CALIFORNIA
AIR RESOURCES BOARD

NACAA Spring Membership Meeting

April 30th 2019

CARB ON-ROAD HEAVY-DUTY LOW NOx RULEMAKING

MOBILE SOURCE CONTROL DIVISION

CALIFORNIA
AIR RESOURCES BOARD

OUTLINE

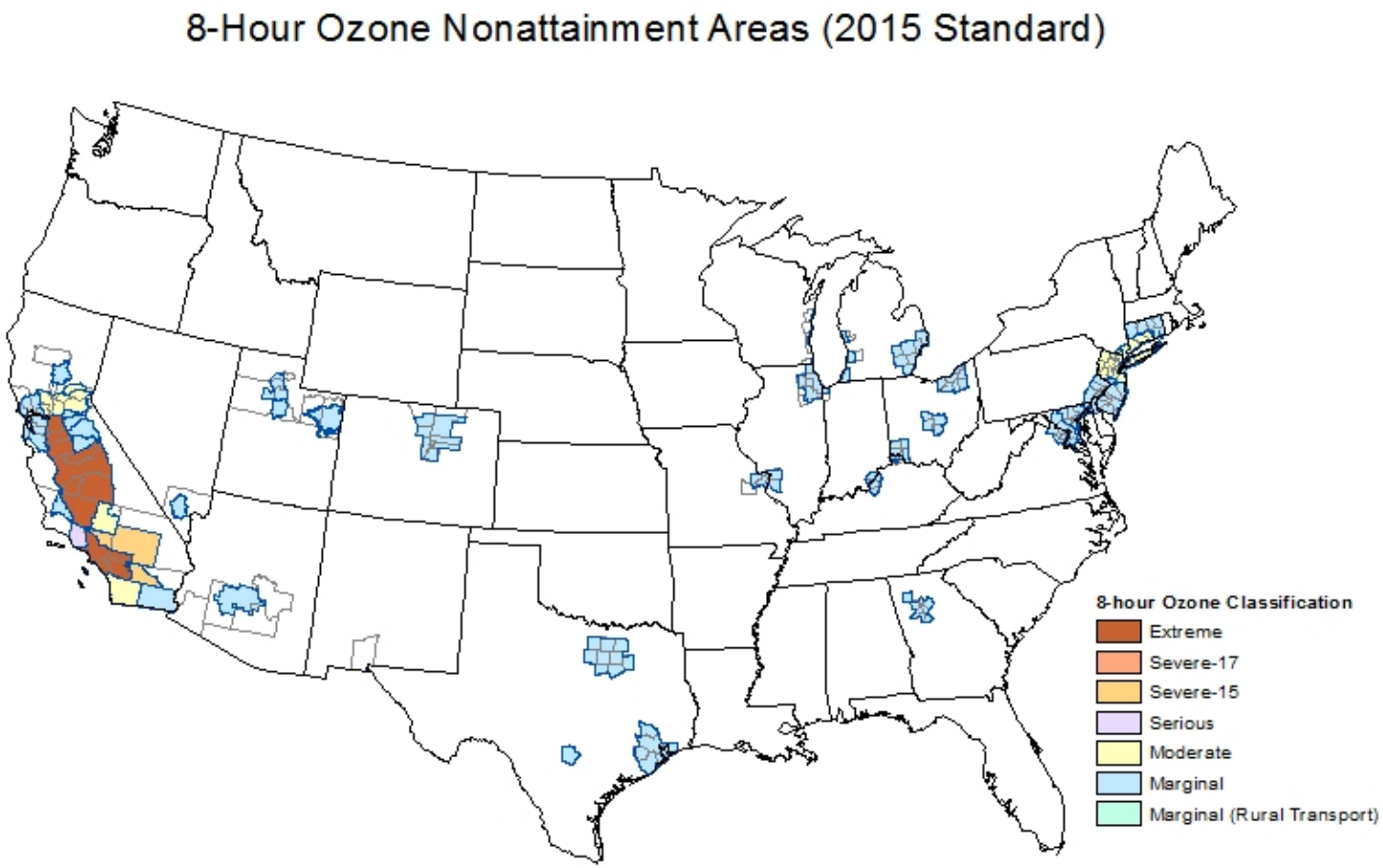
- **Background re Why Heavy-Duty NOx Rulemaking is Needed and What CARB is Doing**
  - CARB pursuing zero emission heavy-duty where it makes sense
  - And cleaner traditional vehicles elsewhere
- **Technologies Available for Reducing Emissions**
  - How we know emission reductions are feasible and cost-effective
- **CARB Heavy-Duty NOx Omnibus Rulemaking**
- **Support from Other States Would Benefit Entire Country**

BACKGROUND

NEED FOR EMISSION REDUCTIONS, HEAVY-DUTY TRUCK EMISSIONS CONTRIBUTION

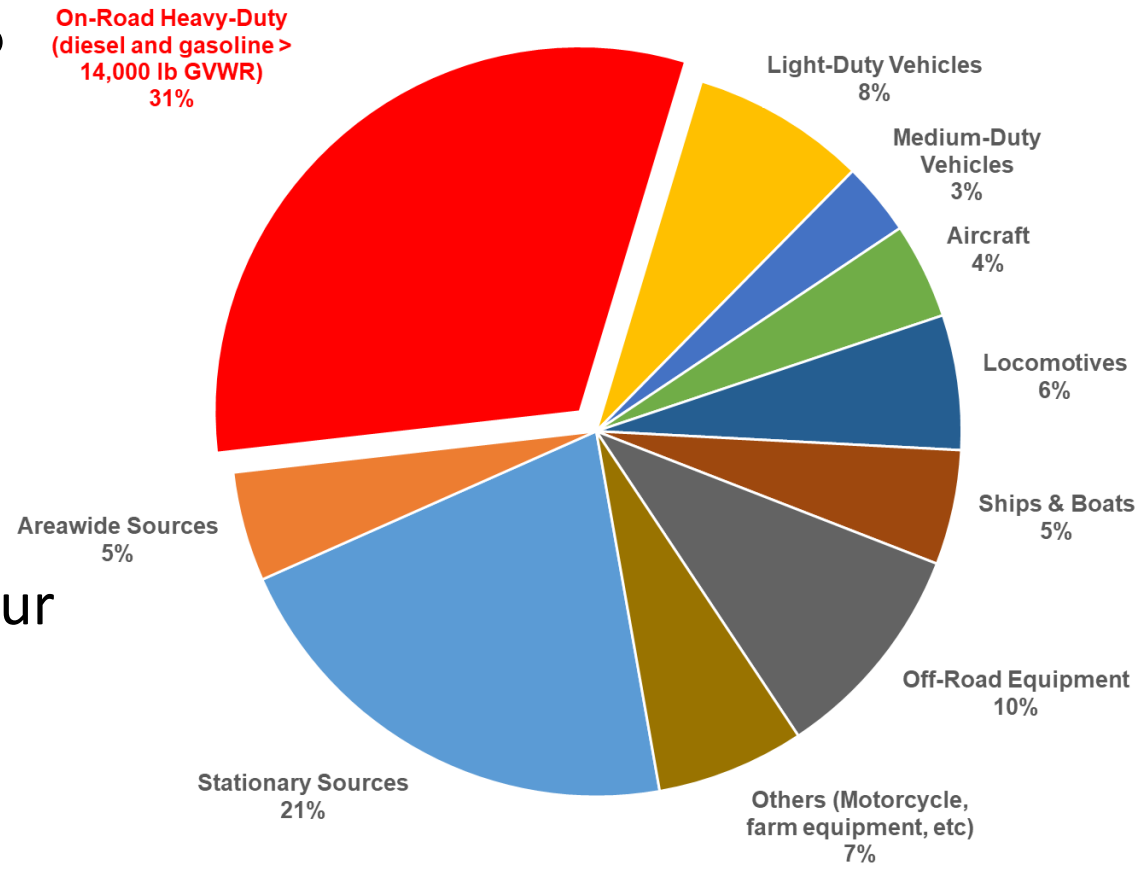
AIR QUALITY CHALLENGES

- Over 12 million California residents breathe unhealthy air
- Serious challenges to meeting ozone standards in extreme nonattainment areas of California
- Nonattainment areas exist nationally in large metropolitan areas, particularly in US northeast



KEY NOx EMISSIONS SOURCES

- Heavy-duty trucks currently contribute to nearly one third of overall NOx in California
- Heavy-duty trucks are expected to contribute to one third of national NOx emissions from transportation in 2025
- South Coast Air Basin must cut NOx 80 percent by 2031 to attain the 75 ppb 8-hour ozone NAAQS
  - NOx is also a precursor to secondary PM2.5



Source: CEPAM: 2016 SIP - Standard Emission Tool
https://www.arb.ca.gov/app/emsinv/fcemssumcat/fcemssumcat2016.php

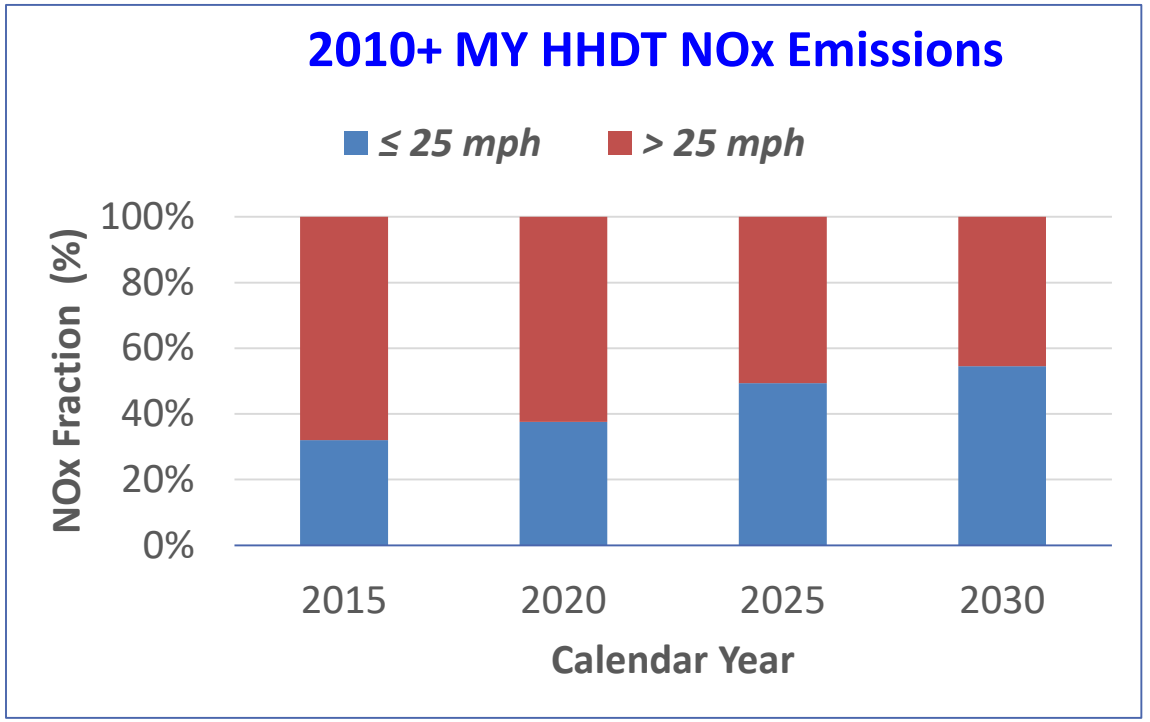
CARB IS PURSUING ZERO EMISSION HEAVY-DUTY WHERE IT MAKES SENSE: HD ZEV REGULATIONS

- **Innovative Clean Transit**
  - Transition to zero emission buses 2023 to 2040
- **Zero Emission Airport Shuttle Bus**
  - Public and private fixed-route
  - All zero emission by 2036
- **Advanced Clean Trucks**
  - Require zero emission truck sales of class 2B and above
  - Begin with 2024 model
  - Large fleet reporting requirement
- **Zero Emission Transportation Refrigeration Units**
- **Zero Emission Drayage Trucks**
  - Fleet requirement expected 2026+

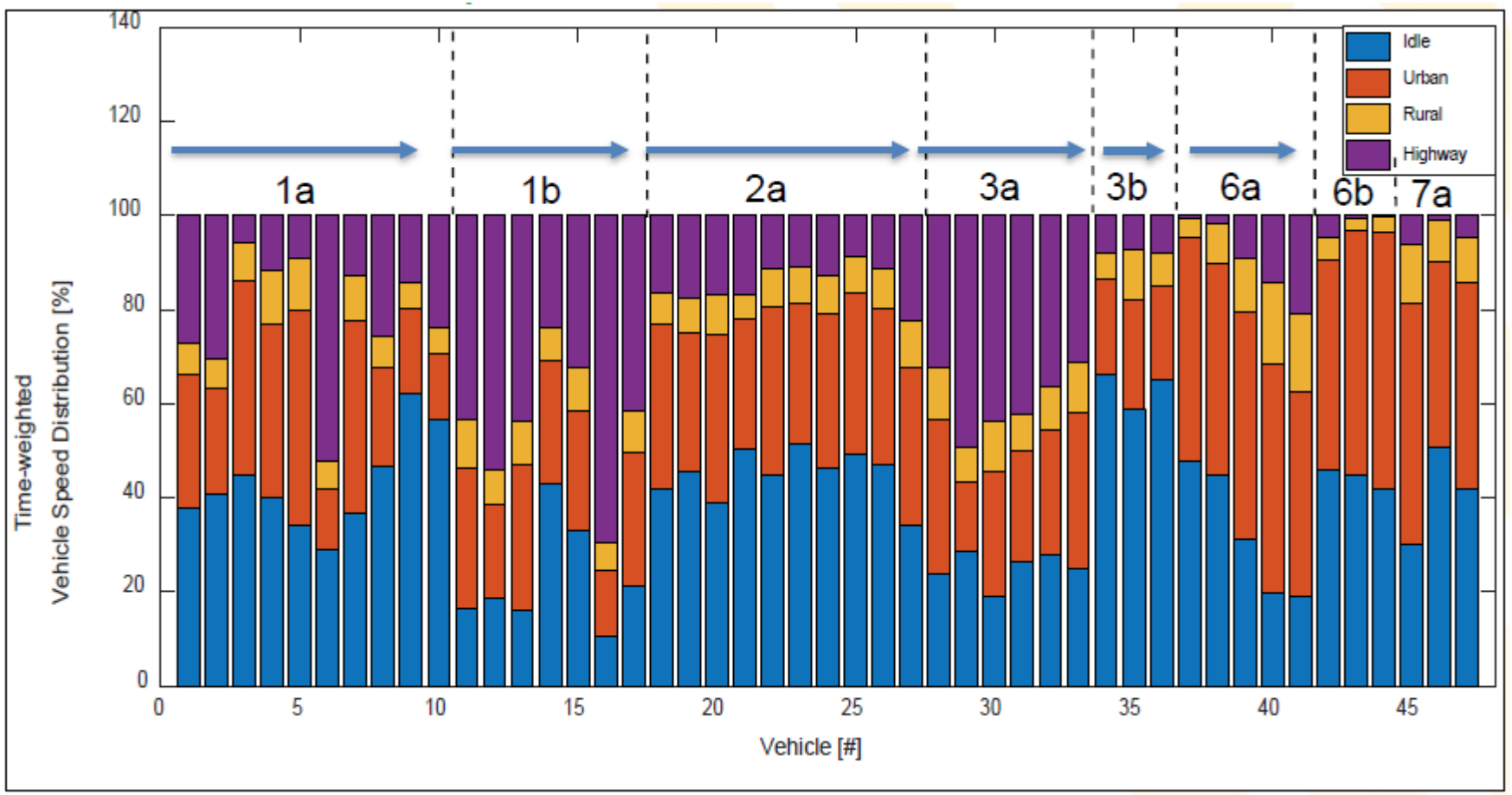
Innovative Clean Transit: https://www.arb.ca.gov/msprog/ict/ict.htm
Zero-Emission Airport Shuttle Bus: https://www.arb.ca.gov/msprog/asb/asb.htm
ZE HD Powertrain Certification: https://ww2.arb.ca.gov/our-work/programs/zero-emission-powertrain-certification
Advanced Clean Trucks: https://www.arb.ca.gov/msprog/actruck/actruck.htm
ZEV Fleet Assessment Workshop: https://www.arb.ca.gov/msprog/zevprog/zevprog.htm

NOx CONTROL UNDER LOW SPEED / LOW LOADS IS IMPORTANT

- NOx emissions from low-speed operation to become increasingly significant, due to SCR inefficiency at low loads
  - By 2030, low-speed/low-load emissions projected to be over half of heavy-duty truck emissions!



HEAVY-DUTY TRUCKS IDLE A LOT

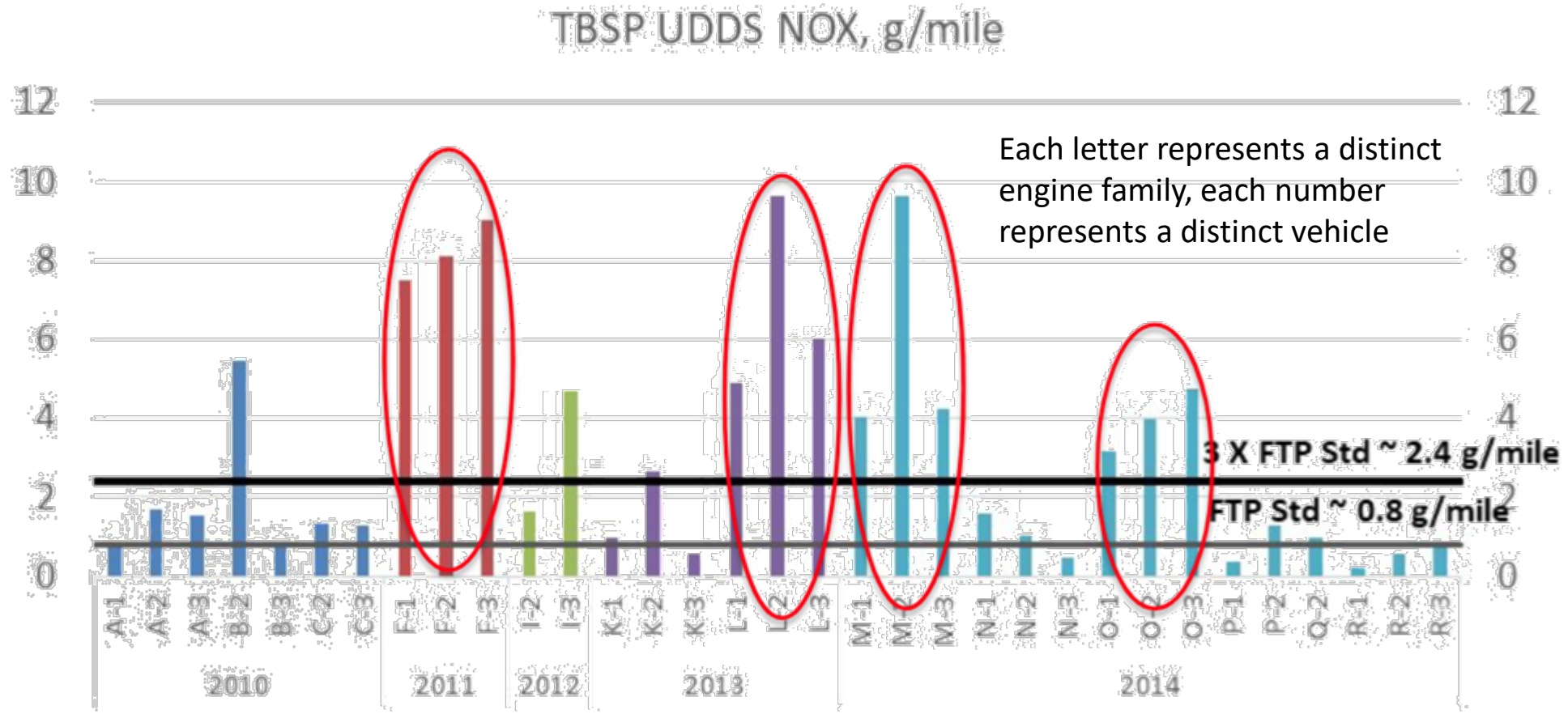


- 100 heavy-duty vehicles in California: vehicles across all categories idle for a significant fraction of operation time

Category	EMFAC Class	Vocation
1a	T7 NNOOS, NOOS, CAIRP	Long haul
1b	T7 tractor	Short haul
2a	T7 POLA	Port Drayage
3a	T7 Single Construction	Tractor construction
3b	T7 Single Construction	Cement mixer
6a	T6 instate small	Food/Beverage
6b	T7 instate heavy	Food/Beverage
7a	T7 Single	Goods distribution

- R. Pondicherry, B. Demirgok, B. Selimi, M. Besch, A. Thiruvengadam, D. Carder, “In-use Activity and NOx Emissions from On-Highway Vehicles Using Tail-Pipe NOx Sensor”, 2019

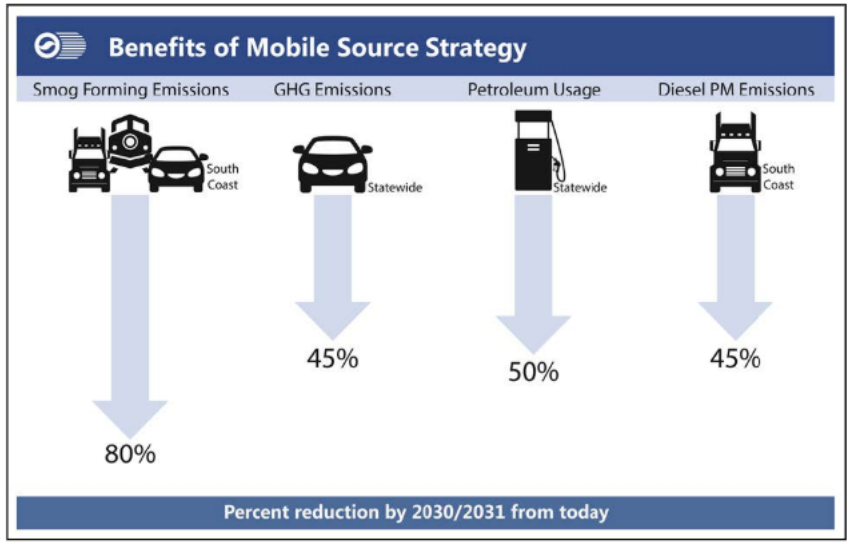
REAL-WORLD HEAVY-DUTY DIESEL NOx EMISSIONS



- CARB's Truck and Bus Surveillance has tested 35 trucks covering MY 2010-2014 and 13 engine families from 7 manufacturers
- Data showing emissions well above certification levels in many cases

CALIFORNIA STATE IMPLMENTATION PLAN (SIP)

- Mobile Source Strategy
  - Establish new engine standards effectively 90 percent cleaner than today's standards
  - Ensure in-use performance and emission control durability
  - Increase penetration of zero emission technologies
  - Importance of national standards for heavy-duty trucks
- State Implementation Plan (SIP)
  - 80 percent NOx reductions needed by 2031 in South Coast
  - Emission reductions in 2031: 24 tons per day NOx from CA standards, 28 tpd from federal standards
  - https://www.arb.ca.gov/planning/sip/2016sip/rev2016statesip.pdf

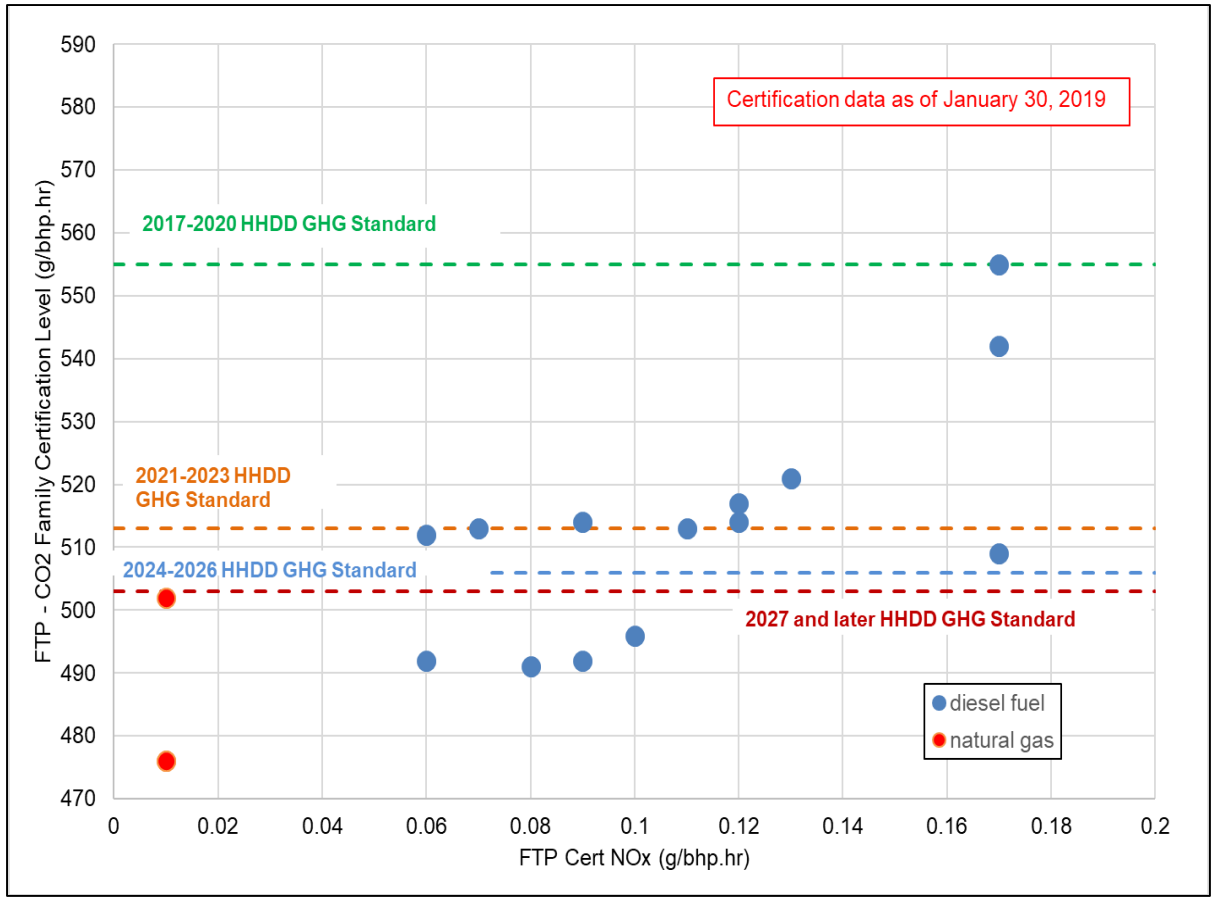


TECHNOLOGIES AVAILABLE TO REDUCE EMISSIONS

POTENTIAL FOR COST-EFFECTIVE EMISSION REDUCTIONS

WHERE MANUFACTURERS ARE CERTIFYING HEAVY-DUTY ENGINE FAMILIES TODAY

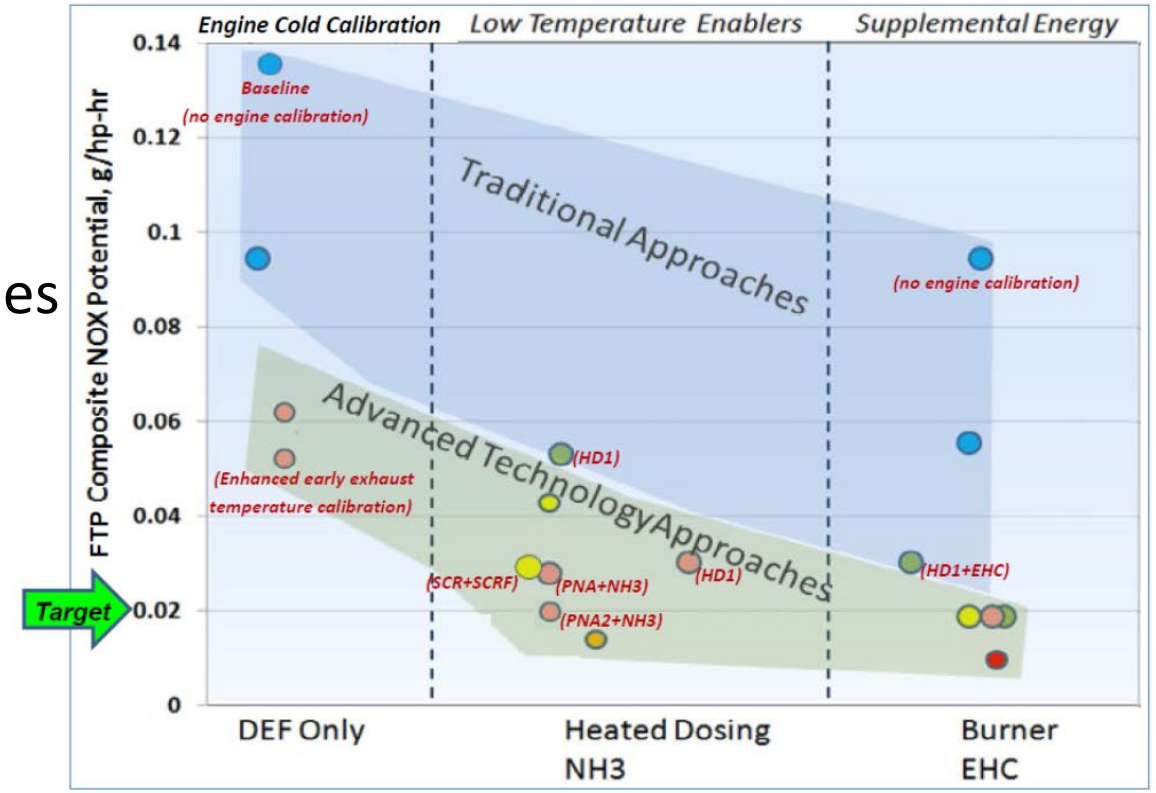
- Some NOx certification levels below 0.1 g/bhp-hr with CO_2 emission levels already near or below the 2027 MY Phase 2 GHG Standards
- Some NOx certification levels close to the certification standard with high CO_2 emission levels, indicating that these engine families will need to be updated soon

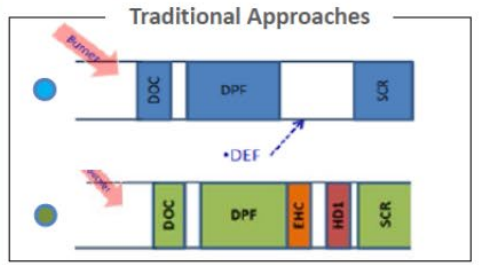


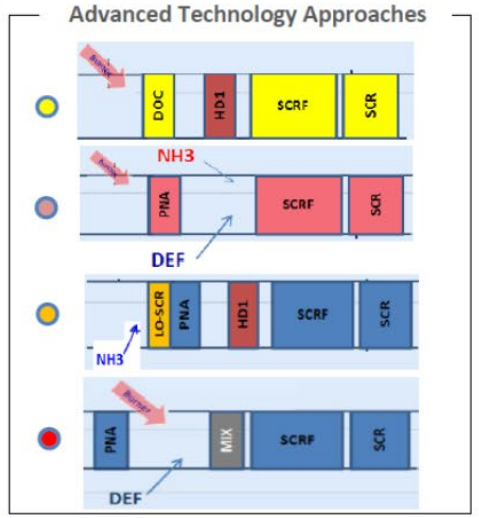
Emission certification levels for CARB certified 2019 MY heavy heavy-duty engines (GVWR > 33,000 lbs)

MULTIPLE TECHNOLOGY PATHS AVAILABLE FOR MEETING FUTURE STANDARDS

- Engine Calibration Strategies
  - Increased EGR
  - Post-injection
  - Increased idle speed
- Aftertreatment System Strategies
  - Increased catalyst size
  - Advanced catalysts
  - Improved urea injection control
  - Heated dosing
  - Twin SCR systems with dual dosing
- Engine Hardware
  - Cylinder deactivation
  - EGR cooler bypass
  - Turbo bypass
  - Charge air cooler bypass
  - Stop-start systems
  - Early exhaust valve opening (EEVO)







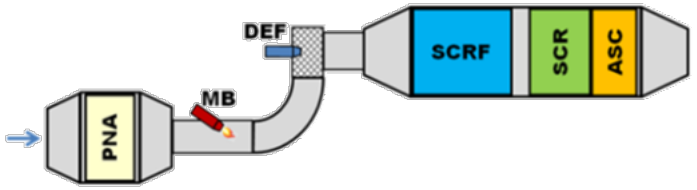
Preliminary estimates of cost-effectiveness **< $3/lb NOx** (well within the cost-effectiveness of previous rulemakings, cheaper than stationary sources controls)

SWRI LOW NOx DEMONSTRATION PROGRAM

- Funded jointly by CARB, SCAQMD, U.S. EPA, CHEDE, MECA and POLA with support from Volvo, Cummins
- Program includes several stages:
  - Stage 1/1b – Low NOx Feasibility Demonstration on CNG and Diesel Engine (Completed)

    Target NOx: 0.02 g/bhp-hr on the FTP and RMC

    Final diesel aftertreatment system configuration: PNA + miniburner + SCRF + SCR + ASC



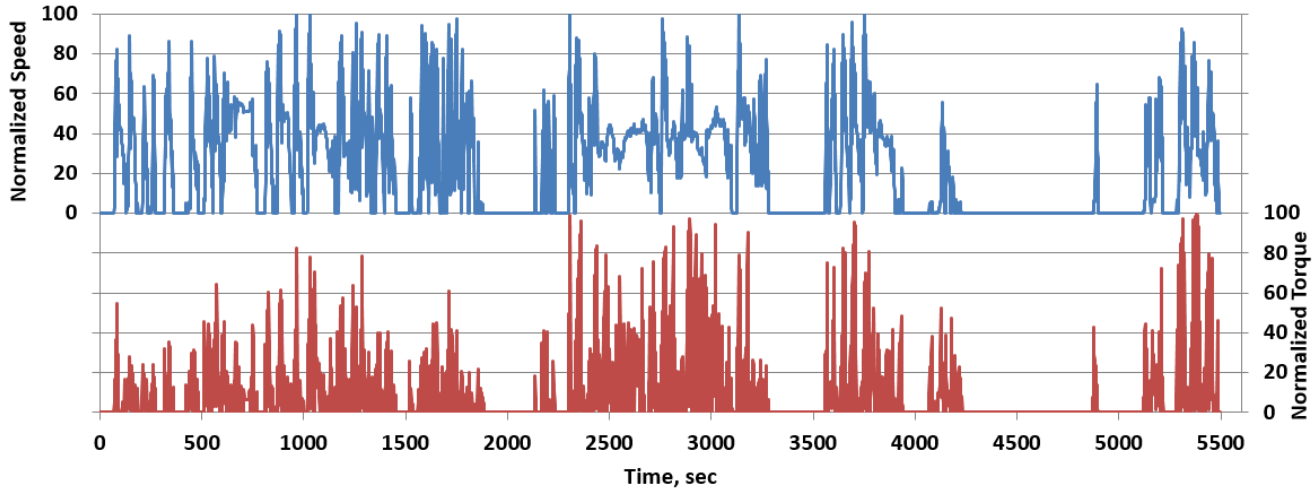
    Final test results: CNG: 0.010 / 0.001 g/bhp-hr on FTP / RMC-SET

    Diesel: Pending filter ash cleaning and retest

* https://ww3.arb.ca.gov/research/veh-emissions/low-nox/low-nox.htm

SWRI LOW NOx DEMONSTRATION PROGRAM

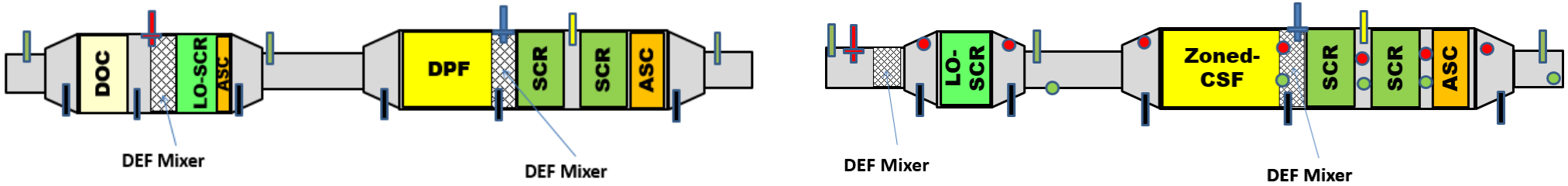
- Stage 2 (expected completion date- Jun 2019) –
  - Development of a Low Load Cycle (LLC)
    - Based on large set of real-world activity data from 751 vehicles
    - Several candidate cycles developed, final cycle will most likely be 90 minutes in length



  - Low load NOx control – Extending calibration of Stage 1 engine to low load operation
  - Evaluation of metrics (fueling rate, CO2 emission, work) to properly quantify emissions at low loads

SWRI LOW NOx DEMONSTRATION PROGRAM (cont'd)

- Stage 3 – Low NOx Demonstration on an Alternative Non-Turbocompound Diesel Engine (expected completion date- Dec 2019)
  - Target NOx: 0.02 g/bhp-hr on the FTP and RMC and optimization on LLC
  - Considering several candidate aftertreatment system configurations



- Stage 3b – Additional Low NOx Related Engine Hardware Development (Completed)
  - Evaluated several systems- cylinder deactivation (CDA), turbine bypass, EGR cooler bypass, charge air cooler (CAC) bypass, insulated exhaust manifold
  - Will continue development of CDA and EGR cooler bypass in Stage 3

CARB HEAVY-DUTY NOX OMNIBUS RULEMAKING

KEY ELEMENTS, TIMING, CALIFORNIA VS FEDERAL STANDARDS

KEY LONG-TERM RULEMAKING ELEMENTS

- Exhaust Emission Standards
  - FTP/RMC-SET NOx: 0.0x g/bhp-hr
  - New Low Load Cycle NOx: (1 to 3) x FTP
  - PM 2.5: 0.005 g/bhp-hr

- Heavy-Duty In-Use Testing (HDIUT)
  - Current program targets sustained high speed and high load operation only
  - Revise program to ensure real world emission reductions are achieved
    - Cover real-world full duty cycle emissions (include low load, idle, and start emissions)
  - Take full advantage of NOx sensors/telematics for compliance determination or screening
    - Ensure emissions are controlled across the in-use fleet through the useful life

KEY LONG-TERM RULEMAKING ELEMENTS (cont'd)

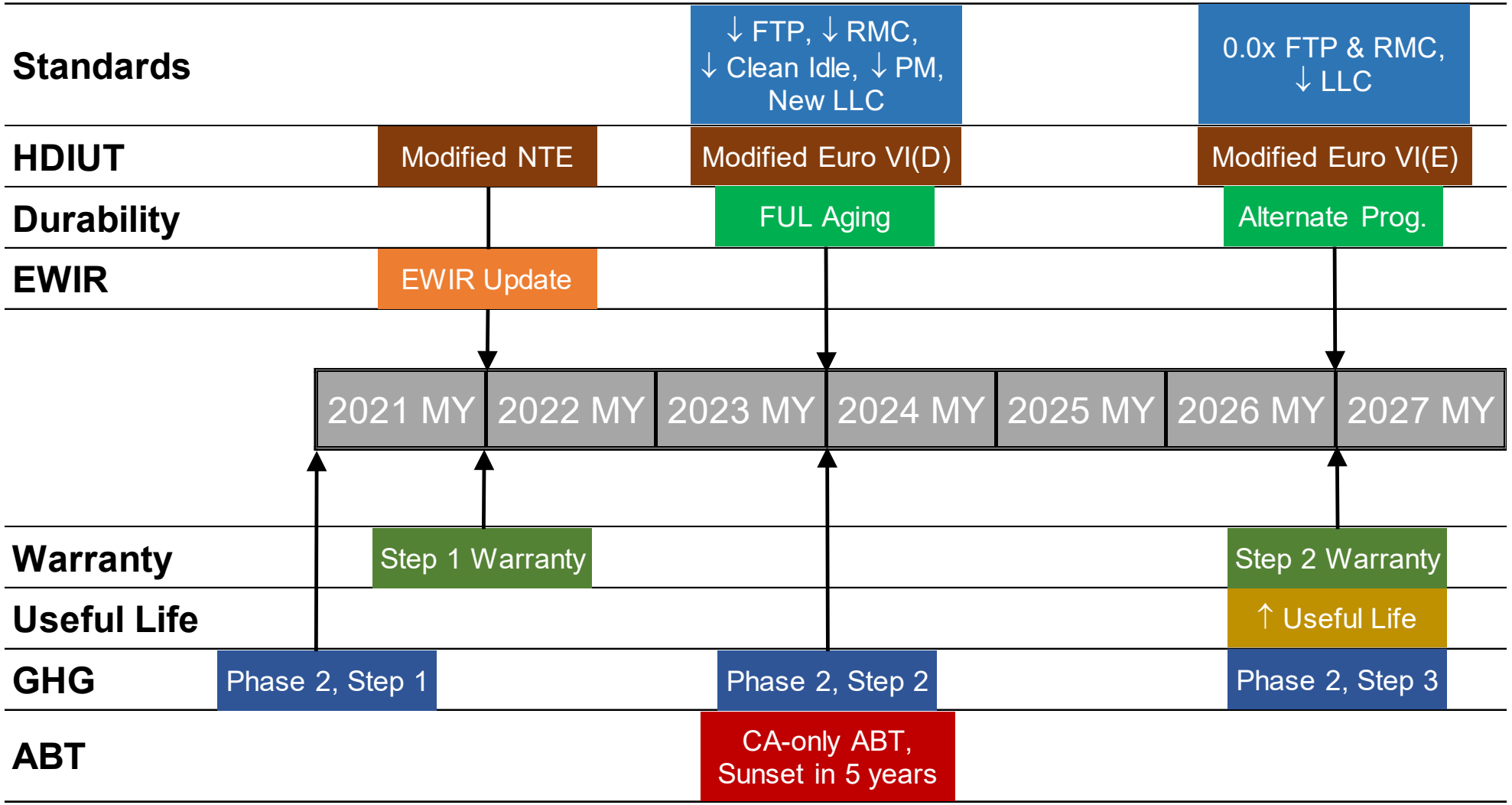
- Durability Demonstration
  - Extended and more defined dynamometer aging of engine and aftertreatment system to:
    - Develop deterioration factors (DF) that better reflect real world deterioration
    - Verify emission related component durability
  - Considering alternative durability demonstration using combination of dynamometer aging plus in-use NOx sensor data collection and reporting

- Useful Life and Warranty
  - Lengthen useful life to reflect the current longevity of engines and emission control components
  - Lengthen warranty period to reflect the lengthened useful life

RULEMAKING PUBLIC PROCESS, CARB WHITE PAPER

- Staff Outreach
  - Manufacturers, EMA, and technology providers
  - Workgroup meetings, workshops, and individual one-on-one meetings
- Manufacturers Expressed Concerns
  - Currently locking on engine design/plans to meet the 2024 MY Phase 2 GHG
  - Need for sufficient product development time to incorporate NOx with Phase 2 GHG
- Staff White Paper
  - Staff's assessment of what is achievable with the 2024 through 2026 MY engines
  - Provide manufacturers some insight going forward, so that they can incorporate potential NOx requirements with their 2024 MY engines development plans
  - Released on 4/18/2019
  - Posted on CARB's website at: https://www.arb.ca.gov/msprog/hdlownox/white_paper_04182019a.pdf

CARB LOW NOx IMPLEMENTATION TIMELINE

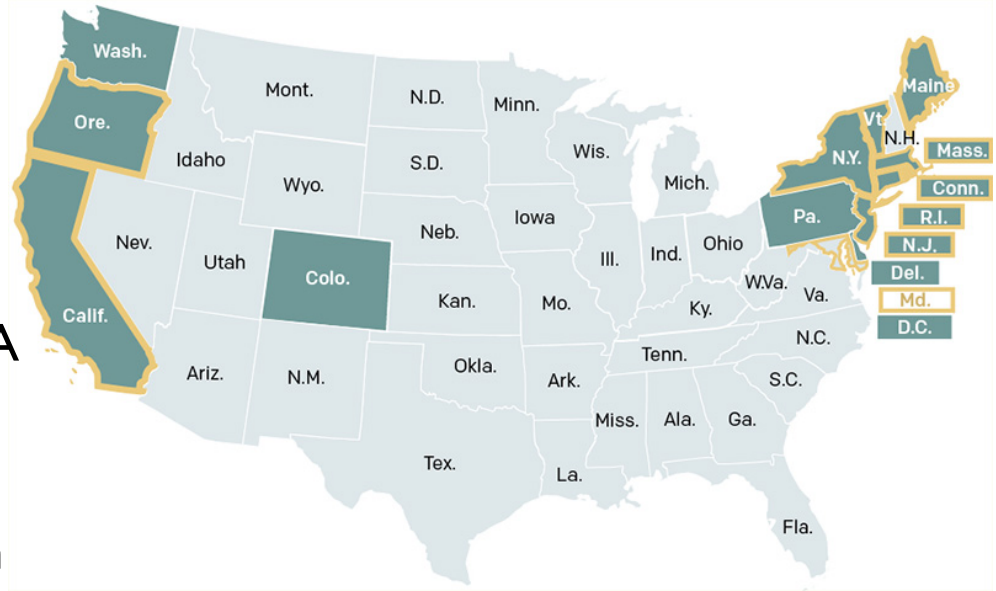


CARB REGULATORY TIMELINE, COORDINATION WITH U.S. EPA

- April to September, 2019: workgroup meetings and workshops
- Proposal to Board at March 2020 Board Hearing
- U.S. EPA Cleaner Trucks Initiative Notice of Proposed Rulemaking expected later in 2020
  - National heavy-duty low NOx program is critical for California
    - Out-of-state trucks account for more than half of heavy-duty VMT in California
  - CARB has worked closely with U.S. EPA technical staff to coordinate CARB omnibus rulemaking with U.S. EPA's cleaner truck initiative
  - To the extent possible, harmonized CA-federal requirements are desirable

BENEFITS TO 177 STATES SUPPORTING CARB LOW NOx RULEMAKING

- California Standards to take effect earlier than the federal Cleaner Trucks Initiative, 2024 vs. 2027
  - Earlier, stricter California standards provide a proving ground for technologies, strategies, facilitate long-term reductions nationwide
- Heavy-duty truck emission benefits more cost-effective than stationary sources controls
- States outside California can:
  - Track California efforts, and publicly express support
  - Opt into program:
    - Per section 177 of the Clean Air Act, states can adopt California standards without the need to seek U.S. EPA approval
    - Light-duty:13 states have adopted California's LEV standards while 9 have also adopted the ZEV program (as of December 2018)



CONTACTS / USEFUL LINKS

CONTACTS

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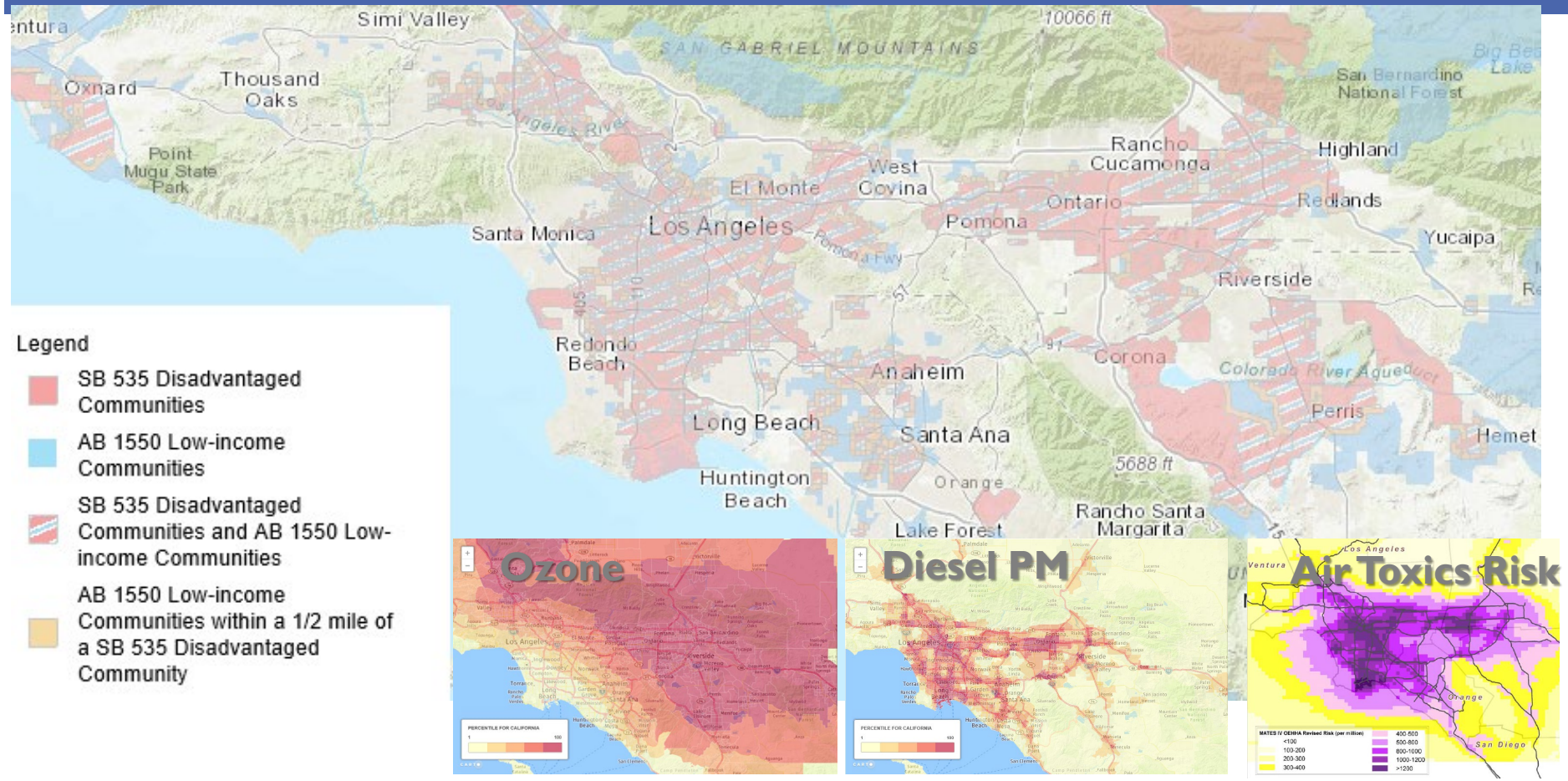
USEFUL LINKS

Govdelivery signup
https://public.govdelivery.com/accounts/CARB/subscriber/new?topic_id=listserv
Topic: Heavy-Duty Low NOx

ARB Low NOx Rulemaking
https://www.arb.ca.gov/msprog/hdlownox/hdlownox.htm

BACKUP

NEED SOLUTIONS ROBUST ON MULTIPLE SCALES



- Global
- Regional
- Community Air Protection

Mobile Source Emissions overlay these vulnerable populations

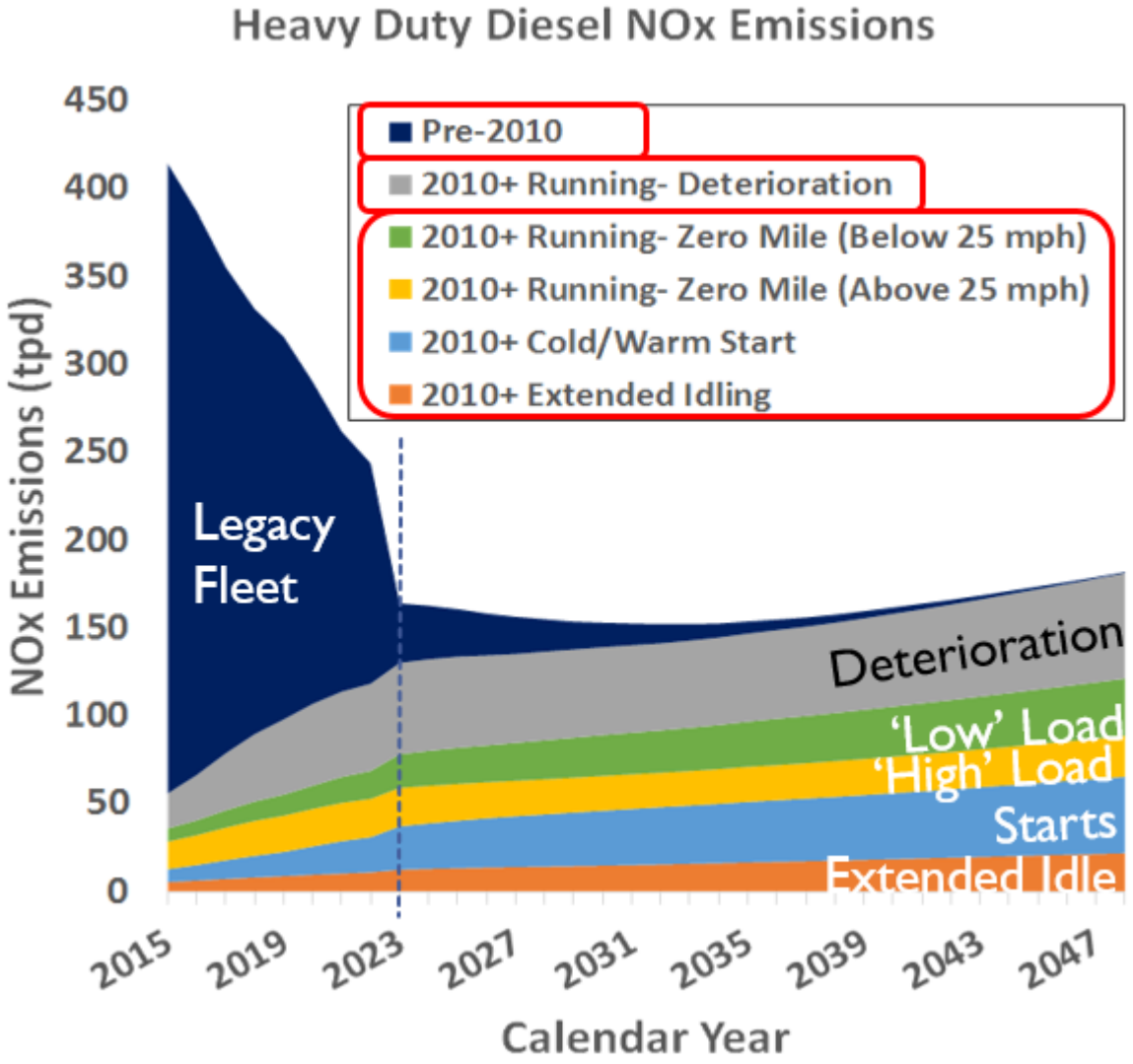
HEAVY-DUTY DIESEL NOx EMISSIONS BREAKDOWN

'til 2023:

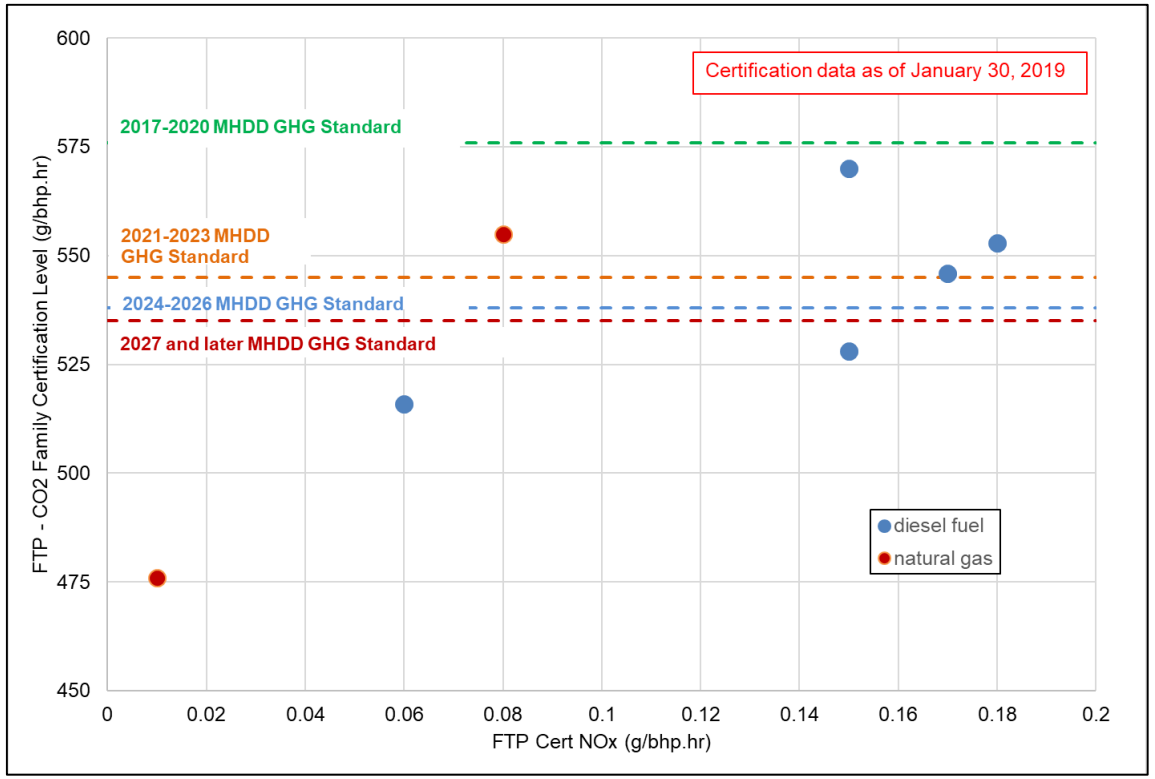
- Non-SCR trucks dominate NOx

Beyond 2023:

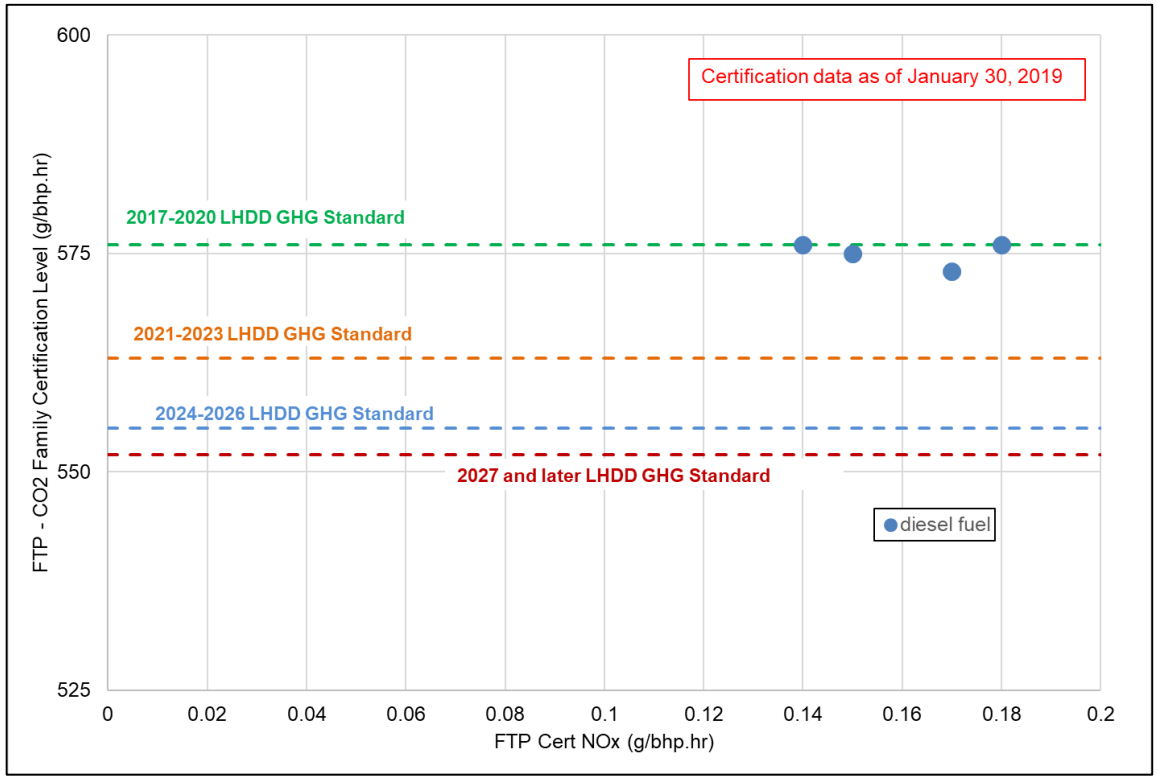
- Deterioration-related emissions largest
  - Need HD I/M and extended warranty
- Running, start and idling emissions also significant
  - Need lower standards, low-load cycle, improved in-use testing
- Multi-pronged holistic approach required



WHERE MANUFACTURERS ARE CERTIFYING ENGINES TODAY



Emission certification levels for CARB certified 2019 MY medium –heavy-duty engines (GVWR 19,501 to 33,000 lbs)



Emission certification levels for CARB certified 2019 MY light heavy-duty engines (GVWR 14,001 to 19,500 lbs)