ARB Technology Assessment, NGV Emissions and Engine Development

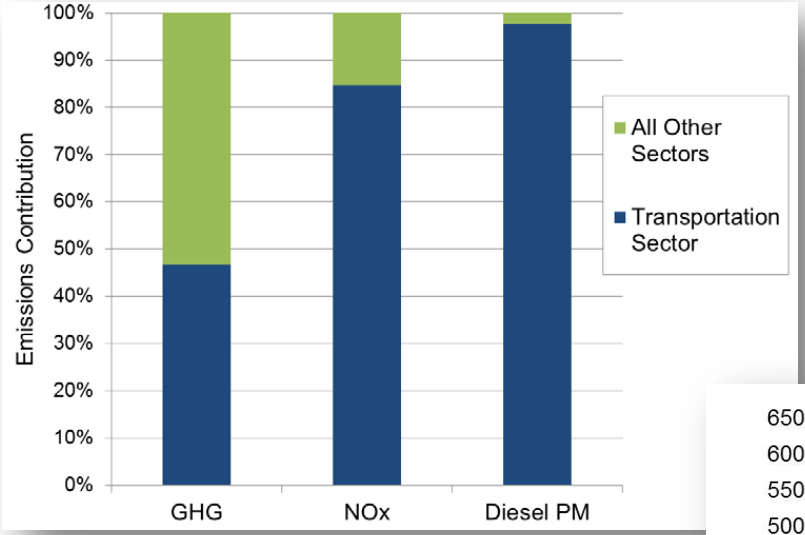
October 20, 2015
Natural Gas Vehicle Technology Forum
San Francisco, California

California Environmental Protection Agency
Air Resources Board

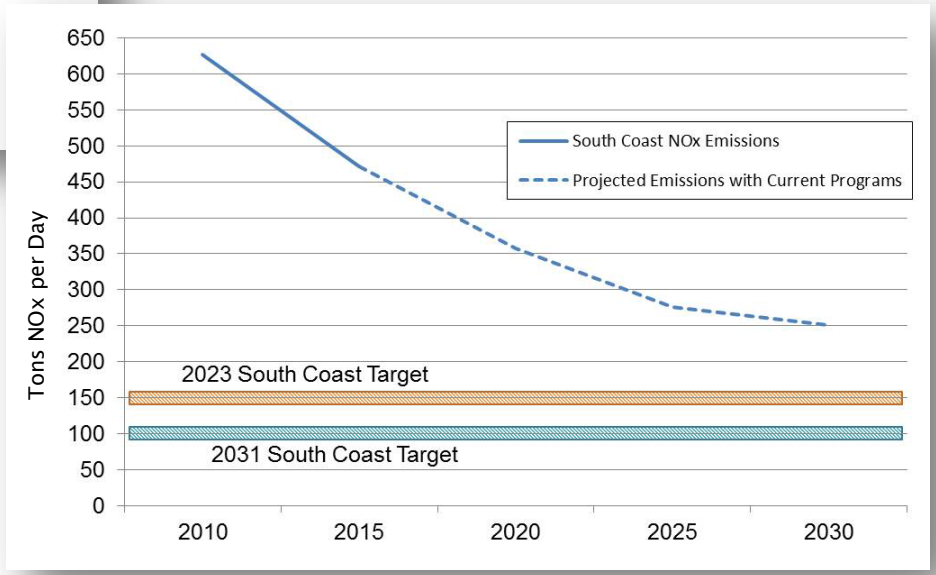
Overview

- Background
- Technology and Fuels Assessment Update
- In-use NOx from current engines
- NOx from future natural gas engines
- Funding opportunities
- Conclusions

Transportation key in CA



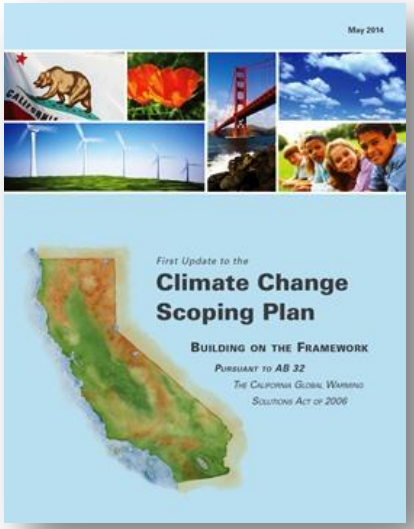
Crosscuts multiple air quality issues



Significant challenges remain:

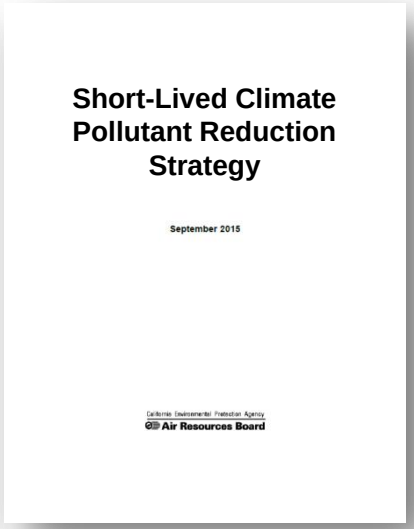
- Ambient Air Quality
- Petroleum Reduction
- Greenhouse Gas Emissions

Ongoing ARB planning efforts

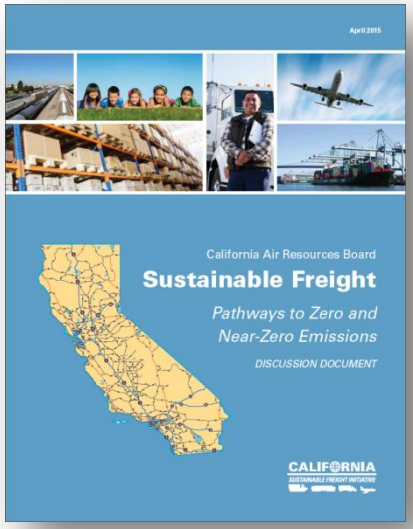


Updating for new mid-term target: 40 percent below 1990 levels by 2030

ARB approaches for SIPs due in 2016 to meet 2023 and 2032 NAAQS



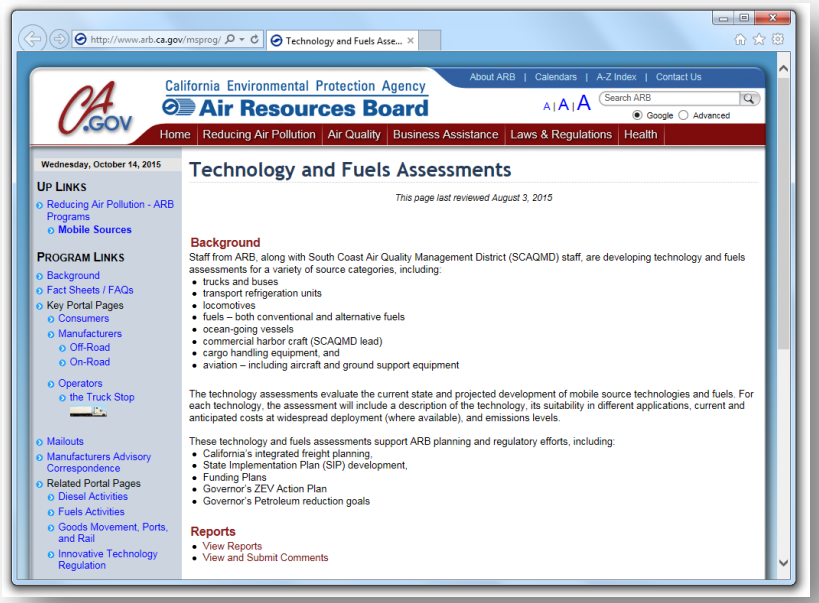
Reducing emissions of Black Carbon, Fluorinated Gases and Methane



ARB contributions to California's Sustainable Freight Transportation Strategy due in 2016

Technology and Fuels Assessment Process

- Majority of this material covered in more depth in the Technology and Fuels Assessments
- For more information, or to submit/view comments, see our webpage:



http://www.arb.ca.gov/msprog/tech/tech.htm

ARB Technology and Fuels Assessments

- Assess current and emerging technologies and fuels ability to reduce
  - Criteria Pollutants
  - Toxic Air Contaminants (TACs)
  - Greenhouse Gases (GHGs)
- Lays technical stage for Sustainable Freight Transport Strategy and future State Implementation Plans
- Includes
  - Modes: Trucks and Buses, Transport Refrigerators, Rail, Marine, Aviation, Cargo Handling
  - Fuels: Conventional, Alternative, Bio and Renewable

Technology Assessment Elements

- Technology description
- Readiness – current development status
- Fueling needs, strengths and limitations, key performance parameters
- Cost and new vehicle emission levels (per vehicle)
- Conclusions and findings – technology status, cross-sector findings

Opportunities to Participate

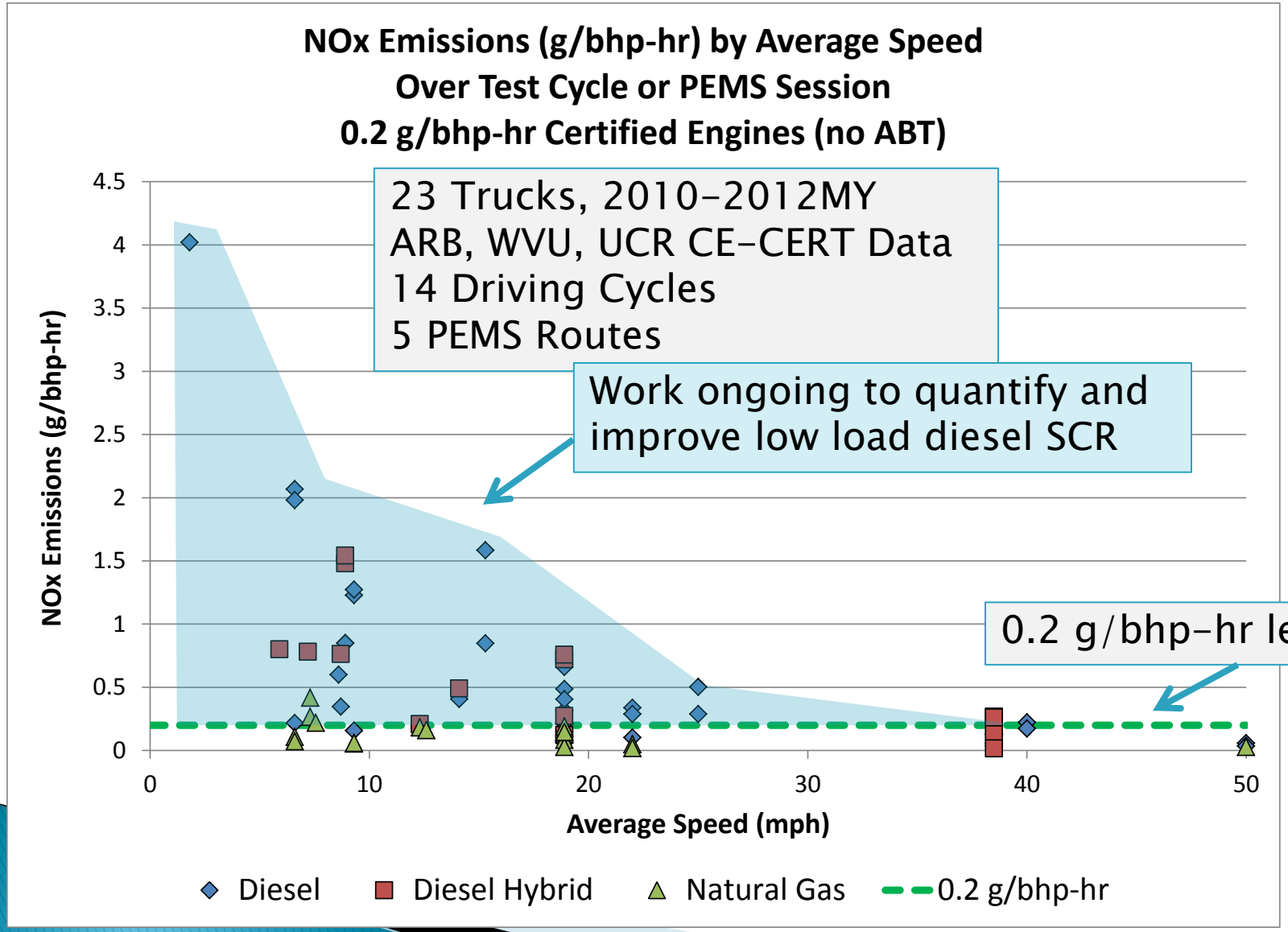
- Tech Assessment Workshops held May & September 2014
- Board hearing (informational) December 2014
  - Technology and Fuels Assessment Results
  - Sustainable Freight Strategy (draft released April 2015)
- Comment open on released Draft Tech Assessments:
  - Heavy-Duty Technology and Fuels Overview — April 2015
  - Engine/Powerplant and Vehicle Efficiency — June 2015
  - Transport Refrigerators — Aug. 2015
  - Commercial Harbor Craft (with SCAQMD) — Aug. 2015
  - Lower NOx Heavy-Duty Diesel Engines — Sept. 2015
  - ***Low Emission Natural Gas*** and Other Alternative Fuel Heavy-Duty Engines — ***Sept. 2015***
  - MD and HD Battery Electric Trucks and Buses — Oct. 2015
  - more sector specific reports pending
- Submit written comments: http://www.arb.ca.gov/msprog/tech/techreport/comments.htm
- Meet with staff at any time to provide input

NOx from Today's Natural Gas Engines

Today's Natural Gas Emission Standards

- Required certification standards for both diesel and natural gas truck and bus engines
  - 0.2 g/bhp-hr NOx
  - 0.01 g/bhp-hr PM
- Today's engine technology
  - Stoichiometric engine w Three-Way Catalyst (TWC)
  - Cooled Exhaust Gas Recirculation

NOx Emissions Variation by Duty Cycle



In-use NOx Challenges at Low Speed

- Staff analysis ongoing:
  - Natural gas emissions controls are maintaining high NOx conversion efficiency at low-speed
  - Diesel emissions compliant but higher than we'd like at low-speed
  - Future certification requirements need to strengthen in-use performance for all fuels
  - Potential in-use NOx benefits during low-speed, low-load operation from current SI NG engines relative to current diesel designs
  - Both engine types control NOx well at high speed and load conditions characteristic of majority of fuel usage and emission conditions

NOx from (near) Future Natural Gas Engines

Lower NOx Natural Gas Engine Development

- South Coast AQMD, Cummins Westport, Cummins Inc., California Energy Commission, SoCalGas
  - Project started: 2013
  - Develop ultra-low NOx emission natural gas engines
  - Target: 0.02 g/bhp-hr NOx
  - Test system durability through engine to vehicle chassis integration
  - Integrated project to be placed in commercial service for one year and performance evaluated
  - 8.9L entering vehicle demonstration
  - 15L commercialization on hold:
    - Technology transfer to 12L
    - Generic NG engine availability gap beyond 12L
  - Project completion by end of 2017

Lower NOx Natural Gas Engine Development

- South Coast AQMD, Power Systems International, Ricardo, SoCalGas, with the Gas Technology Institute
  - Project started: 2015
  - 8.8 L Natural Gas Engine
  - Intended for Class 4-7 On-Road use
  - Target: 0.02g/bhp-hr NOx

Lower NOx Natural Gas Engine Development

- ARB, SwRI to demonstrate maximum NO_X reduction possible from 12L natural gas engine
  - Project Started: 2013
  - Will use engine tuning practices, thermal management and aftertreatment strategies
  - Target:0.02 g/bhp-hr NOx with minimal or no GHG penalty
  - Project completion by mid-2016

- Project Updates Website:
  http://www.arb.ca.gov/research/veh-emissions/low-nox/low-nox.htm

Technologies Being Evaluated

- Advanced Engine Control Technologies
  - Port Fuel Injection
  - Advanced Air to Fuel Ratio Control
  - Cooled EGR
  - Dedicated EGR
  - Faster Light-off
- Advanced Aftertreatment Technologies
  - Advanced TWC
  - Close-coupled Light-off
  - Ammonia Slip Catalyst

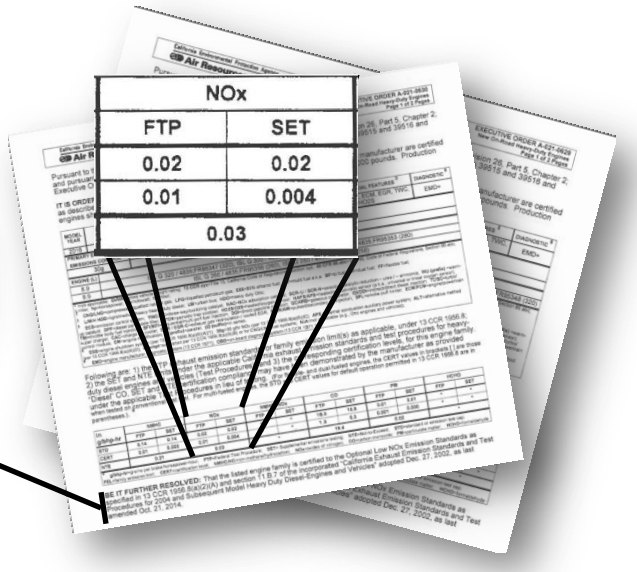
Low-NOx Standard

- ARB adopted optional Low NOx Standards (2013)
- ARB funding research to demonstrate feasibility
  - 0.02 g/bhp-hr NOx
- Systems integration is critically important
  - Use of combined Engine Management and Aftertreatment System Control to maintain in-use performance and emissions control efficiency over engine use variability
  - Address in-use emissions to ensure standards are achieved in real world
- Marginal volume production cost estimated $250-300/NG engine for TWC upgrade to 0.02g/bhp-hr Low NOx

Low-NOx Standard

- First engine certified to most stringent optional NOx standard of 0.02g/bhp-hr September 2015

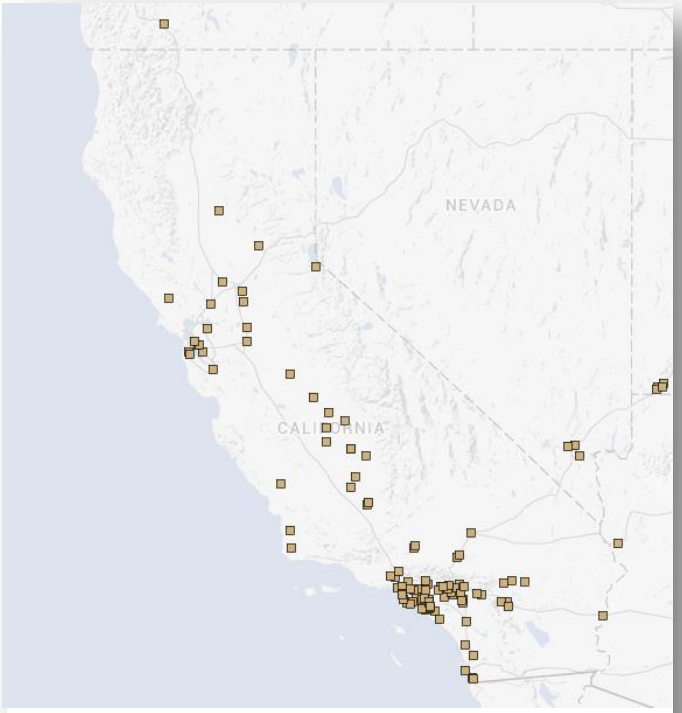
BE IT FURTHER RESOLVED: That the listed engine family is is certified to the Optional Low NOx Emission Standards



- Commercial release mid-2016 for urban bus, other applications thereafter
- Optimistic additional 0.02g/bhp-hr NG engine models available soon
- ARB intends 2017 start for development of a mandatory Low NOx Standard

Natural Gas Fueling Infrastructure publicly accessible to HD trucks

- Refueling infrastructure
  - 636 CNG stations (105 in CA)
  - 73 LNG stations
  - 7000+ Diesel stations (for comparison)
- Class 6-8 CNG fueling coverage in CA
- ARB continues to evaluate Truck Fueling Infrastructure
  - Natural gas
  - Electricity
  - Hydrogen



Class 6-8 CNG Stations
(DOE AFDC)

Funding Opportunities

- California Energy Commission funding to date
  - $51.5 M for 15 biomethane projects
  - $17 M for 62 NG fueling stations
  - $64.6 M for 4470 cars and trucks

- California Energy Commission 2015/16 funding plan includes
  - $10 M for natural gas vehicle incentives
  - $5 M for natural gas infrastructure

Funding Opportunities

- California Clean Truck, Bus, and Off-Road Vehicle and Equipment Technology Program
  - Created by Senate Bill 1204 (2013)
  - Funded with Cap-and-Trade auction proceeds
  - Complements existing ARB Air Quality Improvement Program (AQIP) and Energy Commission funding
- ARB public process to develop annual funding plan for AQIP and auction proceeds funding
  - $7M specifically for Low NOx Truck Incentives in 2015/16 funding plan pending funding appropriation
  - Intended to follow first come, first served structure
  - Expecting subsequent year growth to support demand and encourage production of additional engines
- Workshops starting in early 2016 for 2016/17 funding plan

Conclusions

- ARB encouraging participation in strategy development efforts
- Draft sector Technology Assessment report for Low Emission Natural Gas HD Engines released for comment
- Low NOx engines burning renewable fuel poised to make important contributions in the combination of zero and near zero technologies
  - First Low NOx NG engine has certified to ARB's most stringent Optional 0.02g/bhp-hr NOx Standard
  - Research continuing to demonstrate other Low NOx emission engines
  - Wider range of 0.02g/bhp-hr Low NOx NG engines on horizon
  - Deep GHG reduction possibilities with rollout of Renewable Natural Gas projects
- Dedicated Low NOx truck incentive funding planned for FY2015/16 and beyond (subject to appropriation)
- ARB intends to begin regulatory development in 2017 of a mandatory Low NOx Standard

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