

Planned Activities and Measures for Addressing On-Road Heavy-Duty NOx Emissions



October 20, 2016
Fresno, California

California Environmental Protection Agency

 **Air Resources Board**

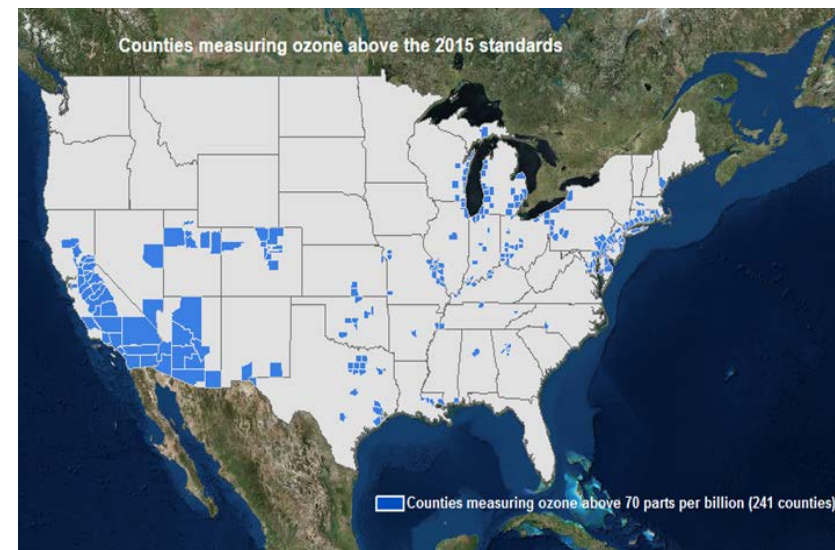
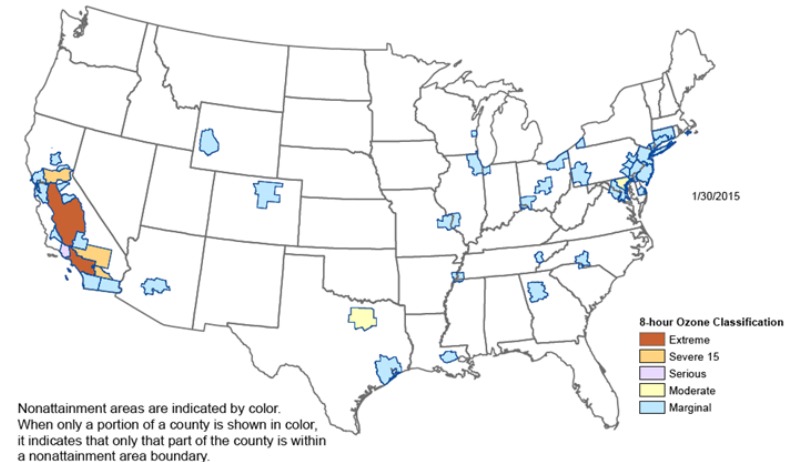
Today's Presentation

- ▶ Need for NOx Reductions
- ▶ Heavy-Duty Research Activities
- ▶ Planned Low NOx Measures
- ▶ Next Steps

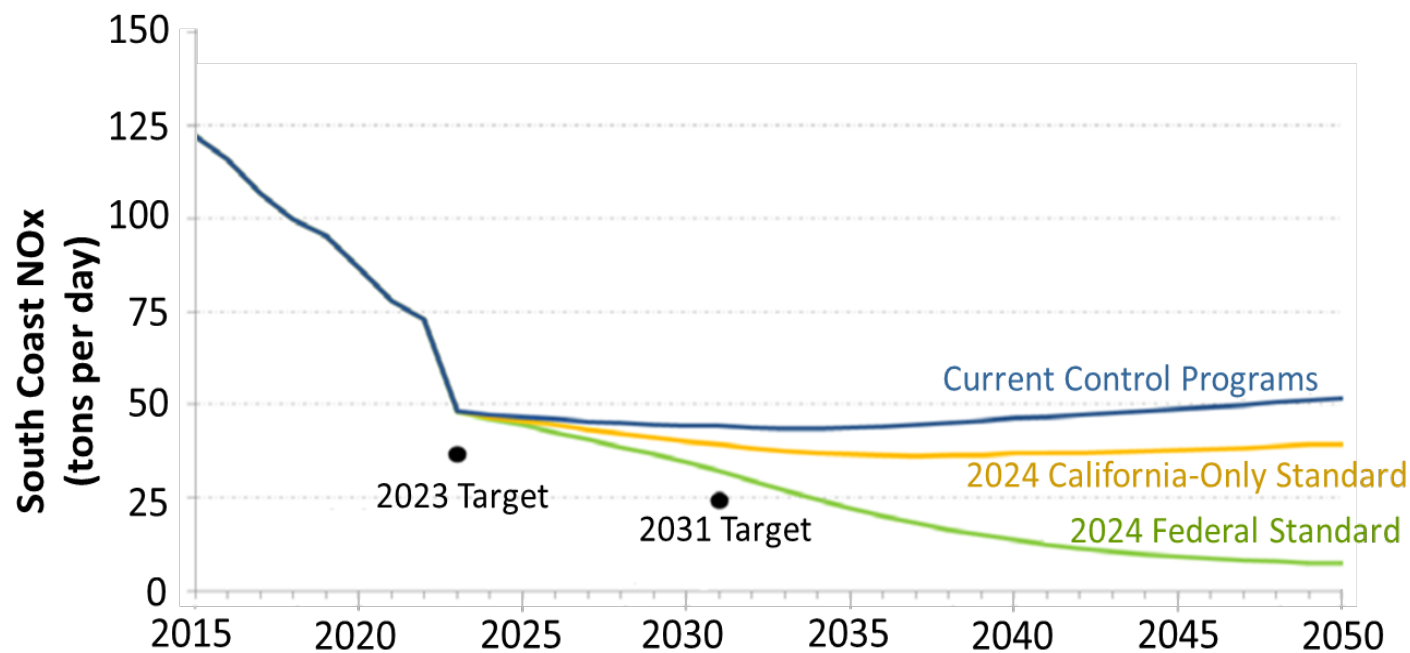
Significant NOx Reductions Needed in California

- ▶ Significant NOx reductions needed to meet ozone standards in South Coast:
 - ~70% reduction by 2023
 - ~80% reduction by 2031
- ▶ Heavy-duty (HD) trucks emit 33% of statewide NOx, 509 tons per day
- ▶ 2015 NAAQS for ozone strengthened
- ▶ National standards are critical

8-Hour Ozone Nonattainment Areas (2008 Standard)



Importance of Federal Standards



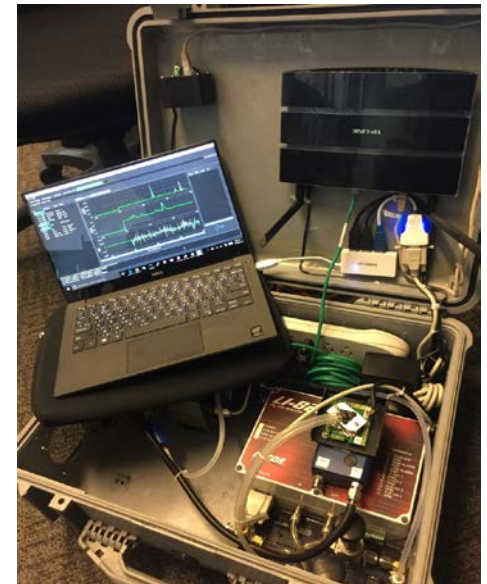
- ▶ **Trucks sold out-of-state**
 - Account for 60% of HD truck miles traveled in the South Coast
 - Not required to meet California new engine standards
- ▶ **U.S. EPA action is critical to meet the NAAQS**

U.S. EPA Commitment to Develop National Low-NOx Standards

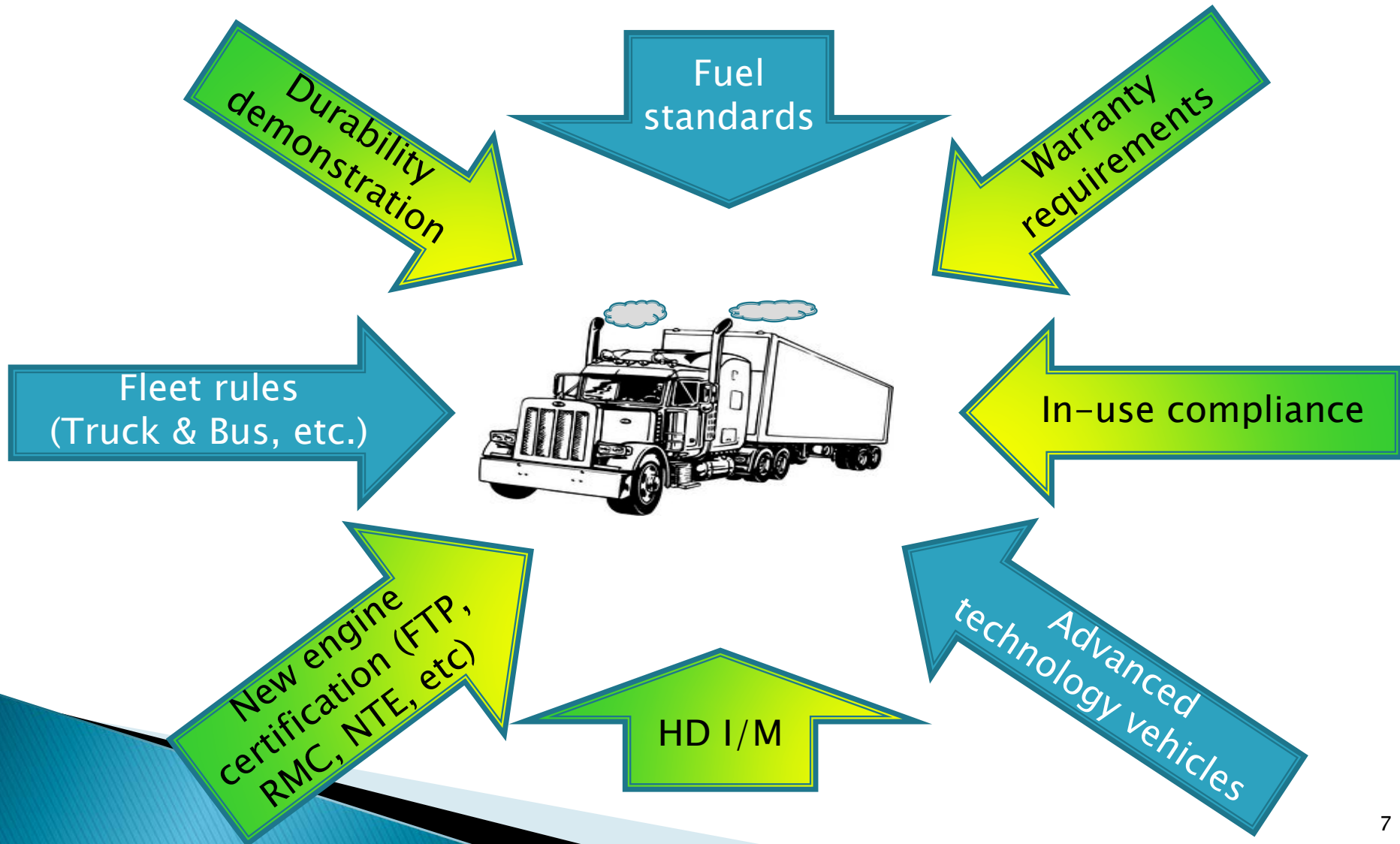
- ▶ ARB submitted formal comments on Phase 2
- ▶ Petition submitted:
 - South Coast, San Joaquin Valley, and Bay Area air districts
 - 9 other state and local air control agencies
- ▶ Phase 2 Preamble: “EPA believes the opportunity exists to develop, in close coordination with CARB and other stakeholders, a new, harmonized national NOx reduction strategy for heavy-duty on-highway engines.”

So How Do We Address HD NOx?

- ▶ **Must achieve 90% reduction in emissions**
- ▶ **Holistic approach needed**
 - Low NOx standard most important
 - Take current 0.2 g NOx standard down to 0.02 g
 - Other significant measures critical
 - Consider creative solutions
 - Regional nature of problem
 - Rapid advances in vehicle connectivity



Many Programs Must Work Together to Ensure Low NO_x from Trucks



ARB Heavy-Duty Vehicle Research Purpose

HD
RESEARCH

- ▶ **ARB-funded research supports multiple heavy-duty programs:**
 - Lowering NOx emission standards
 - Improving compliance and performance
 - Improving emission inventory
 - Ensuring after treatment continues to operate as vehicles age

- ▶ **Lessons learned from previous and ongoing research**
 - Engine load is important for today's emission after treatment systems
 - Today's regulatory procedures do not adequately address vehicle real world operations

Low NOx Standard – Stage 1 Project

HD
RESEARCH

▶ ARB R&D for Diesel and Natural Gas Solutions

- Engines: 13 liter diesel and 12 liter natural gas engines
- Target NOx emission rate: 0.02 g/bhp-hr (90% reduction)
- Cost: \$1.6 million Completion date: December 2016
- Contractor: Southwest Research Institute (SwRI)

Evaluated Multiple Control Technologies

HD
RESEARCH

▶ Engine calibration

- Exhaust gas recirculation, multiple injections, elevated idle speed, etc.

▶ Advanced after treatment systems

- Advanced catalysts
- Heat addition options
- Diesel exhaust fluid injection options

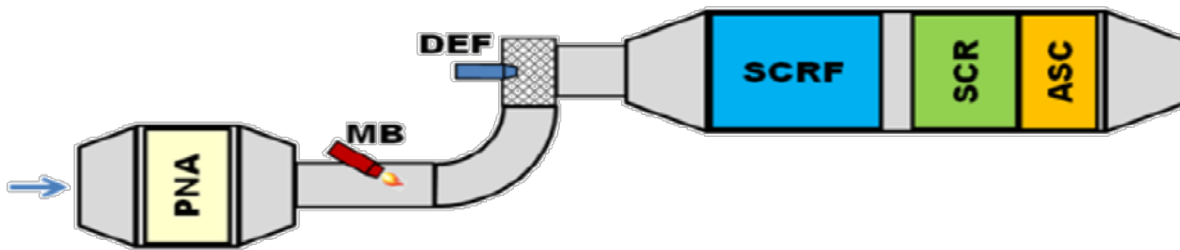


▶ Examined > 30 configurations in detail

- Multiple paths to achieve > 90% reduction in NOx

Demonstration Results

- ▶ Technology package selection
 - Ranking based on NO_x performance, minimum fuel penalty, cost, complexity, and durability
- ▶ Top four ranking packages tested on engine dynamometer
- ▶ **Demonstrated well below 0.02 g/bhp-hr NO_x**
 - 0.012 g/bhp-hr NO_x
- ▶ Final demonstration on aged parts – November 2016



PNA: Passive NO_x Adsorber

MB: 10 kW Mini Burner

DEF: Diesel Exhaust Fluid

SCR: Selective Catalytic Reduction

DPF: Diesel Particulate Filter

SCRf: SCR catalyst coated DPF

ASC: Ammonia slip catalyst

Continue R&D on Low NOx Demonstration

HD
RESEARCH

▶ **ARB R&D – Low Load Optimization (Stage 2)**

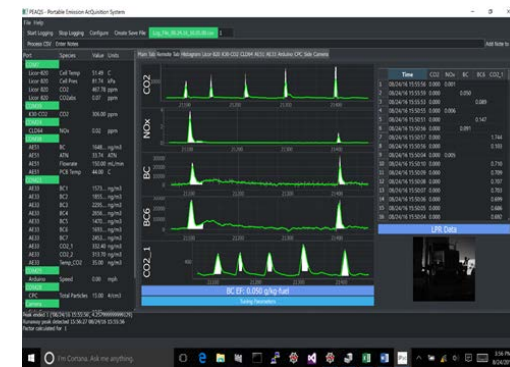
- Optimize system for low load
- Develop new low load certification cycle
- Contractor: SwRI

▶ **Planned ARB R&D**

- Complement Stage 2 effort with additional diesel engine
 - Representative of future engine configuration
 - Potential support from partners: U.S. EPA, MECA, air districts, etc.

Understanding Real World Emissions

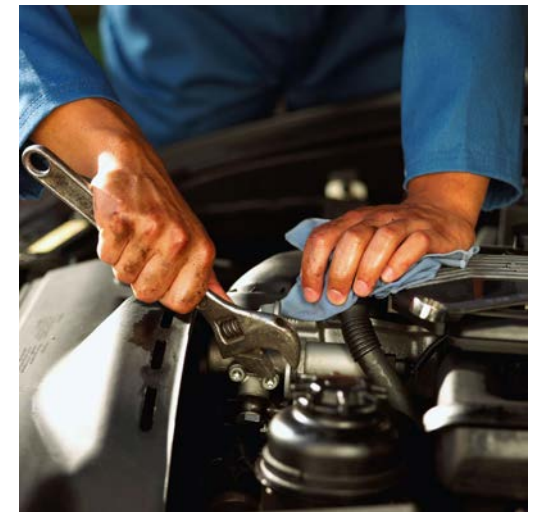
- ▶ **Activity and emissions of vocational vehicles**
 - Contractor: UCR (Two contracts)
- ▶ **Emissions at certification versus on-road**
 - Contractor: UCR
- ▶ **Evaluation of In-Use Compliance Methods**
 - In-house effort
- ▶ **Monitor emissions and degradation of on-road fleets at ports and on highway, and monitor near roads**
 - Multiple universities and two in-house efforts



Development of Improved Heavy-Duty Inspection/Maintenance

HD
RESEARCH

- ▶ **Examine Durability of Repairs**
 - In-house effort
- ▶ **Inspection and Maintenance (I/M)**
 - Contractor: UCR



Planned On-Road Heavy-Duty Measures to Reduce NOx

PLANNED
MEASURES

- ▶ Establish Low-NOx Engine Standard
- ▶ Improve In-Use Emission Performance



Current Heavy-Duty Engine Standards

PLANNED
MEASURES

- ▶ 2010 and newer model year HD engines
 - NOx: 0.2 g/bhp-hr
 - PM: 0.01 g/bhp-hr
- ▶ Optional low-NOx standards
 - Adopted in 2013
 - NOx: 50%, 75%, 90% lower than 2010 standards
 - Two engines certified to the optional standards
 - 8.9 liter natural gas engine - 0.02 g/bhp-hr (90% below standard)
 - 6.7 liter natural gas engine - 0.10 g/bhp-hr (50% below standard)



Establish Low-NOx Engine Standard

PLANNED
MEASURES

► Goal:

- Develop HD low-NOx engine standard
- Develop low-load certification cycle
- Work collaboratively with U.S. EPA to establish national low-NOx engine standard

► Timeframe:

- ARB Board date: 2019
- Implementation schedule: 2023 - 2027



Improve In-Use Emission Performance

PLANNED
MEASURES

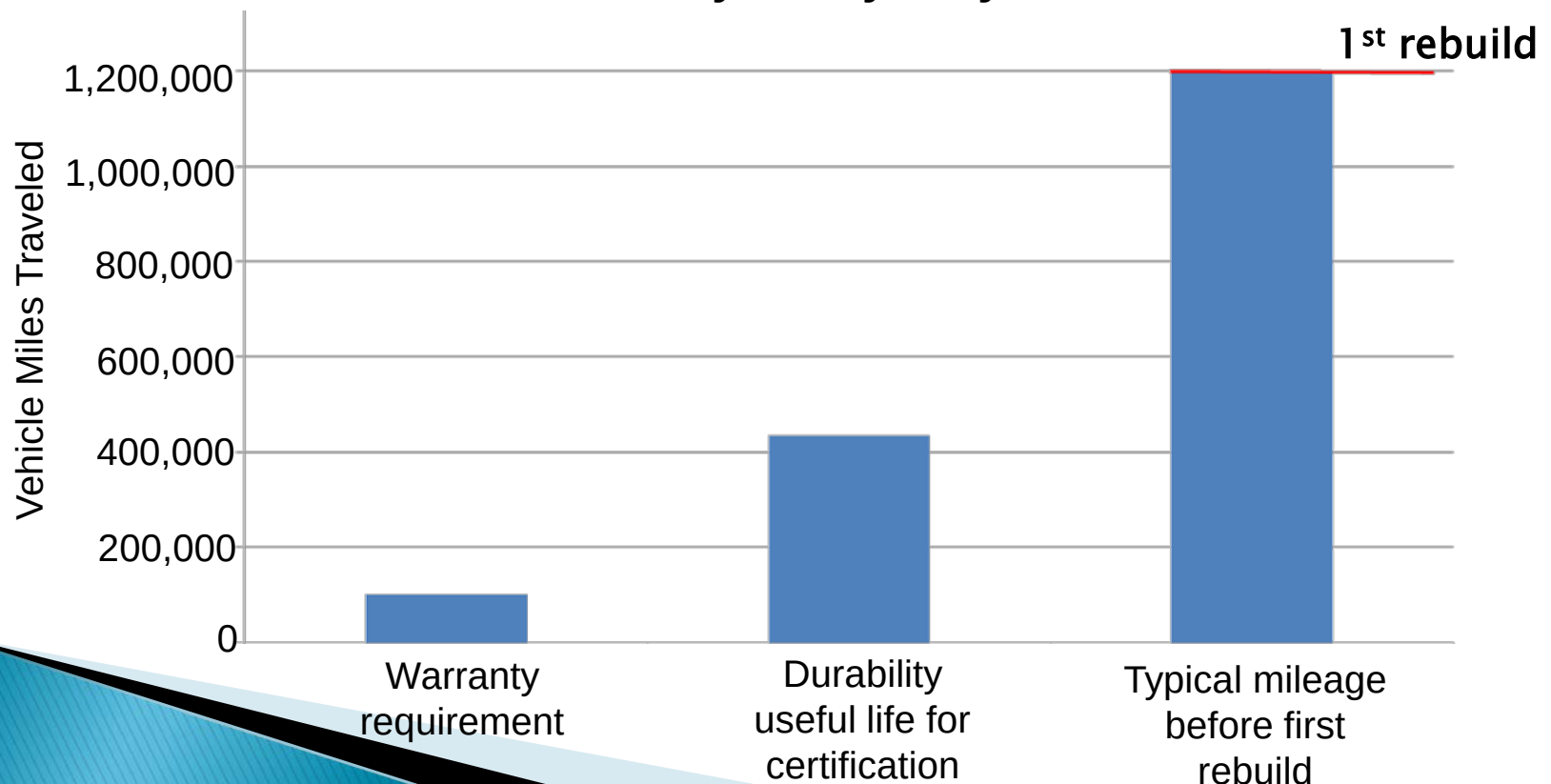
- ▶ **Goal:** Ensure vehicles operate at their cleanest levels in-use
 - Revise Warranty and Useful Life Requirements
 - Revise Manufacturer Required In-Use Testing Protocol
 - Comprehensive HD I/M
- ▶ **Timeframe:**
 - ARB Board date: 2017-2020
 - Implementation schedule: 2018+

Improve In-Use Emission Performance – Warranty and Useful Life

PLANNED MEASURES

- ▶ Current warranty and useful life requirements do not adequately reflect the real-world longevity of modern HD trucks and buses

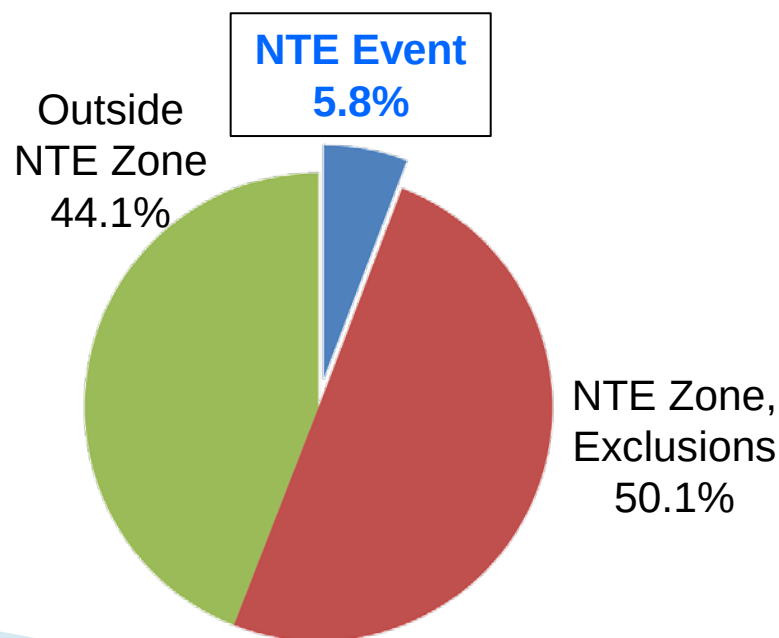
Class 8 Heavy-Heavy Duty Truck



Improve In-Use Emission Performance – Manufacturer Required In-Use Testing Protocol

- ▶ Current in-use compliance requirements, Not to Exceed (NTE), apply only in certain conditions
- ▶ Cannot fully assess emissions during the majority of in-use operations

Fraction of Time



Improve In-Use Emission Performance – Comprehensive Heavy-duty I/M

PLANNED
MEASURES

- ▶ Take advantage of on-board diagnostic (OBD) system for 2013 and newer vehicles
 - Consider remote OBD/telematics
- ▶ Require HD repair shop licensing/mechanic competency
- ▶ Evaluate use of remote emission sensing
- ▶ Ensure after treatment systems (diesel particulate filters and SCR systems) are operating properly



Next Steps

▶ HD Research

- Low NOx research – Stage 1 this year, Stage 2 by end of 2018
- Emissions during real-world driving – by end of 2017
- HD I/M and repair durability – by end of 2017

▶ HD Regulations

- Stakeholder engagement:
 - Nov. 3, 2016: Low NOx engine standards & warranty changes workshop
 - More workshops through 2019
- Board dates:
 - 2017: Warranty improvements
 - 2019: Low NOx engine standards
 - 2020: Comprehensive HD I/M program