Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards

Overview Briefing of the Proposal

APRIL 2022

Context for EPA Heavy-Duty Proposal

- The heavy-duty industry is diverse, spanning delivery trucks, tractor-tailers, school buses, and other types of vocational vehicles
- Heavy-duty vehicles contribute significantly to local, regional, and global air pollution
- The Clean Air Act gives EPA authority to set standards for heavy-duty engine and vehicle emissions to protect public health and welfare
  - In considering stringency, EPA's feasibility assessment must consider technologies needed to reduce the air pollutant emissions, lead time needed to bring technologies to the market, and cost for the industry to comply
  - Standards for hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NOx) and particulate matter (PM) must "reflect the greatest degree of emission reduction achievable …", for the applicable model year, and provide a minimum of 4 years lead-time, and 3 years of stability between new standards
- EPA's last heavy-duty rulemaking for these pollutants was over 20 years ago, with standards that phased in through 2010.

Categories of Highway Vehicles

Light-Duty Vehicles

Medium-Duty Vehicles

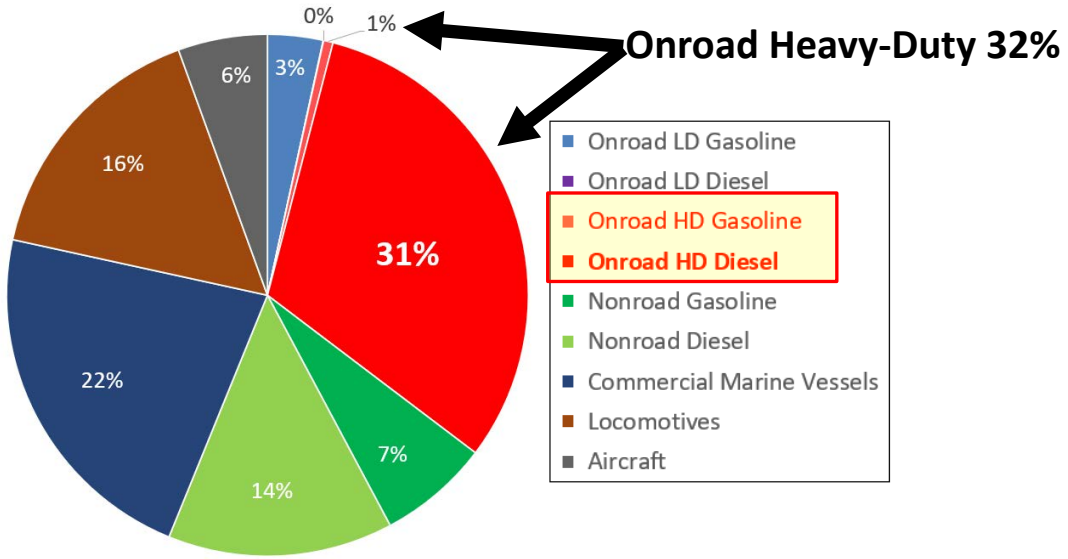
Heavy-Duty Engines & Vehicles

This proposed action's primary focus is on **heavy-duty vehicles and the engines/powertrains** which drive them

Highway Heavy-Duty Vehicle Emission Inventories

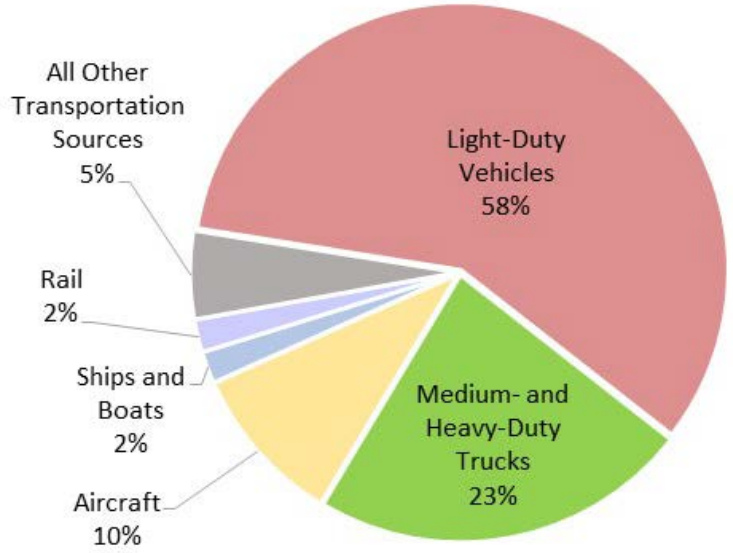
- Heavy-duty vehicles contribute significantly to local, regional, and global air pollution
  - Largest source of mobile source NOx
  - Second largest source of GHG emissions in the transportation sector

Mobile Source NOx (2045)



MOVES3 for onroad and nonroad and 2016 Emissions Modeling Platform for all other mobile sectors

Mobile Source GHGs (2019)



"Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019," EPA 430-R-21-005

History of EPA's Heavy-Duty Standards

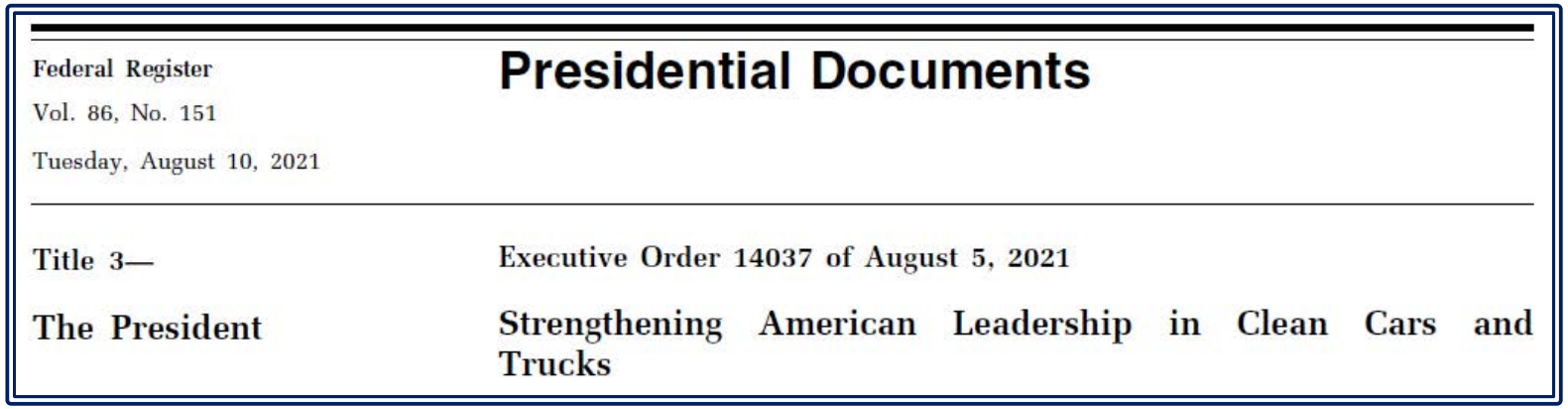
Criteria Pollutants

- Progressively more stringent vehicle emissions standards over the past 40 years have led to engines today that are >90% cleaner for NOx, PM, HC, and CO
- EPA's last rulemaking was over 20 years ago, with standards that phased in through 2010. Emission reductions for NOx and PM can be achieved primarily through catalyst and particulate filter technologies.

GHG Pollutants

- In 2011 ("Phase 1") EPA set first-ever GHG standards for heavy-duty engines and vehicles, coordinated with fuel efficiency standards established by the Dept. of Transportation; in 2016 EPA issued "Phase 2" GHG standards.
- Phase 1 standards phased in through 2018, and the Phase 2 standards phase in through 2027
- Primary focus was significant development and introduction of advanced gasoline and diesel vehicle technology
- In combination, Phase 1 and Phase 2 standards are expected to result in ~ 30% reduction in heavy-duty vehicle GHG emissions

EPA's Clean Truck Plan: A Road Map to a Zero Emission Future



Federal Register
Vol. 86, No. 151
Tuesday, August 10, 2021

Presidential Documents

Title 3—
The President

Executive Order 14037 of August 5, 2021

Strengthening American Leadership in Clean Cars and Trucks

EPA is developing multiple heavy-duty rules under our Clean Truck Plan, consistent with EO 14037:

1) This proposal to set more stringent NOx standards for **heavy-duty engines & vehicles** beginning in model year (MY) 2027 and tightening the "Phase 2" greenhouse gas (GHG) emissions for MY 2027 and beyond.

2) An upcoming proposal to set more stringent emissions standards for **medium-duty vehicles** for MY 2027 and later. These revised standards will be proposed in combination with new standards for **light-duty vehicles** for MY 2027 and beyond.

3) An upcoming proposal to set "Phase 3" GHG standards for **heavy-duty vehicles** beginning as soon as MY 2030 that are significantly stronger than the MY 2027 GHG standards.

Overview of Proposal

- EPA presents two regulatory options for new NOx standards:
  - Both would change key provisions of the heavy-duty emission control program
    - Proposed Option 1: starts in MY 2027 with final step in MY 2031 that provides up to 90% reduction in NOx standard over the city (FTP) and highway (SET) driving cycles*
    - Proposed Option 2: starts in MY 2027 with no phase-in; provides 75% reduction in NOx standard over the FTP and SET driving cycles
  - Request comment on both regulatory options and the range in between them, as well as an Alternative presented

- Targeted updates to existing Heavy-Duty GHG Phase 2 Program
  - Proposal would revise MYs 2027 and later GHG emission standards for specific vehicle subcategories to reflect known electric vehicle products

*level of reduction varies by useful life period and engine regulatory class

Proposed Criteria Pollutant Program

Key Program Elements to Reduce Emissions

- The proposal includes changes to 4 key program elements
  - **Test Procedures**
  - **Regulatory Useful Life**
  - **Numeric Emission Standards**
  - **Emissions Warranty**

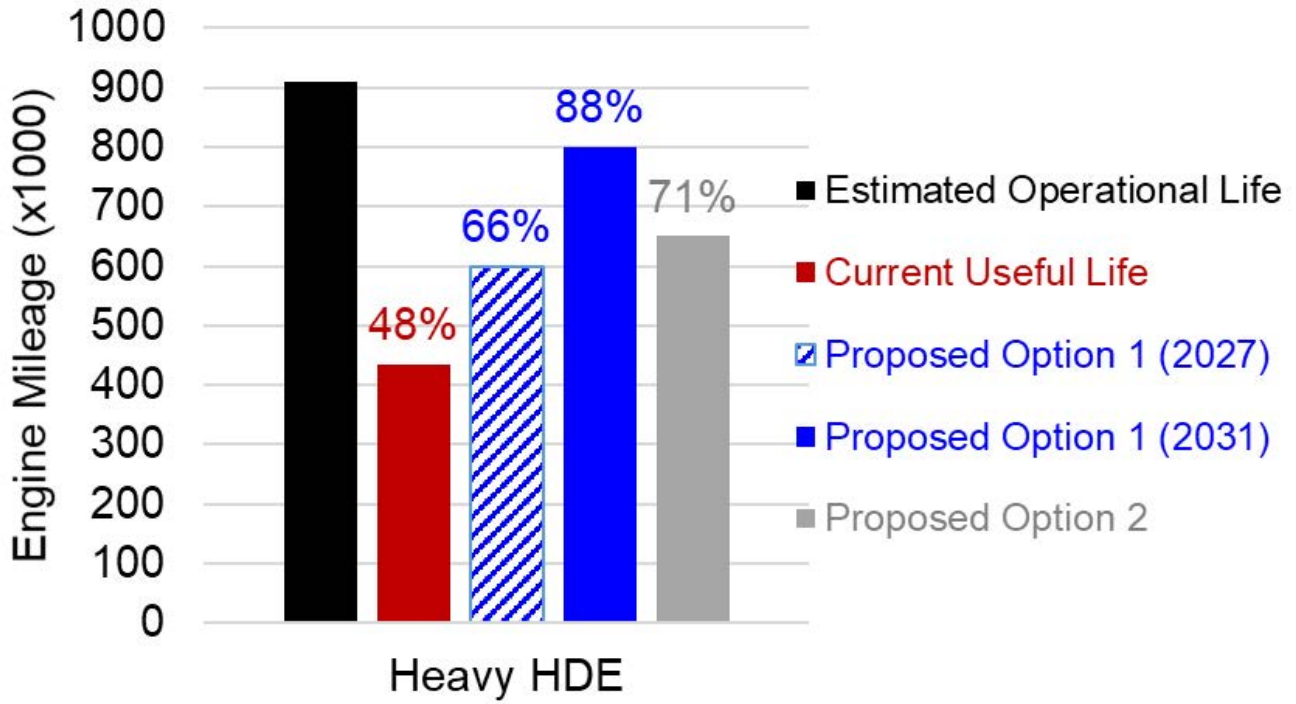
Applying Four Program Elements:
Update Test Procedures

- Significant data collected by EPA, OEMs, and many other stakeholders makes it clear that EPA's existing test procedures do not adequately address all vehicle operations

- EPA is proposing to change existing test procedures, and add new test procedures to cover all vehicle operations
  - New laboratory duty cycle (a "low-load" cycle) and standards to cover stop-and-go and idle operation
  - Updated test procedure and standards for vehicles on-the-road ("off-cycle")
  - Lower emissions standards for the existing laboratory duty cycles that cover FTP and SET operation

Applying Four Program Elements:
Update Regulatory Useful Life

- We estimate the "operational life" of engines based on average mileage at time of rebuild or replacement.
- Our rebuild and replacement data suggest engines remain in the field at least twice their current regulatory useful life across all heavy-duty classes.
- Longer useful life can ensure engines are designed to meet emission standards through more of their operational life
  - Values also must be technically grounded in the capabilities of the emissions control technology



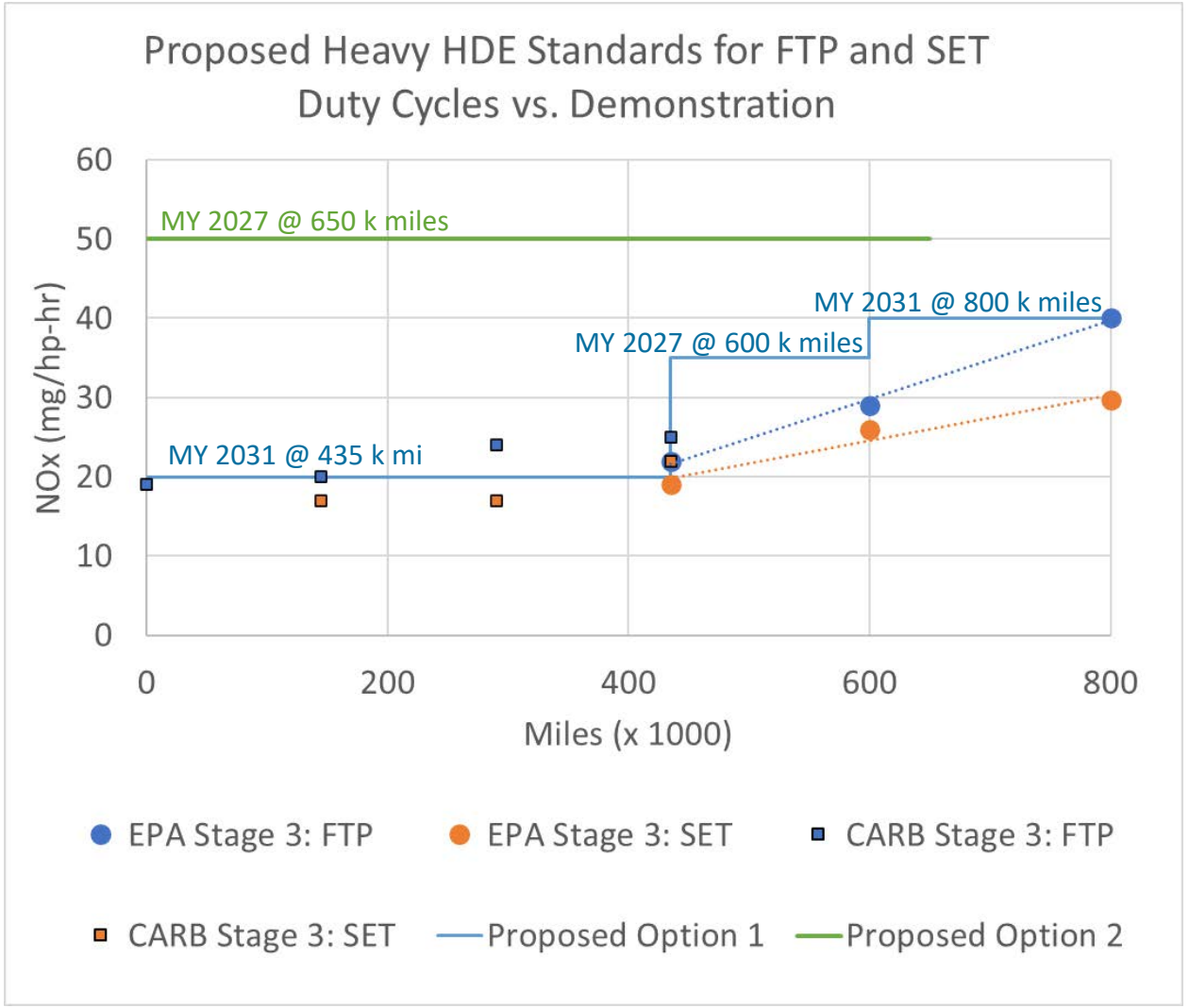
Values shown are % of operational life

Applying Four Program Elements:
Update Emissions Standards

- Evolution of today's selective catalytic reduction (SCR) technology and use of existing cylinder deactivation hardware can reduce NOx emissions by 90% or more for diesel engines over a wide range of engine operation:
  - Close-coupled SCR (or dual SCR) allows the catalyst to warm up quickly
  - Cylinder deactivation under low-load conditions keeps the SCR catalyst warm
- Strategies to optimize three-way catalyst performance can reduce HC and CO emissions from gasoline engines
- Multi-year engine demonstration program at SwRI
  - Accelerated aging of two aftertreatment systems to the equivalent of 800,000 miles
  - Laboratory testing of advanced technologies on regulatory cycles and on-the-road (or in-use) cycles
    - Regulatory cycles: FTP (urban driving), SET (highway driving), and the LLC (low load cycle)
    - Five on-the-road cycles that cover a range of operation from ports and city operation, to highway operation through the mountains
- These technologies are well understood, already in production, and are not expected to negatively impact reliability of the model year 2027 products

EPA's Demonstration Project

- EPA's demonstration project built on CARB's multi-year demonstration program at Southwest Research Institute
- Modifications made to CARB Stage 3 aftertreatment system to improve performance:
  - Additional diesel exhaust fluid mixer for underfloor SCR system
  - Zone coated soot filter was replaced with a separate diesel oxidation catalyst and diesel particulate filter that was aged to the equivalent of 435,000 miles
- The complete aftertreatment system was aged to the equivalent of 800,000 miles



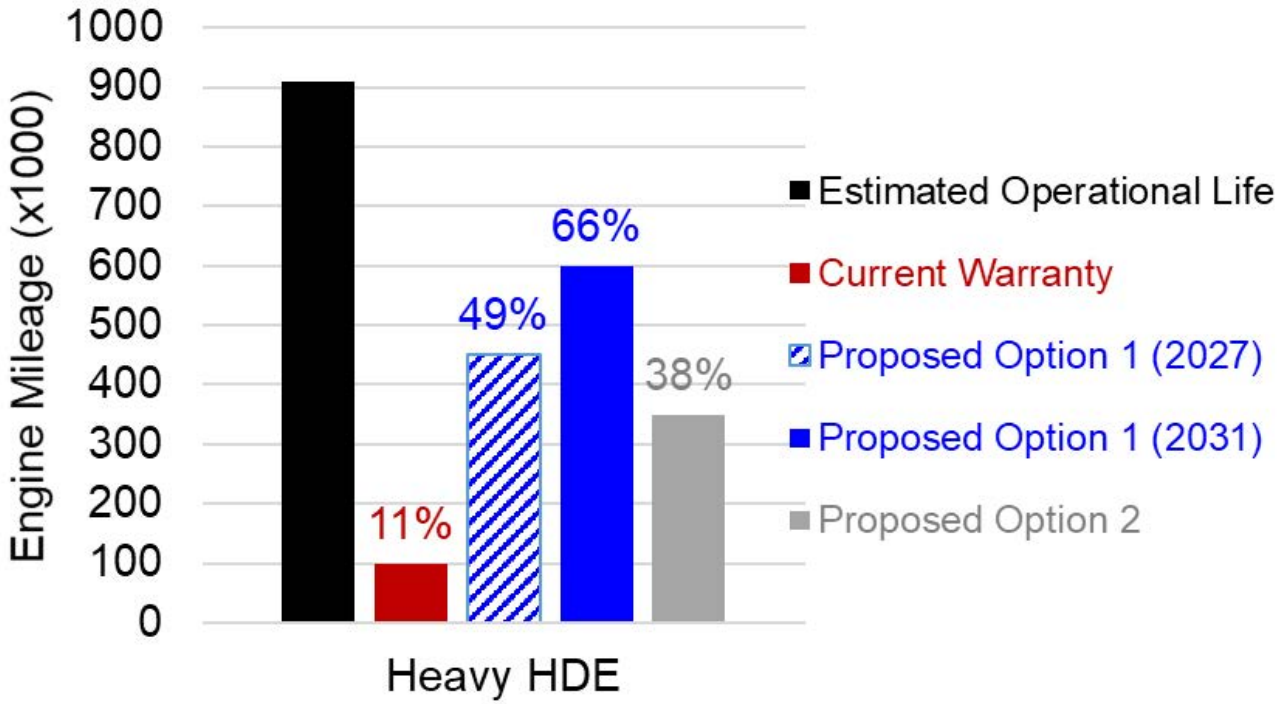
Applying Four Program Elements:
Update Emissions Standards

	Reduction from current FTP and SET driving standard (%)	Key differences between Options*
Proposed Option 1 (MY 2031)	90% for Light, Medium and Spark Ignition HDE	• Provides phase-in to lower levels of standards, whereas proposed Option 2 begins fully in 2027. • Includes lower numeric standards for all duty cycles than proposed Option 2
	90% for Heavy HDE at IUL	
Proposed Option 2	75% for all HDE	• Standards could be met with less improvement to the durability of the technology than required for the proposed Option 1.

*Useful life and warranty periods vary between Options

Applying Four Program Elements:
Update EPA Emissions Warranty

- Warranty ensures end-users don't bear all the risk of emission technologies that fail prematurely
- Current warranty periods for most heavy-duty engine classes cover a small fraction of real-world operation
- We propose to lengthen warranty, in part, because owners are more likely to make repairs and less likely to tamper if emission controls are covered by warranty



Values shown are % of operational life

Note: We estimate the "operational life" of engines based on average mileage at time of rebuild or replacement.

Heavy Heavy-duty Diesel Cost per Engine

Scenario	Total Technology Cost per Engine in 2031*	Increase in Initial Cost**	Emission Repair Costs for MY2031 Vehicle***
Proposed Option 1 (Increment from Baseline)	$3,900	3.3%	-$90
Proposed Option 2 (Increment from Baseline)	$3,200	2.7%	$3,900

*Undiscounted, 2017 dollars

** Applying an estimated price of $119,000 for a Class 8 tractor

**Estimated cost per vehicle during the first 14 Years of MY2031 long-haul combination truck equipped with HHDE; discounted at 3%; negative values denote lower costs (i.e., savings in emission repair expenditures)

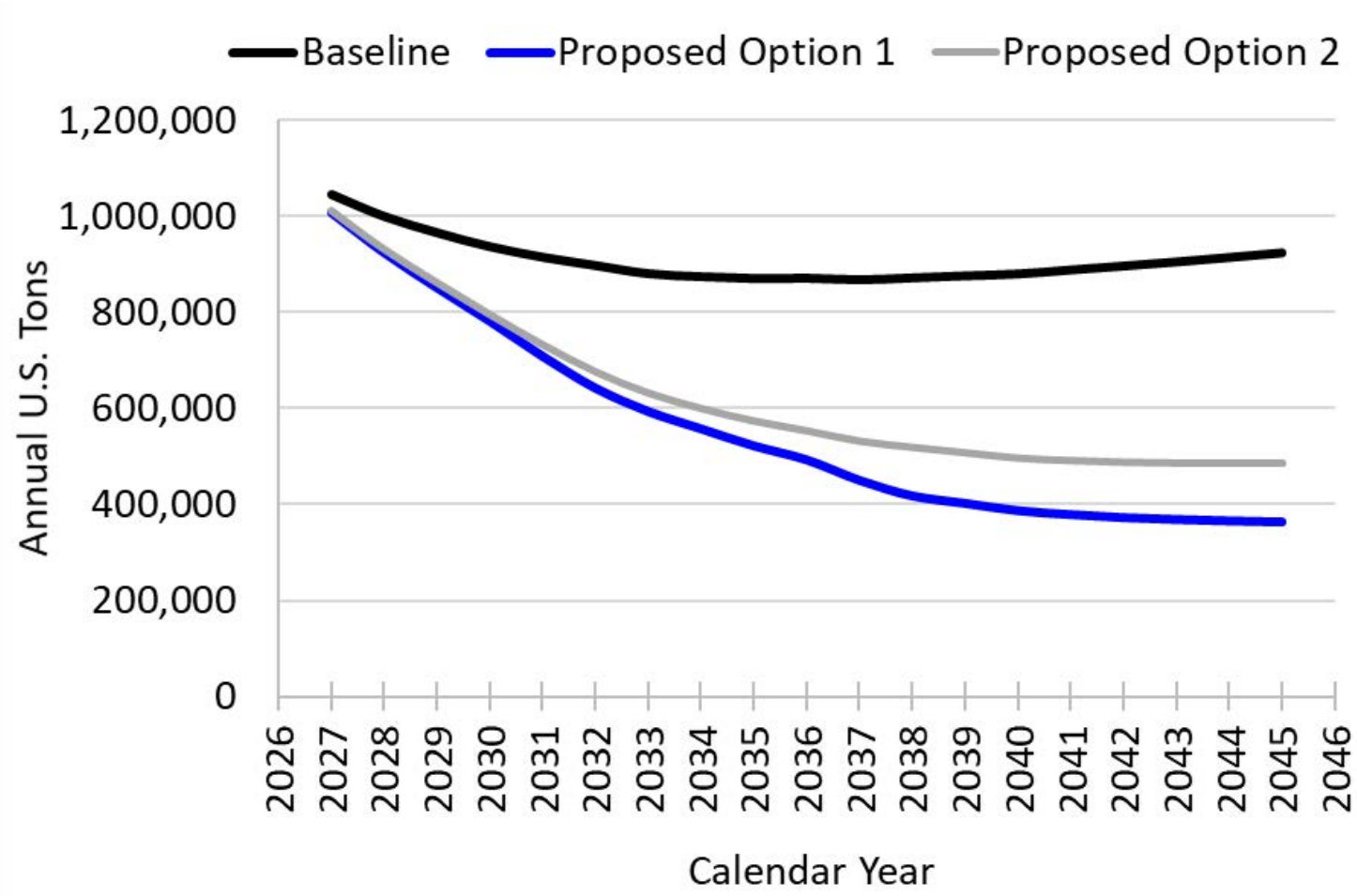
- Cost per engine for all other engine classes are lower
- Costs per engine reflect manufacturers' costs
  - Includes: adding new emission control technologies, improving durability due to longer useful life periods, covering repairs under longer warranty periods
- Increases in costs may differ from how manufacturers choose to price products
- Emission repair costs reflect operating cost impacts estimated for owner/operators and differ for different types of vehicles.

Program Costs

- Similar manufacturer costs for proposed Options 1 and 2
  - Similar technology employed for both scenarios
  - Higher costs of proposed Option 1 largely reflect production of more durable products (due to longer useful life periods)
- Operating costs reflect different balancing of program elements
  - Option 1 has larger increase in diesel exhaust fluid consumption to meet lower NO_X levels
  - Option 2 includes higher emission repair costs versus Option 1
- EPA does not expect the proposed program would result in market disruptions based on our technology assessment, cost estimates and detailed assessment of the "pre-buy" and "low-buy" phenomenon included in the proposal

	Present Value of Costs through Calendar Year 2045 (3% DR, Billions 2017$)		
	Manufacturer Costs	Operating Costs	Program Total Costs
Proposed Option 1	$23	$4	$27
Proposed Option 2	$21	$9	$30

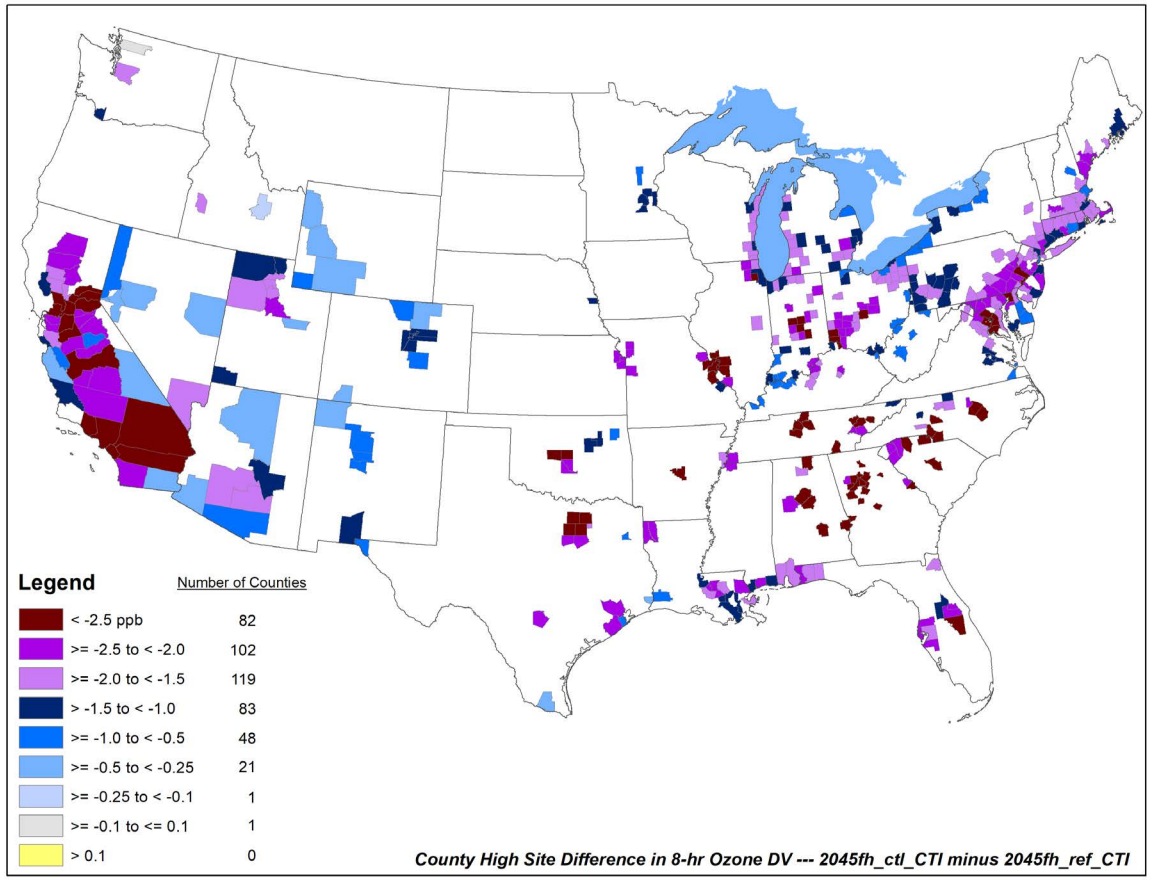
Heavy-Duty Highway NO_x Emissions Inventory: Baseline versus Proposed Options 1 and 2



	NO_x Reduction (%)	
	CY 2036	CY 2045
Proposed Option 1	43%	61%
Proposed Option 2	37%	47%

Projected Air Quality Improvements of Option 1

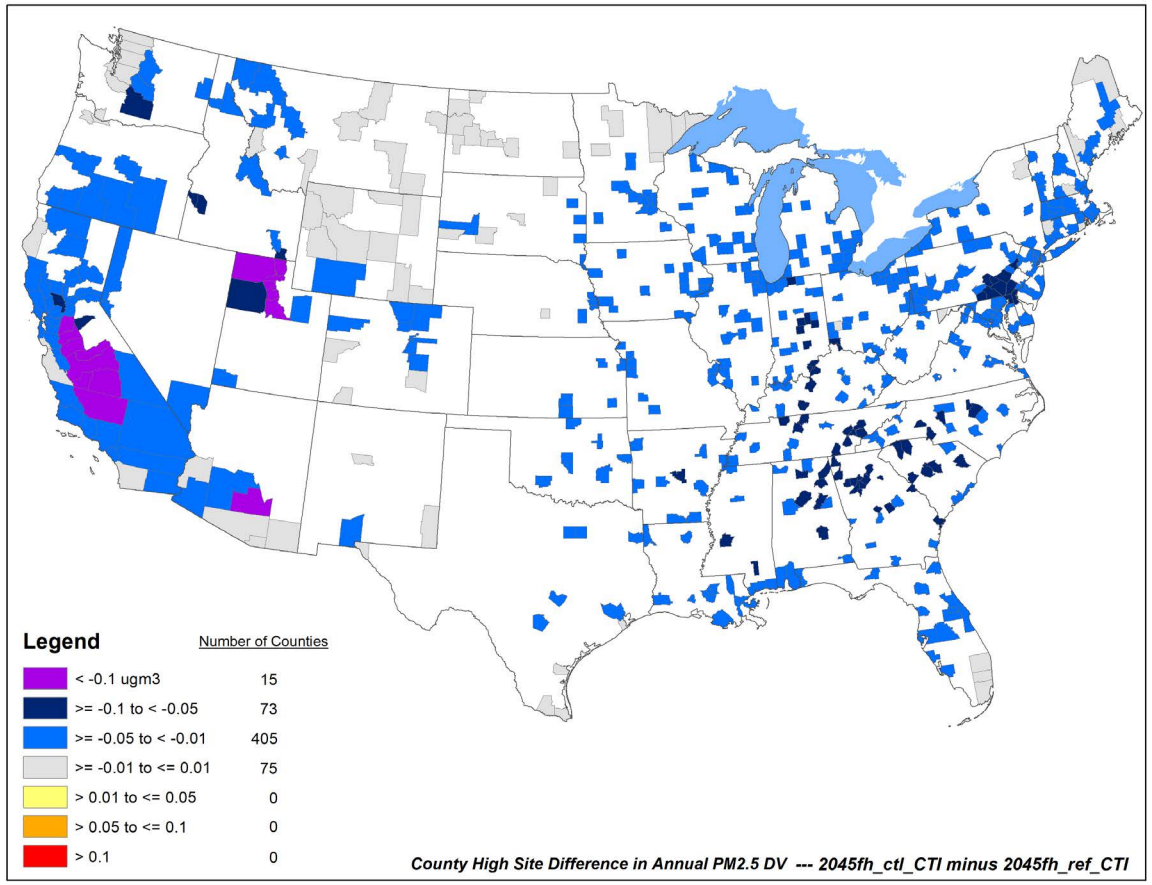
- The proposed Option 1 would reduce concentrations of ozone and $PM_{2.5}$ across the country
- Ozone decreases are especially significant
  - Average pop-wtd decrease in ozone design value for all counties in 2045: 2.2 ppb
- Modeling projects some continued nonattainment in 2045 without the proposal, including in areas outside CA
  - 15 counties in CA, NY, CT, UT, WI, TX
- The proposed Option 1 would reduce concentrations in counties projected to be over the standard
  - Average pop-wtd decrease in ozone design value for all counties where reference case is projected above the level of the NAAQS (70 ppb) in 2045: 3.0 ppb



Projected Change in 8-hour Ozone Design Values in 2045 for the proposed Option 1

Projected Air Quality Improvements of Option 1

- The proposed Option 1 would reduce concentrations of ozone and $PM_{2.5}$ across the country
- Meaningful decreases in annual $PM_{2.5}$
  - average pop-wtd decrease in annual $PM_{2.5}$ design value for all counties in 2045: 0.04 ug/m^3
- Modeling projects some continued nonattainment in 2045 without the proposal
  - 12 counties in CA and AZ
- The proposed Option 1 would reduce concentrations in counties projected to be over the standard
  - average pop-wtd decrease in annual $PM_{2.5}$ design value for all counties where reference case is projected above the level of the annual NAAQS (12 ug/m^3) in 2045: 0.05 ug/m^3



Projected Change in Annual $PM_{2.5}$ Design Values in 2045 for the proposed Option 1

Environmental Justice Analysis

- The most significant impacts of this rule would be reducing the impacts of HD trucks on regional ozone and $PM_{2.5}$
- In the 2045 baseline (i.e., without the rule), areas with the worst ozone and $PM_{2.5}$ are disproportionately people of color
- The biggest air quality improvements from the rule would occur in these areas
- We have also conducted a detailed analysis of the populations living near major truck routes
  - About 72 million people live within 200 meters of a truck route
  - More likely to be people of color and have lower incomes

Benefits and Net-Benefit Comparisons

- Health benefits from reductions in ozone and $PM_{2.5}$ outweigh the costs for both the proposed Options 1 and 2
  - Upper and lower estimates of benefits reflect combinations of alternative $PM_{2.5}$ and ozone mortality studies that yield more and less conservative benefits totals
- Present Values reflect the stream of rule-related costs and benefits between 2027-2045

	Present Value through Calendar Year 2045 (3% DR, Billions 2017$)	
	Health Benefits	Net Benefits
Proposed Option 1	$88 - $250	$61 - $220
Proposed Option 2	$71 - $200	$41 - $170

Opportunities to Reduce Emissions Before 2027

- Both the proposed Option 1 and the proposed Option 2 provide opportunities to reduce heavy-duty truck emissions prior to 2027
  - Incentivize early adoption of new technologies by providing opportunities for emission credits ahead of MY 2027
  - Allow battery-electric and fuel cell electric vehicle manufacturers to generate NOx emission credits

Summary of the Alternative

- Significantly more stringent than the proposed Options 1 and 2 – as well as CARB's Omnibus standards – due to combination of numeric level NO_X emission standards, useful life periods, and lead time of the Alternative
  - 20 mg/hp-hr NOx standard for full useful life
  - Longest useful life periods and emissions warranty for all engine categories compared to all scenarios

- Currently are unable to conclude that the Alternative is feasible in the MY 2027 timeframe over the useful life periods in the Alternative
  - Due to deterioration in the emission control technologies that we have evaluated to date
  - We would need additional supporting data or other information in order to determine that the Alternative is feasible in the MY 2027 timeframe to consider adopting it in the final rule

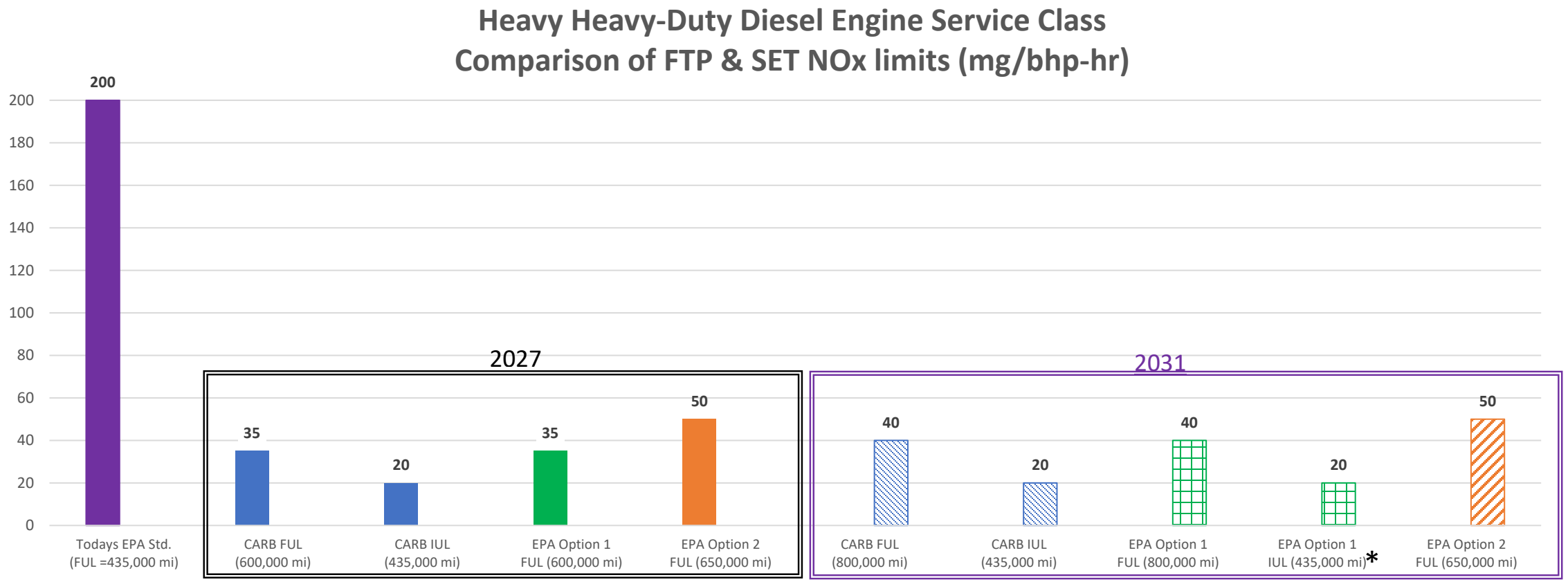
Key Requests for Comment on Criteria Pollutants

- All aspects of proposed Options 1 and 2 standards, as well as the Alternative standards
  - Standards for each duty cycle; one- and two-step approaches; implementation dates of MYs 2027 and 2031
- A request for comment for interim in-use NOx standards under proposed Option 1 for heavy-heavy duty engines (40 to 100% higher than proposed Option 1 standards for testing that occurs at certification for MYs 2027 -2033)
- Proposed test procedures
  - New LLC for heavy-duty CI engines; applying SET duty cycle for heavy-duty SI engines; off-cycle standards for CI; request for comment on off-cycle standards for SI engines
- Useful life and warranty periods of proposed Options 1 and 2, as well as range in between and the Alternative
  - Other approaches to warranty (e.g., graduated warranty phases)
- Proposed approaches to increase likelihood of emission control maintenances (e.g., revised inducement strategies, improved serviceability)
- Proposed durability requirement for manufacturers choosing to generate NOx emission credits from battery-electric or fuel cell electric vehicles

Technical Work Included in the Proposal

- New assessment of NOx emission aftertreatment system (EAS) aged out to the equivalent of 800,000 miles (See Preamble Section III, Draft RIA Chapter 3, EPA Technical Memo "Test Results from EPA Diesel Demonstration")
- New cost estimation for EAS and CDA from peer-reviewed teardown study conducted by FEV (See Draft RIA Chapter 3)
- New methodology for projecting emission warranty costs (See Draft RIA Chapter 7)
- New, peer reviewed, analysis on the potential impacts of EPA regulations on heavy-duty vehicle sales (pre- and low-buy) (See Draft RIA Chapter 10)

Comparison of EPA Proposal and CARB Omnibus

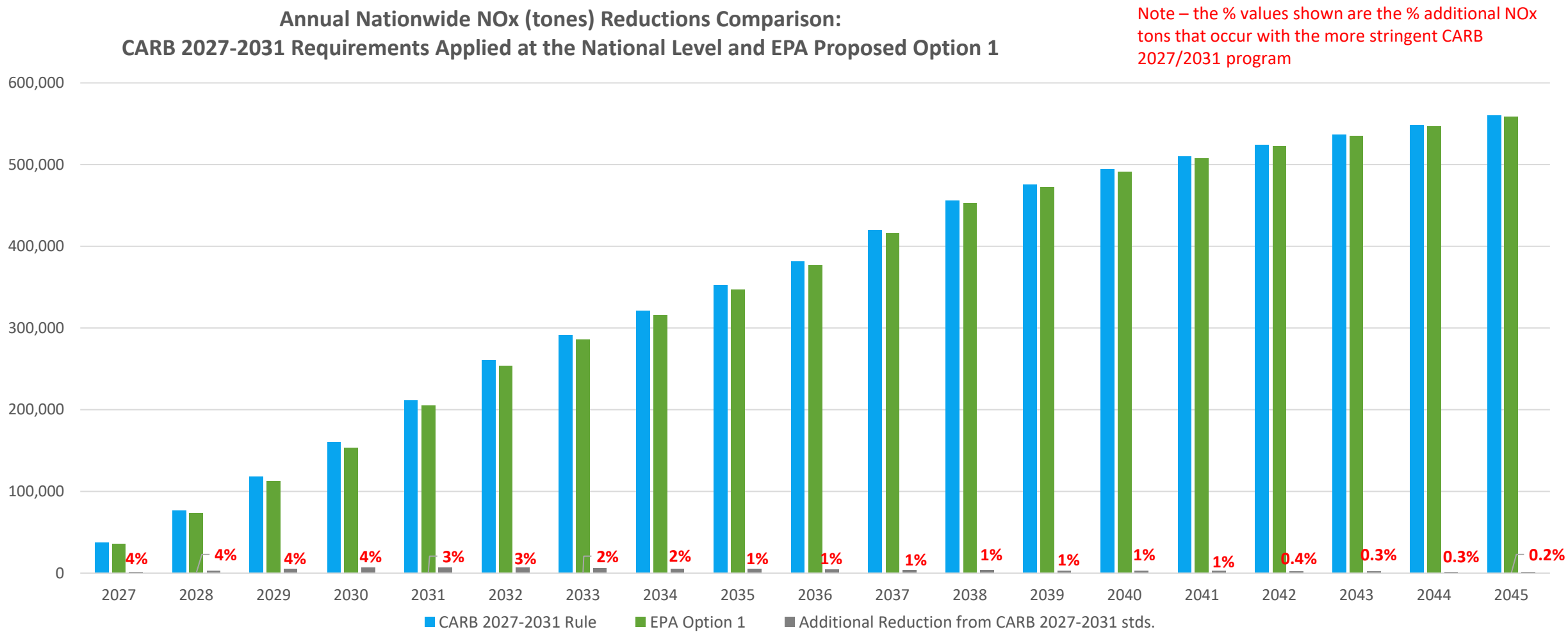


*In the proposal, EPA requests comment regarding if EPA should also establish an intermediate useful life standard for the heavy heavy-duty service class for MY 2027.

Comparison of EPA Proposal and CARB Omnibus: Heavy Heavy-Duty Diesel Engine Service Class

	EPA Option 1	EPA Option 2	EPA Alternative	CARB HD Omnibus Rule
MY 2027				
FTP & SET cycle NOx standards (mg/hp-hr)				
@ Intermediate Useful Life	request comment	request comment		20
@ Full Useful Life	35	50	20	35
Low Load Cycle NOx standard (mg/hp-hr)	90	100	100	90
Idle NOx standard (g/hr)	5 (optional)	10 (optional)	10	5
In-use moving average window NOx std.	2x lab cycle value	1.5x lab cycle value	1.5x lab cycle value	2x lab cycle value
Intermediate Useful Life (miles)	-	-		435,000
Full Useful Life (miles)	600,000	650,000	850,000	600,000
Emissions Warranty (miles)	450,000	350,000	800,000	450,000
MY 2031				
FTP & SET cycle NOx standards (mg/hp-hr)		Same as MY 2027	Same as MY 2027	
Intermediate Useful Life	20			20
Full Useful Life	40			40
Low Load Cycle NOxstandard (mg/hp-hr)	100			100
Idle NOx standard (g/hr)	5 (optional)			5
In-use moving average window std.	1.5x lab cycle value			1.5x lab cycle value
Intermediate Useful Life (miles)	435,000			435,000
Full Useful Life (miles)	800,000			800,000
Emissions Warranty (miles)	600,000			600,000

Comparison of EPA Option 1 and CARB Omnibus NOx Reductions



Data from draft RIA Table 5-49

Targeted Revisions to Heavy Duty GHG Phase 2

Background: HD GHG Program Highlights

- Standards set by heavy-duty regulatory categories, e.g., tractors, vocational vehicles, large pickups/vans

- Phase 1 vehicle standards implemented 2014 through 2018; Phase 2 program started in MY 2021, fully phase in by MY 2027

When designing program in 2016, EPA envisioned these technologies *could* be used to meet Phase 2:

- Engine, transmission, and driveline improvements
- Extended and workday idle reduction technologies
- Aerodynamic devices
- Lower rolling resistance tires
- Automatic tire inflation systems
- Weight reduction
- Engine stop start
- Powertrain hybridization
- Combustion optimization
- Improved air handling
- Reduced friction within the engine
- Improved emissions after-treatment technologies
- Engine waste heat recovery

Background: How Does the GHG Phase 2 Program Work?

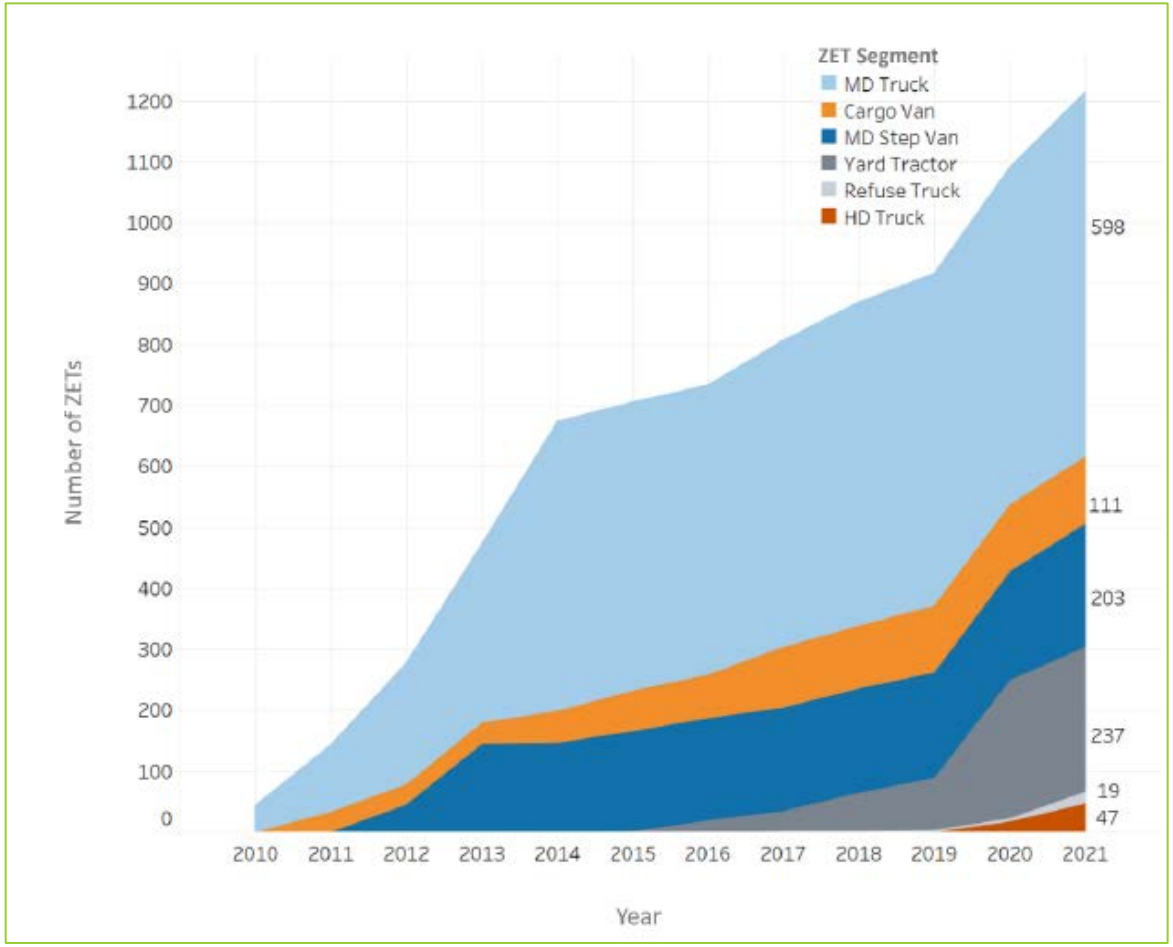
***Performance-based* standards to capture the diversity in heavy-duty vehicles and operations**

- Standards are first differentiated between tractors and vocational vehicles as shown in detail on the next slide
  - Vocational vehicles are divided into 23 different **subcategories for setting standards** – 8 of these are for specialized vehicles
  - For tractors, standards are divided into 10 different **subcategories** for standards
  - In total, there are 33 unique HD vehicle subcategories for standards for Model Year 2027 (in addition to the MY 2021 and MY 2024 standards)
- Vehicles are produced that have emissions at, above, or below the standard, and a company's compliance is based on a *sales-weighted average*
- Averaging, Banking and Trading (ABT) program allows emissions credits to be generated and used in meeting the standards

Historic Opportunity for Clean Air provided by Zero-Emission Vehicles: A Turning Point in the Heavy-Duty Industry

- In early stages of significant transition in the history of heavy-duty on-highway sector— shift to zero-emission vehicle (ZEV) technologies
- Presents an opportunity for significant reductions in heavy-duty vehicle emissions
- Major trucking fleets, manufacturers and U.S. states have announced plans to transition the heavy-duty fleet to zero-emissions technology
  - Recent introductions and growing plans for zero-emission technology into a number of heavy-duty vehicle market segments (figure right)

Cumulative U.S. Zero-Emission Truck Deployment



Source: Zeroing In on Zero-Emission Trucks, CALSTART, January 2022

Proposed Increase in Stringency of GHG Phase 2 MY 2027 Standards in Consideration of the Evolving EV Market

- Projected EV production levels in HD market based on known and projected EV product offerings – four major vehicle types shown on the right
- Proposed adjusting the Phase 2 GHG emission standards by sales-weighting the projected EV production levels of the four vehicle types and increasing the stringency of the MY 2027 standards
- Further reductions will be considered starting as early as MY 2030 in the heavy-duty GHG "Phase 3" rule (consistent with E.O. 14037)

Vocational: School Buses
(e.g., Thomas Built Saf-T-Liner Jouley, Blue Bird--3 models--Vision, All American, and Micro Bird)

Vocational: Urban Buses
(e.g., Proterra ZX5, Gillig Battery Electric)

Vocational: Local Delivery Trucks
(e.g., Peterbilt 220EV, Freightliner eM2)

Tractors: Regional Haul Tractors
(e.g., Volvo VNR Electric, Freightliner eCascadia, Peterbilt 579EV, Kenworth T680E)

Proposed Revisions to GHG Standards in the HD 2027 NPRM

- We used EPA certification data, California Advanced Clean Truck (ACT) mandate values, industry product announcements, and other data sources to project the expected percentage of EVs in the national market for MY 2027 for vocational vehicles (which includes school buses, urban buses, and delivery trucks) and tractors (which includes day cabs)
- EV manufacturers today are certifying into nearly all of the vocational vehicle subcategories, with school and urban buses in many of these, and into day cab tractor subcategories
- The data shows that these EV products are being certified in 17 of the 33 Vocational and Tractor regulatory categories defined in the Phase 2 program structure
- We estimate a market penetration of 1.5% ZEVs in these categories in MY 2027
  - Request information and data available that would support higher HD ZEV penetration rates in this timeframe (e.g., 5 or 10% or more)
- We propose to increase the stringency of the MY 2027 standards for these 17 vehicle categories to reflect the market penetration of ZEVs in these vehicle categories
  - Request comment on the potential for progressively more stringent CO_2 standards across model years 2027, 2028 and 2029

Additional request for comments on HD GHG Phase 2 program revisions

Phase 2 includes large CO_2 credit multipliers for MY 2027 and earlier vehicles with advanced technology, designed to incentivize the market.

EPA requests comment on three different approaches to limit the potential impact on GHG emissions due to the EV credit multipliers. With all three approaches, EVs would continue to be deemed to have zero grams CO_2 per ton-mile emissions for vehicles produced over the cap.

1. All EVs certified in California in MY 2024 through MY 2027 would not receive the advanced technology credit multiplier that currently exists.

2. Cap use of the multiplier to reflect a 1% level of EV production.

3. Transition the credit multipliers by lowering them each model year.

Public participation

- EPA welcomes public input into this rulemaking

- More information on the proposal and how to provide input is available on the EPA rule webpage: *https://www.epa.gov/regulations-emissions-vehicles-and-engines/proposed-rule-and-related-materials-control-air-1*

- Goal is to issue final rule in December 2022
  - To provide Clean Air Act 4-year lead-time to enable new NOx standards to begin in Model Year 2027