California Air Resources Board Heavy-Duty Low NOx and Phase 2 GHG Plans

Kim Heroy-Rogalski, P.E.
Chief
Mobile Source Regulatory Development Branch

May 23, 2017

California Environmental Protection Agency
Air Resources Board

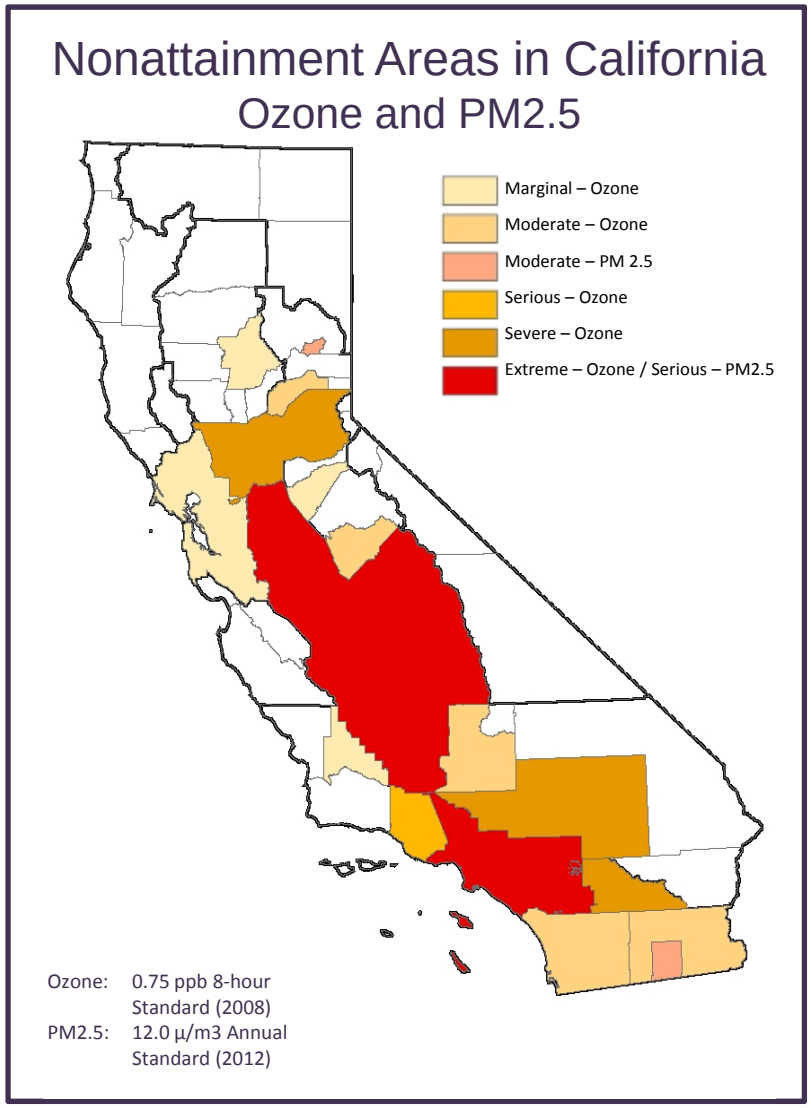
Outline

- California Air Quality Needs
- California Planned Heavy-Duty Measures
- Heavy-Duty Low NO_X Research
- Heavy-Duty Low NOx Workgroups

California Air Quality Needs

California's Ozone and PM Challenges

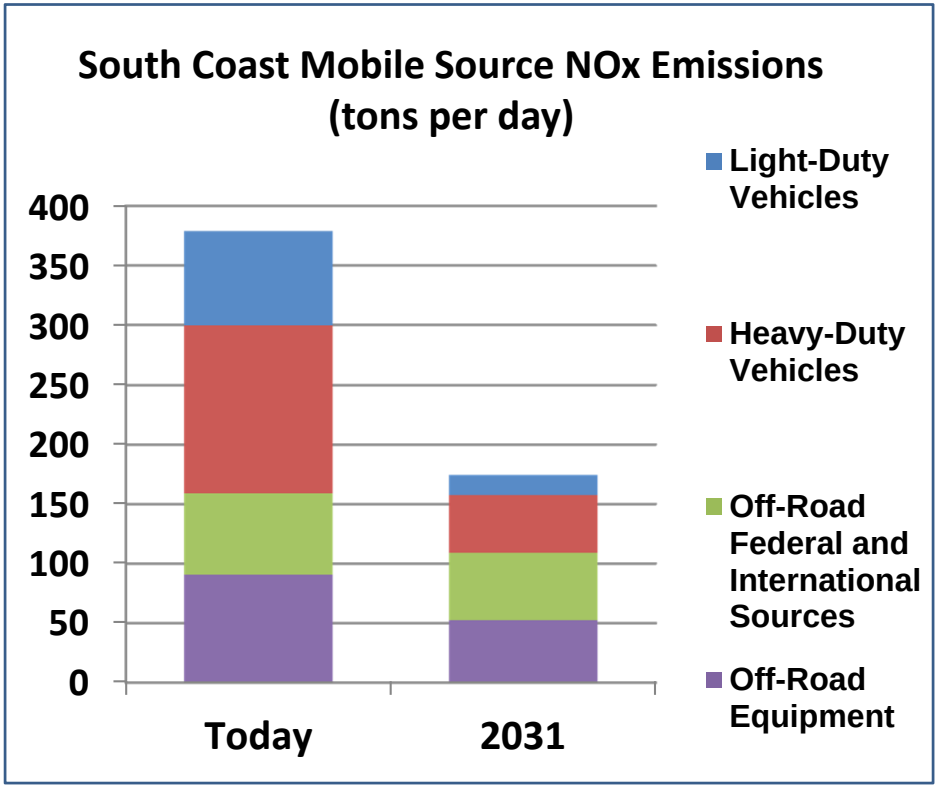
- **Over 12 million Californians breathe unhealthy air**
- **Most areas expected to attain standards by 2026**
- **Key challenges:**
  - South Coast ozone
  - San Joaquin Valley PM2.5



South Coast Emissions Inventory

Key Sources

- **Current program NOx benefits by 2031**
  - Mobile source emissions reduced over 50 percent
  - Heavy-duty vehicle emissions reduced by nearly 70 percent
- **Heavy-duty trucks and federal sources remain largest contributors**
- **Heavy-duty (HD) trucks emit 33% of statewide NOx, 509 tpd**



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
- **2015 NAAQS for ozone strengthened**
- **National standards are critical**

Lower –Emitting Trucks Needed to Meet Ambitious GHG Targets in California

- **Assembly Bill 32 –1990 levels by 2020**
- **Senate Bill 32– 40% below 1990 levels by 2030**
- **Executive Order S-3-05 – 80% below 1990 levels by 2050**
- **Governor Brown's Inaugural Address - Reduce petroleum use in cars and trucks by up to 50% by 2030**

California Planned Heavy-Duty Measures

Heavy-Duty Truck Rulemakings
Scheduled Board Dates

Rulemaking	Scheduled Board Hearing Date
Revisions to Periodic Smoke Inspection Program	October 2017
California Phase 2 GHG Standards	October 2017
Revisions to the Warranty Period and Recall Authority Requirements	December 2017
Revisions to the - NOx Standard and Test Procedures, - In-Use Compliance Program, and - Durability/Useful Life Requirements	2019
Heavy-duty Inspection and Maintenance	2020

Smoke Inspection Amendments

- **Periodic Smoke Inspection Program (PSIP) and Heavy-duty Vehicle Inspection Program (HDVIP) currently require:**
  - Annual testing for fleets of 2+ trucks
  - 40% opacity limit
  - Roadside testing
- **Staff proposing:**
  - Lowering opacity limit to 5% for filter equipped, 20%-40% for non-filter equipped trucks
  - Reporting of annual testing
- **Workshops held in September 2016, February 2017, May 2017**
- **More info at** https://www.arb.ca.gov/msprog/hdim/hdim.htm

Smoke Inspection

CARB GHG Rules Currently In Place

- **Tractor-Trailer GHG Regulation (In-use fleet rule)**
  - Adopted December 2008
  - Long-haul tractor and trailer aerodynamics
  - Low rolling resistance tire

- **California Phase 1 GHG Regulations (manufacturer rule)**
  - Harmonized with Federal Phase 1 Program (December 2013)
  - Began 2014, fully phased in by 2018
  - Manufacturers ability to certify in California (Deemed to comply with California Phase 1, if certified federally)
  - CARB ability to enforce regulatory requirements

Phase 2 GHG

U.S. EPA Adopted Federal Phase 2 GHG Regulations

- **Second phase of federal heavy–duty GHG standards for vehicle manufacturers**
  - Final rulemaking published Oct. 2016
- **Establishes technology forcing standards for engines and vehicles**
  - Combination Tractors
  - Trailers (not regulated in Phase 1)
  - Vocational Vehicles
  - Heavy-Duty Pick-ups and Vans
- **Phase in model year 2021 to 2027 (from 2018 for trailers)**
- **Average payback: 2 to 4 years**

Proposing to Adopt California Phase 2 Regulation that Harmonizes with Federal Phase 2

- Harmonize with the federal rules in structure, timing, and stringency
  - Enables California to certify vehicles and engines
  - Enables California to enforce requirements
  - If Federal Phase 2 is revoked, ensures California requirements will remain in place
- No "deemed to comply" for certification
- California differences to facilitate enforcement, align with existing California programs, and provide additional incentive for advanced technologies
- First California Phase 2 workshop held Feb. 6, 2017: https://www.arb.ca.gov/msprog/onroad/caphase2ghg/caphase2ghg.htm

Possible Areas Where California Phase 2 may Differ from Federal Phase 2

- **Credit Provisions**
  - Additional credits for use of Low-Global Warming Refrigerants
  - Additional requirements for Plug-in Hybrid Electric Vehicles to qualify for advanced technology credit multiplier
- **Label Information**
  - Additional information to be included in vehicle and trailer labels to aid in enforcement
  - Require “light-duty style” consumer labels for heavy-duty pick ups and vans
- **Vocational Custom Chassis**
  - Exclude transit buses from these provisions

Possible Areas Where California Phase 2 may Differ from Federal Phase 2 (continued)

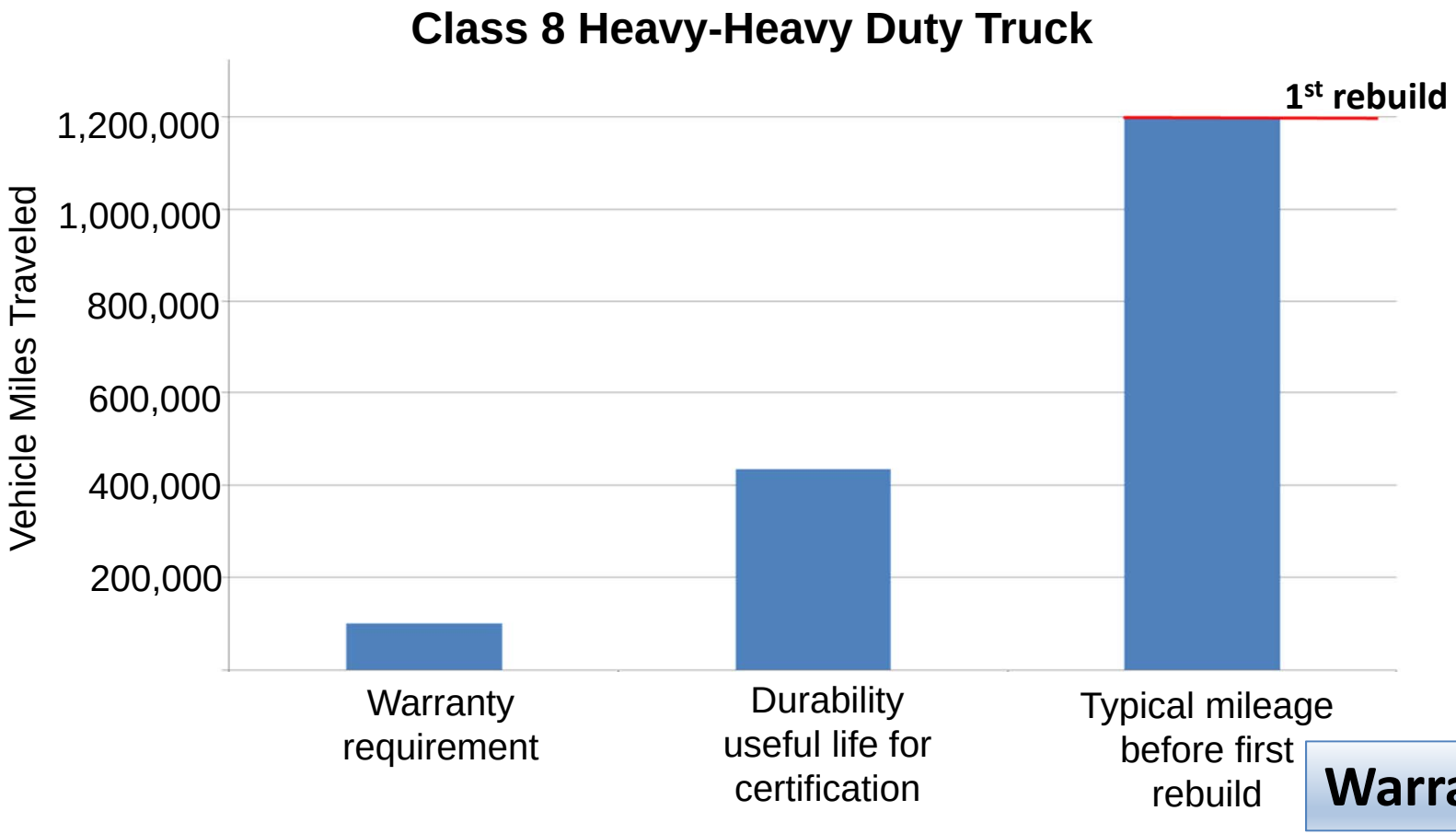
- **Engine and Vehicle Certification Requirements**
  - Require vehicle manufacturers to report engine family and additional air conditioning (A/C) system information
- **Natural Gas Engine Requirements**
  - Continue to include ethane in the hydrocarbon emission standards for natural gas compression-ignition engines
- **Sunset provisions of Tractor-Trailer GHG Rule that impact model year 2018 and newer trailers**
- **Other minor changes**

CARB's CA Phase 2 website

https://www.arb.ca.gov/msprog/onroad/caphase2ghg/caphase2ghg.htm

Heavy-duty Warranty Revisions

- **Current warranty requirements do not adequately reflect the real-world longevity of modern HD trucks and buses**
- **Considering lengthening minimum emissions-related warranty period and improving recall authority**



CARB Current NOx Standards

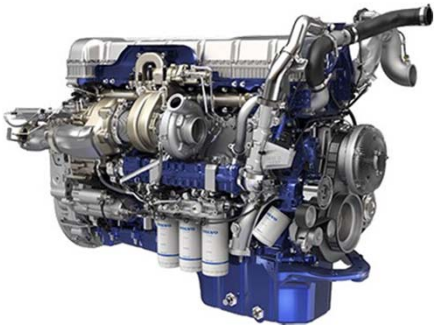
- **Current Mandatory NOx Standard: 0.20 g/bhp-hr**
- **Optional NOx standards**
  - 90%, 75%, and 50% below 2010 NOx standards
  - 0.02 g/bhp-hr, 0.05 g/bhp-hr, and 0.10 g/bhp-hr

- **CARB Certified Engines:**
  - 8.9L ISL G – CNG certified to 0.02 g/bhp-hr (90% below)
  - 6.7L ISB6.7 G – CNG certified to 0.1 g/bhp-hr (50% below)

Low NOx Standards

Establish Low-NOx Engine Standard

- **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

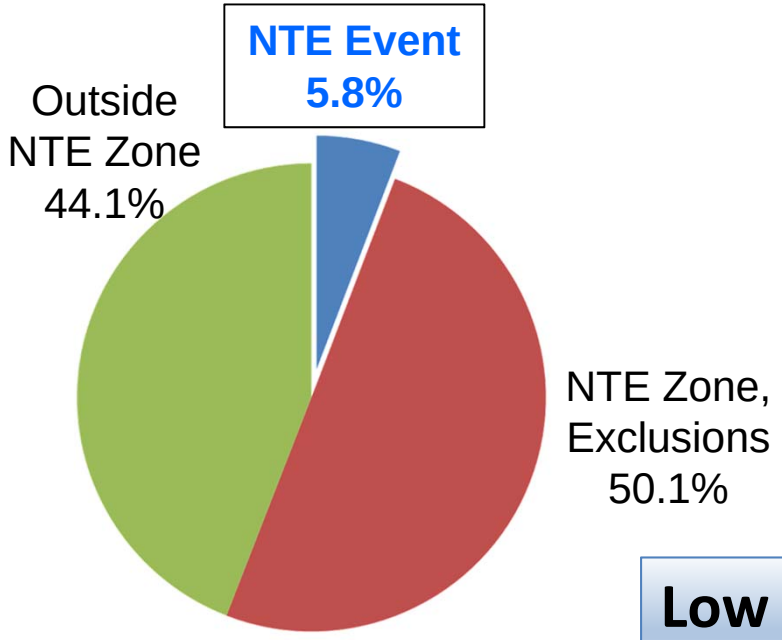
https://www.arb.ca.gov/msprog/hdlownox/hdlownox.htm

Low NOx Standards

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

- **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



Low NOx Standards

Stakeholder Engagement

- First workshop on Low NOx held on Nov. 3, 2016
- Several workgroup meetings held in the last 3 months
- Five workgroups
  - HD Certification Standards and Test Procedures Workgroup
  - HD In-Use Compliance/Testing/Not-to-Exceed Workgroup
  - Warranty Workgroup
  - Durability/Useful Life Workgroup
  - Emissions Inventory Workgroup
- Purpose
  - Provide stakeholders the opportunity to provide suggestions and comments
  - Exchange data and ideas between CARB staff and stakeholders to make informed decisions
- Detailed workgroup description and how to join: https://www.arb.ca.gov/msprog/hdlownox/files/workgroup_description.pdf

Comprehensive Heavy-duty I/M

- 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 aftertreatment systems (diesel particulate filters and SCR systems) are operating properly
- More info at https://www.arb.ca.gov/msprog/hdim/hdim.htm

Heavy-Duty Low NO_X Research

ARB Heavy-Duty Vehicle Research
Purpose

- **ARB-funded research supports multiple heavy-duty programs:**
  - Lowering NOx emission standards
  - Improving compliance and performance
  - Improving emission inventory
  - Ensuring aftertreatment (AT) continues to operate as vehicles age

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

HD Low NO_x Research Activities

- **Stage 1 – Low NOx Feasibility Demonstration**
  - Carb Funding: $1.6M
  - Contractor: SwRI
  - Additional support: MECA, Volvo
  - Final report at: https://www.arb.ca.gov/research/veh-emissions/low-nox/carb_2017-04-30_03-19503_finaledit.pdf

- **Stage 2 – Low Load Duty Cycle (LLC) Development/ LLC NOx Control**
  - CARB funding: 1.05M
  - Contractor: SwRI

- **Stage 3 – Low NOx Demonstration on an Alternative Non-Turbocompound (TC) Engine**
  - Funding: CARB, AQMD, and Others (Total: $1.375M)
  - Contractor: SwRI
  - Additional support: MECA

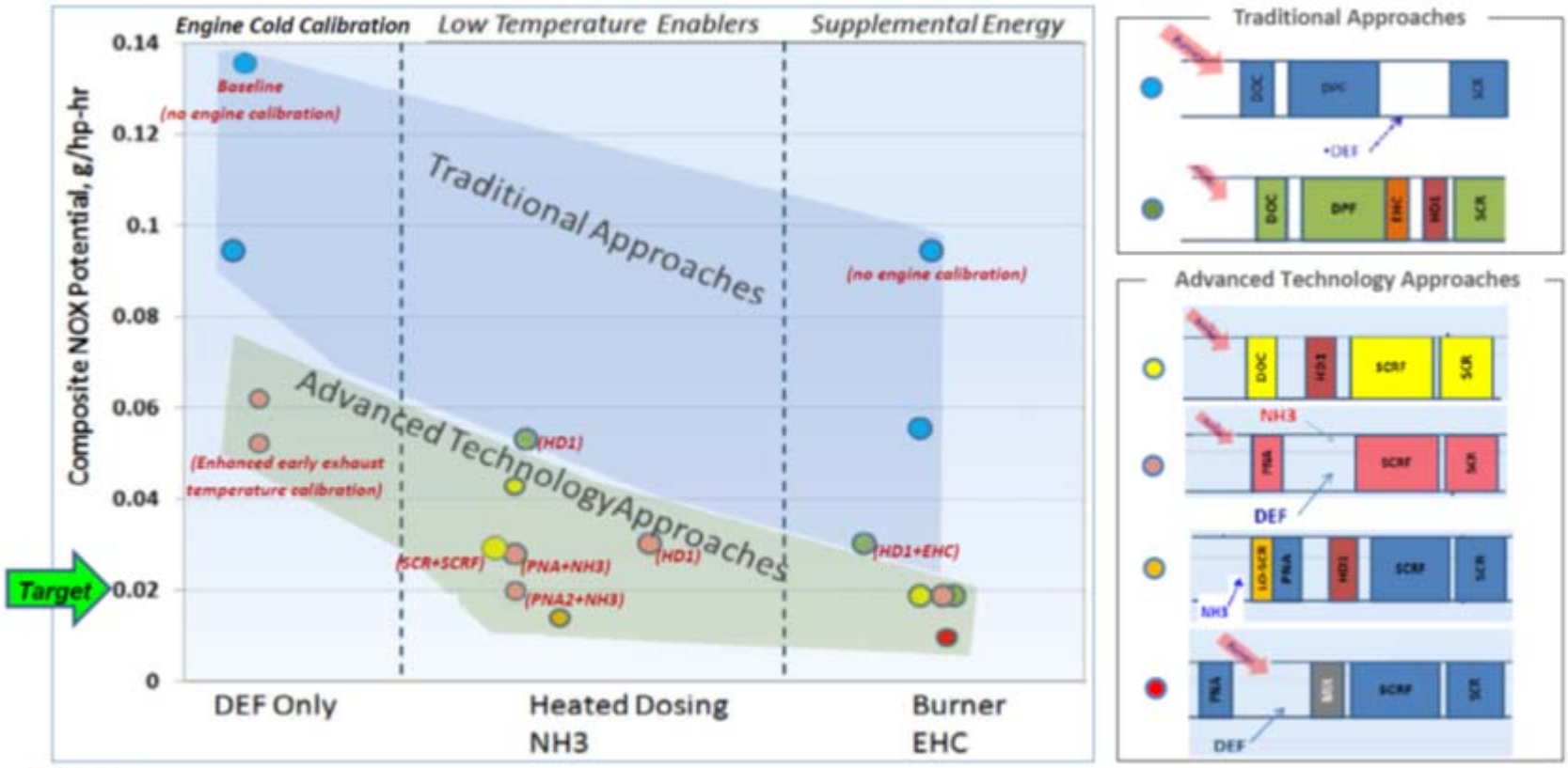
Stage 1: Low NOx Program
Objectives

- **Started October 2013**
- **Completion date: May 2017**
- **Optimization on regulatory cycles**
  - Target NOx on aged parts: 0.02 g/bhp-hr on the FTP and RMC
- **Includes a natural gas and diesel engine**
- **Solution must be technically feasible for production**
- **Solution must be consistent with path toward meeting future GHG standards CO_2, CH_4, N_2O**

More information:
https://www.arb.ca.gov/research/veh-emissions/low-nox/low-nox.htm

Stage 1: Diesel – AT System

Screening Test Results



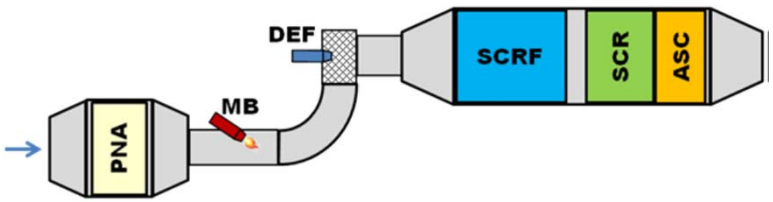
Acronyms

DOC: diesel oxidation catalyst; ***DPF***: diesel particulate filter; ***SCR***: selective catalyst reduction; ***Burner***: 10kw mini-burner; ***EHC***: electrically heated catalyst; ***HD1***: heated DEF dosing; ***SCRF***: SCR catalyst coated DPF; ***PNA***: passive NOx adsorber; ***PNA2***: PNA with altered catalyst formulation; ***NH3***: gaseous ammonia injection; ***LO-SCR***: close-coupled light-off SCR

Multiple potential pathways to achieve NOx emissions below 0.02 g/bhp-hr

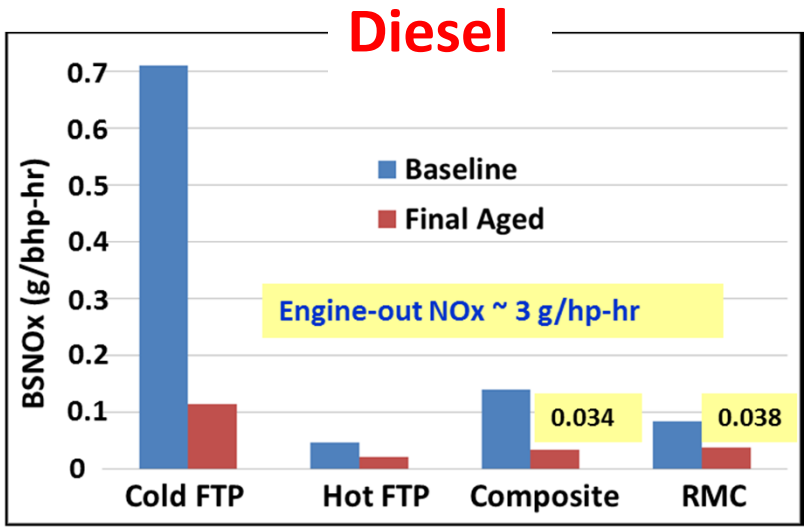
Stage 1: Diesel – AT System
Final Low NOx Configuration

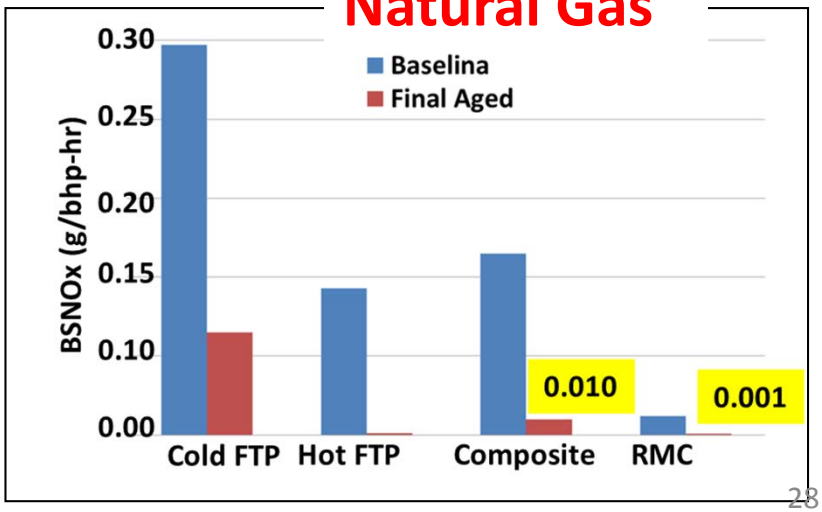
- **Screened approximately 33 technology packages**
- **Ranked them based on NOx reduction potential, fuel penalty, cost, durability, and complexity - based on Program Advisory Group**
- **Top four ranking packages tested on engine dynamometer with oven aged parts**
- **Demonstrated well below 0.02 g/bhp-hr NOx on oven aged development parts**
  - **PNA+MB+DEF+SCRF+SCR+ASC**
  - 0.012 g/bhp-hr NOx



Stage 1: Test Results - NOx

- Final parts aged on engine thermally and chemically
- Unexpected PNA canning failure during aging
- PNA and SCRF were cleaned, recovered, and continued aging to the full useful life
- Despite canning failure results were encouraging:
  - Diesel NOx : 0.034 g/bhp-hr on FTP and 0.038 g/bhp-hr on the RMC
  - CNG NOx: 0.010 g/bhp-hr on FTP and 0.001 g/bhp-hr on the RMC





Stage 2: LLC Development/ Optimization on Low Load Profiles

- **Follow-on project to Stage 1**
  - Initiated in January 2017
  - Completion by June 2018
  - ARB funding: $1 M
  - Contractor: SwRI
    - NREL as subcontractor for LLC development

- **Engine/AT system from Stage 1**
  - **Stage 1b** contract being considered–aging of **new** AT parts for use in Stage 2

- **Program tasks/objectives:**
  - Evaluate low load duty cycle profiles to develop LLC
  - Optimize emission control over several vocational cycles and the LLC and determine impacts on GHG
  - Evaluate accuracy of broadcast torque at low loads
  - Evaluate other testing metrics for determining in-use emissions at low loads

Stage 3: Low NOx Demonstration
Alternative Engine Platform

- **Follow-on project to Stages 1 and 2**
  - Kick off in summer of 2017
  - Co-funded by ARB, AQMD, and others: $1.325M Total
  - MECA support: AT system and final aging
  - Engine platform without WHR (likely 2017 model year)
  - AT system may be different than that demonstrated in Stages 1 and 2

- **Optimization on**
  - FTP, RMC, and CARB Idle
    - Target NOx emission rate: 0.02 g/bhp-hr on FTP and RMC
  - LLC developed in Stage 2

How can ARB best engage other states in our efforts?

Questions?

Mike Carter, Assistant Division Chief
Mobile Source Control Division
email: mcarter@arb.ca.gov

Kim Heroy-Rogalski, Branch Chief
Mobile Sources Regulatory Development Branch
email: mailto:kheroyro@arb.ca.gov

Stephan Lemieux, Manager
On-Road Heavy-Duty Diesel Section
Lead: Heavy-Duty Low NOx Program
email: Slemeiux@arb.ca.gov

Ron Haste, Manager
Off-Road Controls Section
Lead: Warranty Period Revisions
email: rhaste@arb.ca.gov

Renee Littaua, Manager
Strategic Planning and Development Section
Lead: California Phase 2 GHG Regulations
email: rlittaua@arb.ca.gov