

# Advanced Clean Local Trucks Workshop

April 25, 2017

Sacramento, California

Mobile Source Control Division

California Environmental Protection Agency

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**Air Resources Board**

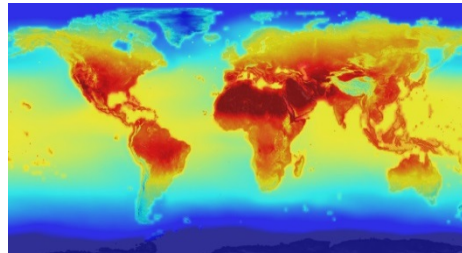


# Overview

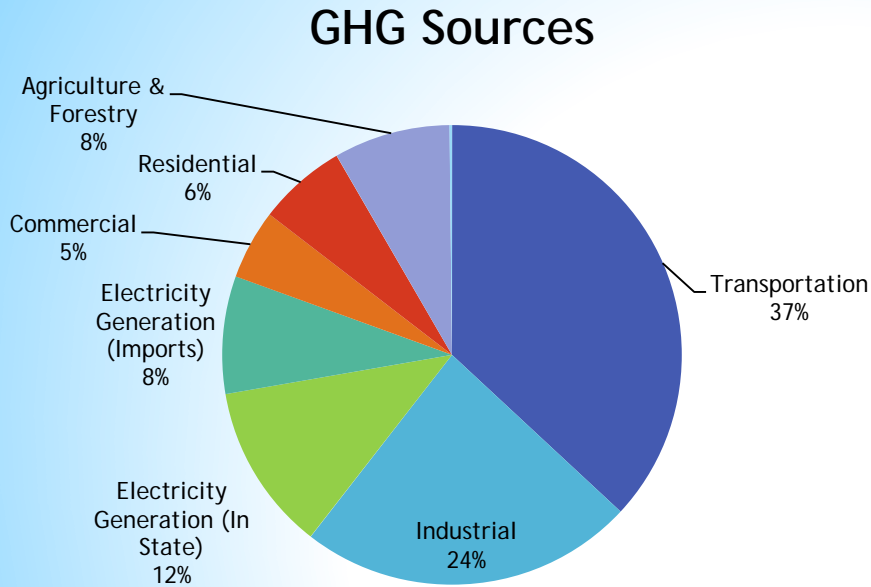
- Background
- Manufacturer sales requirement proposal
- Fleet operations survey
- Energy efficiency ratios
- Cost examples
- Vocational aerodynamics

# Challenges in California

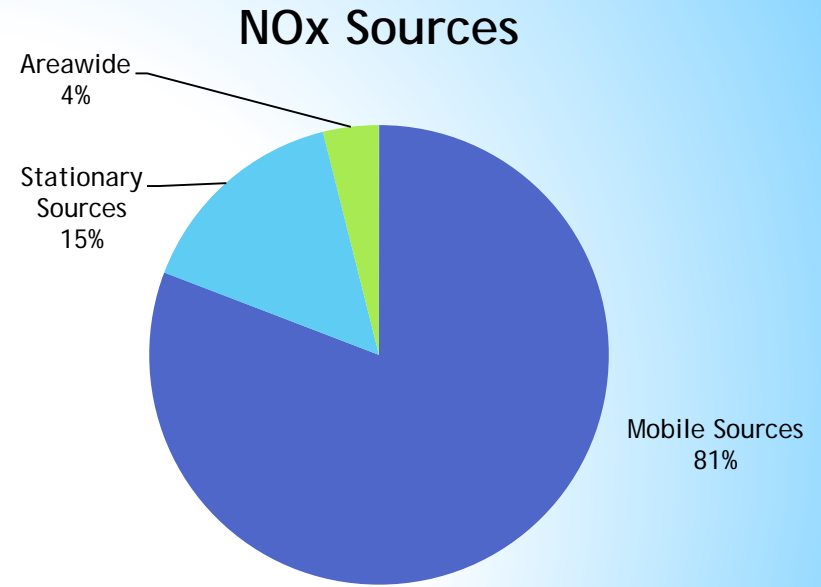
- Localized toxic air pollutants
- Regional air quality
  - Ozone, particulate matter, etc.
- Climate protection
- Dependence on fossil fuels
- Traffic congestion



# Transportation is Largest Emissions Source in California



Total 2014 Greenhouse Gas (GHG) Emissions  
441.5 MMT CO<sub>2</sub>



Total 2015 NOx Emissions  
1886 tpd NOx

# Zero Emission Truck Market Expanding

- Mitsubishi Fuso is first major manufacturer to bring a battery electric truck to market in 2017
- Workhorse Group announced plans for first range extended battery electric pickup truck (similar concept to existing step vans)
- Ford recently approve electric drivetrains in its qualified vehicle modifier program
- BYD expanding existing California bus facility to produce all electric trucks
- Multiple zero emission truck/equipment manufacturers in market



- European market commercialization expected ~2019
  - Ford demonstrating battery-electric Transit vans in London
  - Mercedes planning 1,500 battery-electric Sprinter vans for Germany

# Advanced Clean Local Truck Regulation Overview

- Accelerate early market for zero emission trucks
  - Centrally fueled, low average speed, stop-and-go operation
- Evaluating initial manufacturer sales requirement
  - Class 2B to Class 8 vocational
  - Role of plug-in electric hybrids, range extenders, electric PTO options
- Long term transition to performance based goals
- Board consideration 2018



# Benefits of Zero Emission Vehicles

- GHG and criteria pollutant reductions
- Petroleum use reduction
- Two to six times more efficient than a conventionally fueled vehicle
- Reduced brake wear/dust
- Decreases direct exposure to criteria pollutants
- Less potential for hazardous fluid/gas leaks
- Potential benefits to electrical grid
- Opportunity to use all forms of renewable energy
- Noise reduction
- Synergies with other innovative transportation system

# Short-Term vs Long-Term GHG Reduction Goals

- Short-term goal to expand zero emission truck market
  - Accelerate zero emission vehicle market
  - Increase scale, and decrease initial upfront costs
  - Strengthen support network and supply chain
  - Outreach and workforce training
  - Data collection and analysis to inform long term strategy
- Long-term goal to maximize GHG reduction
  - Transition to a regulatory structure based on GHG performance metrics beyond 2030
  - Zero emission technologies, logistic efficiencies and other innovative technologies and integrated transportation systems



# Advanced Clean Cars Regulation

- Requires light duty vehicle manufacturers to sell zero emission vehicles in California
- Establishes a credit system which allows trading
  - Includes passenger cars and up to Class 2A vehicles
  - Class 2B-3 vehicles can generate optional credits
- Has successfully introduced over 250,000 zero emission cars in California

# Proposal Concept

- A percentage of medium- and heavy-duty sales by chassis manufacturers must consist of zero emission capable vehicles
- Manufacturers must generate credits equivalent to a percentage of their total model year sales
- Three main categories: Class 2B-3, Class 4-7, Class 8
  - Percentage requirement will be based on annual Class 2B-7 vehicle sales
  - Class 8 vehicles will not have a percentage requirement but can earn credits

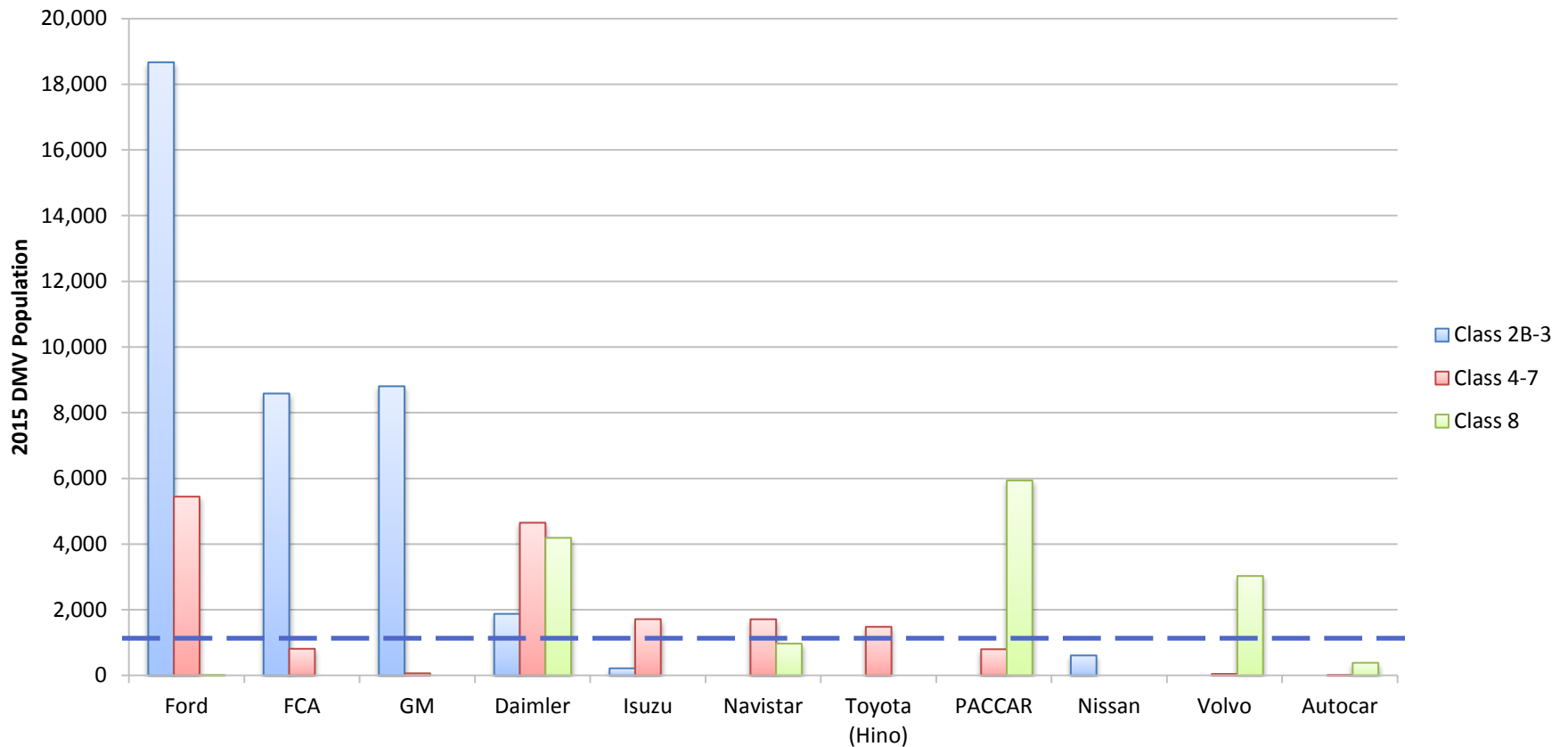
# Proposed Regulated Party

- Chassis/vehicle manufacturers would be required to meet annual sales percentage requirements in California
  - If selling 1,000 or more units annually in classes 2B – 7
- Separate sales targets
  - Class 2B-3 (GVWR: 8,501-14,000 lbs)\*
  - Class 4-7 (GVWR: 14,001 – 33,000 lbs)
- Optional credits for Class 8 vehicles can be applied to Class 4-7 obligation
  - No credit trading between other categories
- Exempt manufacturers can generate credits

\* Must exclude Class 2B-3 vehicles sales if used to generate credits for Advanced Clean Cars Regulation compliance

# Annual Truck sales in California

## 2015 California Vehicle Population by Manufacturer



# Proposed Regulatory Schedule

- Begins with 2023 vehicle model year
- Early action credits for pre-2023 models
- Credits tracked by model year
- Manufacturers may delegate authority to a sub-manufacturer to complete assembly with advanced technology

Model Year	Percentage of CA Sales	Total CA Sales*
2023	2.5%	1,350
2024	5.0%	2,700
2025	7.0%	3,780
2026	8.5%	4,590
2027	10.0%	5,400
2028	10.0%	5,400
2029	13.0%	7,020
2030	15.0%	8,100
Total		38,000

\* CA Vehicle Sales are estimated based on 2015 Class 2B-7 Population

# Technology Categories

- Zero emission vehicle (ZEV) (ie: no combustion)
  - Battery electric
  - Fuel cell electric
  - Catenary electric
- Battery-electric vehicle with conventionally-fueled range extender (BEVx)
  - Motive power comes from electric motor
  - Combustion source range limited to 70% of all electric range
- Transitional zero emission vehicle (TZEV)
  - Zero emission vehicle operation until battery depleted
  - Can operate solely on conventional power source (ie: hybrid drive system)

# Proposed Credit Generation

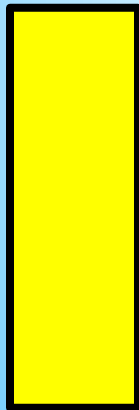
- Zero emission vehicle credits
  - Minimum 50 mile zero emission range or
  - Additional credits for zero emission range above 125 miles
  - Apply to Executive Officer for battery on-route charging
- BEVx credit based on all electric range
- Higher credit for optional Class 8 sales
- Initial TZEV credit up to 50% of BEVx credit

	Class 2B-3	Class 4-7	Class 8
ZEV (50-125 mile range)*	1.0	1.0	1.5
BEVx (35-75 mile EV range)	0.5	0.5	0.75
BEVx (75-125 mile EV range)*	0.75	0.75	1.0

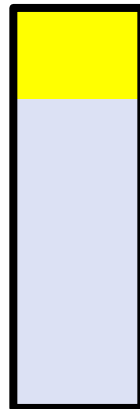
\* Add 0.1 credits per 10 miles of additional range above 125 miles.

# Minimum Credit Requirements

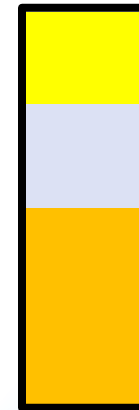
- Credit obligation can be met by combination of ZEV and BEVx credits
  - Credit “floor” for pure ZEV’s
- ZEV “floor” can start low and increase over time



ZEV credits can fill the full percentage requirement



BEVx credits can fill most of the percentage requirement



TZEV credits can fill some of the percentage requirement



# Sales Reporting

- Online manufacturer reporting system for vehicle sales
  - Similar reporting as for Advanced Clean Cars
  - Credit sales reported to ARB for compliance tracking

# Other Questions

- Should infrastructure development be supported?
- Should vehicle usage data be required?
- How to report collect additional data and information for decision making?
- What information should be shared with public?
- What vehicle certification methods needed to validate credit amounts?

# Zero-Emission Heavy-Duty Vehicle Certification Procedures

- Standardized evaluation criteria would validate zero-emission vehicle performance
  - Support Advanced Clean Local Trucks, HD GHG Phase 2, and other potential technology-advancing CARB regulations and incentive programs
  - Enable informed decision making to fleets and market
- Procedures would be mandatory in order to enable California sale

# Certification Procedure

## Key Questions

- What performance criteria should these procedures evaluate?
- How to quantify zero emission range?
- Should procedures be vehicle/chassis-specific, apply to the zero-emission drive system only, or a combination of both?
- Other stakeholder questions, comments, or suggestions?

# Certification Procedure Public Process

- Zero-Emission Heavy-Duty Vehicle Certification Procedures Public Work Group meetings
  - Spring/Summer 2017
  - Detailed discussion of certification procedure development, opportunity for public suggestions and feedback
  - Open to all interested stakeholders
- Ongoing staff discussions with interested stakeholders
- Contact: Matt Diener, ARB lead staff for zero-emission certification, [matthew.diener@arb.ca.gov](mailto:matthew.diener@arb.ca.gov) or (626)575-6684

# Freight GHG Reduction Strategies (Long Term)

- Accessory electrification
- Aerodynamic technology
- Autonomous trucking
- Drone technology
- Electric power take off (PTO)
- Geo-fencing
  - Electric miles, NOx/GHG optimization, other
- Low rolling resistance tires
- Platooning
- Real-time route optimization, planning and logistics
- Engine start-stop technology
- Vehicle weight reduction
- Waste energy recovery
- Zero emission vehicles
- Other

# Fleet Survey

# Fleet survey

- To seek feedback on fleet operations, truck duty cycles, and types of trucks used
- Data used to better understand how regulations will affect individual fleets and market potential
- Asking for feedback by May 15, 2017
  - Send comments to Paul Arneja at [paul.arneja@arb.ca.gov](mailto:paul.arneja@arb.ca.gov)

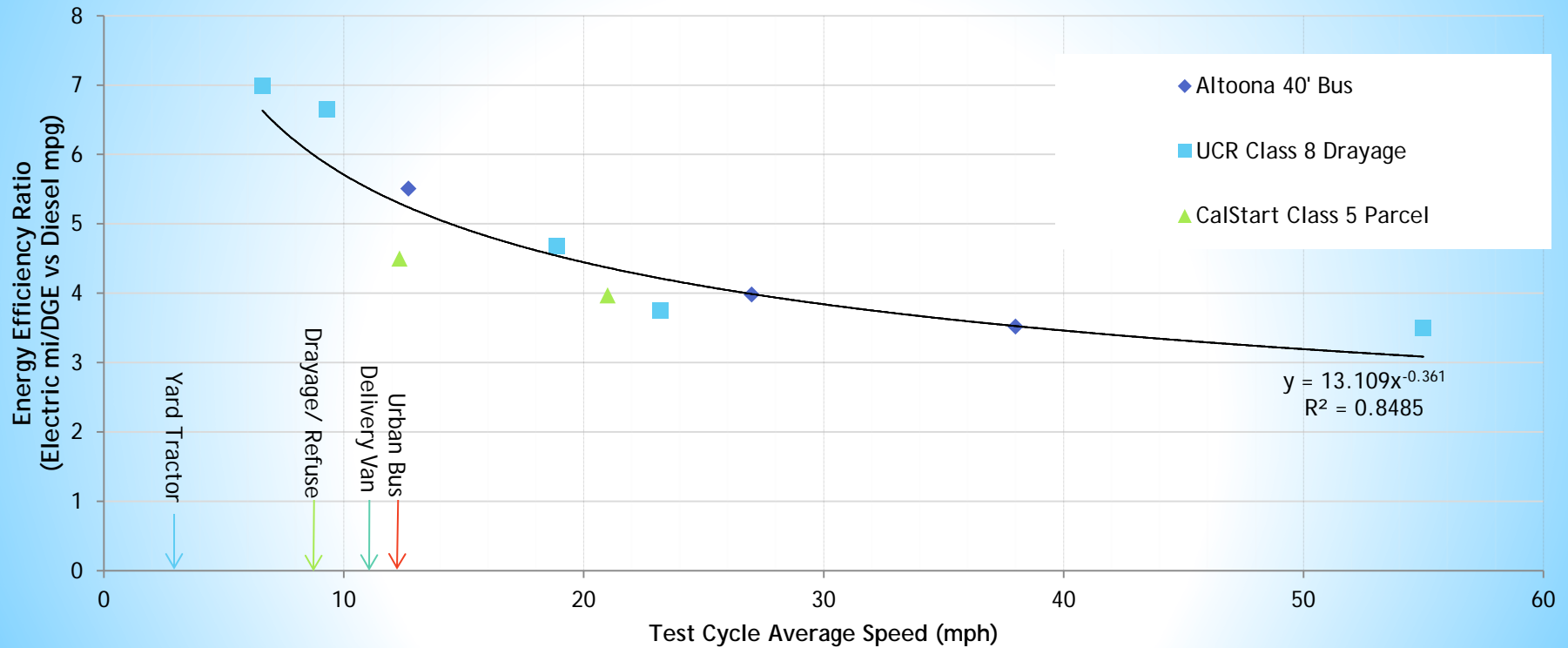


# **Energy Efficiency Ratios for Electric Vehicles**

# Battery Electric Vehicle Efficiency Data

- Evaluated available recent study data for truck and buses
  - Battery electric and diesel on same test cycles
  - Drayage trucks, transit buses, step vans
- Results shows battery electric energy efficiency improves as average speed decreases
- In-use results show similar results

# Battery Electric Truck and Bus Efficiency Highest at Lower Speeds



Altoona Bus Tests (2010 and newer buses) <http://altoonabustest.psu.edu/buses/>

Battery Electric Parcel Delivery Truck Testing and Demonstration. California Energy Commission. Gallo, Jean-Baptiste, Jasna Tomić. (CalHEAT). 2013.

Performance Evaluation of TransPower All-Electric Class 8 On-Road Truck. Johnson, Kent, J. Wayne Miller, and Jiang Yu Xiao.

[http://www.calstart.org/Libraries/CalHEAT\\_2013\\_Documents\\_Presentations/Battery\\_Electric\\_Parcel\\_Delivery\\_Truck\\_Testing\\_and\\_Demonstration.sflb.ashx](http://www.calstart.org/Libraries/CalHEAT_2013_Documents_Presentations/Battery_Electric_Parcel_Delivery_Truck_Testing_and_Demonstration.sflb.ashx)

# Costs

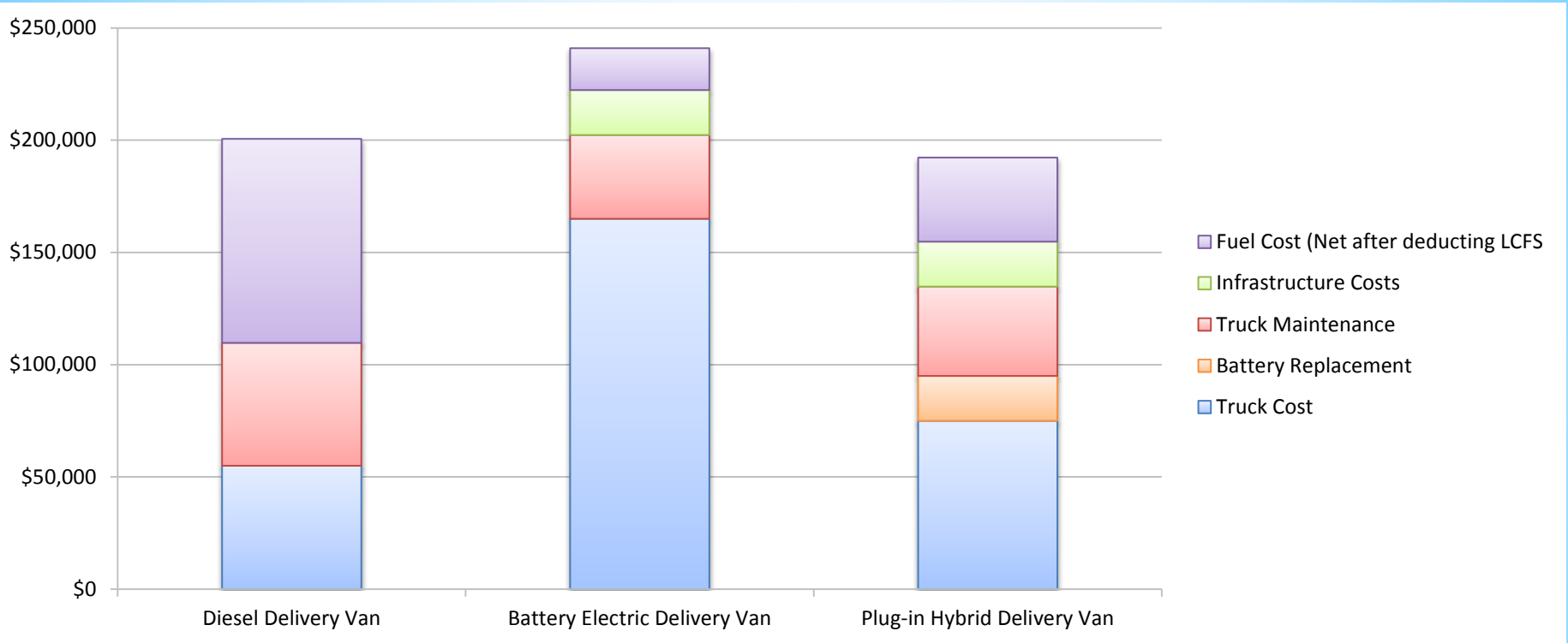
# Zero Emission Cost Considerations

- Advanced technology trucks have a higher upfront capital cost
- Battery and fuel cell costs declining
- Vehicle costs to decline with scale
- Require infrastructure upgrades
  - PG&E and SCE are proposing to reduce/eliminate infrastructure upgrades for battery electric trucks and buses (SB 350)
- Significant fuel savings compared to diesel in most cases
  - Depends on charging strategy, utility rate, and average speed
- LCFS program reduces costs (based on fuel type and use)
- Maintenance is expected to be lower than conventional trucks
- Total cost of ownership should continue to improve

# Potential Changes with SB350 and LCFS

- The IOU's proposals for SB 350 transportation electrification could reduce or eliminate the cost of upgrading infrastructure for electric vehicles
- Updating the LCFS value for electric trucks from 2.7 to 5.0 will result in battery-electric trucks earning more credits per kWh used.
  - Assuming a credit value of \$100, the value goes from \$0.06/kWh to \$0.14/kWh
- Total cost of ownership for a battery-electric vehicles could decrease significantly in California

# Example Delivery Van Costs Today



## Assumptions:

25,000 mi/yr, 12 year lifetime, with average speed of 11 mph

Fuel cost: \$2.92 per gallon diesel, \$0.13/kWh (SCE overnight charging)

Plug-in hybrid: For a 60 mi. trip, assume 50 mi. operating on electricity and 10 mi on gasoline.

LCFS Value: \$0.06/kWh

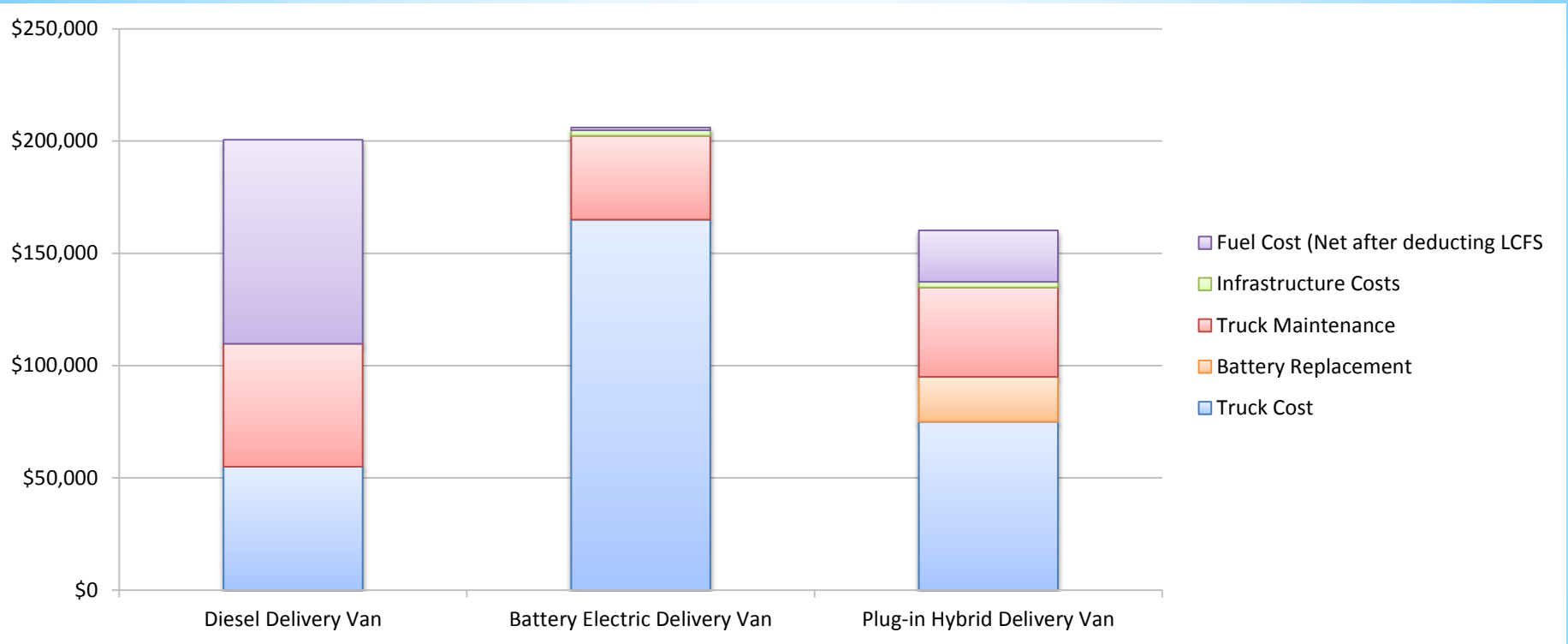
8 mpg for diesel van, 10 mpg for plug-in hybrid van, 1.0 kWh/mi for electric van

Maintenance: \$0.22 per mile, 30% reduction for battery electric, slightly higher for plugin

Infrastructure: \$20,000 per electric truck

Large order of plug-in hybrid delivery vans

# Example Delivery Van Costs (with SB 350 and LCFS updates)



## Assumptions:

25,000 mi/yr. , 12 year lifetime, with average speed of 11 mph

Fuel cost: \$2.92 per gallon diesel, \$0.13/kWh (SCE overnight charging)

Plug-in hybrid: For a 60 mi. trip, assume 50 mi. operating on electricity and 10 mi on gasoline.

LCFS Value: \$0.14/kWh

8 mpg for diesel van, 10 mpg for plug-in hybrid van, 1.0 kWh/mi for electric van

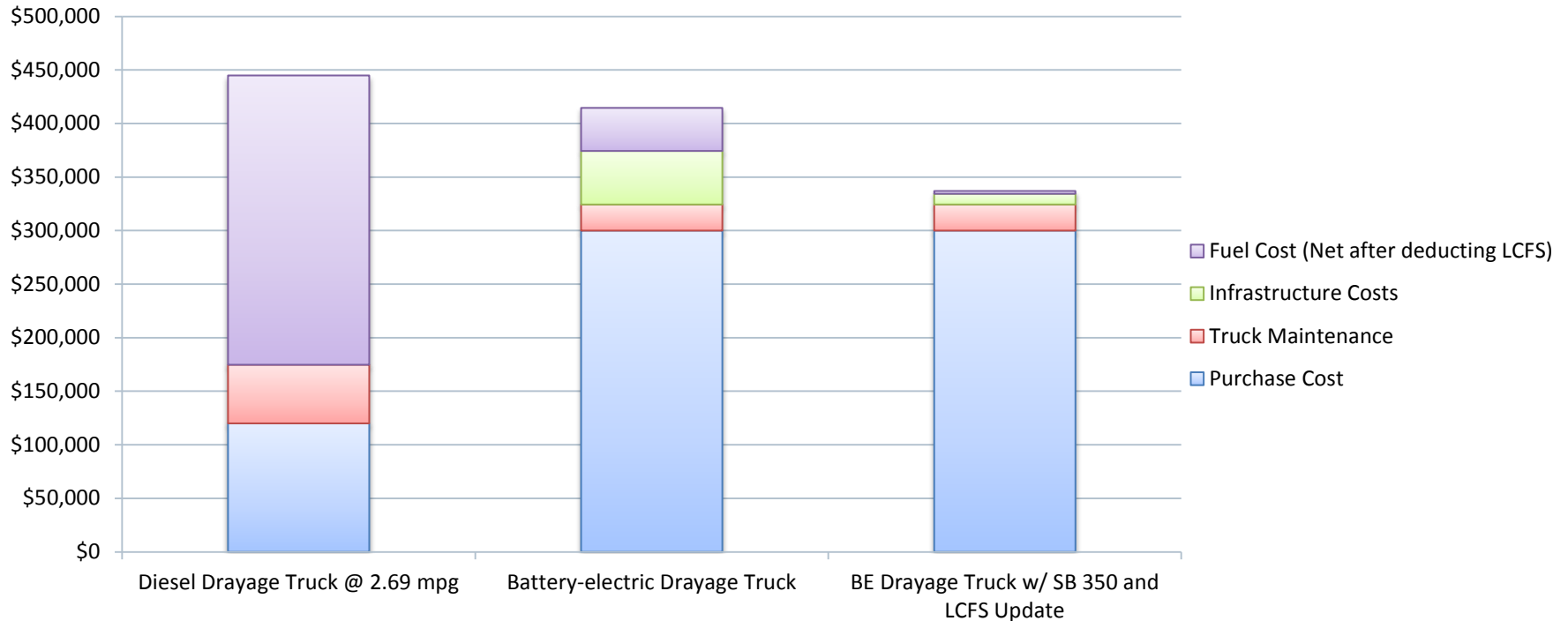
Maintenance: \$0.22 per mile, 30% reduction for battery electric, slightly higher for plugin

Infrastructure: \$2,500 per electric truck

Large order of plug-in hybrid delivery vans



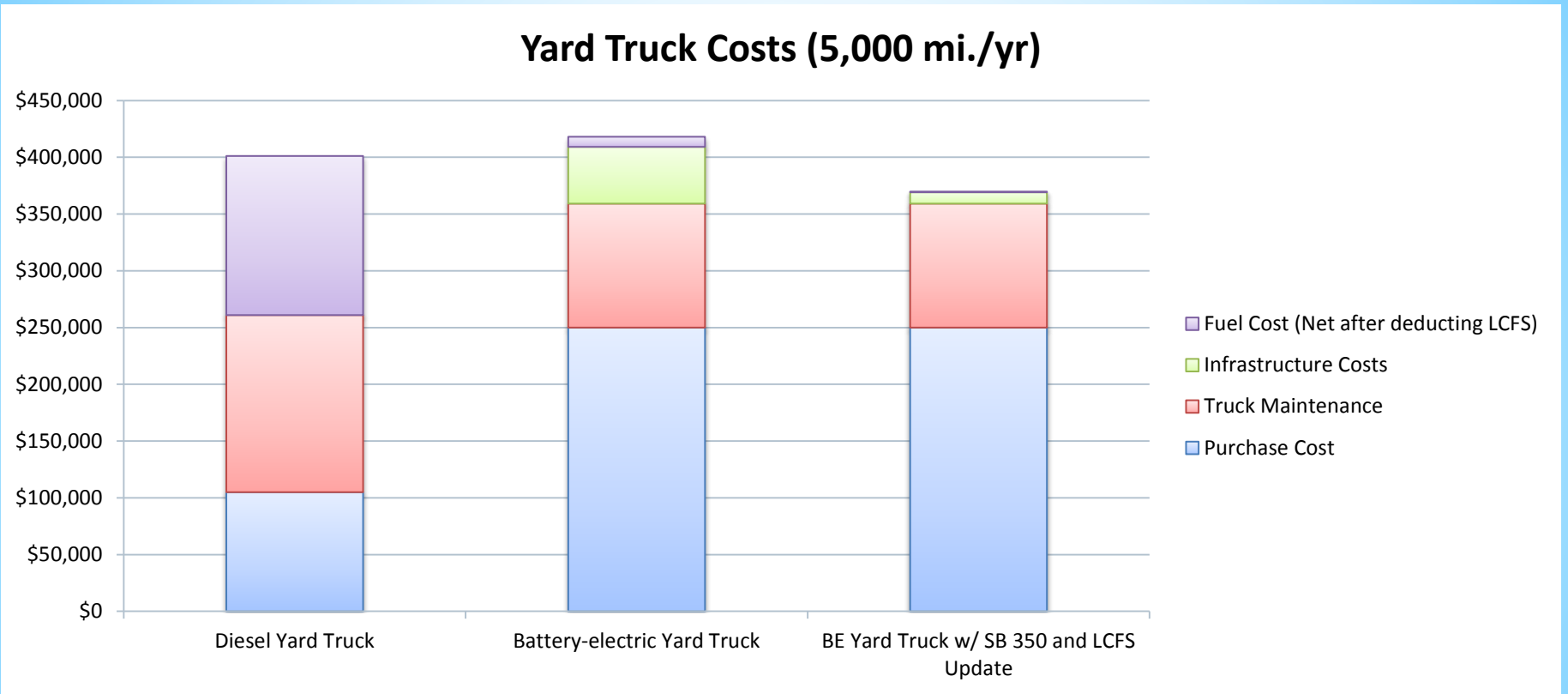
# Example Drayage Truck Costs (Local Operations)



## Assumption:

- 25,000 mi/yr. , 12 year lifetime
- Fuel cost: \$2.92 per gallon diesel, \$0.13/kWh (SCE overnight charging)
- LCFS Value: \$0.06/kWh, after update \$0.14/kWh
- 2.69 mpg for diesel drayage truck, 2.1 kWh/mi for drayage truck
- Maintenance: \$0.14 per mile, 30% reduction for battery electric
- Infrastructure: \$50,000 per electric drayage truck today, \$10,000 after SB 350

# Example Yard Truck Costs



- Assumptions:
  - 5,000 mi./yr. , 12 year lifetime
  - Fuel cost: \$2.92 per gallon diesel, \$0.13/kWh (SCE overnight charging)
  - LCFS Value: Currently \$0.06/kWh, after update \$0.14/kWh
  - 1.71 mpg for diesel yard truck, 1.9 kWh/mi for drayage truck
  - Maintenance: \$2.60 per mile, 30% reduction for battery electric
  - Infrastructure: \$50,000 per electric drayage truck today, \$10,000 after SB 350

# Cost Reduction Over Time

- Battery costs are decreasing rapidly and are projected to continue dropping\*
- As vehicle sales volumes increase, costs per vehicle are expected to decline due to economies of scale
- We are interested in collecting data on how prices change with increased production volumes
  - BYD expects prices for their drayage truck to drop roughly 50% with 12,000 sales, and for prices for their yard truck to drop 50% with 1,000 sales

\* California Air Resources Board, *Battery Cost for Heavy-Duty Electric Vehicles (Discussion Draft)*

# **Vocational Aerodynamics**

# Aerodynamic Potential

- Aerodynamic devices shown to reduce GHG emissions in heavy-duty trucks
- ARB Tractor-Trailer Greenhouse Gas and US EPA Phase 1 & 2 rules have integrated aerodynamic features into Class 7-8 heavy-duty trucks
- Based on the ARB/NREL Study
  - U.S. EPA recognized the GHG benefit of aerodynamic devices on vocational box trucks
  - US EPA Phase 2 rule offers credits for the use of aerodynamic devices on vocational trucks



# Aerodynamic Devices Can Save Fuel

Aerodynamic Device(s)	Fuel Consumption Reduction (%)		
	Road Load @ 45 mph	Road Load @ 55 mph	Road Load @ 68 mph
Side skirts	6.1	5.6	5.2
Front fairing	5	6	6.9
Side skirts + front fairing	10.3	10.4	10.4
Rear fairing	2.7	3.3	3.8

# How to Incentivize Aerodynamic Improvements

- Credit for using aerodynamic designs or technologies in Vocational Class 4-6 Truck
- Manufacturers could earn credits by either:
  - Showing reduced drag compared to a baseline using an innovative design; or
  - Using front fairing/side skirt technology



# Vocational Class 4-6 Aerodynamic Credit Proposal

- Manufacturers could obtain the aerodynamic credit via one of two options:
  - Implement side skirt and front fairings or
  - Achieve a 5% reduction in coefficient of drag demonstrated by using either wind tunnel or coast down testing to show that the vehicle reduces drag over the baseline by at least 5%
  - Testing will be done in accordance with SAE J1263/SAE J2263 or SAE J1526 test procedures
- The aerodynamic improvements would be applied to a percentage of the new truck sales

