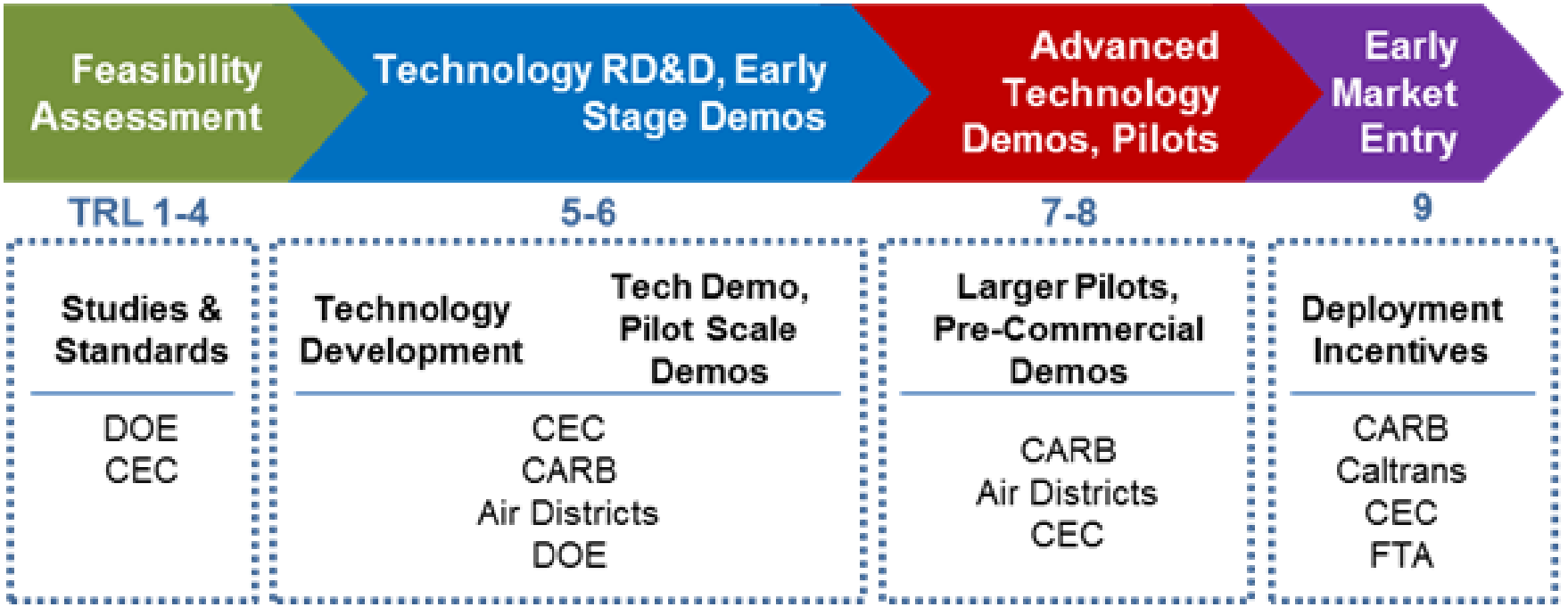
New CARB Rules to Cut Pollution from Freight



Timeline shows Board consideration

Updated 1/28/19

Investing to Advance Technology



- Incentives accelerate technology advancement and reward early adopters ahead of pending regulations
- Regulations complement incentives
- Focus on disadvantaged communities

Clean Technology Vouchers

Hybrid and Zero-Emission Voucher Incentive Project (HVIP)

- Established in 2010: Over 6,800 vouchers and $326M committed (3/1/19)
- Transit, school and shuttle buses; utility and delivery trucks (zero-emission, hybrid and low NOx)
- Up to $300K for FC truck or bus plus $100K/bus for station
- First fuel cell bus voucher delivered in March 2019
- CaliforniaHVIP.org

Clean Off-Road Equipment Voucher Incentive Project (CORE)

- Initiated in 2018
- Zero-emission yard trucks, large forklifts, ground support equipment, TRUs and rubber tire gantry cranes
- Funding available later in 2019

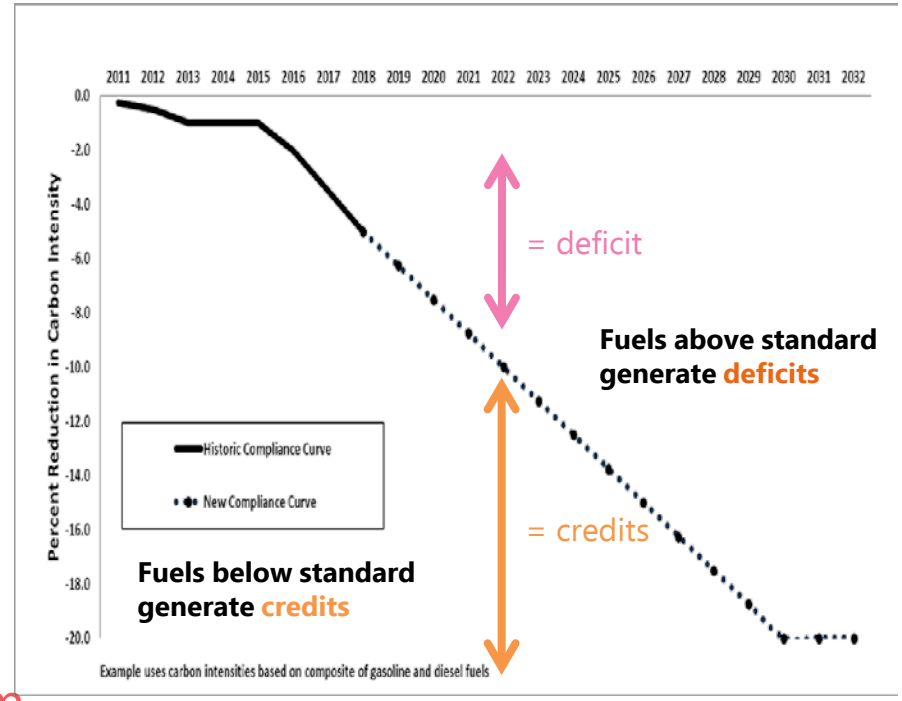
Volkswagen Mitigation Trust

- California's allocation: **$423 million**
- Approved Beneficiary Mitigation Plan details 5 funding categories, 4 are open to hydrogen & fuel cell technology:
  1. **$130M** for Zero-emission transit, school and shuttle buses (up to $400,000 for a FCEB)
  2. **$90M** for Zero-emission Class 8 freight and port drayage (up to $200,000 for a FCET)
  3. **$70M** for Zero-emission freight/marine (competitive)
  4. **$5M** for light duty H2 infrastructure
- Funding available statewide starting this summer
- ww2.arb.ca.gov/vwmitigationtrust

Low Carbon Fuel Standard (LCFS)

- Reduce carbon intensity (CI) of transportation fuel 20% by 2030
- Fuel providers can opt-into LCFS to generate credits for using lower-carbon fuels
- Credits have monetary value and can be traded in the LCFS market.
- For more information:

https://www.arb.ca.gov/fuels/lcfs/lcfs.htm



Bus/Fuel Type	Example CI(1)	Annual Credit Value(2)
FCEB using H2 from generic LCFS lookup table pathway	120	$8,702
FCEB & H2 from zero-CI electrolysis	10	$24,949

1. CIs shown are for illustrative purposes and subject to change.
2. Based on 6.5 mi/kg FCB fuel efficiency, $200/MT LCFS credit value, and 40,000 mi/year

H2 and Fuel Cell Pilot and Demonstration Projects

- Greenhouse Gas Reduction Funds for Low Carbon Transportation
  - 10 of 30 projects ($112M) awarded since FY 2014-15 involve hydrogen and fuel cell technology
  - SunLine, AC Transit and Orange County Transit
    - 25 FECBs and 3 hydrogen stations/or upgrades
  - 10 Class 8 trucks – Kenworth/Toyota – Port of Los Angeles
    - 2 large capacity Shell hydrogen stations in Wilmington and Ontario
  - 5 Class 8 plug-in hybrid fuel cell trucks
  - 19 fuel cell delivery vans – 2 projects with UPS
  - Fuel Cell Ferry – Golden Gate Marine
  - 2 fuel cell 242,000 lb. capacity yard trucks
  - Electric top loader with fuel cell and wireless charging
  - Fuel cell yard truck and battery yard truck: side-by-side comparison

Pilot Commercial Deployment Projects

SunLine FCEBs & On-Site Hydrogen Generation

- Funding: $12.6M grant, $17.8M total
- Thousand Palms, Coachella Valley
- 5 NewFlyer Xcelsior® XHE40 Buses
  - 40’ FCEBs, standard propulsion system
  - Ballard FCveloCity-HD 85kw modules
- Nel Hydrogen Production/Fueling Station
  - Modular PEM electrolyzer
  - 900 kg/day, 350 bar – 30 buses
  - Complete turnkey solution
- Buses delivered January 2019
- Station complete August 2019

SunLine TRANSIT AGENCY

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BALLARD

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Pilot Commercial Deployment Projects

Fuel Cell Electric Bus Commercialization Consortium

- Funding: $22.3M grant, $45.5M total
- 20 NewFlyer Xcelsior® XHE40 Buses

10 buses to Orange County (Southern CA)	10 buses to AC Transit (SF Bay Area)
Trillium/Air Products • Delivered LH2 • 1,750 kg/day - up to 50 buses • Service bay upgrade • Commissioning in May 2019	Messer, LLC – Station upgrade • Delivered LH2 • 1,050 kg/day – up to 30 buses • Commissioning in Dec. 2019
First 2 buses accepted, all buses to be deployed in June 2019	

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Demonstration Projects

Port of Los Angeles Shore-to-Store

- Funding: $41.1M grant, $82.5M total
- 10 hydrogen fuel cell Class 8 trucks
  - Kenworth truck w/ Toyota FC technology
  - 60 kg on-board storage
  - Developed in partnership with California Energy Commission, DOE and SCAQMD
- Two large-capacity H2 refueling stations
  - Wilmington and Ontario, California
  - Delivered gas, 1500 kg/day capacity, 700 bar
- First truck delivered summer 2019
- Stations complete spring 2020

THE PORT OF LOS ANGELES · TOYOTA · Shell · The Port OF Hueneme · ups · South Coast AQMD · CALIFORNIA CLIMATE INVESTMENTS Cap and Trade Dollars at Work

Demonstration Projects

Fast Track Fuel Cell Truck

- Funding: $5.1M grant, $6.8M total
- 5 plug-in hybrid fuel cell electric Class 8 trucks
  - 3 trucks – update existing EV Navistar chassis, Hydrogenics fuel cells
  - 2 trucks – Peterbilt glider, Loop Energy fuel cells
- Drop-and-swap mobile tube trailers and chargers at Port of LA and Fontana
- Demonstration partners: TTSI and Daylight Transport
- Project complete: Spring 2020

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Demonstration Projects

Fuel Cell Hybrid Electric Delivery Van

- Funding: $4.3M grant, $9.5M total
- UPS in Ontario and surrounding areas
- 15 FC hybrid delivery vans
  - Retrofitting existing UPS vans
  - Based on prototype built in partnership with DOE and CEC
  - Integration by Unique Electric Solutions
  - Hydrogenics 30kw fuel cell engines
- Goal: develop fuel cell retrofit kit
- Complete: Spring 2021

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UES UNIQUE ELECTRIC SOLUTIONS

The University of Texas at Austin
Center for Electromechanics

HYDROGENICS
SHIFT POWER | ENERGIZE YOUR WORLD

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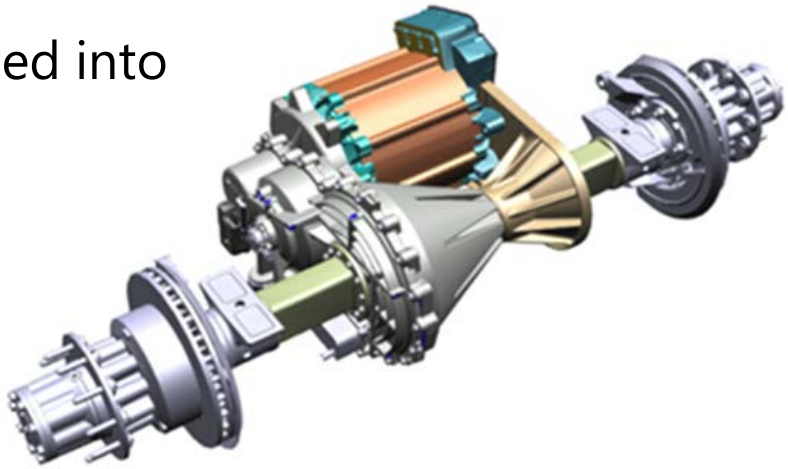
Demonstration Projects

Next Generation Fuel Cell Delivery Van

- Funding: $5.8M grant, $11.7M total
- UPS in Ontario and surrounding areas
- 4 FC hybrid electric delivery vans
  - Linamar - Gen 2.0 eAxle design integrated into new Ford F-59 chassis
  - Ballard - 30kw fuel cell engines
- Goal: develop FC retrofit kit
- Complete: Spring 2021



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LINAMAR Power to Perform

BALLARD®

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Demonstration Projects

Zero-Emission Hydrogen Ferry

- Funding: $3M grant, $5.5M total
- Fuel cell ferry – 22 knots top speed and up to 84 passengers
  - BAE Systems – electric propulsion system
  - Hydrogenics – three 120kw fuel cells
  - On-board H2 storage for 2 days of operation
  - Air Liquide - 350 bar tube trailer at dock
- Ferry operational in September 2019
- Project complete in Spring 2020.

GOLDEN GATE ZERO EMISSION MARINE

BAY SHIP & YACHT CO.

BAE SYSTEMS

HYDROGENICS

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RED AND WHITE FLEET SAN FRANCISCO CRUISES

Sandia National Laboratories

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Demonstration Projects

Fuel Cell Hybrid Electric Top Loader

- Funding: $6.5M grant, $15.4M total
- Electric top loader demonstration
  - Hyster-Yale – build and integrate
  - Nuvera – two 45kW fuel cell engines
  - WAVE – two 250kW wireless charging systems
- Mobile refueler to provide hydrogen
- Fenix Marine Services will operate yard trucks in Port of LA
- Project complete: Spring 2020

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HYSTER-YALE GROUP

NUVERA®

WAVE Wireless Advanced Vehicle Electrification

FENIX MARINE SERVICES

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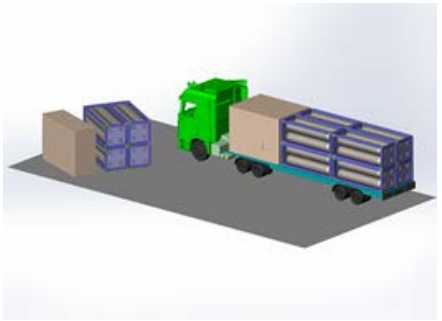
Demonstration Projects

Hybrid Fuel Cell Yard Truck

- Funding: $5.8M grant, $12.1M total
- 2 hybrid fuel cell 242,000 lb capacity yard trucks
  - BAE Systems powertrain-270hp, 3800 ft-lb torque
  - Ballard FCveloCity-HD 85kw fuel cell modules
  - 20 kg on-board H2 storage @ 350 bar
- HTEC stationary-placed mobile tube trailer
  - 400 kg storage at 450 bar
  - 2 kg/min dispensing
- TraPac will operate yard trucks in Port of LA
- Project complete: Spring 2021



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Demonstration Projects

Port of Long Beach Off-Road Technology Demonstration

- Funding: $5.3M grant, $8.3M total
- 3 battery electric top handlers (Taylor and BYD)
- Electric yard truck side-by-side comparison

Battery Electric	**Fuel Cell Electric**
Kalmar & Transpower	CNHTC* and Loop Energy
931 kW $LiFePO_4$ battery pack	56kW PEM fuel cell
70 kW charging station	Air Products mobile fueler

* China National Heavy Duty Truck Group Co. (CNHTC)

- SSA Marine will deploy yard trucks at Pier E in Port of Long Beach
- Project complete: Spring 2020

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Fuel Cell Electric Vehicle