

Technology Update: Hybrid and Battery-Electric Trucks

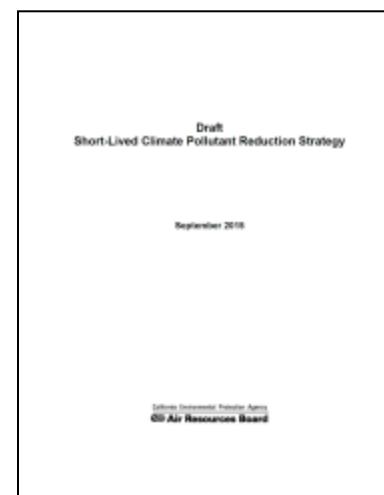
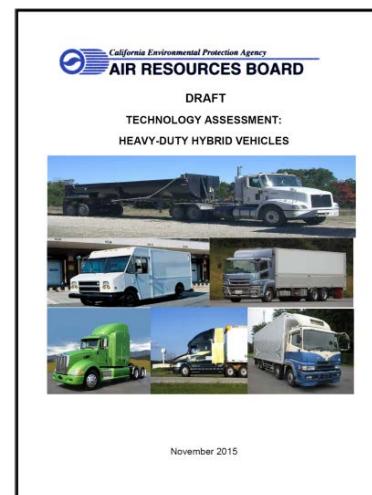
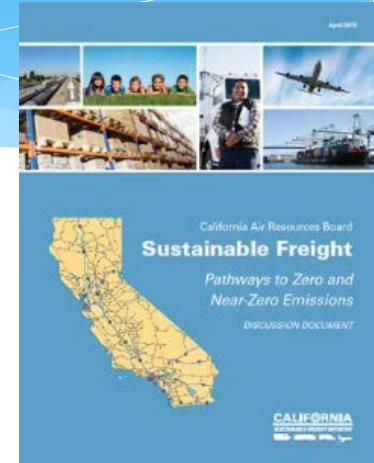
ARB Efforts to Support Advanced Medium- and Heavy-Duty Truck Technologies

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UC Davis Institute of Transportation Studies
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ARB Technology Assessments Support Multiple Planning Efforts

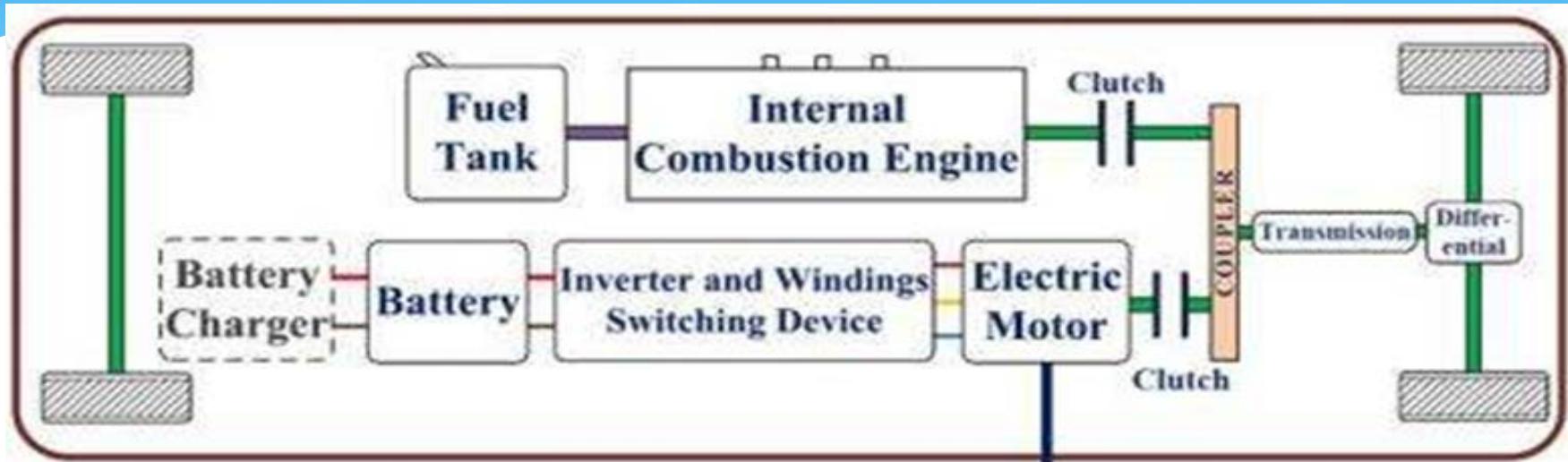
- * Mobile Source Strategy framework supports:
 - * SIP
 - * Scoping Plan
 - * Sustainable Freight
- * Heavy-Duty Diesel, Natural Gas, Hybrid, BEV, & Fuel Cell EV Technology Assessments
 - * 5 – 10 year outlook
 - * For medium- and heavy-duty vehicles (8,500 lbs.+)
- * Clear need for diverse technology portfolio



Hybrid Vehicles



What is a Hybrid Vehicle?



Degree of hybridization:

Micro
hybrid

Mild
hybrid

Full hybrid

Plug-in
hybrid

Hybrids Currently Best Suited for Urban Driving Cycles

- * High kinetic intensity: Heavy urban start-and-stop, aggressive acceleration/deceleration events, high idle time
 - * Examples: Refuse haulers, transit buses, package/delivery trucks
- * Utilize electric power take-off (ePTO)
 - * Examples: Utility and tree trimming services
- * In future:
 - * Class 3-8 rural/intracity and regional delivery, and drayage
 - * Plug-in hybrids for utility/bucket, drayage truck applications
 - * Line haul trucks may adopt mild hybridization as efficiency standards tighten

>2,500 Medium-/Heavy-duty Hybrids On Road in CA

Vehicle Type	Technology Readiness	Number in Service in CA
Parcel Delivery	Commercially available	830
Uniform & Linen Delivery		110
Beverage Delivery		440
Food Distribution & Other Trucks		680
Buses (Transit, Shuttle, School)		470
Other		Demos: Utility/Bucket Trucks, Drayage

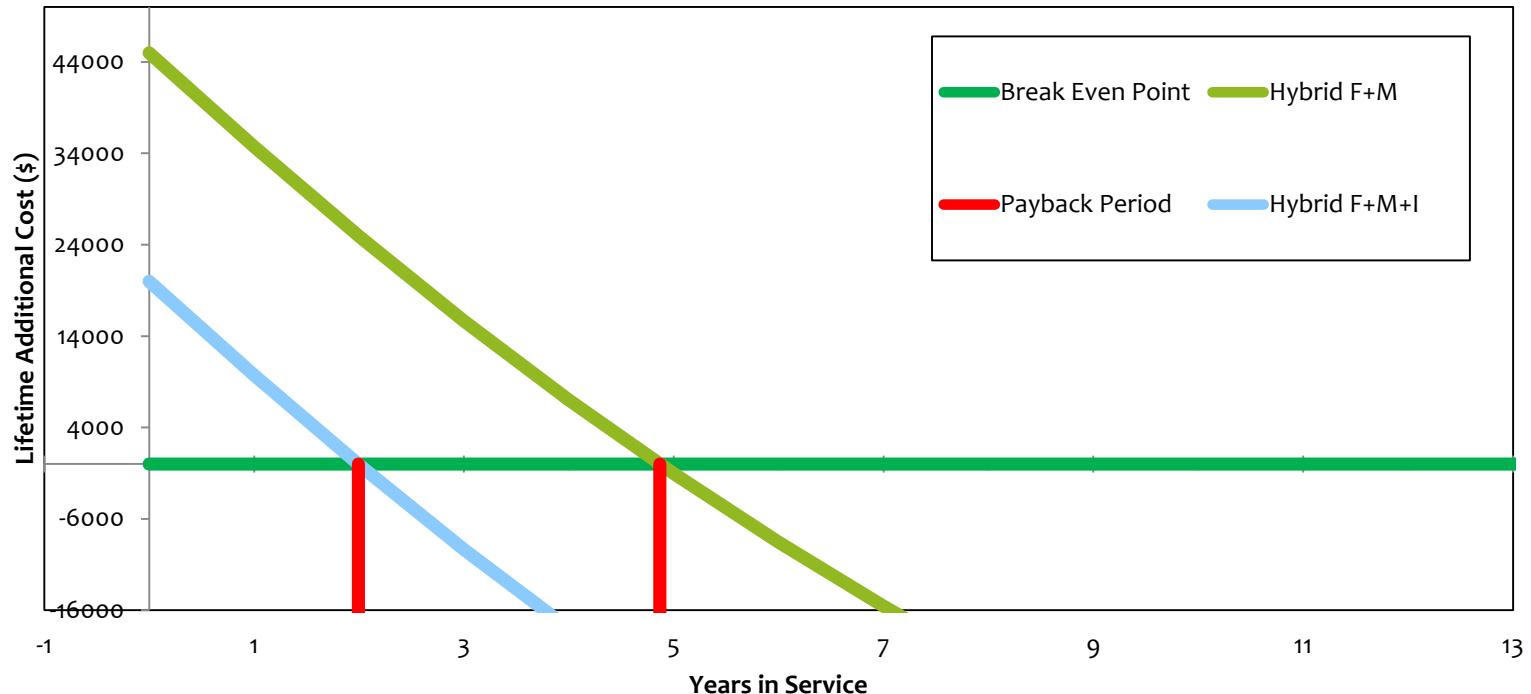
- Many more in use overseas, most in China, South America, Europe, India

Overcoming Market Challenges

- * Cost: ~20% to 50% of vehicle purchase cost
 - Costs relatively high at low volume
 - Solutions: O&M savings, incentives, increasing volumes
 - O&M cost savings can offset increased purchase cost in as little as ~5.5 years
- * Performance: High-power demand applications
 - Solutions: Battery improvements, system optimization
- * Weight: Weight penalty of 300 lbs.-4,500 lbs.
 - Solutions: Light weighting, route selection
- * Certification: OBD and NOx emissions challenges
 - Solutions: Innovative Technologies Regulation, improve engineering designs and system integration

Hybrid Technologies Can provide Overall Cost Savings to Fleets

Class 8 Hybrid Beverage Delivery Truck – Case Study *
(Based on Today's Costs)



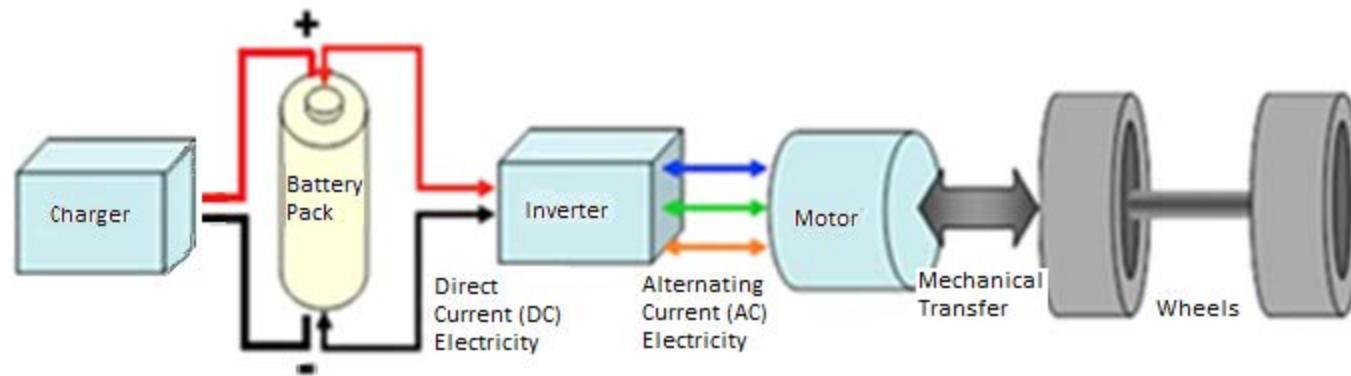
"F" = Fuel savings, "M" = Maintenance Savings "I" = Incentives

* NREL "Coca-Cola Refreshments Class 8 Diesel Electric Hybrid Tractor Evaluation: 13-Month Final Report" - NREL/TP-5400-53502 August 2012- K. Walkowicz, M. Lammert, and P. Curran

Battery-Electric Vehicles (BEVs)



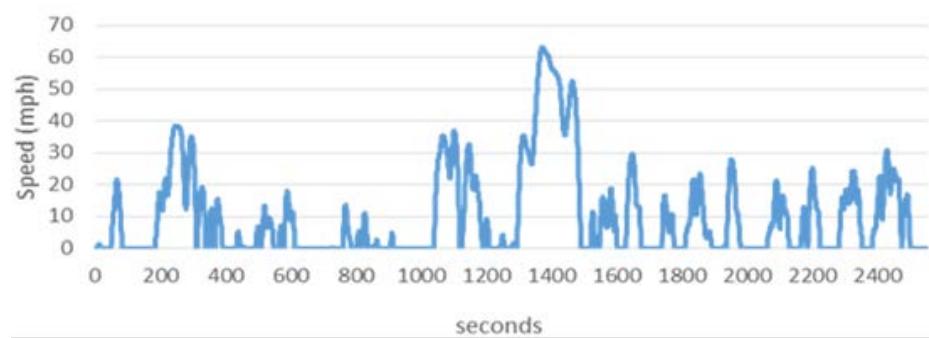
What is a Battery-Electric Vehicle?



- * A vehicle using batteries as the sole source of power
- * Components:
 - Electric motor
 - Battery pack and battery management system

Optimal BEV Duty Cycle is Similar to Hybrid's

- * Urban or suburban routes
- * Frequent start and stop
- * High idle times/lower average speeds
- * Daily ranges of 100 miles or less
- * This makes them particular suitable in early years for:
 - Transit buses
 - Shuttle buses
 - Delivery trucks

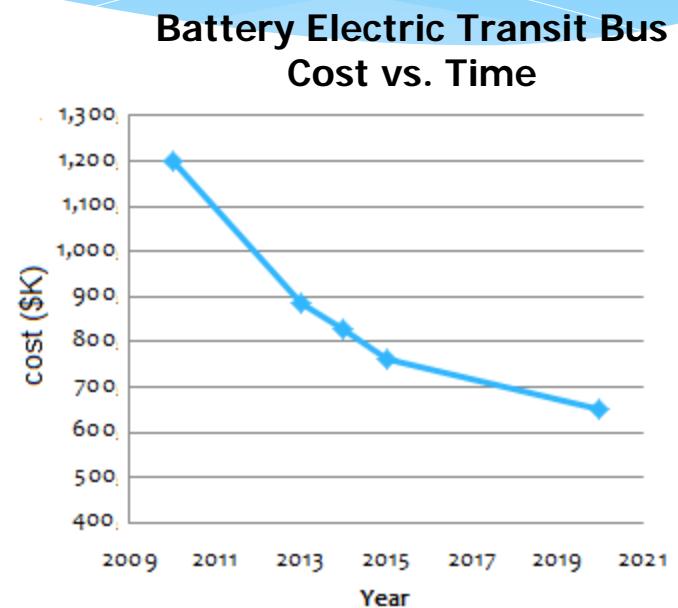


Hundreds of Medium-/Heavy-Duty BEVs in California

Vehicle Type	Technology Readiness	Number in Service
Transit Bus	Commercially Available	~40 in California, >2,500 worldwide
School Bus	Limited Commercial	4 in California
Medium-Duty	Limited Commercial	300+
Heavy-Duty (> 14,000 lbs. GVWR)	Demonstration	2 Drayage 1 Refuse

Overcoming Market Challenges

- * Range
 - Solutions: Battery improvements, fast-charge technology
- * Incremental cost (Bus: ~ 50% of purchase cost)
 - Solutions: O&M savings, incentives, increasing volumes
- * Weight
 - Solutions: Battery improvements, light weighting
- * Charging/infrastructure
 - Solution: Incentives



ARB Efforts to Support Advanced Truck Technologies

- * ARB incentives supporting technology development
 - * Low Carbon Transportation Investments and AQIP
 - * <http://www.arb.ca.gov/msprog/aqip/aqip.htm>
 - * Zero-Emission Truck & Bus Pilot Commercial Deployment
 - * Multi-Source Facility Demonstration
 - * Zero-Emission Drayage Truck Demonstration
 - * Goods Movement Emission Reduction Program
 - * <http://www.arb.ca.gov/bonds/gmbond/gmbond.htm>
- * Regulatory efforts
 - * Advanced Clean Transit – 2016
 - * Last Mile Delivery – 2017
 - * Zero Emission Airport Shuttle Buses – 2017-2018
- * Advanced technology trucks are here
 - * Challenges exist, but so do solutions